Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks

Deliverable report D1.4

Context	
Deliverable title	Analysis of the legal framework
Lead beneficiary	WMU
Author(s)	Dr. Tafsir Johansson, Dr. Aspasia Pastra & Dr. Rían Derrig
Work Package	WP01
Deliverable due date	31 April 2022
Document status	
Version No.	1
Type	REPORT
Dissemination level	**PUBLIC**
Last modified	25 August 2022
Status	RELEASED
Date approved	25 August 2022
Approved by Coordinator	Prof. Cédric Pradalier (CNRS) Signature:
Declaration	Any work or result described therein is genuinely a result of the BugWright2 project. Any other source will be properly referenced where and when relevant.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 871260

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This deliverable in its current form remains a working-draft. The research team is in the process of addressing comments and feedback from members of the Senior Advisory Group.

The World Maritime University shall make report deliverable 1.4 publicly accessible after the publication titled “Building a Trust Ecosystem for Remote Inspection Technologies in Ship Hull Inspections” is formally published (open-access) in October 2022.

ACKNOWLEDGMENTS

This chapter derives from the findings from project BUGWRIGHT2: Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks (Task 1.4) – funded by the European Union's Horizon 2020 research and innovation program under grant agreement No. 871260. The authors would like to thank Professors Ronán Long and Clive Schofield, Ms. Elnaz Barjandi, Ms. Jill Järnsäter, Ms. Mercedes Troisi Allende and Ms. Flora Lim of the World Maritime University–Sasakawa Global Ocean Institute, and the Nippon Foundation for their generous support. The researchers also gratefully acknowledge support from the following members of the Senior Advisory Group:

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2. Ms. Mona Swoboda; Program Manager, Inter-American Committee on Ports (CIP) Organization of American States;
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5. Captain Yoss LeClerc; President & CEO at Logistro Consulting International Inc.; President, International Harbour Masters Association;
6. Mr. Aron Frank Sørensen; Head of Marine Environment, Baltic and International Maritime Council;
7. Dr. Miguel Núñez Sánchez; Spanish Civil servant (Special Services) at Ministerio de Transportes, Movilidad y Agenda Urbana
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15. Mr. Frode Rødølen; CEO, VUVI AS (West Underwater Inspection Ltd), Norway;
16. Mr. Andreas Åberg; Senior Surveyor, Department of Inspections, Remote Survey Center;
17. Mr. Geir Axel; Oftedahl, Breakthrough (Innovations) Director, Performance Coatings, Jotun A/S;
18. Mr. Enrico Carrarra; Senior Technical Officer, Registro Italiano Navale;
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48. Mr. Xiang Linhao; Science & Technology Innovation and Test Center, China Classification Society.

EXECUTIVE SUMMARY

The emergence of Robotic and Autonomous Systems has garnered momentum in the regulatory and policy communities due to its potential to deliver reduced fuel consumption, less emissions and increased operational profits, together with reducing administrative burdens for highly competitive industries. One of the key issues in the maritime domain concerns the use of service robotics for various purposes in the shipping and associated industries, including the certification standards and regulations that ought to be applied at the international, European and national levels. In addition, service robotics or remote inspection techniques and associated technologies have vital regulatory applications in the context of inspection and control, enforcement and compliance, as well as in meeting requirements. A novel aspect of applying autonomous robotics relates to the task of visual inspection, thickness measurement of steel plates and hull cleaning along with the climate change mitigation benefits derived from cleaner hulls. This in turn can contribute to the attainment of specific targets under Goals 13 (Climate Action) and 14 (Life Below Water), and 15 (Life on Land) of the UN 2030 Agenda for Sustainable Development.

In this scope, the multi-robot ship-hull survey system explored under the auspices of BUGWRIGHT2 has the potential to change the way massive structures are being inspected. This change will eventually benefit personnel and environmental safety, including the reduction of fatigue on board while maintaining or improving European shipping competitiveness, thus, paving the way for better and safer regulations and standards. Markedly, the current framework governing common minimum standards, while commendable, requires a thorough re-assessment to mark out incidental issues that could arise after the deployment of available techniques. Researchers assert that the incidental issues could act as a barrier that could stall the market growth resulting in an unwanted impasse.

Against the foregoing the principal focus of the World Maritime University (WMU) (pursuant to s. 2.1.3 of the Description of Actions) has been to identify the regulatory barriers and policy framework impacts while maintaining, if not improving the efficiency of the current inspection and control regime. This has materialized through four distinct strands of research. Initial tasks focused on analyzing international standards developed by concerned international bodies. To that end, researchers have reviewed international agreements, including the United Nations Convention on the Law of the Sea, the UN Framework Convention on Climate Change, and the Paris Agreement; the International Maritime Organization treaty regime; intellectual property rights further to World Intellectual Property Organization and related standards; along with the certification requirements and standards pursuant to the International Organization for Standardization framework.

Following this, a comparison on selected case studies regarding the regulation of robotics in the United States of America, the Netherlands, Canada, Norway, China and Singapore has been conducted to understand how leading countries are paving the way to autonomous operations, more specifically inspections and cleaning, through technological advancements. These case-studies have helped researchers exemplify the existing usage of different regulatory tools in the aviation and automotive sectors that in turn, have provided a sketch of the overall regulatory landscape for autonomous robotics.

Subsequently, the European Union legal framework examines the possibility of autonomous inspection robots being used to undertake inspection tasks conducted on the basis of port State jurisdiction in European Union Member States' ports, examines the possibility of autonomous inspection robots being used to undertake inspection tasks conducted on the basis of port State jurisdiction in European Union Member States' ports. A brief overview of technical research concerning such robots is offered. The research then outlines the EU legal framework concerning port State jurisdiction, and contextualises this legal landscape by recalling the history of attempts at EU and international level to regulate in response to maritime disasters since the 1980s. Based on a close reading of the PSC Directive, alongside analysis of the aims pursued and policy options proposed in the context of the European Commission's significant ongoing work on a review of this instrument, the research ultimately argues that the adoption of autonomous inspection technologies could offer significant benefits, permitting more efficient completion of existing inspection tasks and potentially changing what is and is not considered feasible in inspection scenarios.

Finally, the key take-aways from individual strands of assessment have been carefully conceptualized to illustrate a set of current needs in the form of a draft regulatory blueprint, which could be fully exploited by concerned regulatory bodies, as well as national and international agencies that deal with remote inspection techniques in Europe and across the world. Researchers note that this blueprint that serves as the final product of analysis from the three primary strands will be invaluable to the International Maritime Organization when responding to member states' request to streamline important provisions in the process of developing international guidance on remote survey using remote inspection techniques.

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- BUGWRIGHT2 Description of the Action (DoA)

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A. LIST OF PUBLICATIONS (2020 – 2022) FOR TASK 1.4

This section contains an overview of the publications produced by the World Maritime University between 2020 and 2022 in accordance with the pre-determined tasks under work package 1.4 (Legal Insight). The publications contain findings from the main report found in section C titled "Principal Research Report (2020 – 2022) for Task 1.4" (all publications attached immediately after this section).

A.1 SUMMARY OF PUBLICATION ON INTERNATIONAL ARRANGEMENTS

Title	International Standards for Hull Inspection and Maintenance of Robotics and Autonomous Systems		
Abstract	Hull inspection in the operational routine of commercial shipping is a regulatory obligation. This ensures seamless and smooth operations of commercial shipping vital to the global economy and the international supply chain. Failure to carry out these tasks may result in adverse consequences for the industry leading to poor maintenance, poor performance and increased fuel consumption. In this era of digital advancement, service robots are integrated into the rudimentary manual inspection system. The systems are based on machine learning and capable of interacting with the environment to achieve pre-set goals and offer affordable and efficient alternatives. These advanced AI-based alternatives are set to change the entire survey and maintenance landscape. While technological advancements continue, the regulatory governance side to these alternative technological solutions is gathering momentum and calls for a state-of-the-art analysis in light of the standardized requirements at play under the existing international regime.		
Publisher	Cambridge University Press		
Duration of Work	October 2020 – April 2022		
Impact Factor	**2020** – **6.276** 10 out of 182 Political Science 4 out of 94 International Relations **2018** – **4.508** 1 out of 91 International Relations 1 out of 176 Political Science **2017** – **4.517** 1 out of 85 International Relations 2 out of 169 Political Science		
Status	**Under-review**	**Proof-stage**	**Published**
	-	-	x
Citation	**-**		
Impacts Following Publication	**Text Reads**	**Total Downloads**	**Presentations**
	-	**-**	45 Conference on Oceans Law and Policy, 2022 (700+ registered participants)

A.2 Summary of Publication on International Arrangements

Title	Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers		
Abstract	The current regulatory landscape that applies to maritime service robotics, aptly termed as robotics and autonomous systems (RAS), is quite complex. When it comes to patents, there are multifarious considerations in relation to vessel survey, inspection, and maintenance processes under national and international law. Adherence is challenging, given that the traditional delivery methods are viewed as unsafe, strenuous, and laborious. Service robotics, namely micro aerial vehicles (MAVs) or drones, magnetic-wheeled crawlers (crawlers), and remotely operated vehicles (ROVs), function by relying on the architecture of the Internet of Robotic Things. The aforementioned are being introduced as time-saving apparatuses, accompanied by the promise to acquire concrete and sufficient data for the identification of vessel structural weaknesses with the highest level of accuracy to facilitate decision-making processes upon which temporary and permanent measures are contingent. Nonetheless, a noticeable critical issue associated with RAS effective deployment revolves around non-personal data governance, which comprises the main analytical focus of this research effort. The impetus behind this study stems from the need to enquire whether "data" provisions within the realm of international technological regulatory (techno-regulatory) framework is sufficient, well organized, and harmonized so that there are no current or future conflicts with promulgated theoretical dimensions of data that drive all subject matter-oriented actions. As is noted from the relevant expository research, the challenges are many. Engineering RAS to perfection is not the end-all and be-all. Collateral impediments must be avoided. A safety net needs to be devised to protect non-personal data. The results here indicate that established data decision dimensions call for data security and protection, as well as a consideration of ownership and liability details. An analysis of the state-of-the-art and the comparative results assert that the abovementioned remain neglected in the current international setting. The findings reveal specific data barriers within the existing international framework. The ways forward include strategic actions to remove data barriers towards overall efficacy of maritime RAS operations. The overall findings indicate that an effective transition to RAS operations requires optimizing the international regulatory framework for opening the pathways for effective RAS operations. Conclusions were drawn based on the premise that policy reform is inevitable in order to push the RAS agenda forward before the emanation of 6G and the era of the Internet of Everything, with harmonization and further standardization being very high priority issues		
Publisher	Journal of Marine Science and Engineering (MDPI)		
Duration of Work	January 2021 – May 2021		
Impact Factor	2.574		
Status	**Under-review**	**Proof-stage**	**Published**
	-	-	x
Citation	2		

Impacts Following Publication	Text Reads	Total Downloads	Presentations
	1862 (as of 2 August 2022)	-	-

A.3 Summary of Publication on European Union Analysis

Title	Maritime Remote Inspection Technology in Hull Survey & Inspection: A Synopsis of Liability Issues from a European Union Context		
Abstract	Vessel hull inspection is a regulatory obligation. Adherence to procedural requirements forged by classification societies helps avoid numerous adverse consequences. In this era of technological innovation, drones, crawlers and underwater submersibles, aptly known as Remote Inspection Technologies, represent emerging technologies, and are being tested to conduct surveys and inspections that will gradually replace human presence on board ships and in-water. However, counter arguments have also emerged against the usage of these AI-based alternatives. Liability is one crucial drawback that could potentially discourage innovation and market growth, especially at the European Union level. Ship owners require a "safety net" as they are a part and parcel of global commerce. Then again, survey and inspection via technologies require the involvement of multiple actors, which makes it difficult to apportion liability. Solutions are required, especially at the European Union level, so that member states could move forward in a spirit of partnership, and nurture and foster technological innovation through partnership. Against the foregoing, this article delves into the European Union liability landscape and outlines some of the critical challenges and strategic ways forward for consideration.		
Publisher	Journal of International Maritime Safety, Environmental Affairs, and Shipping Volume 5, 2021 - Issue 4 (Taylor & Francis)		
Duration of Work	September 2021 – December 2021		
Impact Factor	Between 1.0 – 1.994 (2022 TBC)		
Status	**Under-review**	**Proof-stage**	**Published**
	-	-	x
Citation	-		
Impacts Following Publication	**Text Reads**	**Total Downloads**	**Presentations**
	738 (as of 2 August 2022)	Information not available	-

A.4 Summary of Publication on National Comparative Analysis

Title	Building a Trust Ecosystem for Remote Inspection Technologies in Ship Hull Inspections

Abstract	The article contributes to the discussion concerning the role of trust in robotic and autonomous systems (RAS), with a sharp focus on remote inspection technologies (RITs) for vessel inspection, survey and maintenance. To this end, the article provides a first-hand insight into one of the major findings from BUGWRIGHT2* --- a collaborative project co-funded by the European Union's Horizon 2020 Research and Innovation programme that aims to change the European vessel-structure maintenance landscape. In doing so, this article explores trust from a psychological perspective, reflecting on its characteristics and predictors, followed by a discussion on the AI-trust ecosystem as envisaged by the European Commission. Structured interviews with thirty-three subject matter experts guide the main analysis revealing that trust is an essential precondition for integrating RITs into the current manual-driven inspection system. A synoptic overview of the vital trust-elements is provided before carving out the ways forward for developing a trustworthy environment governed by Human-Robot Interaction.		
Publisher	Journal of Law, Innovation and Technology (Taylor & Francis)		
Duration of Work	August 2021 – April 2022		
Impact Factor	1.78		
Status	**Under-review**	**Proof-stage**	**Published**
	-	x	Forthcoming Volume 10.2 (October 2022)
Citation	-		
Impacts Following Publication	**Text Reads**	**Total Downloads**	**Presentations**
	-	**-**	-

A.5 Summary of Publication on European Union Analysis

Title	Autonomous Ship Inspection Robots under Port State Jurisdiction: The EU Legal Framework
Abstract	This article examines the possibility of autonomous inspection robots being used to undertake inspection tasks conducted on the basis of port State jurisdiction in European Union (EU) Member States' ports. A brief overview of technical research concerning such robots is offered. The article then outlines the EU legal framework concerning port State jurisdiction, and contextualises this legal landscape by recalling the history of attempts at the EU and international level to regulate in response to maritime disasters since the 1980s. Based on a close reading of the Port State Control Directive, alongside analysis of the aims pursued and policy options proposed in the context of the European Commission's significant ongoing work on a review of this instrument, it is clear that the adoption of autonomous inspection technologies could offer significant benefits, permitting more efficient completion of existing inspection tasks and potentially changing what is and is not considered feasible in inspection scenarios.
Publisher	International Journal of Marine and Coastal Law (Taylor & Francis)

Duration of Work	August 2021 – April 2022		
Impact Factor	1.78		
Status	**Under-review**	**Proof-stage**	**Published**
	-	-	x
Citation	-		
Impacts Following Publication	**Text Reads**	**Total Downloads**	**Presentations**
	-	**-**	-

A.6 Summary of Publication on Regulatory Blueprint

Title	Maritime RAS Techno-regulatory Regime: Six Blocks of Dynamic Influence Towards Good Environmental Stewardship		
Abstract	This submission discusses Remote Inspection Techniques (RIT), their deployment in biofouling survey and maintenance, their harmonization with international requirements for semi-autonomous platforms, as well as highlights positive implications of internationally harmonized RIT standards with the European Union (EU) vessel hull inspection regime. RIT, in this context, represent systems based on machine learning that offer time-efficient and perhaps cost-effective alternatives to existing manual-driven survey and maintenance operations. These Artificial Intelligence (AI)-based alternatives are projected to save ship's operation time that make up a significant portion of running costs. Most recently, COVID-19 provided an impetus to test RIT for conducting statutory and classification surveys remotely. However, the integration of RIT raises concern for the viability of common minimum standards developed by international organizations, especially from an environmental perspective. The initial findings unveiled at COP26 stressed the need to mitigate biofouling build-up which explicitly contributes to increased greenhouse gas emissions. Therefore, niche sources and technological tools for environmental excellence cannot be overlooked. Moving forward, efforts to maintain good environmental stewardship at the EU level will not only require the seamless integration of RIT, but also a guarantee that all techno-regulatory elements vital to the semi-autonomous platform are streamlined into policy through international multi-stakeholder consultation. Techno-regulation, against the backdrop of this chapter, has an expanded application, and considers regulatory governance schemes in addition to the common definition --- affecting human behavior by injecting norms, values and principles and rules in technical equipment.		
Publisher	Intersentia, Cambridge, UK (University of Bournemouth EELF 2022 Book)		
Duration of Work	November 2021 - ongoing		
Impact Factor	-		
Status	**Under-review**	**Proof-stage**	**Published**

	-	X (as of 2 August 2022)	-
Citation	**-**		
Impacts Following Publication	**Text Reads**	**Total Downloads**	**Presentations**
	-	-	-

B. PUBLICATIONS ATTACHED

The following publications have been attached to this section of the report:

1. International Standards for Hull Inspection and Maintenance of Robotics and Autonomous Systems (all processes complete; forthcoming August 2022: click here to access e-version on google drive)
2. Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers (published: click here to view online published version);
3. Maritime remote inspection technology in hull survey & inspection: A synopsis of liability issues from a European Union context (published: click here to view online published version);
4. Building a Trust Ecosystem for Remote Inspection Technologies in Ship Hull Inspections (review complete, publication accepted, forthcoming October 2022: click here to access e-version on google drive);
5. Autonomous Ship Inspection Robots under Port State Jurisdiction: The EU Legal Framework (work-in-progress: click here to access e-version on google drive); and
6. Maritime RAS Techno-regulatory Regime: Six Blocks of Dynamic Influence Towards Good Environmental Stewardship (publication currently under proof-stage: click here to access e-version on google drive).

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7

International Standards for Hull Inspection and Maintenance of Robotics and Autonomous Systems

TAFSIR JOHANSSON*

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7.1 Introduction

Artificial intelligence (AI)–integrated robotic technologies, commonly referred to as robotics and autonomous systems (RAS), provide innovative – perhaps even revolutionary – new solutions for cutting-edge industries that offer great potential for the maritime sector. Specific present and potential applications of RAS will enhance both safety and efficiency by allowing the completion of tasks that are otherwise risky and onerous. This chapter focuses on standardization of rules and

* This chapter derives from the findings from project *BUGWRIGHT2: Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks* (Task 1.4) – funded by the European Union's Horizon 2020 research and innovation program under grant agreement No. 871260. The views and opinions expressed are those of the authors and do not reflect the official policy or position of BUGWRIGHT2 consortium members, the International Maritime Organization or any of the classification societies. The author would like to thank the Nippon Foundation, staff members of the World Maritime University-Sasakawa Global Ocean Institute, especially, Professors Ronán Long and Clive Schofield, and Dr. Jon Skinner, Mr. Thomas Klenum, Mr. Sean Pribyl and Mr. George Giazlas for their invaluable support.

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requirements for RAS involved in ship survey and maintenance, with a sharp focus on bulk carriers.[1]

Evolving RAS refinements are undoubtedly progressing at an extraordinary pace. An illustrative precedent was the then "revolutionary" introduction of autonomous automotive technologies to the global industry. Automotive automation can be traced back to the mid-1920s and continues to transition from semiautonomous vehicles to state-of-the-art fully autonomous vehicles in the land-based transport sector.[2] Technological breakthroughs via RAS to advance autonomous or self-piloting platforms in the ocean domain gained momentum much later, most notably through the initiation of the Norwegian project, Maritime Unmanned Navigation through Intelligence in Networks (MUNIN).[3] Current efforts are focused on combining the concepts of "autonomy" and "unmanned" into a holistic concept to guide future ocean-based transport modes.[4]

While work on developing fully autonomous vessels progresses, the last decade has seen more conspicuous success integrating RAS within the maritime sector – especially with "service robotics." The services provided by these robots have numerous and significant advantages, safety being foremost, over conventional methods that require strenuous, if not at times extreme, human effort. Designed and programmed to complete tangible actions by combining the best of two worlds (robotics and AI), the vision behind the deployment of service robots is similar to that of "autonomous vessels," achieving optimum safety, reliability and efficiency with less human intervention, as well as anticipated cost-savings.

Service robots in the shipping industry provide a wide range of other practical marine services. A noteworthy contemporary area of this application involves visual inspection and maintenance of commercial vessel hulls. These tasks enhance vessel upkeep and maintenance – an unavoidable obligation for ship owners and operators, and one required by IMO instruments. Scientists and engineers are also introducing reconfigured

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[1] The discussion touches upon both primary and secondary application domains of BUGWRIGHT2: outer hull and storage tanks (in relation to bulk carriers).

[2] KESHAV BIMBRAW, *Autonomous Cars: Past, Present and Future – A Review of the Developments in the Last Century, the Present Scenario and the Expected Future of Autonomous Vehicle Technology*. PROCEEDINGS OF THE 12TH INTERNATIONAL CONFERENCE ON INFORMATICS IN CONTROL, AUTOMATION AND ROBOTICS 191 (2015).

[3] ØRNULF JAN RØDSETH, *From Concept to Reality: Unmanned Merchant Ship Research in Norway*. IEEE UNDERWATER TECHNOLOGY 1–4, 6–10 (2017).

[4] *Id.*, at 1, 3–4, 6, 8–10.

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service robots into maintenance practices to alleviate the need for humans to work in dangerous or dirty environments, as well as "to improve its image into one with productive and cost saving elements requiring the need for highly skilled, tech-savvy engineers."[5]

Outer hull inspection and maintenance of commercial vessels is a niche area where service robots are being tested and introduced to ship owners and operators to replace traditional methods of survey that are time consuming. Service robots engineered to perform outer hull and storage inspections and benefit from advances in "metamorphic" RAS capabilities.[6] Holistically, RAS capability have transitioned from limited to multifaced functions requiring both specific and diverse standards, such as for micro aerial vehicles (MAVs), autonomous underwater vehicles (AUVs) and magnetic-wheeled crawlers (MWCs).[7] As manufacturers move from single-use to polyfunctional service robots, standardization became a concern.[8] RAS should embrace and adhere to critical safety, quality, performance and efficiency standards developed in a cooperative and common effort; the earlier in the life cycle the better.

The emergence of service robots has attracted attention at the European Union (EU). Meeting standards tailored for RAS is a priority emphasized by recognized organizations (ROs), including the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). The EU High-Level Expert Group on AI has explored elements for reliable and trustworthy AI, and envisions the creation of a necessary horizontal foundation that

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5 Michael John Farnsworth et al., *Autonomous Maintenance for Through-Life Engineering*. Through-life Engineering Services 395, 397 (Louis Redding & Rajkumar Roy eds., 2014); *N.B.* "ship" and "vessel" are used interchangeably and follows the definition of "ship" found in Marine Environmental Protection Committee Res. MEPC.207(62), annex 26 (July 15, 2011) (hereinafter 2011 Guidelines).

6 Luigi Pagliarini & Henrik Hautop Lund, *The Future of Robotics Technology*, 3 J. of Robotics Networking & Artificial Life 270 (2017); *see* Kasper Stoy et al., Self-Reconfigurable Robots: An Introduction 5–7 (2010); *see also* N. A. Stravopodis et al., *An Integrated Taxonomy and Critical Review of Module Designs for Serial Reconfigurable Manipulators*. Advances in Service and Industrial Robotics: Proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region 3–4 (Karsten Berns & Daniel Görges eds., 2020).

7 *Id.*

8 Gurvinder S. Virk et al., *ISO Standards for Service Robots*. Advances in Mobile Robotics: The Eleventh International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines 1–2 (2008).

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could topple current regulatory, ethical and societal barriers with a singular innovation of establishing trust between manufacturer and the end-user.[9] To achieve this objective, particularly in the business-to-consumer domain, the High-Level Expert Group promotes the value of universal designs and the need to remain in conformity with specific technical standards for safety and transparency.[10]

At the international level, the International Organization for Standardization (ISO) has been active in RAS standardization since 1947.[11] Classification societies today operate in tandem with the ISO and other ROs. In the maritime domain, the procedural rules developed through consultation with international bodies assist integrating RAS applications in mandatory surveys under international law. Similar to land-based technologies, the functionality of technologies applied in the ocean domain are evaluated on standard safety and performance standpoints. For international provisions on safety and performance standards, it is a common practice to turn to the International Maritime Organization (IMO) and recognized classification societies. While it is important to understand the implications of new service emerging technologies on the law of the sea, there is also a need to observe how other international governmental and nongovernmental organizations impact innovation, safety and protection of the marine environment.

The previous discussion highlights the central work of the IMO, which details biofouling and the pertinent international regulatory arrangements covering operational and procedural standards pertinent to introducing new shipping technologies in specific niche areas. Hereafter, the discussion focuses on identifying the crucial barriers – followed by an expository analysis of international technology-based standards within the framework of the safety and environmental protection aspects of the law of the sea. The chapter concludes by considering some strategic tools that may assist and enable a much-needed harmonization process.

7.1.1 Setting the Scene: RAS Terms and Concepts

The term RAS is of recent origin. In defining the term "robots," the ISO *Vocabulary* utilizes scientific terms referring to mechanical systems that

[9] Ethics Guidelines for Trustworthy AI, Report of the High-Level Expert Group on Artificial Intelligence, at 1–36, European Commission (2019).
[10] *Id.*, at 19, 22.
[11] VIRK ET AL., *supra* note 8, at 2.

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can move "within its environment, to perform intended tasks."[12] In its definition, ISO keeps the performance aspect open-ended respecting the degree of autonomy or level of a systems' dependency on human interaction when performing intended tasks.[13] The ISO defines "service robots" as those that "perform useful tasks for humans" (except those that are used in industrial automation applications).[14] The ISO/TC 184 Technical Committee further classifies service robots into personal service robots and professional service robots with the latter comprised of those that are used in commercial tasks and operated and monitored by a properly trained operator. While the definition of "professional service robot" acknowledges the integration of human intervention to initiate and stop an operation, it does not clarify what "monitor" entails.[15] Professional service robots have image sensors that convert photons into electrical signals that are then analyzed by inspectors. Therefore, according to section 2.12 (professional service robot) when read together with section 2.17 (operator), "monitoring" may pertain to actions undertaken by the operator to observe how the robot "itself" is performing, or alternatively, the "inspection function" being undertaken by the robot. The word "monitor" is imprecise and may create confusion.

7.1.2 Biofouling Degrades Vessel Performance

About 100,000 commercial vessels of more than 100 tons constitute the global maritime shipping industry, which is the cornerstone of global trade and commerce.[16] Among this number, some 9,734 large ships and 4,759 very large ships in operation are over the age of five years.[17] This global shipping fleet depends on efficiency and optimal vessel performance. "Hull resistance" is a primary issue that degrades hull performance, hindering the ship's capacity to operate efficiently.[18] Hull fouling or

[12] International Organization for Standardization, Robots and Robotic Devices: Vocabulary § 2.6 (2012).
[13] *Id.*, § 2.2.
[14] *Id.*, § 2.10.
[15] *Id.*, § 2.17.
[16] UN Conference on Trade and Development, Review of Maritime Transport, at 4, U.N. Doc. UNCTAD/RMT/2019/Corr.1, U.N. Sales No. E.19.II.D.20 (2020); *see also* Jean-Paul Rodrigue & Theo Notteboom, *Maritime Transportation*. The Geography of Transport Systems 151, 171 (Jean-Paul Rodrigue ed., 5th ed. 2020).
[17] *Id.*, at 9, table 3 (ships by age and size).
[18] Panos Deligiannis, *Ship Performance Indicator*, 75 Marine Pol'y 204, 205 (2017).

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biofouling makes ships less efficient and contributes substantially to increased emissions.[19] In technical terms, hull fouling increases water resistance to the hull, thereby increasing energy usage and affecting scheduling and maintenance costs.[20]

Hull inspection and maintenance are cost interlinked with energy efficiency improvements and can curb emissions.[21] While the IMO's efforts to control invasive species through the International Convention for the Control and Management of Ship's Ballast Water and Sediment, 2004 heralds a new era for marine environmental protection, transportation of invasive species through biofouling with ships as vectors has drawn the IMO's attention on the importance on hull inspection and maintenance.[22]

7.2 The International Legal Regime

7.2.1 IMO 2011 Guidelines

At the international level, the primary forces driving outer hull inspection cleaning and maintenance are twofold: (1) to inspect the biofouling status of a ship; and (2) to address elevated risks that could result in safety and environmental concerns. These twofold motivations reside at the crux of the IMO's work reflected in the *2011 Guidelines for the Control and Management of Ship's Biofouling to Minimize the Transfer of Invasive Aquatic Species* (hereinafter 2011 Guidelines).

The 2011 Guidelines are designed to facilitate the implementation of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 ("BWM Convention") and the International Convention on the Control of Harmful Anti-fouling

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[19] *Id.*, at 204; *see also* Roar Adland et al., *The Energy Efficiency Effects of Periodic Hull Cleaning*, 178 J. OF CLEANER PROD. 1, 2 (2018).

[20] *See* U.S. COAST GUARD, Pub. No. CG-D-15-15, VESSEL BIOFOULING PREVENTION AND MANAGEMENT OPTIONS REPORT, at v (2015); *see* M. P. Schultz et al., *Economic Impact of Biofouling on a Naval Surface Ship*, 27 BIOFOULING 87–89 (2011); H. WANG & N. LUTSEY, LONG-TERM POTENTIAL FOR INCREASED SHIPPING EFFICIENCY THROUGH THE ADOPTION OF INDUSTRY-LEADING PRACTICES 3–8 (2013).

[21] "Fouling of the hull can increase fuel consumption up to 15 percent." *See* ANTHONY F. MOLLAND ET AL., SHIP RESISTANCE AND PROPULSION (2017); *see* also Adland et al., *supra* note 19, at 2. *See also* INTERNATIONAL MARITIME ORGANIZATION, THIRD IMO GREENHOUSE GAS STUDY 2014 (2015).

[22] U.S. COAST GUARD, *supra* note 20, at v.

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Systems on Ships, 2001 ("AFS Convention") in conjunction with Guidance for the Development of a Ship Energy Efficiency Management Plan (SEEMP). Recognizing the significance of evidence-based studies that concluded that all ships contribute to some degree to biofouling after immersion in water, the 2011 Guidelines prescribe "in-water" inspection, cleaning and maintenance procedures as additional measures for antifouling installation and maintenance.[23]

Specific provisions of in-water inspection, cleaning and maintenance can be found in section 7 of the 2011 Guidelines. As the first step, the 2011 Guidelines prescribe the inspection of niche areas of the ship that have a high probability of prolific build-up of hard-shell fouling, allowing operators to optimize target zones for cleaning and maintenance.[24] In this context, the 2011 Guidelines suggest two options for conducting inspections: human divers and remotely operated vehicles (ROVs; Figure 7.1).[25] Considering the absence of a preset definition of ROV within the framework of the 2011 Guidelines, it is reasonable to assert that ROVs deployed in hull inspections belong to "inspection-class ROVs" that are consistent with the ISO definition of "professional service robots" that are monitored by an operator. These types of robots are real-time "acoustic eyes" with a smaller footprint compared to "intervention-class ROVs" that are not typically equipped with tooling equipment.[26]

Post inspection, member states are advised to perform risk assessments prior to cleaning and maintenance to minimize environmental threats associated with cleaning actions, such as biological, toxic effects from employed substances.[27] While the 2011 Guidelines did not anticipate the use of ROVs for those tasks, if there had been such a provision, the high operational costs associated with deploying "intervention-class

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23 Section 2.1 defines "biofouling" as "the accumulation of aquatic organisms such as micro-organisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment," and "in-water cleaning" as the "physical removal of biofouling from a ship while in the water." *See* 2011 Guidelines, *supra* note 5, § 2.1.

24 "Niche areas" are defined as "mean areas on a ship that may be more susceptible to biofouling due to different hydrodynamic forces, susceptibility to coating system wear or damage, or being inadequately, or not, painted, e.g., sea chests, bow thrusters, propeller shafts, inlet gratings, dry-dock support strips, etc." *See* 2011 Guidelines, *supra* note 5, §§ 2.1, 6.9.1 ("niche areas").

25 *Id.*, § 7.4.

26 Romano Capocci et al., *Inspection-Class Remotely Operated Vehicles: A Review*, 5 J. of Marine Sci. & Eng'g 1, 4–6 (2018).

27 2011 Guidelines, *supra* note 5, § 7.6.

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Figure 7.1 Underwater inspection using ROV.
Source: Diving Status (permission to use image granted by copyright holder)

ROVs" would likely be debated.[28] All in all, the 2011 Guidelines emphasize the need to exercise due diligence to provide a continuous cycle of cleaning and maintenance.[29]

7.2.2 International "Standards" and the Regulatory Regime

Among the three relevant international organizations, the ISO is chartered with mandating and developing standards.[30] The widely accepted definition of "standard" can be found in one of the earliest ISO publications *The Aims and Principles of Standardization*, published in 1972. This publication defines "standard" as "[t]he result of a particular standardization effort, approved by a recognized authority" that "may take the form of: (1) a document containing a set of conditions to be fulfilled (*norme* in French); and (2) a fundamental unit or physical constant, for example, ampere, meter, absolute zero (Kelvin)(*étalon* in French)".[31] The same definition is incorporated verbatim by the American National

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[28] Capocci et al., *supra* note 26, at 3.
[29] 2011 Guidelines, *supra* note 5, § 7.10.
[30] The two other organizations are the International Electrotechnical Commission (IEC) and the International Telecommunication Union (ITU).
[31] TERRENCE ROBERT BEAUMONT SANDERS, THE AIMS AND PRINCIPLES OF STANDARDIZATION 18 (1972).

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Standard Institute (ANSI) and is commonly referred to by other national standard developing organizations.[32]

The development of product standards is predominantly private-sector driven.[33] But what is remarkable about this phenomenon is the coexistence of mandatory and voluntary standards, which stems from a complex private–public relationship that blurs organizational boundaries and creates legal ambiguity.[34] This begs the question: Where do standards fit into the hierarchy of the regulatory governance regime? To answer this question, Lindøe and Baram address voluntary "soft" standards as well as regulatory "binding" standards, illustrating the usefulness of both types within a given national framework.[35]

The pyramidal diagram proposed by Lindøe and Baram depicts a transcending pyramidal model with three distinct layers: (1) a "soft" private standards making up the bottom foundational layer (with embedded methodological and behavioral); (2) a middle layer composed of private technical and administrative standards adopted by regulators that forms the compliance regime (this layer is characterized as "authoritative" and therefore, according to authors "constitute *de jure* or *de facto* requirements that must be heeded by the targeted set of private actors");[36] and (3) a top layer entitled "law, orders and regulations" that forms the "command and control" domain comprised of government-mandated regulations.[37]

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[32] National Bureau of Standards, NBS Special Publication 74 (1977).
[33] Eduardo Fosch Villaronga & Angelo Golia, Jr., *Robots, Standards and the Law: Rivalries between Private Standards and Public Policymaking for Robot Governance*, 35 Comput. L. & Sec. Rev. 35, 129–30 (2019); *see* Charles Sabel et al., *Regulation under Uncertainty: The Coevolution of Industry Regulation*, 2 Regul. & Governance 1, 2 (2017); *see also* Maha Salem et al., *Towards Safe and Trustworthy Social Robots: Ethical Challenges and Practical Issues*. International Conference on Social Robotics 584, 589 (Adriana Tapus et al. eds., 2015).
[34] Jean-Christophe Maur & Ben Shepherd, *Product Standards*. Preferential Trade Agreement Policies for Development: A Handbook 197, 199 (Jean-Pierre Chauffour & Jean-Christophe Maur eds., 2011).
[35] Preben H. Lindøe & Michael S. Baram, The Role of Standards in Hard and Soft Approaches 236 (2020).
[36] *Id.*, at 236–37; *see also* Lan Ayres & John Braithwaite, Responsive Regulation 39 (1992).
[37] *N.B.*, the authorities of the "top layer" determine whether the regulatory regime in question will enact hard law or soft law on the subject matter, and depending on that decision, this layer is composed of enacted laws, orders and regulations. Lindøe & Baram, *supra* note 35, at 236–37.

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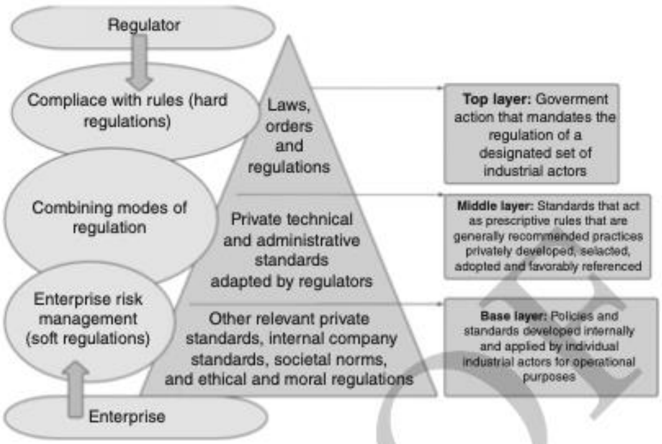

Figure 7.2 "Standards" in the regulatory governance regime.
Source: Adapted from Preben H. Lindøe and Michael S. Baram[38] (used with permission)

This transcending model underlines the importance of standards derived from private-industry forces. Private prompted standards, guidelines and norms serve as external nongovernmental forces paralleling and supporting the regulatory regime (Figure 7.2). Adherence and compliance boost the economic value of those industries while also serving the public interest.[39] Since the public interest is one of the core mandates of government, regulators are encouraged to incorporate international industrial and private standards, whenever applicable, as a means to enhance the efficiency and optimization of the regulatory regime. Capitalizing on industry-based standards developed by both international nonprofit and industry organizations enables member state regulators to maintain a robust regulatory regime as well as maneuver in a landscape that is shared with other stakeholders.[40]

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[38] Preben H. Lindøe & Michael S. Baram, *The Role of Standards in Hard and Soft Approaches to Safety Regulation*. Standardization and Risk Governance: A Multi-disciplinary Approach 236 (Odd Einar Olsen, Kirsten Voigt Juhl, Preben H. Lindøe & Ole Andreas Engen, eds., 2020).
[39] *Id.*, at 239, 250.
[40] *Id.*, at 250.

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7.2.3 *State-of-the-Art International Standards and RAS Integration*

Condition, statutory and classification surveys comprise the typical inspection regime that enable issuance of recommendations for maintenance and repairs during the operational lifetime of a ship. Of the three types, condition surveys are nonperiodic surveys and are generally conducted by surveyors at the request of ship owners, cargo owners, charterers, insurance companies, port state authorities, flag state authorities or P&I clubs to determine the overall condition of the vessel, including the ship's statutory and class certification status. In certain instances, P&I condition surveys can be viewed as a check and balance to surveys performed by class and flag states by revealing deficiencies.[41]

Statutory and classification surveys follow the statutory and class rule requirements (for all ship types), and lead to the issuance of statutory and classification certificates, respectively. For statutory surveys, the scope and intervals are determined by international conventions, codes ratified by flag states, and rules and requirements of flag states and port states. In other words, statutory rules detail stipulations by member states' flag administrations in accordance with international regulations ratified by the flag state. Adherence requires ship owners to obtain certificates attesting compliance with these standards.[42] Until the end of the twentieth century, survey and certification procedures were diffused in a wide range of international instruments. These procedures, although generally sharing a common content and intent, gave rise to nonstandardized survey approaches and dates under the many IMO conventions in force since 1966.[43]

Moving toward a harmonized synchronized method, the IMO's Harmonized System of Survey and Certification (HSSC) has addressed

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[41] Gard, Experiences from Condition Surveys of Bulk Carriers, www.gard.no/web/updates/content/52989/experiences-from-condition-surveys-of-bulk-carriers (last visited Feb. 15, 2022) (online).

[42] It is important to note that "[p]ort state control and flag state inspections cover the statutory requirements. Classification Societies perform most of the surveys based on the statutory requirements and by authorization of a flag state." *See* Sabine Knapp & Philip Hans Franses, Analysis of the Maritime Inspection Regimes: Are Ships Over-inspected? 3 (2016).

[43] *See*, for example, International Convention for the Safety of Life at Sea, 1974, Nov. 1, 1974, 32 U.S.T. 47, 1184 U.N.T.S. 2 (as amended) (hereinafter 1974 SOLAS); International Convention on Load Lines, 1966, Apr. 5, 1966, 18 U.S.T. 1857, 640 U.N.T.S. 133 (as amended) (hereinafter CLL 66/88); International Convention for the Prevention of Pollution from Ships, 1973, Nov. 2, 1973, 34 U.S.T. 3407, 1340 U.N.T.S. 61 (as amended) (MARPOL); International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, Feb. 13, 2004, (IMO, BWM/CONF/36) (BWM Convention).

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future survey procedural matters that have for a considerable period of time resulted in duplication of effort (for individual survey requirements imposed under different conventions for different niche areas of a vessel).[44] Patently, the harmonization objective of the HSSC achieves seamless procedural standards governing inspection and maintenance tasks through a set of uniform surveys that better address various convention requirements.[45] Considering the advanced age of large and very large vessels in the current world fleet, harmonized statutory surveys (periodic survey, intermediate survey, annual survey, underwater inspection of ship's bottom and additional survey) are necessary for effective monitoring to enhance compliance with maritime safety and environmental rules. These harmonized statutory surveys found in the HSSC are accompanied by references to schemes developed by classification societies and are considered to be at the cutting edge of standards in the maritime world.[46] Additionally, ISO standards on service robot performance developed by the ISO/TC 299 Technical Committee on Robotics establishes international standards for the determination of performance criteria that contain technical specifications as well as operational procedures.[47] Those ISO standards are primarily developed taking into account indoor environments, and therefore do not apply to verification or validation of environmental or safety requirements.[48] As such, the discussion on ISO standards is left outside the scope of this section.

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[44] The first "Global and Uniform Implementation of the Harmonized System of Survey and Certification" adopted by the IMO entered into force on February 4, 2000. In 2019, the 2017 HSSC was amended and updated to reflect amendments to the BWM Convention, MARPOL and 1974 SOLAS. No survey-specific changes were made during the amendment. The amendments are set out in annex XX to IMO Document III 6/15. International Maritime Organization Res. A.1120(30) (Dec. 6, 2017) (as amended) (Survey Guidelines under the Harmonized System of Survey and Certification, 2017).

[45] *N.B.* HSSC is an attempt to unify survey requirements under mandatory conventions including 1974 SOLAS. *See also* International Maritime Organization Res. 1049(27) (Nov. 30, 2011) (International Code on the Enhanced Programme of Inspections during Surveys of Bulk Carriers and Oil Tankers, 2011).

[46] HSSC, *supra* note 43, §§ 4.3.2.2, 5.9.2, annex 1.

[47] With reference to ISO 18646-1:2016 (Robotics – Performance Criteria and Related Test Methods for Service Robots – Part 1: Locomotion for Wheeled Robots); ISO 18646-2:2019 (Robotics – Performance Criteria and Related Test Methods for Service Robots – Part 2: Navigation) etc. developed by the ISO/TC 299 Technical Committee.

[48] International Standards Organization, *Robotics: Performance Criteria and Related Test Methods for Service Robots*, www.iso.org/committee/5915511/x/catalogue/p/1/u/0/w/0/d/0 (last visited Dec. 20, 2020) (online).

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Here, it is important to note that in this discussion on state-of-the-art, the role of classification society surfaces for two obvious reasons. First, many flag administrations are not equipped with the adequate technical, experience, resources or the broad international coverage necessary to meet the international survey requirements.[49] To this end, international conventions, such as SOLAS and CLL 66/88 have deferred to ROs to assist those administrations in the much-needed statutory surveys to comply with the objectives set by the IMO.[50] However, any attempt to narrow the role of classification societies to just "survey assistance" is likely to undermine their positive and multifaceted influence in the "cradle-to-grave" concept of the world commercial fleet. Classification rules developed by classification societies are of paramount importance with respect to design plans, construction, sea trials and other trials – all of which are key building blocks of the maritime environment and safety regime.[51]

The second reason for referencing the work of classification societies is the significance of existing promulgated rules (i.e., bulk carrier structural rules, detailed standards rule on how to perform hull surveys and, most importantly, the manner in which these rules encompass the operational procedures for RAS integrated inspections). The work of the International Association of Classification Societies (IACS) is noteworthy as a prominent group composed of the "big 12."[52] The IACS Unified Requirements (URs) on survey and certification are supplemented

[49] Sean M. Holt, *Class Survey: A Former Surveyor Looks at the Origins and Current Status of Classification Societies*, Maritime Exec., July 30, 2017.

[50] Id. *N.B.* This includes conducting "minimum two inspections of the outside of the outside of the ship's bottom during any five-year period (*see* 5.7), except where SOLAS 74/88, regulation I/14(e) or (f) is applicable. One such inspection should be carried out on or after the fourth annual survey in conjunction with the renewal of the Cargo Ship Safety Construction Certificate or the Cargo Ship Safety Certificate." *See* HSSC, *supra* note 43, § 4.6.1.

[51] Classification societies serve two distinct roles. The public role is assumed as an IMO RO, and the private role is assumed when conducting inspections on behalf of the ship owner. International Association of Classification Societies, Classification Societies: What, Why and How? www.iacs.org.uk/media/7425/classification-what-why-how.pdf, at 5 (last visited Sept. 20, 2020) (online); *see* International Maritime Organization Res. MEPC.2385(65) (May 17, 2013) (amendments to the annex of the Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships); International Maritime Organization Res. MSC.350(92) (June 21, 2013) (amendments to SOLAS 74/88); International Maritime Organization Res. MSC.349(92), pt.1 §§ 2.4–2.5 (June 21, 2013) (Code for Recognized Organizations).

[52] Lloyd's Register (LR), American Bureau of Shipping (ABS), Bureau Veritas (BV), China Classification Society (CCS), Croatian Register of Shipping (CRS), Det Norske Veritas (DNV), Korean Register (KR), Nippon Kaiji Kyokai (NK), Registro Italiano Navale

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by a number of recommendations in the form of guidelines coupled with twenty-six documents amalgamated under the label of UR Z family-of-requirements.[53] Briefly stated, the UR Z requirements are seen as a positive reflection on the IACS's expertise in advanced detailed requirements and recommended procedures for hull surveys designed to identify structural defects or corrosion that might compromise a ship's structural integrity, inter alia.[54]

The UR Z7 titled *Hull Classification Surveys* is most relevant as it supports intervention procedures for special surveys, annual surveys and intermediate surveys, which are aligned with the IMO's HSSC requirements.[55] An examination of the different sections of UR Z7 reveals attention to detail. For example, section 1.4 stresses that all subsequent surveys following repairs should include taking thickness measurements of structures in specific areas where close-up survey is required.[56] Other useful standards include precise guidelines for hull inspection and maintenance, elaborately explained in the texts of several UR Z, including Z7.1, Z7.2, Z10.2, Z10.4, Z10.5, Z13 and Z16.

In terms of RAS procedural recommendations, IACS Recommendation 42 titled *Guidelines for Use of Remote Inspection Techniques for Surveys* sets the stage for acceptable remote inspection techniques (RITs) via RAS platforms that are followed by specific conditions and procedures that need to be considered in the survey process.[57] Recent literature published by Laura Poggi et al. considers the incorporation of a group-based non-exhaustive list of RITs as a positive attribute of Recommendation 42.[58] For example, while technologies under "drone" category could be used for visual examination during flight-mode, and even enable visual inspection

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(RINA), Polish Register of Shipping (PRS), Indian Register of Shipping (IRS), and the Russian Maritime Register of Shipping (RMS).

53 International Association of Classification Societies, Requirements Concerning Survey and Certification, International Association of Classification Societies (2017).

54 *Id.*

55 *N.B.* A special survey is one that is carried out every five years for renewal of Classification Certificate.*Id.*,at 13, 19.

56 *Id.*, at 51.

57 International Association of Classification Societies, Recommendation 42 Guidelines for Use of Remote Inspection Techniques for Surveys § 1.1 (2016) ("Remote inspection techniques may include the use of: - Divers; - Unmanned robot arm; - Remote Operated Vehicles (ROV); - Climbers; - Drones; and - Other means acceptable to the Society") (Recommendation 42).

58 Laura Poggi et al., *Recent Developments in Remote Inspection of Ship Structures*, 12 Int'l J. of Naval Architecture & Ocean Eng'g 881, 882 (2020).

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in enclosed spaces, such as, ballast tanks and cargo holds, "crawlers" would have the capability of inspecting structures through direct contact with the structure.[59] As per Recommendation 42, survey results via RAS could be obtained through the performance of two tasks: close-up surveys and gauging.[60] In addition to close-up surveys and gauging, Recommendation 42 prescribes that "means thickness-gauging and non-destructive testing could be required in conjunction" with the use of RIT.[61] As a follow-up to these RAS tasks, and should the RIT reveal damage or deterioration requiring attention, the surveyor is prescribed to conduct another close-up survey to verify the results obtained through the RAS platform as a part of the monitoring and compliance system.[62]

Invaluable standards in relation to procedures corresponding to interventions utilizing RAS can be found in UR Z17 titled *Procedural Requirements for Service Suppliers*.[63] As of 2019, twelve classification societies have implemented UR Z17 (which came into effect as of July 1, 2020) and considered tacit acceptance of the procedural standards developed by IACS.[64] It is important to note that procedural standards under UR Z17 primarily govern the approval and certification processes of service suppliers that provide a *broad* range of services of practical value.[65] This includes both statutory and classification services provided by firms that carry out "in-water survey on ships, mobile offshore units by divers or remotely operated vehicles," as well as firms that engage in "thickness measurement using RITs as an alternative means for close-up survey of the structure of the ships."[66]

As a part of the general procedure, UR Z17 emphasizes that the service provider needs to be approved by the concerned society prior to operations, especially in instances where the surveyor of the society uses the results provided by the service provider to reach decisions affecting both

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59 *Id.*
60 Recommendation 42, *supra* note 56, § 1.2.
61 *Id.*, § 3.2.
62 *Id.*, § 1.2.
63 International Association of Classification Societies, Z17: Procedural Requirements for Service Suppliers (online) (hereinafter UR Z17).
64 UR Z17 has been implemented by the CRS, PRS and the IRS as well as nine out of the ten members of IACS: LR, ABS, BV, CCS, DNV, KR, NK, RINA and RMS. International Association of Classification Societies, Unified Requirements, www.iacs.org.uk/publications/unified-requirements/ (last visited Sept. 21, 2020) (online).
65 UR Z17, *supra* note 62.
66 *Id.*, § 4.12.

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classification and statutory services.[67] The approval and certification procedure entails submission of an exhaustive list of documents outlined in section 5.1.1 of UR Z17. Subsequent to approval, the service supplier should maintain the "general requirements" on training and demonstrate competence of the "human element" comprised of operator, technical personnel and inspector.[68] Data control is an important aspect covered under the general requirements to the extent that service suppliers are under an obligation to demonstrate the ability of computer software used for the "acquisition, processing, recording, reporting, storage, measurement assessment, and monitoring of data".[69] With a view to ensuring good-quality services provided by suppliers, UR Z17 prescribes the maintenance of a documented system covering codes of conduct for: maintenance and calibration of equipment; training programs for operators, technicians and inspectors; supervision and verification to ensure compliance with operational procedures; and recording or reporting of information.[70]

Under the UR Z17 procedural requirements, the scope of engagement for firms or service suppliers using ROVs is limited to in-water survey and/or internal hull survey of compartments filled with water.[71] As the title indicates, the main objective of section 3 of annex I is to govern surveys using ROVs should the ship owner seek an alternative to a dive-survey. The requirements found in this part of annex I can be classified into seven principal building blocks that range from procedures governing the human element, to procedures covering reporting and verification of results. With regard to the human element, important criteria for ROV requisite supervisors and ROV operators is a minimum two-years and one-year experience, respectively, in know-how on handling ROVs.[72] When maneuvering equipment (outlined in section 3.6.1), the service supplier has an explicit obligation to follow documented operational procedures and guidelines with reference to: "guidance for the operation and maintenance of the ROV, if applicable, and methods and equipment to ensure the ROV operator can determine the ROV's

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67 *Id.*, §§ 4.3–4.4.
68 *Id.*, § 5.2.
69 *Id.*, § 5.2.6.
70 *Id.* §§ 5.5.1, 2.1 (defining "service supplier").
71 *Id.*, § 3.1.
72 *Id.*, §§ 3.4.1, 3.5.2.

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location and orientation in relation to the vessel."[73] In doing so, ROV operators must have knowledge of inter alia the ship's underwater structure, nondestructive testing in accordance with recognized national or international industrial standards, underwater communication system and bearing clearance measurements. Postoperation provisions include documentation of results in the form of a report produced by the firm or supplier followed by verification and signature of the attending surveyor.[74]

Finally, provisions for using RIT applications in close-up surveys of a ship's structure rest in a distinct section under annex I of UR Z17. Section 16 of annex I is dedicated to procedural and operational requirements and is deemed as a theoretical extension of IACS Recommendation 42. In theory, a close-up survey is an examination "where the details of structural components are within the close visual inspection range of the surveyor" and is an integral formality satisfied, if required, during annual, intermediate and special (or renewal) surveys for detecting fractures, buckling, substantial corrosion and other types of structural deterioration.[75] Accordingly, a close-up survey may be performed in association with thickness measurements.[76] The extent of a close-up survey may also serve as an additional task, which could be determined after completion of the overall examination on the hull structure.[77]

Traditionally, the agenda for close-up surveys are included in a planning document alongside other particulars and conducted via physical access in selected holds and tanks of the ship under survey.[78] Within the same operational framework, RITs are now integrated into IACS international standards to serve as *alternatives* that come with an obligation to provide information that one would generally obtain from a close-up survey through physical access.

Focusing on the human element, UR Z17 prescribes requirements to be satisfied by the supplier. These include training and qualification of operators, practical work experiences for supervisor and operator,

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[73] *Id.*, § 3.7.2.
[74] *Id.*, § 3.8.
[75] *Id.*, § 1.4.1.
[76] *Id.*
[77] International Association of Classification Societies, Recommendation 76: IACS Guidelines for Surveys, Assessment and Repair of Hull Structure § 3.2.1 (2008).
[78] *Id.*, at 15, § 4.3.4.

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documented procedures and guidelines containing planning preliminaries (plan), operational specifics (handling/operating equipment) and postoperational requirements (collection and storage of data).[79] Similar to section 3 of annex I, section 16 of annex I concludes with a verification clause whereby the supplier is under a procedural duty to have the surveyor's verification for each job that is conducted using one or more of the RITs referred to in section 16.1.[80]

The permissible limits of RAS application are succinctly embedded within the international standards. The work of IACS in developing international standards for survey and maintenance, and the functional integration of RAS into the survey agenda is commendable because of the pragmatic benefits. As rightly noted by Laura Poggi et al., the many recommendations issued by IACS over the years is a glimpse into the perplexities of on-board surveys that anticipate "a series of preventive operations" for allowing safe entrance into spaces and "reaching significant heights and inaccessible zones." These tasks translate into an "increase in risks, time and costs of inspection."[81] However, when analyzing UR Z17 requirements against individual classification society rules, there appear to be limitations in the international standards set by IACS. While the basic instructive building blocks for using ROVs in in-water surveys and RITs for close-up surveys are visible, UR Z17 neither covers the safety details, such as risk management system and safety assurance, nor the "third-party liability" clause. Those are important segments that require meaningful coverage given that IACS now allows the integration of RAS technologies – all of which require individual safety and liability considerations.

Notably, a majority of the provisions found in sections 3 and 16 of annex I of UR Z17 are focused on ROVs that are maneuverable underwater machines or tethered submersibles.[82] With the caveat that suppliers should have documented operational and procedural guidelines, UR Z17 supplements a handful of UAV-related requirements spread across section 16 of annex I in a brief manner. Clearly, the features related to RITs for RAS operating on water surfaces or underwater differ from unmanned aerial vehicles (UAVs) and require a proper delineation

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[79] UR Z17, *supra* note 62, § 16.8.
[80] *Id.*, at 40, § 16.8.
[81] Poggi et al., *supra* note 57, at 881.
[82] Robert D. Christ & Robert L. Wernli, Sr., The ROV Manual: A User Guide for Remotely Operated Vehicles 53–54, 536–45 (2d. ed. 2014).

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of procedural and operational guidance in a more organized fashion. Significantly, section 16.1 incorporates two separate terms, "drones" and "UAVs," under the overarching definition of "remote inspection techniques," creating confusion by raising the question as to the differences between those two technologies.

Moving forward, individual classification societies have developed individual guidance notes that serve as best practice for class surveys requiring the use of UAVs.[83] These individual efforts also cover in scope robotic crawlers or magnetic crawlers that are "tethered or wireless vehicles designed to 'crawl' along a structure by means of wheels or tracks," and have the technical capacities to operate both in the air and underwater.[84] Nevertheless, in developing recommendation and requirements, classification societies consider the three basic international standards, IACS Recommendation 42, UR Z7 and UR Z17.[85]

7.3 Perceived Barriers and the Way Forward

Achieving regulatory excellence is complex and difficult. For success, four distinct but interrelated constraints must be addressed: (1) the intrinsic, specific and unique architecture requiring regulation; (2) the social norms surrounding the subject matter; (3) the rules of the market; and (4) the law.[86] Lessig views these four elements as regulatory blocks. The law stands out as the most readily available and has the most influence on the other three.[87] Further complications achieving RAS regulatory excellence is the plurality of existing laws in the form of class rules corresponding to RAS statutory standards, published by IACS, as

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[83] *E.g.*, American Bureau of Shipping, Guidance Notes on Using Unmanned Aerial Vehicles (2018); China Classification Society, Guidelines for Use of Unmanned Aerial Vehicles for Survey (2018); *see also* Germanischer Lloyd Aktiengesellschaft, Rules for Classification and Construction (2009). Also note that Germanischer Lloyd Aktiengesellschaft has gone further by developing rules on the design and construction of ROVs and AUVs. Those comprise the technical requirements, which are not covered by IACS.

[84] American Bureau of Shipping, Guidance Notes on the Use of Remote Inspection Technologies (2019).

[85] *Id.*, at ii.

[86] Bridget M. Hutter, *A Risk Regulation Perspective on Regulatory Excellence*. Achieving Regulatory Excellence 101–04 (Cary Coglianese ed., 2016); *see* Lawrence Lessig, Code: And Other Laws of Cyberspace, Version 2.0, at 124 (2006).

[87] Lessig, *supra* note 85, at 124.

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well as those of individual classification societies. While UR Z17 could be viewed as a concrete step toward harmonization of operational procedures for outer hull inspection and maintenance, it is noteworthy that there are no rules that bar other societies outside the "big 12" from developing their own class rules. In fact, that is the tradition for both IACS members and non-IACS members, resulting in numerous subject matter documents.

The development of de facto standards is not universally considered desirable and there is a school of thought that notes the negative impact of standards on innovation.[88] This perspective underscores four characteristic features (of standards) to show the casual nexus between *standards* and *innovation* that can result in both positive and negative effects.[89] Of the four noteworthy features, "variety" is deemed casual to negative effects on innovation by reducing choice, deterring market concentration and promoting premature selection of technologies.[90] Therefore, the reduction of variety allows the exploitation of economies of scale.[91] However, the reality of maritime RAS technologies is one of continuous innovation that enables manufacturers and service providers to table dozens of products able to perform the same tasks for an end-user's convenience.

Companies are introducing leading-edge dual-purpose service drones that include aerial inspection micro drones and drones with depth sensing. Depending on the size of the vessel, these drones can measure defects such as metal corrosion, metal erosion, wear and tear and even design flaws. The same trend can be observed in other professional service robots such as magnetic crawlers and ROVs. A methodology to establish standards based on product categorization could reduce variety and thereby serve as a foundation to guide future technology *without inhibiting innovation.*[92] Technological innovation therefore should not be hindered from setting standards because they can guide the standards and attract investment in complementary technologies.[93] This barrier

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[88] Knut Blind, The Impacts of Standardization and Standards on Innovation 10 (2013).
[89] *Id.*, table 2.
[90] The four features are: compatibility/interoperability, minimum quality/safety, variety reduction and information. *See id.*
[91] G. M. Peter Swann, The Economics of Standardization 6 (2000).
[92] *Id.*, at 7. *N.B.* UR Z17 does not cover operational and safety procedures for drones and other means for inspection and cleaning tasks, as indicated in the list found in IACS Recommendation 42.
[93] Blind, *supra* note 88, at 9.

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would greatly be reduced by revising UR Z17, which references only a single professional service robot (i.e., ROVs). Further discussion among IACS members is warranted with due consideration given to other types of standard equipment found in IACS Recommendation 42.[94] This process would promote development of safety requirements for other categories of service robotic products that could added to UR Z17 alongside existing ROV requirements.

At present, biofouling hazards and future concepts are already covered under IMO's 2011 Guidelines as well as in the harmonized HSSC rules. Using IMO requirements as a basis, IACS developed class rules that embrace RAS and characterizes the organization as forward-thinking. Despite differences in strategic direction, there is some alignment between relevant IMO provisions and UR Z17 standards. For example, both IMO and IACS endorse the usage of divers and ROVs for outer hull in-water survey. The principal thread that helps align the two is section 7.4 of the 2011 Guidelines.[95] Yet this section remains inadequate, as ROVs are not the only marketed equipment that has the potential to perform hull surveys on bulk carriers. Bureau Veritas reportedly has already conducted the first close-up inspections and ultrasonic thickness measurements via aerial drones, confirming that this type of professional service robot is mature.[96] Accordingly, section 7.4 of the *2011 Guidelines* needs to remain open-ended to ensure there is no ambiguity.

Regulatory symmetry between IMO standard recommendations and IACS requirements could be achieved by incorporating the term "remote inspection technique" in the text of section 7.4. Moreover, considering that RAS emerges as an alternative to physical access to structures, an amendment should be directed at aligning the definition of close-up survey found in the international code on the enhanced program of inspections during surveys of bulk carriers and oil tankers (2011 ESP Code) after consultation between IMO and IACS.[97] As a recognized technical advisor body within the framework of IMO, IACS is in privileged position to facilitate dialogue, such as on the types of technologies

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[94] Recommendation 42, *supra* note 56, § 1.1.
[95] *See* 2011 Guidelines, *supra* note 5, § 7.4 (permitting usage of both "diver" and "ROV," both of which are recognized by IACS for in-water inspection).
[96] Bureau Veritas, Press Release, Seeing Remotely: Bureau Veritas Performs First Survey by Drone (Mar. 4, 2020).
[97] Poggi et al., *supra* note 57, at 883.

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permitted by the IMO and performance evaluation schemes for regulators.

Establishing a solid international foundation would ensure professional service robots are categorized by either the level of control or the level of autonomy. RAS experts envision a future where the different operational modes of service robots will rest on autonomous systems (i.e., a system capable of making decisions by direct interaction with the environment). Although outside the present scope of service robots, the IMO Maritime Safety Committee (MSC) is conducting a regulatory scoping exercise for a maritime autonomous surface ship (MASS), defined as: "a ship which, to a varying degree, can operate independently of human interaction."[98] As a first step in this scoping exercise, experts have adopted four degrees of autonomy:

- First degree: A ship with automated processes and decision support
- Second degree: A remotely controlled ship with seafarers on board
- Third degree: A remotely controlled ships without seafarers on board
- Fourth degree: A fully autonomous ship[99]

Although the current RAS control paradigm adopted for professional service robots is supervised autonomy, experts are exploring the full potential of the current system that may evolve into unmanned autonomy.[100] Recalling the supportive role of IACS in IMO's MASS scoping exercise, it would be beneficial to include categorized equipment or equipment classified according to autonomy (taking into account the levels of autonomy for RAS platforms endorsed by IACS). This classification highlights the level of complexity of the individual tasks (inspection/cleaning/maintenance) required by the control platform and informs the precise levels where human intervention might be required. An analysis of the five types of equipment found in IACS Recommendation 42 raises the question: What are the risks of deploying an "unmanned robot arm" or "ROV" or "drones" in the close-up survey process? Clearly, the use of an "unmanned" platform for inspecting a ship's bottom cannot be deemed as semiautonomous given that it is a not

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[98] International Maritime Organization, Press Release, IMO Takes First Steps to Address Autonomous Ships (May 25, 2018).
[99] International Maritime Organization Res. MSC 100/20/Add.1, annex 2 (Dec. 7, 2018) (Framework for the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships).
[100] Lloyd's Register, UNMANNED MARINE SYSTEMS CODE 1–2 (2017).

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a "system that can be operated without personnel."[101] But as full autonomy is on the horizon, further work is required to comprehend risks of AI-based interventions. In short, the essential issue that needs to be addressed by IACS is the risk factor connected with different degrees of autonomy in light of the control paradigms, similar to the scoping exercise conducted by IMO.

Collateral safety standards for all of the different inspection and maintenance RAS product types are also an important factor. Product safety standards are intrinsically related to the product information sheet (PIS) that covers technical or engineering specifications for every product. All products are prone, to some degree, to defects or technical glitches. For service providers, design defects and manufacturing defects could invoke liability (because in-water surveys are statutory in nature).[102] In the long run, this issue complicates the relationship between ship owners and charter parties.[103] This type of defective product liability is separate from the liability regime governing the relationship between a buyer and seller in sales *of goods*. Rather, the international liability seeks to rationalize regional and national laws governing manufacturer liability and consumer protection, as in Product Liability Directive 85/374/EEC.[104]

Professional service robots endorsed by the UR Z and individual classification societies are labeled "equipment" – a term that is synonymous with "product."[105] Each component that goes into making a product needs to be of high quality, especially the ones that are marketed for services involving RITs that are statutory in nature. The quality of those components needs to be assured at the design and manufacturing level. In product liability cases arising in the automotive sector, courts take into account quality and design defects.[106] Therefore, developing the basic PIS

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101 *Id.*, at 3.
102 Woodrow Barfield, *Liability for Autonomous and Artificially Intelligent Robots*, 9 Paladyn: J. of Behav. Robotics 193, 196 (2018).
103 Julie Mangiante, Hull Fouling Clauses and Prolonged Stays, Skuld, Dec. 18, 2019.
104 Council Directive 85/374/EEC, art. 6(1), 1985 O.J. (L 210) 29, 31 (EC).
105 From a manufacturer's perspective, robots are products manufactured through an action or a process and refined for sale.
106 With reference to the automotive sector, Professor Bertolini stresses that "different standards of safety required from products can – at least in part – be determined by decisions of specific bodies, called upon to define the characteristic a given object needs to present . . . [s]uch criteria are normally taken into account by the courts." *See* Andrea Bertolini, *Robots as Products: The Case for a Realistic Analysis of Robotic Applications and Liability Rules*, 5 L. Innovation & Tech. 214, 241 (2013).

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standards specifying the quality of individual components could help manufacturers not only address defects at the design level, but could also prove to be a strong legal defense. Yet UR Z17 does not contain PIS standards. This also holds true for guidance documents produced by classification societies, although organizations such as the China Classification Society and the American Bureau of Shipping (ABS) have made commendable efforts to provide detailed recommendations on equipment standards. There is, however, a regulatory vacuum at the international level with the potential to leave both ship owners and service providers without a safety net. The way forward is not easy. The development of international PIS standards requires a technical mandate. Prima facie, the scope of this work falls under the mandate of ISO/TC 299. Taking this mandate into account, a joint collaboration among IACS, ISO and product manufacturers could develop performance criteria and PIS standards for professional service robots. The result would be valuable and help professional service robots synchronize with the regional and national product liability regime.

Finally, matters related to data storage or data preservation requires special attention lest they create legal concerns on data protection. Image and data gathering tasks are accomplished through machine learning, sensors and algorithms. Once the tasks are completed, the operator shall then deliver those images and data in a format acceptable to the attending surveyor, and survey reports are submitted to the classification society for certification.[107] This process is governed by a contractual agreement between ship owners and service providers or ship owners and a classification society. However, IACS as well as many of the "big 12" classification societies are silent on post data acquisition steps. This could later prove problematic from a data privacy perspective.[108]

In due course, further questions will require clarification in consultation with ship owners. Who is responsible for data and image preservation? How long should survey data and image be preserved? What protection do service providers require against third-party liability? How could classification societies complement regional and national laws on end-user data privacy?

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[107] This process is clearly laid out in guidance documents issued by classification societies. *See, e.g.*, American Bureau of Shipping, *supra* note 83, at 18; *see also* China Classification Society, *supra* note 82, at 17.

[108] This has been confirmed in an interview conducted with a service provider company known as Diving Status.

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7.3.1 Implications for the Law of the Sea

The forgoing issues raise two distinctly different strands of analysis – the legal status of professional service robots in the United Nations Convention on the Law of the Sea (UNCLOS) and the affect harmonized standards governing new technology may have on the treaty.

Part XIII of UNCLOS concerns "marine scientific research" (MSR).[109] Although MSR is undefined in the texts of part XIII, the term is important to protect the marine environment.[110] Assessment of data sets gathered through surveys acquired via technology is included in MSR. Examples of this are ripe in ocean research: the surveying of the ocean floor by submarines; ocean data collection with the help of floaters and gliders launched by ships or planes; and sensor-based platforms incorporating advanced modeling systems that gather highly complex data sets. Historically, the greater portion of MSR has been moored to areas under national jurisdiction, underscoring the importance of the "consent" regime.[111] Coastal state competence is sometimes unclear, such as whether the legal status of gliders and floaters constitute "operational oceanography."[112] Fortunately, however, the equipment used in vessel inspection and maintenance, while arguably within the ambit of MSR, are generally deployed when the vessel is berthed, anchored or dry-docked within internal waters.[113]

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109 *See* United Nations Convention on the Law of the Sea pt. XIII, Dec. 10, 1982, 1833 U.N.T.S. 397 (UNCLOS). MSR is "any study or related experimental work designed to increase man's knowledge of the marine environment." Alfred H. A. Soons, Marine Scientific Research and the Law of the Sea 6 (1982).

110 Tara Davenport, *Submarine Communications Cables and Science: A New Frontier in Ocean Governance?* Science, Technology and New Challenges to Ocean Law 226 (Harry N. Scheiber, James Kraska & Moon-Sang Kwon eds., 2015); *see* Soons, *supra* note 109, at 14. *See also* Tafsir Johansson, Ronan Long & Dimitrios Dalaklis, *The Role of WMU-Sasakawa Global Ocean Institute in the Era of Big Data*, 14 J. of Ocean Tech. 22, 28–29 (2019).

111 James Kraska et al., *Bio-logging of Marine Migratory Species in the Law of the Sea*, 51 Marine Pol'y 394, 399 (2015).

112 Tobias Hofman & Alexander Proelss, *The Operation of Gliders under the International Law of the Sea*, 46 Ocean Dev. & Int'l L. 167, 168 (2015); *see also* Katharina Bork et al., *The Legal Regulation of Floats and Gliders: In Quest of a New Regime?* 39 Ocean Dev. & Int'l L. 298, 307, 311 (2008).

113 For operation of UAVs beyond twelve nautical miles or the territorial sea, it is important to observe the civil aviation rules. *See* Sean T. Pribyl, *Regulating Drones in Maritime and Energy Sectors*. Handbook of Unmanned Aerial Vehicles 1, 14 (Kimon P. Valavanis & George J. Vachtsevanos eds., 2018).

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Ronán Long has noted that from a human rights perspective, technology is a tool that can be used to improve compliance with law and policy.[114] Could technology help improve compliance with safety law and policy? The answer is contingent on the intended purpose of deploying such technology and the benchmarking of performance over a defined period. "Intentionality" occurs when operational objectives become aligned with international objectives. Whether compliance improves can only be determined by comparing vessel performance and energy efficiency levels between two bulk carriers: one that has been surveyed and maintained manually with one that has used service robots. Until such a comparison has been conducted, the use of new technology should not disrupt the duties and obligations in international law.

International safety standards could not be clearer. The flag state must take necessary measures under UNCLOS for ensuring "safety at sea." Article 94 of UNCLOS provides a detailed but nonexhaustive list of flag state responsibilities, including construction and seaworthiness.[115] The integration of professional service robots into the survey and maintenance aspects of article 94 are subject to the same, if not higher, expectations.

Writing, sensing and shaping are subset indicators of intentionality or terraforming practices that continuously shape and structure the desired environment.[116] Published standards form a part of the writing "subset" and are rooted in the governing dynamics of "environing technology."[117] Therefore, both normative published international technology-based standards and informative detailing RAS procedures impact the modern technological environment. Equipment endorsed by the IMO and classification societies is deployed with clear and precise objectives. The regional and national objectives are deeply ingrained in the environmental objectives of UNCLOS. This bolsters support for the proposition that UNCLOS promotes the application of international harmonized

114 Ronán Long, *A European Law Perspective: Science, Technology, and New Challenges to Ocean Law*, Science, Technology and New Challenges to Ocean Law 63, 78 (Harry N. Scheiber, James Kraska & Moon-Sang Kwon eds., 2015).

115 *See* UNCLOS, *supra* note 108, art. 94(3).

116 Sverker Sörlin & Nina Wombs, *Environing Technologies: A Theory of Making Environment*, 34 Hist. & Tech. 101, 105–08 (2018).

117 "[O]ften these technologies are also connected to writing, as documenting is intrinsic to many activities, especially those which are circulated in society and over time. UNCLOS or the IPCC Fifth Assessment Report are examples of writing (documents) that environ." *See id.*, at 7.

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standards on niche technologies, supporting the second strand of this discussion.

Shipping is intrinsically a global enterprise and is therefore best regulated at the international level. Currently, the maritime international regime is "based on two interdependent bodies consisting of an umbrella framework formed by customary law, UNCLOS, and Chapter 17 of Agenda 21, and a regulatory regime consisting of instruments adopted by the member states of the IMO."[118] The *Code for the Implementation of Mandatory IMO instruments* is a bridge to connect this "interdependency," requesting flag state administrations to give UNCLOS and IMO instruments "full and complete effect" to ensure that "a ship is fit for the service for which it is intended."[119]

Part XII of UNCLOS sets forth an obligation for member states to take all measures to prevent pollution of the marine environment from any source. In this endeavor, states shall use the "best practicable means at their disposal and in accordance with their capabilities."[120] Pollution prevention measures under part XII should ideally include all potential sources including "pollution from vessels" by regulating "design, construction, equipment," inter alia.[121] Part XII establishes a global and regional cooperation regime with reference to "competent international organizations" to facilitate development of "international rules" consistent with UNCLOS.[122]

General accepted international rules and standards (GAIRS) fits within the UNCLOS framework as a legal mechanism for safeguarding the marine environment.[123] GAIRS are the gateway to synergistic integration with other international treaties and agreements, allowing "new concepts, such as precaution and biodiversity to become part of UNCLOS normative structure."[124] GAIRS embraces standards developed by competent

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118 Proshanto Kumar Mukherjee & Abhinayan Basu Bal, The Status of International and Regional Conventions Relating to Ship Source Marine Pollution in States in the Baltic Region 8 (2011).
119 International Maritime Organization Res. A.973(24), § 4 (Dec. 1, 2005) (Code for the Implementation of Mandatory IMO Instruments).
120 UNCLOS, *supra* note 108, art. 194(1).
121 *Id.*, art. 194(3).
122 *Id.*, art. 197.
123 *See Id.*, arts. 21(2), (4); 39(2)(a)–(b); 41(3); 53(8); 60(3),(5), (6); 94(2)(a); 94(5); 211(2), (5), (6)(c); 226(1)(a); 271.
124 Richard Barnes, *The Continuing Validity of UNCLOS.* The United Nations Convention on the Law of the Sea: A Living Instrument 459, 472 (Jill Barrett & Richard Barnes eds., 2016), *citing* David Freestone, *International Fisheries Law*

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international organizations compatible with the scope, intent and objectives of UNCLOS. This rule of reference is spread across a number of articles throughout UNCLOS, including article 211, pollution from vessels, which is an implicit reference for cooperation through the IMO.[125] Moreover, article 237 adopts an approach of "openness and complementarity" to all other regimes with respect to protection of the marine environment.[126] Thereby, the rules of reference via GAIRS not only offer consistency with IMO regulatory instruments but also includes IMO ROs and their rules and requirements. Conversely, through their respective functions, classification society standards complement the rules of IMO, which in turn ensures the effective and efficient implementation of environmental provisions of UNCLOS.

7.4 Conclusion

The most obvious manifestation behind the surge in the use of professional service robots for survey and maintenance of niche areas embodies is the same as the use of autonomous vessels more generally: enhanced performance maintaining world-class safety and environmental standards. There are promising prospects for integrating RAS into niche areas that have been traditionally accessed through physical presence. Whether or not there will be universal consensus to replace

Since Rio: The Continued Rise of the Precautionary Principle. International Law and Sustainable Development: Past Achievements and Future Challenges 135 (Alan Boyle & David Freestone eds., 1999).

125 This is reflected in numerous provisions of UNCLOS that require states to "take account of," "conform to," "give effect to" or "implement" the relevant international rules and standards developed by or through the "competent international organization" (*e.g.*, IMO). *See, e.g.*, UNCLOS, *supra* note 108, arts. 22; 39; 41(4)–(5); 53(9); 60(3), (5); 61(2), (5); 119(2); 197–202; 204–05; 207(4); 208(5); 210(3); 211(1)–(6); 212–14; 216; 217(1), (4), (7); 218(1); 220(7); 222–23; 238–39; 242–44(2); 246(3), (5), (5)(d); 248–49; 251–53 (1)(b), (4), (5); 254(1)–(4); 256–57; 262–63(3); 265; 266(1); 268–273; 275(1)–(2); 276(1); 278; 297(1)(c); 319(2)(a); *see also* Report of the Secretariate of the International Maritime Organization, Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization, U.N. Doc. LEG/MICS.8, at 8 (Jan. 8, 2014); Agustin Blanco-Bazan, *The Environmental UNCLOS and the Work of IMO in the Field of Prevention of Pollution from Vessels*. International Maritime Environmental Law, Institutions, Implementation and Innovations 31, 32–37 (Andree Kirchner et al. eds., 2003).

126 Seline Trevisanut et al., *Introduction*. Regime Interaction in Ocean Governance: Problems, Theories and Methods 1, 12 (Seline Trevisanut et al. eds., 2020).

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traditional human-centric techniques with RAS, the demand for remote services will only increase, highlighting the need for harmonized rules.[127] Under the auspices of IACS, a governance framework has emerged for both manufacturers and service providers that will harmonize RAS within the maritime industry. Discussions segue into the world of international technology-based standards and raise questions about robustness in the face of product variety, better performance and improved compliance.

Analysis of current technology-based standards for in-water survey and maintenance indicate that they are spatially uneven. In fact, IACS RAS integrated standards as a whole tend to be inadequate compared to the standards developed by IACS members, such as, ABS, Lloyd's Register (LR), Korean Register (KR) and Det Norske Veritas (DNV). Management of change system (by LR, BV, ABS and KR), certifying multisite organizations (by ABS), approval database (by LR), safety management system (by ABS), liability (by ABS), and reporting and data storage (by DNV) are the noteworthy provisions that are covered by individual IACS members.

Gray areas pertaining to operational and technical information likely will hamper integration of technology into the class survey and maintenance regime. To remove those barriers, constructive dialogue is required among the "big 12" and other classification societies. Attention must be drawn to the discrepancies delineated to move forward with the necessary harmonizing of the plethora of existing advisory documents issued by individual classification societies.

Classification societies need to coordinate strategic efforts to standardize the technical and engineering specifications for all equipment approved for conducting inspection and maintenance of a vessels structure. The existing operational procedures, risk-management assessments and new provisions (including product technical specifications should those be developed) should then be added as a subset IACS requirement titled Z-17.1 under the existing UR Z17. If this were achieved, the revision process would be made easier without disrupting the natural flow of UR Z17.

Presently, efforts are duplicative. Guidelines on RITs have been issued by IACS members and it is likely that other classification societies will follow to increase financial gain. All existing guidelines could be

[127] *See Class Societies and Remote Inspection Techniques*, Seadronepro, Aug. 24, 2020.

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streamlined into a standard guideline, unifying approved procedures that concern the usage and deployment of technology for services on ship's outer hull. Furthermore, because the economic value of class rules on hull survey is substantial, it is conceivable that governments as well as national standardization bodies will turn to IACS or individual classification societies for guidance and best practices.[128] However, in its current form, the standards remain disparate, incomplete and insufficient. Without uniformity, at the core of the term "standard," the current landscape only enhances existing criticisms of classification societies.[129]

There are readily available tools that could be applied to resolve these issues. Whatever pathways that are eventually developed, it is advisable that international organizations keep the IMO informed of progress since technology-based standards for hull inspection and maintenance are intertwined with the spirit of the IMO's HSSC and the 2011 Guidelines that adhere to the basic tenets of safety and environment in UNCLOS. For professional service robots that influence vessel performance and reduce emissions, it is undoubtedly a catalyst for positive change.

[128] Jurgen Basedow & Wolfgang Wurmnest, Third-Party Liability of Classification Societies: A Comparative Perspective 7 (2005).

[129] Notably, how conflict of interest may question the efficiency of classification societies. It is also noted that both the *Prestige* and the *Erika* were classed by BS and RINA, respectively – two members of the IACS "big 12". *See* John N. K. Mansell, Flag State Responsibility: Historical Development and Contemporary Issues 131–32 (2009); *see also* Commission Communication on the Applicability of Article 101 of the Treaty on the Functioning of the European Union to Horizontal Co-operation Agreements, 2011 O.J. (C 11), ¶ 316, n.128.

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Article

Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers

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Abstract: The current regulatory landscape that applies to maritime service robotics, aptly termed as robotics and autonomous systems (RAS), is quite complex. When it comes to patents, there are multifarious considerations in relation to vessel survey, inspection, and maintenance processes under national and international law. Adherence is challenging, given that the traditional delivery methods are viewed as unsafe, strenuous, and laborious. Service robotics, namely micro aerial vehicles (MAVs) or drones, magnetic-wheeled crawlers (crawlers), and remotely operated vehicles (ROVs), function by relying on the architecture of the Internet of Robotic Things. The aforementioned are being introduced as time-saving apparatuses, accompanied by the promise to acquire concrete and sufficient data for the identification of vessel structural weaknesses with the highest level of accuracy to facilitate decision-making processes upon which temporary and permanent measures are contingent. Nonetheless, a noticeable critical issue associated with RAS effective deployment revolves around non-personal data governance, which comprises the main analytical focus of this research effort. The impetus behind this study stems from the need to enquire whether "data" provisions within the realm of international technological regulatory (techno-regulatory) framework is sufficient, well organized, and harmonized so that there are no current or future conflicts with promulgated theoretical dimensions of data that drive all subject matter-oriented actions. As is noted from the relevant expository research, the challenges are many. Engineering RAS to perfection is not the end-all and be-all. Collateral impediments must be avoided. A safety net needs to be devised to protect non-personal data. The results here indicate that established data decision dimensions call for data security and protection, as well as a consideration of ownership and liability details. An analysis of the state-of-the-art and the comparative results assert that the abovementioned remain neglected in the current international setting. The findings reveal specific data barriers within the existing international framework. The ways forward include strategic actions to remove data barriers towards overall efficacy of maritime RAS operations. The overall findings indicate that an effective transition to RAS operations requires optimizing the international regulatory framework for opening the pathways for effective RAS operations. Conclusions were drawn based on the premise that policy reform is inevitable in order to push the RAS agenda forward before the emanation of 6G and the era of the Internet of Everything, with harmonization and further standardization being very high priority issues.

Keywords: robotic and autonomous systems; drones; crawlers; remotely operated vehicles; Internet of Robotic Things; data governance; user interface; international standards

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Citation: Johansson, T.M.; Dalaklis, D.; Pastra, A. Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers. *J. Mar. Sci. Eng.* **2021**, *9*, 594. https://doi.org/10.3390/jmse9060594

Academic Editor: Jin Wang

Received: 21 April 2021
Accepted: 26 May 2021
Published: 30 May 2021

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1. Introduction

Digital data, commonly referred to as data, have a ubiquitous influence in the contemporary information-intensive age, as vast quantities of data are created every second, if not microsecond. The dynamic benefits of data acquisition and subsequent usage have led end-users to the general understanding that data have an unfeigned nexus with decision-making processes, especially ones that concern business-as-usual.

Over the years, the term data has found itself being defined in a myriad of ways. It is further observed that each individual definition of data can be characterized as being discipline-oriented. Whether natural science, economy, or law, scholars have put forth respective definitions from the prism, and to the extent, the term data has interacted with the subject matter of respective disciplines [1]. The quintessential definition of data, however, is found in the common lexicon, i.e., the Cambridge English Dictionary which defines the term as "information, especially facts or numbers, collected to be examined and considered and used to help decision-making, or information in an electronic form that can be stored and used by a computer" [2]. All-embracing in content and ambit, the above definition found in the common lexicon reflects the essence of the varying definitions, to all intents, construction, and purposes, propounded by various subject matter experts, e.g., Senn (1982), Clare and Loucopoulos (1987), and Avison and Fitzgerald (1995) [3–5].

Despite the abundance of discipline-led definitions, experts view modern-day dependency on data with a positive outlook. What began as a mere byproduct of business processes, is now incontrovertibly a valuable asset [6,7]. Similar to land-based industrial counterparts, this so-called dependency on data was observed in the maritime and ocean domain, for example, in marine science concentrated on species distribution modelling, geospatial data in maritime boundary delimitation, submarine communications, nautical charts, and marine scientific research of areas beyond national jurisdiction [8–10]. In short, data are invaluable and reside at the crux of work undertaken by stakeholders that participate in effecting a sustainable transformation in relation to maritime and ocean governance.

There is, of course, the shipping industry's constant reliance on "timely and accurate data to feed its logistical plan" [11]. To take but one example, the voyage data recorder (VDR), which is fitted into passenger ships and other ships of 3000 gross tonnage and above, is considered an important compliance tool in line with the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea). Not only has VDR facilitated forensic investigations in post incidents and casualties in the past, but also the data gathered by investigators have remained of interest to stakeholders, including academics and researchers that support "green operations" through performance efficiency to ameliorate overall safety while reducing operational costs. Research on data continues with efforts focusing on exploring the means and methods to process "big data" and "data analytics" from an ethical–socio–technical setting [12,13]. In this journey of exploration, the acquisition and translation of "big data" to promote safety culture is a promising direction taken by the shipping industry, following the illustrative development/precedent in the "Big Data Traffic Information Service" system by the automotive company Toyota in 2013 [14].

Technology is undoubtedly a catalyst of change [15]. This statement itself is well grounded in facts, especially considering the manner in which RAS are currently being integrated and adapted into the operational framework of business activities to obtain data. The shipping industry is certainly no exception. Clean and green shipping, one of the clearest manifestations of RAS integration, comes off as a timely response in mitigating the adverse effects of shipping on climate change where data analysis has an invaluable purpose. Second to this crucial aspect is the integration of RAS to carry out statutory and classification tasks, e.g., annual survey, periodic survey, and special survey coupled with damage repairs, satisfied via conventional methods with a view to obtain real-time data for observation of structural weaknesses, thus altogether contributing to maintaining international vessel performance standards [13]. Once fully integrated, RAS would eventually replace traditional human-led survey, inspection, and maintenance. The end-objective of all RAS-driven operations is to gain optimum accuracy in the process of data acquisition during inspection and to improve post-inspection decisions based on data acquired. For example, outer hull is an area prone to damages caused by biofouling. Determining biofouling status for maintaining vessel speed and increasing maneuverability is contingent on accurate data in relation to a number of integral structures. In principle, the processes are governed by international laws and requirements, adopted at the national level and adhered to by flag state authorities [13].

The paradigm shift of RAS reliance on shipping has already begun [15]. In 2020, Bureau Veritas recorded the test results of using drones for close-up inspections and thickness measurements, setting a milestone in this RAS-deployment continuum [16]. Drones, also known as unmanned aerial vehicles (UAVs), are aircrafts that "can be remotely controlled or programmed to fly a predetermined route using information on a specific asset's condition to target known areas of concern" [17]. The other two existing RAS applications include crawlers and ROVs. Very briefly, the former is designed to "crawl along a structure ... to operate on a vertical surface or hull structures in air or underwater" [17]. The latter is exclusively used in underwater operations to "collect visual data, perform Nondestructive Testing (NDT), and measure plate thickness in difficult-to-reach areas" [17].

RAS-interventions today are very data-centric, as they are translated into activities such as data acquisition, data transfer, data storage, and finally data analyses, which remain the principal foci. Although RAS applications—as they exist today—are best described as systems with "human-in-the-loop", their relevant capabilities are promising, leading to the projection that drones, crawlers, and ROVs will achieve full autonomy in the near future [13,15]. As RAS advances towards full autonomy, there is a clear need to spear through the current data governance and corresponding management practices to assess whether procedural details, rules, and requirements follow a water-tight approach securing much needed precautions that would otherwise give rise to complications from the get-go stage.

In furtherance of the foregoing, this paper discusses the results gathered from the European Union Horizon 2020 funded project titled Autonomous Robotic Inspection and Maintenance on Ship Hulls (BUGWRIGHT2) while addressing two pragmatic questions: what are the thorny issues that could invoke data liability in an RAS-led vessel survey and inspection operation, and what are the pathways through which those issues could be mitigated? The motivation behind seeking answers to the above emanates from the current vacuum that exists in the regulatory setting that could call on liability implications that are purely legal in nature. It is important that service robotics engineers, as they move from "human-in-the-loop" technology to "full autonomy" technology, remain aware that technology and law reside in the same continuum and are therefore interrelated. Technology should progress, but in that process, it must be ensured that such progress does not breach or violate any contemporary legal provisions that are globally sensitive in nature. Data acquisition is one subject matter of crucial importance to both engineers as well as global, regional, and national regulators. Simply put, a solution is required before RAS is in mass deployment and before the topic of data protection reaches the contentious stage.

With a view to finding a solution to the questions posed above, this article focuses on identifying the principal data barriers existing in the international techno-regulatory framework (which is followed by ship owners, classification societies, as well as the operational folks engaged under the title of service providers), as well as potential solutions for consideration based on the theoretical construct of data governance. International norms and standards set by the International Association of Classification Societies (IACS) are the ones that regulate all RAS vessel survey activities and are sporadically revised as needed to ensure that the provisions are fit-for-purpose. Based on the current setting as it exists, it is correct to state that shipowners lack a techno-regulatory safety net to protect the non-personal data linked to their asset. The growing needs to eliminate liability drawbacks from such an absence are being discussed in different platforms at the European Union level, including the European Commission funded project, ROBotics technology for Inspection of Ships (ROBINS).

With the above in mind, the paper commences with an examination of the characteristic peculiarities of the two main classes of data, and this evidently supports the placement of RAS-acquired data under the category of non-personal data, and further allows the authors to explore non-personal data decision domains and building blocks. This is followed by an analytical highlight of the types of stakeholders involved in the non-personal data business model with specific reference to human and non-human actors. Subsequently, this paper provides an expository review of the state-of-the-art international legal framework that maritime RAS falls within. This is done with reference to current international data-related rules and requirements, highlighting the entities typically engaged in vessel survey and inspection operations involving RAS data acquisition, analysis, and validation.

Additionally, an attempt is made to provide an incisive examination of the architecture of Internet of Robotic Things (IoRT) in the context of maritime RAS and through the prism of data. Thereafter, a comparative examination is conducted to highlight best practices offered by selected IMO-recognized organizations, referred to as classification societies that are proactively engaged in regulating vessel survey and inspection processes, including the main subject matter of this article, i.e., data. The major drawbacks of the current international framework are extracted to underline noteworthy challenges before carving out ways forward that provide a first-hand synoptic insight into the regulatory blueprint developed by researchers of the World Maritime University (WMU) under the ongoing BUGWRIGHT2 project. The paper concludes with takeaway notes synthesizing important points gathered from previous discussions, and ones that will allow for digital serenity as maritime RAS engineering progresses.

2. Materials and Methods

To satisfy the aims and objectives of this paper, a combination of the doctrinal and comparative methods was employed. The doctrinal methodology is basically concerned with doctrinal research, which in turn is a combination of "legal theory research" and "expository research" [18]. Given that the paper focuses on technologies engineered to collect data, "legal theory research" (which underpins the detailed study of legal doctrines and principles, jurisprudence, and legal philosophy) remains outside the scope of the work [18].

To promote the results of this article, the authors relied on the technological regulatory (techno-regulatory) international framework (as a part of the "legal theory research") that governs all RAS affairs under IMO's rule of reference. Reliance on the international framework was unavoidable given that they are followed by the RAS community at large, including engineers, manufacturers, technology specialists of RAS, human–machine interface psychologists, shipowners, flag states, as well as service providers. The primary method is therefore expository research that is concerned with the study of technology-based legislation, international treaties, and scholarly literature that touch upon data-related laws, rules, and requirements with respect to RAS—applications of which are in force. This methodology is used to analyze the extant law (i.e., *de lege lata*), pointing out its drawbacks and deficiencies. The subject must be thoroughly understood in order to determine what the law should be in the future (i.e., de lege ferenda). Needless to say, this approach highlights the continuum of past, present, and future in terms of the progress of the law aimed at technologies.

It is important to note that expository research mainly comprises detailed the examination of legal texts that govern the usage of RAS, including international rules and requirements found in legislative material and international legal instruments. In the world of the science–policy interface, these are known as "black-letter law". The exposition of legal texts in the research process includes non-treaty instruments, relevant scholarly literature such as textbooks, academic and professional journals containing legal, management and governance opinions and expert commentaries, standard form international contracts, and the like.

The comparative methodology—essentially comprising comparative research—is used to compare best practices offered. It extends to the examination of law and legal practices in light of current developments, the object of which is to carry out a comparative analysis. The information so gleaned can lead to obtaining an insight into best international practices. Comparative legal research is deemed to be an important tool that can help the researcher to review and juxtapose best practices through rational comparisons. Within the framework of comparative research, interviews were also conducted with relevant stakeholders of the data management process, including an executive of a service supplier company, a legal expert, an IT shipping consultant and a drone team of a maritime technical service company.

It is envisaged that the final outcome of the examination and critical analysis of techno-law carried out through the use of the doctrinal and comparative methods of legal research leads to strategic proposals and pragmatic alternatives being presented by the authors. These should take into account the specific aspects of RAS data governance and management that need changing or introduced. The proposals for ongoing regulatory development should be aimed at making future laws more coherent, precise, and practical (de lege feranda), thereby providing adequate security and protection to beneficiaries.

3. Results

3.1. Theoretical Construct: Dissecting the Dimensions of Data

Despite contemporary high usage, the term "data governance" continues to remain elusive [19,20]. With reference to the definitions implemented by the Data Management Association (DAMA), the term "data governance" is viewed as "the allocation of authority and control and shared decision making over the management of data assets" [21]. With this definition in mind, secondary sources have carved out the end-objectives of data governance: enhancing data quality, data value, and reducing data-related cost and risk [22–25].

At the outset, it is important to note that the principal concept behind data governance brings to the forefront the need for the comprehension of the inherent dichotomy that lies between personal and non-personal data, since any given data could be a combination of different datasets and transformed into "personal data" in cases where there is processing power and data availability (Mattoo and Meltzer, 2018; Chatzimichali and Chyrostomou, 2019) [26,27]. The definition of personal data, which is of practical significance and far from being of theoretical interest, is intrinsically related to data that directly or indirectly relates to an identified or identifiable natural person (Finck and Pallas, 2020) [28].

A concrete definition of "personal data" is found in the EU's Regulation 2016/679 on the General Data Protection Regulation (GDRP). According to Article 4(1) GDPR, the term personal data is defined as "any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person" [29] (Article 4.1). Non-personal data, on the other hand, venture outside the scope of identifiable natural person, as they relate to industrial and anonymized raw machine-generated data [30].

Legal and business-environment facets pertaining to non-personal data are regulated by the European Union's (EU) Regulation 2018/1807, as outlined in the framework for the free flow of non-personal data in the European Union—an exemplary governance tool that aims to achieve data-driven growth and innovation between the EU Member States. In the above Regulation, non-personal data are conceptualized as "data other than personal data", as defined in Paragraph 9 of the GDPR and include anonymized datasets used for big data analytics and data on maintenance needs for industrial machines [31]. The Regulation moves unjustified barriers for the free movement of non-personal data and applies to EU natural or legal persons that provide data processing services (e.g., collection, recording, storage, use, disclosure by transmission, dissemination of data), giving individuals and organizations the opportunity to collect and disseminate non-personal data and to use data centers or cloud services located within the EU while protecting individual privacy.

In the context of terminology differentiation, it is also important to note the distinction between data governance and data management, since "governance" is the de facto overarching term within which data management resides. Data governance is related to the upper-level planning and the decisions about the allocation of responsibilities, access, control, and use of data, as opposed to data management, which is linked to the implementation and monitoring of governance-related decisions [32]. Recently published literature indicated that "data management" encompasses the essential sequence of the following activities: collection, storage, processing, using, sharing, and destroying of data [33]. Conversely, data governance ensures appropriate data management and provides the relevant processes and structures for formally managing information and for protecting data as a strategic asset [33–35].

There is also a narrower focus that merits further observation, namely that organizational and technical perspectives should be jointly included in a proper data governance framework [36]. Recent efforts include the work by Abraham et al. [25], who set out to conduct an in-depth literature review that eloquently identified the following data decision domains and building blocks with regards to non-personal data:

Governance mechanisms:

- Identification of the data owner/data manager/data consumer
- allocation of responsibilities
- decision-making authority
- organizational policies and standards
- coordination with the stakeholders;

Application of governance mechanisms on the organizational scope, data scope, and domain scope:

- Quality and integrity of project-related organizational data
- data governance between firms
- machine-generated data
- privacy requirements
- data architecture
- data lifecycle
- data storage;

Antecedents of data governance:

- Internal and external factors that precede data governance practices, such as organizational culture and industry;

Outcomes of data governance:

- Measurement of data governance effectiveness on organizational strategy and business performance [25].

Most of today's data governance programs address goals in two or three data decision domains. Within the settings of the above cited data governance framework, several interrelated decision domains remain dormant: (a) data architecture; (b) data quality; (c) data security and data access; (d) data lifecycle; (e) metadata; and (f) data storage and infrastructure [25,32,37].

The first decision domain, i.e., "data architecture", is a term that refers to the blueprint that aligns data assets with the organizational strategy and sets designs to meet data requirements [21]. In short, the architectural policies and standards denote how data are processed, stored, distributed, and used. Data architecture helps to facilitate the flow of data within an organizational ecosystem by developing interrelated and bidirectional data pipelines. The second domain known as "data quality" focuses on the ability of data to fulfill their intended use through precision, timeliness, completeness, and credibility [32].

In this regard, specific organizational metrics are utilized to safeguard data quality. As for the decision domain that is explicitly tied with safeguarding measures, "data security" as the third domain touches on many issues, including privacy, confidentiality, intellectual property policies, data access, and third-party access [38]. The third domain does not ignore the possibility that effective organizational security mechanisms and tools could help protect data from unauthorized access and corruption throughout their lifecycle.

Similar to biorhythm, the lifecycle of data under the fourth decision domain titled "data lifecycle" captures the intricate timespan of the life of data from its generation and maintenance, up to the very point of their deletion. Data lifecycle represents the approach of archiving and retiring big data until it no longer makes sense to retain them, leading to the assumption that overmanaging information could lead to the waste of capital resources [39]. In terms of data generation, "metadata", whether created manually or automatically, is the fifth category conceptualized as "data-about-data" or as "information stored in IT tools that improves both the business and technical understanding of data and data-related assets" [38]. Metadata are stored in a location different from the original data and are generally invisible to the end-user. There are different types of data that can be considered as "metadata": title, author, keywords, permissions, geolocation of an image, copyright information, date and instruction for the users, among others. Finally, "data storage and infrastructure", the sixth decision domain, is about maintaining or archiving digital data on different types of media for usage by computer devices [40]. Technological storage options are ample whereby technology provides economical and reliable solutions for storage arrangements.

3.2. Carving Out the Stakeholders of Non-Personal Data

The need to identify the types of stakeholders that directly or indirectly affect or are directly or indirectly impacted by data decision domains (described in the previous section) with regards to non-personal data is unavoidable in discussions related to data governance. As the first step, one must be cognizant of the key human and non-human actors both within and outside the organization [41]. The interactions between multiple actors have their roots in the actor–network theory (ANT), which is quite often utilized to analyze systems in the fields of social sciences, international relations, and information technology [42].

ANT explores the relational ties within a network in which knowledge is perceived as the product of a network of heterogeneous actors [42]. ANT examines the construction and transformation of heterogeneous networks and collaborative designs, taking social and technical aspects into account. Each network has a generalized symmetry, and each actor has an equal role to play. Therefore, ANT sets the framework for alliance among humans, machines, tools, computers, and other non-human agents. Actions are a conglomerate of many agency groupings that must be slowly untangled [43,44]. An actor–network relationship is never stabilized, owing to the fact that agents are not isolated from each other and are constantly involved in the process of actions and reactions [42,45].

Human actors in a data framework that concerns "machines" are the stakeholders who are involved in and are affected by data-based decisions and actions. The stakeholders that belong to the data governance framework are the participants that are involved in information sharing throughout the data supply chain management [46].Potential stakeholders range from manufacturers, software developers, service providers, business clients, information architects, data governance practitioners, metadata analysts, operations staff, and end-users [47]. Then there are non-human actors that interact with the above: policies and regulations, market demands, economic circumstances, semiotics, technological tools and infrastructure, inter alia [41].

It would seem that the notion of a "governance network" that introduces human and non-human actors' interrelations is of paramount importance in order to mark out the stakeholders that belong to the service robotics non-personal data framework. In doing so, one will come across an important detail: human agents are not unique when it comes to shaping and influencing reality, and for this reason, non-human actors' role in an actor–network domain should not be diminished [44]. Any given system contains diverse entities whereby each entity is a sum of other smaller actors. Inevitably, international standards embedded within the scope of policies and regulations, viewed as a non-human factor, influence the manner in which tasks are completed, covering the essentials that are required. In doing so, international standards cement the close and enduring partnership between and among the stakeholders in the fulfilment of non-personal data acquisition, analysis, and validation objectives.

3.3. RAS and the Internet of Robotic Things: Through the Prism of Data

In its Recommendation titled ITU-T Y.2060, the International Telecommunication Union (ITU) describes the Internet of Things (IoT) as an all-embracing international infrastructure for the informatics and communication society (International Telecommunication Union, 2012; Yousif, 2018) [48,49]. Consequently, IoRT comes forth as a concept that amalgamates IoT and cloud robotics, where cloud robotics is a combination of robotics and cloud computing, with the latter opening the digital doorway for sharing, processing, and storing interoperable information [49]. For maritime RAS, this corresponds to close-up information on vessel structures and thickness measurements of suspect areas.

The fabric of the IoRT architecture anticipates communication of information via five interdependent layers. Localized movements with the help of actuators and the conversion of signals or stimuli (light, motion, sound, and heat) to electrical domains via a wireless sensor network (WSN) form a part of the "hardware layer" that leverages information to the "network layer", which encompasses cellular connectivity, short and medium-range communication technologies, Worldwide Interoperability for Microwave Access (WiMAX), Z-Wave, ZigBee, and low power wide area network (e.g., LoRa) [50]. Within the architecture of IoRT, the "Internet layer" plays a central role, in so far as it supports lightweight information processing, inter alia, through transport protocols including data distributed services (DDS) in the robotics system for carrying out a number of principal tasks, listed as follows: "publish/subscribe messaging, multicast support, real-time instant messaging, packet switched networking, alternative to Transport Control Protocol, disseminating of networked embed system, providing privacy to datagram protocol, message queuing for middleware environment, lightweight local automation, and directly addressing publish/subscribe based communication for real-time embedded systems" [50]. The most invaluable layer of the architecture is the "infrastructure layer", which in turn comprises five distinct and interrelated components, namely a robotic cloud platform, M2M2A cloud platform support, IoT business cloud services, big data services, and an IoT cloud robotics infrastructure [50]. User interaction and interface through monitoring and visualization is realized in the last IoRT architecture element known as the "application layer"—the technical potentials of which are expanding [49,50]. Finally, the aforementioned individual but interconnected layers facilitate data acquisition from the physical world, which are fed to the application layer for observation. The advancements through machine learning (ML), a branch of artificial intelligence, are seen to have revolutionized the IoRT architecture with fast and smooth fault diagnosis, making "ships safer, easier to use and more efficient" [51,52].

Turning to maritime RAS for vessel survey, inspection, and maintenance, it was observed that the key parameters in the implementation and acceptance of RAS platforms in shipping industry are related to operational safety [15]. The so-called operational safety concerns ease of operation during intervention by "human-in-the-loop" during data acquisition, communication and data management, data security, energy autonomy, and power source. Although communication and data management tasks today are conducted using both paper and digital systems, data integrity is nevertheless ensured to a certain extent through the introduction of some form of a blockchain system in the data management process [15]. As the focus remains on integrating RAS into the current manual system, data security and the effectiveness of data collection, data processing, and distribution of analysis outputs (e.g., defects autodetection) need to be demonstrated, ensured, and proven in an effective manner. For each of the three types of maritime RAS, the data communication system in maintaining the data decision dimension needs to be thoroughly revisited in light of user interface (see Table 1). Otherwise, RAS platforms are likely to lack trustworthiness among the stakeholders of the business model. Software developers need to provide details of international standards used and apply those standards to satisfy the data security requirements. For a clear understanding of the different stages involved in RAS in survey and inspection, a diagram (see Figure 1) is presented to familiarize the reader with a real live scenario.

Table 1. State of autonomy, class, and user interface of maritime drones, crawlers, and ROVs.

Maritime Drones: Aviation/Air			
Titles in usage	**State of autonomy**	**Classes**	**User interface**
micro aerial vehicle, unmanned aerial vehicle (UAV), uncrewed aerial vehicle, remote inspection technology, remote inspection vehicle, multidrone system, multi-UAV, drone	Supervised autonomy (machine–human); remotely controlled	A1 (<250 g to <500 g): fly over people but not assemblies; A2 (<2 kg): fly close to people; A3 (<25 kg): fly far from people; CO (<250 g): can fly in subcategory A1 and A3; C1 (<900 g): can fly in subcategory A1 and A3; C2 (<4 kg): can fly in subcategory A1 and A2; C3 and C4 (<25 kg): can fly in subcategory A3). * **Note:** European Union Aviation Safety requires completion of training and passing of exams defined by the national authority for operating drones under category A1, A2, A3, C1, C2, C3, and C4 [53].	High-performance data processing task can be achieved using computer graphical user interface (GUI) or natural user interface (NUI). GUI comprises a control panel, parameter viewer, camera viewer, and requested behaviors viewer. On the other hand, NUI types include visual body interaction, visual marker interaction, hand gesture interaction, and speech command interaction [54]
Crawlers: Climbers on Structures (Predominantly Above Water):			
Titles in usage	**State of autonomy**	**Classes**	**User interface**
Magnetic crawler, vertical surface magnetic crawler robot, remote inspection technology, remote inspection vehicle, magnetic utility crawler, magnetic crawler solutions, crawler	Supervised autonomy (machine–human); remotely controlled	Vacuum adhesion type: pneumatic climbing robot, articulated-limb crawler using rubber suction cups; magnetic adhesion type: electromagnetic wheeled crawlers; propeller type: see [55]	High-performance data processing task can be achieved using a 3D tracking concept and robot operating system. Specific location information is transmitted by tracking unit and visuals are communicated by built-in cameras [56].
ROVs: Underwater (Liquid Environment):			
Titles in usage	**State of autonomy**	**Classes**	**User interface**
ROV, remotely operated underwater vehicle submersible, autonomous underwater vehicle, remote inspection technology, remote inspection vehicle	Supervised autonomy, supervised autonomy (machine–human), remotely controlled using cable and tether	Observation class (up to 100 kg, 300 m typical depth rating): DC voltage, 110/220 V DC/AC voltage); mid-sized class (from 100 kg to 1000 kg, 2000 m typical depth rating): 440/480 V, AC voltage; work-class (>1000 kg, >3000 m typical depth rating): 440/480V [57].	The electronic architecture is fitted with computers—one is located at the surface and is connected to a monitor through which the user can view images taken by the camera and other sensors, and the second is located in the ROV's electronic contained. Both computers control the thruster and the underwater arm to read and process the sensor signal whereby all tasks are performed using data acquisition cards and National Instruments hardware. Communication is materialized via Ethernet protocol [58].

Sources: Adapted by authors from [53–58].

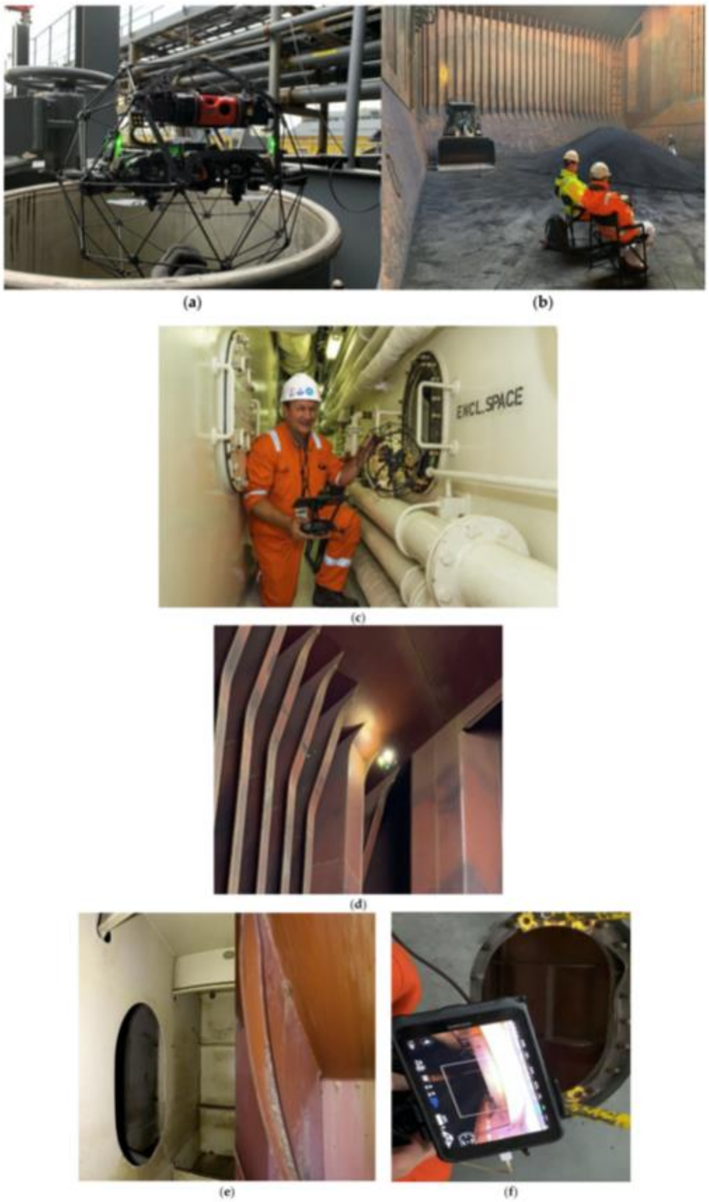

Figure 1. *Cont.*

(g)

Figure 1. Overview of the operational sequences considering a drone as a case-study: a typical RAS calibration situation (**a**) and supervised-control during classification survey (**b**); a drone before "accessing" an enclosed space (**c**); drone during survey and inspection (**d**); visual image captured through drone (**left**) (**e**,**f**); data acquisition (**g**). Data can be live-streamed through video conference to facilitate remote surveys if required.

3.4. International Maritime Data Governance Standards

The data obtained and used via RAS clearly belong to the non-personal data domain, given that they concern a vessel and not a natural person. Usage of RAS for gathering non-personal data in shipping, as promulgated in the texts of IACS, stems from two main objectives: (1) to inspect the biofouling status of a ship and (2) to address elevated risks in other structural areas that could result in safety and environmental concerns [59,60]. For statutory surveys, the guidelines in IMO's "Guidelines for the Control and Management of Ship's Biofouling to Minimize the Transfer of Invasive Aquatic Species" issued in 2011 provides two options for conducting in-water inspection: human divers and remotely operated vehicles [60]. In other words, conducting inspection via ROV, i.e., a form of remote inspection technology (RIT), is acceptable and could lead to the issuance of statutory certificates by flag states [13].

In this discussion, the role of classification societies cannot be ignored. More than fifty individual classification society members have been quite influential actors within the shipping industry as far as the history of global maritime trade is concerned. Consequently, classification societies play a crucial role in meeting standards, with the focus recently shifting towards goal-based standards (GBS) through the development of standard rules and regulations in direct conformity with United Nations Convention on the Law of the Sea of 1982 (UNCLOS). It is not a coincidence that according to the official IMO website:

> "Goal-based standards (GBS) are high-level standards and procedures that are to be met through regulations, rules and standards for ships. GBS are comprised of at least one goal, functional requirement(s) associated with that goal, and verification of conformity that rules/regulations meet the functional requirements including goals. In order to meet the goals and functional requirements, classification societies acting as recognized organizations (ROs) and/or national Administrations will develop rules and regulations accordingly. These detailed requirements become a part of a GBS framework when they have been verified, by independent auditors and/or appropriate IMO organs, as conforming to the GBS".

The title under which classification societies operate in the process of developing GBS is known as Recognized Organizations (RO), a title spread across a significant number of IMO conventions covering environmental and safety facets. Of the many international organizations that contribute to the creation of global maritime technology-based regulatory standards on classification and statutory rules, the IACS is viewed as the leading non-profit international body. Although the International Organization for Standardization has since 1947 has played the traditional role of developing technological standards for robotics and robotic products, the IACS's parallel efforts to date is observed as being the leader in the creation of a techno-regulatory environment for the maritime industry. In the evolution continuum, it is noted that the IACS has come a long way, in so far as its promulgated standards cover more than 90% of the global cargo carrying tonnage. In short, the IACS governs all policy matters that govern the usage of service robotics in the maritime and ocean industry [60]. Some scholars such as Lindøe and Baram purported that standard(s) are private industry driven and serve as an external non-governmental force that supports the national regulatory regime [61] (see Figure 2). Standards containing classification rules developed by the IACS are certainly no exception [60]. Classification surveys following classification rules lead to the issuance of classification certificates, which is an attestation of compliance [60].

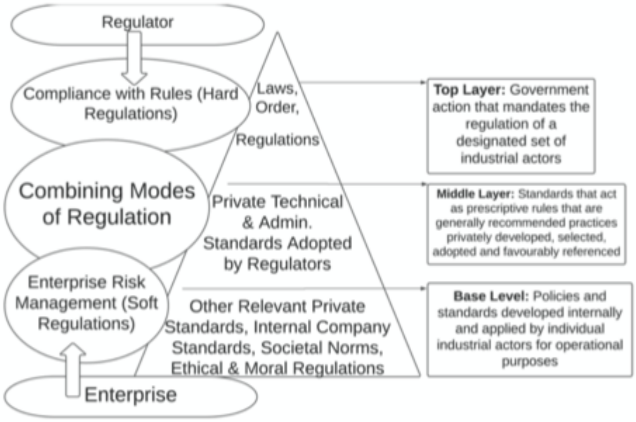

Figure 2. Standards in the regulatory governance regime. Source: Adapted by authors from [61].

Currently, the state-of-the-art survey and certification provisions reside among the various Unified Requirements (UR) developed by the IACS, such as UR Z3, UR Z7.1, UR Z7.2, UR Z10.1, and UR Z10.2. Notwithstanding the plethora of rules and requirements, the IACS has duly considered the role that these emerging technologies could play in the survey process through supervised autonomy. IACS UR Z17, titled "Procedural Requirements for Service Suppliers", creates a regulatory regime that permits the usage of RAS within the ambit of classification survey and is a strong reminder of the IACS's progressive and forward-thinking nature in this technological savvy era. Among the many important provisions, "control of data" as found in s. 5.2.6 of IACS UR Z17 is pertinent to the current discussion on data governance [62]. S. 5.2.6 provides that:

> "When computers are used for the acquisition, processing, recording, reporting, storage, measurement assessment and monitoring of data, the ability of computer software to satisfy the intended application shall be documented and confirmed by the service supplier. This shall be undertaken prior to initial use and reconfirmed as necessary." [62]

Demonstrating adequate control over data as noted in the above section is a pre-condition to the authorization and subsequent certification of service suppliers by the concerned classification society. Under IACS UR Z17, RAS are permissible pursuant to Sections 3 and 16 of Annex I [62]. The former section applies to firms or service providers that have the capacity to carry out in-water survey on ships (and mobile offshore units) with the help of remotely operated vehicle (ROVs). The latter section applies to firms or service suppliers using RIT (ranging from UAV, ROVs, climbers, unmanned robot arm, drones, etc.) as an alternative to close-up surveys. A close-up survey is an examination "where the details of structural components are within the close visual inspection range of the surveyor" and is an integral formality satisfied, if required, during annual, intermediate and special (or renewal) surveys for detecting fractures, buckling, substantial corrosion, and other types of structural deterioration [63].

A further investigation into the two relevant Annexes of IACS UR Z17 reveals that a number of actors are associated with what could be termed as the data governance and management regime. The stakeholders called upon to remain engaged at various stages include the concerned classification society, flag state administration, as well as service supplier including supervisor, operator, and surveyor. While the classification society and flag state administration deals with approval and certification aspects, the core actors of the service robotic data regime involve the service supplier, who is under obligation to have documented data collection and storage procedures and guidelines in place with the verification of data acquisition tasks, which remain at the discretion of the attending surveyor. All in all, the supplier bears the main responsibilities of ensuring that platforms with data capture/collection/recording devices are readily available and of observing documented procedures that stipulate requirements for location attribution, validation, and storage of data [62].

3.5. *Comparative Insight: RAS Data Governance Best Practices*

The authors conducted a cross comparative examination with a view of reviewing data governance procedural requirements developed by selected individual member societies (see Appendix A, "Selection Criteria: Class Society Primary Sources on Drones, Crawlers and ROV"). Respondents (including service suppliers, selected classification societies, RAS experts) were also interviewed to confirm that the techno-regulatory provisions were interpreted appropriately. It is noteworthy that in the conduct of the proposed analysis, the IACS UR Z17 data requirement (examined previously) serves as the international evaluative standard against which individual member society rules were benchmarked. Existing rules in the form of best practices aimed at service providers are enshrined by nine individual member societies, i.e., Lloyds Register (LR), Bureau Veritas (BV), Det Norske Veritas (DNV), Registro Italiano Navale (RINA), American Bureau of Shipping (ABS), Russian Maritime Register of Shipping (RS), China Classification Society (CCS), Korean Register (KR), Nippon Kaiji Kyokai (NK); these were the principal materials that were examined out of the twelve IACS member societies (see Appendix A, "Selection Criteria: Class Society Primary Sources on Drones, Crawlers and ROV"). The rationale behind the above selection was guided by the objective of satisfying adequate regional coverage, with LR, BV, DNV, and RINA covering the European Union landscape; ABS representing the Americas; RS covering the Russian region in their own rights; and CCS, KR and NK covering the Asian region. All collected materials were incisively examined through the lens of unique developments.

The results of the cross-comparative examination revealed that while member societies acknowledge IACS UR Z17 as the foundation of respective rules developed in silos, not all selected member societies have explicit provisions on data, let alone innovative out-of-the-box rules. On a positive notion, the term remote inspection technology (RIT) is in principal usage in all classification society guidance documents. We also confirmed that the RIT referred to within guidance documents is synonymous with the term RAS.

In the quest for extracting unique developments, it is apparent that the document titled "Approval of Service Supplier Scheme" captures DNV's diligent effort in regulating the subject matter [64]. Developed in 2016, the above document covers "data storage" rules in s. 16.1.4 of UR Z17's Appendix A. The section covers data storage in the context of RIT-survey reporting and furthers the requirement that all data files should be named after the structure surveyed, and should be stored by the service supplier and readily available at request from DNV for a duration of 5 years [64]. It was also noted that the said provision directly covers the "data storage and infrastructure" decision domain of the data governance framework.

A different approach was observed in the requirements tabled by LR. In the document titled "Procedures for Approval of Service Suppliers", LR upholds the general requirement on "data control" in s. 1.3.7 as found in IACS UR Z17 [65]. The same observation applies to RINA, given that the document titled "Rules for the Certification of Service Suppliers" follows IACS UR Z17 verbatim. LR has nevertheless developed separate guidelines for RIT as well as for unmanned aircraft systems. In terms of RIT, the document titled "Remote Inspection Technique Systems (RITS) Assessment Standard for use on LR Class Surveys of Steel Structure" covers data calibration and analytics, whereas the document titled "Guidance Notes for Inspection using Unmanned Aircraft Systems" provides niche guidance on drone operational as well as data capture and treatment considerations [66,67]. Although the latter document only covers a single RIT, i.e., drones, noteworthy provisions on data can be found in s. 8 entitled "Inspection Data" [67]. Axiomatic from the title, s. 8 branches out into three distinct data-relevant recommendations, with the most important one being s. 8.3, which highlights considerations on data security—an explicit decision domain category on the overarching data governance framework, as discussed earlier [67]. S. 8.3 stresses having appropriate "data security principles, standards and methods" with a view of ensuring that all data acquired receive security and protection against "manipulation or unwanted distribution" [67]. Within the texts of s. 8.3, express reference to ISO/IEC 15408 (on Information Technology–Security Techniques–Evaluation Criteria for IT Security) and ISO/IEC 27001: 2013 (on Information Technology–Security Techniques–Information Security Management Systems) has been provided.

On the American front, best practices are offered in the texts of "Guidance Notes on the Use of Remote Inspection Technologies" developed by the ABS in 2019 [17]. As stated in its "Foreword" note, the document is a holistic approach to governing UAVs, ROVs and robotic crawlers, taking into account rules and requirements as found in IACS Recommendations 42 and 76 and IACS UR Z17 [17]. A remarkable feature of the above document is the manner in which it governs remote inspection vehicle (RIV) post-operation data review and processing tasks, where RIV here is synonymous with both RIT and RAS. Sections 4.9 and 4.11 import detailed requirements that are absent in IACS UR Z17, and prescribe the to-dos in the stages of pre-inspection, during inspection, and post-inspection, touching upon all elements from the data decision domain directly or indirectly. It is important to note that while there is observed adequate emphasis on "data security policies and procedures" in Section 4.11.1.1(h), the paragraph notes that those policies and procedures are to be developed and maintained by the concerned service provider [17]. Whether or not ISO/IEC 15408 and ISO/IEC 27001: 2013 would have been appropriate references is a matter that requires further consideration by concerned members of the ABS.

Among the Asian counterparts, CCS utilizes two distinct documents: one on remote surveys and the other one on the usage of UAVs [68,69]. Of the two, the latter contains provisions on data and information in Section 3, which covers data acquisition, data processing, and data security aspects in a fashion similar to the ABS Guidance Note [68]. Indeed, Section 3 touches on the three stages of inspection (as mentioned above) and prescribes adherence with "statutory or regulatory requirements, company regulations and contractual agreements requirements" [68]. As for NK, the "Rules for Approval of Manufacturers and Service Suppliers" issued in 2020 incorporates IACS UR Z17 rule to the letter in Section 1.4.1, and hence the focus remains confined to the "data control" aspect [70]. The same is observed in the case of KR when observing the texts of Section 5(2)(f) (Annexes 1–11) as found in the document titled "Guidance Relating to the Rules for the Classification of Steel Ships" [71].

Finally, a thorough investigation into the Annexes of the "Guidelines on Technical Supervision of Ships in Service" published by the RS provided interesting insight into the domain of inspection using RIT, inter alia [72]. Unfortunately, neither the general provisions nor the main Annexes of the 2019 Guidelines prescribes data considerations for ship owners and service suppliers, other than prioritizing the basic conditions and procedures for the conduct of such operations.

3.6. Hovering over RAS Governance Gray Areas

The importance of good data governance is internationally recognized. Regions from all across the world have endeavored to regulate data through the adoption of protection and privacy legislation. According to the United Nations Conference on Trade and Development (UNCTAD), a total of 204 countries currently have either national "legislation" or national "draft legislation" (184 countries enacted legislation; 20 countries tabled draft legislation) in place [73]. In other words, statistics show that 66% countries developed legislation, 10% countries developed draft legislation, 19% countries have no legislation, and 5% countries are yet to provide information on the subject matter [73]. A cursory look at the titles of existing national legislation indicated that all status quo efforts remain within the parameters of personal data or personal information protection.

National emphasis to protect personal data is justified. Regardless of the ensuing tension created by the requirements, the big picture renders the international influence or "global reach" of GDPR as the substantiated ground on which this justification rests [74]. As for holistic efforts to safeguard data covering both personal and non-personal categories, six countries (Russia, USA, Australia, Norway, China, and the Netherlands) to date have managed to device cyber strategies [75]. With this in view, the question then is, what progress have the international actors made in the maritime sector?

In an effort to answer the preceding question, it becomes clear that emphasis on both personal and non-personal data security is omnipresent at the international level. Markedly, in the context of non-personal data, "cyber security" is the current buzzword in both the maritime and ocean domain [76]. Cyber security breaches through electronic virus and malware have disrupted commerce on more than one occasion, exposing the vulnerable face of the shipping industry [76]. Even the IMO mainframe has not been spared as it has already encountered a cyber-attack in 2020.

In retrospect, technology applications such as the automatic identification system (AIS), the global positioning system (GPS), the satellite-based long-range identification and tracking system (LRITS), as well as the vessel monitoring system (VMS), while collectively supporting the notion of safety and environmental protection, have also paved the way for discussions on illegal electronic interferences and disruptions, in turn prompting the feasibility of the above systems to be questioned. The inadequacy of the current international regime has called for the need to undertake further action by IMO Member States (MS) that adopted IMO Resolution MSC.428(98) titled "Maritime Cyber Risk Management in Safety Management Systems" in 2017. Bearing in mind the recommendations on maritime cyber risk management embedded within the IMO's "Guidelines on Maritime Cyber Risk Management", the 2017 Guidelines require the incorporation of safety management systems in a company's Document of Compliance by 1 January 2021 (International Maritime Organization, 2017). The 2017 Guidelines are apparently aligned with the overall objectives of International Ship and Port Facility Security (ISPS) Code, developed at the IMO under the International Safety of Life at Sea Convention as well as the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code). Awareness remains at the heart of all international initiatives. However, we assert that awareness while serving as the stepping stone towards good data governance nevertheless requires in-tandem acknowledgment of a number of emerging challenges. The aforementioned statement thus begs the question: what are the existing challenges?

Self-evident from the above discussion, ongoing efforts are apparently concentrated on developing digital awareness among organizations and companies that are vesselcentric. The IMO's current focus remains on maritime autonomous surface ships (MASS), which leaves the bulk of work on RIT regulatory standard development tasks at the hands of the IACS (Johansson, 2021). Although the IACS is closely tied to the IMO through a Memorandum of Agreement (MoA), there are currently no hints that international cooperation on the subject matter will be underway any time soon.

It is axiomatic that the current maritime service robotics data requirements are driven by IACS UR Z17. Prima facie, s. 5.2.6 is terse, rendering the IACS standards insufficient, unsettled, and incomplete. Data security and data storage considerations are overlooked, which are likely to segue into more complex challenges in the future once service robotics are in mass deployment after they are met with acceptance by all flag states and classification societies. This bleak situation is further exacerbated by the lack of a horizontal initiative by member societies to flesh out a much-needed data governance framework. In addition, the existing initiatives are disharmonized, given that there are no restraints that inhibit individual member societies integral to the IACS's "big 12" or the societies outside of the "big 12" from crafting their own class rules [60]. As was observed in the comparative insight segment (previously discussed), this practice is already constant. Some individual member states have promulgated standards that touch upon all the major issues pertinent to the data governance framework, and individual progress is commendable. The nature and scope of those standards are indeed commendable, but it is difficult to single out a document from any member society as containing the data governance "gold standards" for maritime RAS. Again, the member societies that have provided guidance on the subject matter do not cover all types of RITs. This in turn raises the question, do individual types of RIT deployed in vessel inspection and survey require separate attention?

The answer to the question posed above requires an assessment of two different strands of analysis: firstly, the difference in data generated by individual RITs, and secondly and distinctly, the sufficiency of a single ambient data governance framework that ties all important decision domain threads.

With a view of assessing the first strand, the end-product of RITs requires a separate focus. What is observed is that the current permissible limit of RIT deployment is limited to a close-up survey (and thickness measurement where required) of ships' structures and in-water survey (in lieu of docking survey) of ships' underwater structures. Despite the various types of RITs that are available to complete the tasks that remain within the above regulatory limitation, the principal objective is to acquire data for verification and validation by the principal surveyor. RITs have built-in image sensors that transform photons into electrical signals that are then viewed on high-definition display screens, recorded and analyzed by operators engaged in commercial inspection activities. Despite the various types of RITs, the principal objective of all technological deployment remains unchanged. Data, whether generated from a drone, magnetic crawler, or an ROV, still need to adhere to the IACS UR Z17 prescribed form, i.e., high-quality video images and still images, and therefore the format of the end-product will not vary.

Insight into the second strand unveils that a common data governance framework is sufficient to cover all types of RIT relevant actions. Examples of this are seen in the ABS's 2019 Guidance document, which offers a functional and consolidated approach. A close look at its s. 4.9 and s. 4.11 confirms that all "data review" and "data post-processing" provisions are one-size-fits-all and apply to the three ABS-approved remote inspection vehicles (RIVs), i.e., drones, crawlers, and ROVs. Whether or not new technologies with hybrid applications emerge in the future and require separate data governance framework is still a "wait and see" game.

In terms of data preservation, a topic that also needs attention is the duration aspect. As is tradition, once the data acquisition tasks are complete, the operator is under obligation to provide those videos and still images and data in a format acceptable to the attending surveyor for review and examination, after which survey reports are developed and submitted to the classification society for approval and certification. The operational procedures are shepherded by a contractual agreement entered into between ship owners and service providers or ship owners and a classification society. What is apparent is that the IACS, as well as a majority of the individual classification societies that belong to the "big 12", are rather silent on post data acquisition steps, which might indirectly affect the data storage and security dimension. The current practice gives copyright ownership to the service providers, which is also coupled with the right to retain data for a limited duration within which data need to be communicated subject to request from the concerned classification society.

In reality, RITs are programmed to acquire vessel structural information that forms a part of the vessel-history. The vessel itself is a business asset, and from that standpoint, adequate protection should be given to safeguard the information so gathered in the operational process. While charter parties are only interested in assurance of vessel seaworthiness, should the data containing structural defects fall into the wrong hands, unforeseen negative effects could ensue. Shipping is a competitive industry, and that is why asset-related information should be treated with utmost confidentiality. Although not a contentious issue at this point, nonetheless a number of topics require further clarification: Who should retain the copyright ownership of data gathered from RITs? What is the duration of preservation of data and image from close-up and in-water surveys? Should there be any safeguard mechanisms for service providers against third-party liability? These are a few outstanding matters that require consideration in order to create a level playing field for all stakeholders involved in the RIT business model.

4. Discussion Based on Priori Synthesis: Ways Forward

The findings from BUGWRIGHT2 identified a set of twenty-six action items that comprise the international regulatory blueprint (see Table 2). The blueprint accommodates cardinal elements while bearing in mind the mandate of relevant international actors with law-making, technical, and operational capabilities when maneuvering in the so-called business model landscape. All elements address the inconsistencies and barriers that have the potential to impede the successful deployment of emerging service robotic technologies for taking evidence-based decisions in the process of vessel inspection, survey, and maintenance. In exploring niche areas, the propositions tabled in eight out of the twenty-seven items of the blueprint is predicated on the view that data are the nucleus around which the business-model rotates. Therefore, the role of the all actors involved in data acquisition, data processing and analysis, and data validation requires acknowledgment followed by appropriate review and revision.

Table 2. Overview of the regulatory blueprint action items for harmonization of international arrangements (synthesis derived from BUGWRIGHT2 Deliverable 1.4.1).

Underlying Element	Action Item
Interorganizational consultation	**Action Item 1 in conjunction with Action Item 2:** Creation of a forum to take part in revisions and reforms undertaken by IACS in relation to Unified Requirements.
Categorization based on capacity	**Action Item 3:** Classify based on capacity and determine whether MAVs, AUVs, and crawlers fall under the scope of "mobile robots".
Standalone definitions	**Action Item 4:** Consider standalone definitions (in the following manner) for MAVs, AUVs, and crawlers rather than referring to all technologies under the overarching term "remote inspection technologies".
Classification pursuant to degree of autonomy	**Action Item 5:** In order for procedural rules and requirements to keep pace with technological innovation (towards full autonomy), service robots require a form of categorization along the lines of degree of autonomy. A potential way forward is to follow closely the degrees rendered to vessels and how the different stages were set by IMO's MASS (as the first step in scoping exercise).
Operational limitations and conditions for service robotics	**Action Item 6:** Consider operational limitations for MAVs, AUVs, and crawlers that help ensure effective completion of survey process. **Action Item 7:** Consider pre-operation, in-operation, and post-operation conditions for service robots.

Table 2. *Cont.*

Underlying Element	Action Item
Expand existing provisions on "alterations"	**Action Item 8:** Revise provisions in relation to survey and inspection planning, and consider all potential risk assessment options. **Action Item 9:** Indicate in detail the procedures in cases where the service supplier alters the certified system, which in turn affects the quality system. **Action Item 10:** Consider revision to include provisions on certification of multisite organizations under the rules concerning certification. **Action item 11:** Consider revision of existing provisions related to survey procedures) to include a client service system (CSM), live-streaming during remote survey, and real-time collection of survey process information, solutions in case of problem with live-streaming, recording of process and conclusion in the ship log, and conditions for certification. **Action item 12:** Consider technological platforms for facilitation collection and delivery of survey-related information such as computers, intelligent remote glasses, and digital cameras for live-streaming purposes. **Action Item 13**: Consider using more a factual and objective post-reporting system.
Safety management system	**Action Item 14:** Consider incorporating valuable provisions related to a safety management system, with explicit reference to safety policy, safety risk management, safety assurance, and safety promotion.
Liability clause	**Action Item 15:** Consider incorporating a liability clause in UR Z17 for maintaining third-party liability insurance in case of accidents or deaths.
Data governance and management	**Action Item 16:** Hull inspection data should be kept confidential as this may constitute a trade secret for the shipowner. Legitimate practices should be in place for the collection, storage, and use of unpublished data of economic significance. For overcoming barriers to data governance and data management, explicit provisions are needed in the form of a contract that specifies the allocation of responsibilities and roles for the ownership, storage, security, and sharing of information between service suppliers, classification societies, and shipowners. Sound data governance principles are essential to help minimize risks and keep external cyber securities threats out of their networks. The contract should be signed during the planning stage of hull inspection. **Action Item 17:** IACS guidelines should elaborate on their provisions about data management from the use of remote techniques. **Action Item 18:** Data ownership, which is one of the most critical parts of the data governance process, defines the rightful owner of the data elements, sharing policy, and access rights to third parties granted by the data owner. During the planning stage of hull inspection, a clear understanding between service suppliers, classification societies, and ship owners/managers should be maintained about data ownership. **Action Item 19:** Digital data preservation gives reliable protection to information and systems needed to ensure the long-term usability of data and metadata. Clear allocation of responsibility should be given to the party that is responsible for data and image preservation. **Action Item 20:** Distributed data between the different stakeholders intensifies data security efforts between participants in the data process. Cloud environments encounter increased security threats due to inadequate access management and system vulnerabilities. Measures should be in place for the security and confidentiality of remote inspection technology data by all the relevant stakeholders to ensure a sound data governance process. **Action Item 21:** During the planning stage of hull inspection, it should be specified how the data are shared between the different stakeholders to ensure secure data transfer between data owners and users. Provisions should exist about the sharing of data in the formal agreement. A secure industry platform could be utilized for secure data transfer between data owners and users, when saving and sharing the video stream from the remote survey. **Action Item 22:** The current copyright regime does not protect computer-generated data; thus, explicit provisions in the contract should be made to safeguard computer-generated works. **Action Item 23:** Potential liability issues that stem from the use of data should be underlined in the contract. Input material supplied by the asset owner to the service supplier before the hull inspection (i.e., images, drawings, and designs) should not infringe the copyright or other rights of a third party.

Table 2. *Cont.*

Underlying Element	Action Item
Harmonizing statutory and class rules with reference to close-up survey	**Action Item 24:** Consider aligning the definition of a "close-up survey" found in IMO's Enhanced Survey Programme, given that the current definition of close-up survey is inadequate as the IACS created the possibility to use RITs for remote inspection, allowing the surveyor to conduct close-up surveys through sensors.
Controlling variety for optimum quality performance by regulating technical and operational standards	**Action Item 25:** Develop a methodology to establish standards based on product categorization with the aim of reducing variety to identify the best product from all categories of RITs.
Creating a remote inspection technology "trustworthy ecosystem"	**Action Item 26:** There should not only be efforts to market quality products so that smooth integration is possible but also efforts to create lawful, ethical, and robust service robots that can render end-users trust in the products deployed for survey and maintenance tasks.

The first data-themed action item furthered in the regulatory blueprint is a recommendation calling for the security and protection of all data acquired in relation to the structural elements of a vessel. The recommendation tied to the first action item anticipates dialogue and discussion among ship owners and all other actors noted within IACS rules and requirements. Based on constructive exchanges, it should be confirmed whether legitimate practices should be in place for the collection, storage, and use of unpublished data of economic significance. The platform should support recommendations to integrate sound data governance principles in the context of the data decision domains to safeguard information from cyber security threats—a common phenomenon that could lead to unforeseen damages.

The second and third thematic items are founded on a simple notion: IACS is the principal actor that governs sound data governance system for service robotics. However, a consideration of the requirements implemented by other international organizations is important to address incidental loopholes. LR, for example, has referenced ISO/IEC 15408 (Information Technology–Security Techniques–Valuation Criteria for IT Security) and ISO/IEC 27001:2013 (Information Technology–Security Techniques–Information Security Management Systems) in the procedural document that highlight valuable tools for stakeholders in the development of secure IT systems. This invokes the thought whether IACS, as the lead international organization on the topic, should adhere to the same. Through the second item, the authors assert that harmonization can be achieved through an explicit reference of ISO in both IACS Guidelines No. 42 and IACS UR Z17, especially considering the fact that a majority of the countries are concerned with GDPR and personal data, which leaves non-personal data unprotected and vulnerable.

The third item then focuses on finding a pathway to determine data ownership—an important "detail" that should be considered and integrated into the general provisions of IACS UR Z17 procedural requirements. It is through this third action item recommendation where we submit that there should be a clear understanding of the concept "ownership" among service suppliers, classification societies, and ship owners/managers. Generally speaking, "data ownership" is set by the enterprise's upper echelons and is related to the allocation of responsibilities over data [77]. The ownership decisions encompass a wide range of issues such as domains, data availability, accessibility, and frequency of updates [78]. The outcome of the third action item, according to our views, should help determine whether the fourth action item (i.e., incorporation of a separate section on data security and protection) is required within Section 3 and Section 16 of Annex I of IACS URZ17. We hold the position that clear provisions on data control and data security should exist; otherwise, the data governance framework may suffer. Determining which stakeholder organization should retain data ownership when working within a dynamic business model certainly has positive implications. A quality system under ISO 900 series, referred to in documents developed by individual member societies, prescribes accountability as a part of the engagement process under the quality management principles. Provisions on data control and data protection would certainly help monitor data-centric activities by holding the organization responsible for data control and protection accountable, which is a sound way forward.

Incorporating the much-needed provisions in the texts of IACS UR Z17 would also create the right set of circumstances to review the current contractual practices (see Figure 3). This comes as a timely recommendation and serves as the fifth action item. The lack of adequate coverage of the specifics has paved the opportunity for service suppliers to develop contracts based on convenience and as seen fit. The roles and responsibilities for data ownership, storage, security, and sharing of information remain not catered for to say the least and require also an in-depth review of all private contracts developed by service suppliers. It is important to enquire how data are preserved and whether the service suppliers have adequate and reliable mechanisms in place to ensure the long-term usability of data and metadata gathered from RITs and ROVs.

Figure 3. Visual-cycle of the data elements to be included in the contract between service suppliers, classification societies, and asset owners/operators.

Connected to the fifth action item is the need to verify whether organizations in the business model, especially service suppliers have a well-documented organizational "information systems security policy" and "backup strategy", both of which comprise the sixth action item, followed by feasible recommendations for consideration. For the former, a viable way forward could be that the entities of the business model implement tools and techniques to prohibit unauthorized access to programs and information resources. Users should have a unique user identifier (through passwords or other authentication mechanisms) to keep track of users for establishing accountability. As for the latter, i.e., a backup strategy, organizations could consider a digital infrastructure containing schedules for routine backup check and fast recovery tools. Again, one should come across ISO/IEC 15408 and ISO/IEC 27001:2013, which articulates general principles that could inspire a panoply of thoughts leading to concrete solutions post-verification and in cases where both security policy and backup strategy is absent.

The seventh listed action item in the regulatory blueprint corresponds to data transfer and secured sharing. Prior to the commencement of the operational phase, the IACS prescribes a planning stage with a number of items that are discussed at length by the stakeholders involved in the business model. We believe that specific discussions should be aimed at the best ways to share data among the stakeholders with a view to ensuring secure data transfer between the "owner of the data" and the others including end-users. Whether or not this item could encapsulate the incorporation of provisions alongside data control and data protection, or whether this should be covered under the formal contract between service suppliers and ship owners remain at the discretion of the international actors. Notwithstanding, we opine that this is an important step because this also concerns data security, and therefore a secured platform for data transfer between data owners and users could be the best way forward when saving and sharing the video stream from the remote survey. In doing so, the party providing access should implement and administer access restrictions to ensure that only authorized individuals have the ability to access or use information resources. The use of the universal serial bus (USB) for data sharing, according to the authors, should be avoided.

The final action item of the data segment relates to liability and contains a precautionary approach in order to avoid legal consequences. Caution should be exercised by the asset owners when sharing "input material" with the service supplier before the survey, e.g., images, drawings, and designs, lest this infringes the copyright or other rights of a third party. In case of infringement, the service supplier should be held unaccountable against any loss, damage, or other claims arising from such violation. On the other hand, service suppliers should be discouraged from using survey data for marketing reasons without the prior approval of the asset owner. It is understood that the specifics are currently absent in IACS UR Z17, paving the opportunity for service suppliers to develop contracts based on convenience and as seen fit. The roles and responsibilities for data ownership, storage, security, and sharing of information remains ambiguous to say the least. A possible way forward, should IACS deem it appropriate, is to mark out ways to strengthen due diligence on the part of service providers when holding the copyright or ownership of data obtained through the usage of RITs or ROVs.

5. Conclusions

Approximately 100,000 commercial vessels with a displacement of more than 100 tons navigate the oceans and the seas worldwide [79]. Altogether, there are more than 9000 large ships and more than 4000 very large ships that are above the age of five years [80]. Ship owners need to ensure that these vessels are fit for service, which comes off as a requirement under the UNCLOS [80]. Obtaining certification for all class and statutory surveys provides evidence that all survey and inspection related procedures are complete. However, the procedures to ensure fitness depend on the type of survey (annual surveys need around 1–2 days, intermediate surveys take around 3–4 days, specials surveys go around 1–2 weeks), and there is a need to also factor in post-inspection actions to mitigate defects and deterioration. Maritime RAS could just well be the time savior in a world where shipping is conducted in a just-in-time fashion.

Regardless of the many opportunities that surface with maritime RAS technological applications, a well-implemented check and balance system should continue to operate in tandem with classification and statutory tasks. The topic of maritime non-personal data needs separate attention, broadly owing to the fact that a majority of the world's national strategies are struggling to protect data. Alongside personal data, non-personal data protection issues have already emerged, prompting the adequacy of the current data governance framework to be questioned. Questions are directed at international organizations that have an obligation to ensure that legal provisions aimed at governing technological products are free from imbalance and asymmetry. The success of the science–policy interface for maritime non-personal data requires a review of all the building blocks to ensure that asset related information is protected throughout the entire lifecycle. Generic problems and questions on non-personal data protection are likely to recur in other instances once fully autonomous ships using e-navigation and other forms of autonomous communication to establish contact between and among vessels are in place. This could invoke bring in other questions, such as the feasibility and effectiveness of current big data analytical techniques for an increased rate and volume of data—an issue of significant importance in offshore environments that needs to be considered as the industry moves towards the Internet of Shipping [80–85].

It is also necessary to clearly highlight that there are more desired capabilities in the pipeline, such as autonomous maritime RAS that connect automatically with autonomous vessels through machine-to-machine communication and are guided by the principles of AI. As scientists, engineers, and technologists follow the AI route and usher in the advent of the sixth-generation wireless (6G) communication (i.e., the successor of the fifth-generation wireless) for discharging "unprecedented capacity and latency", there needs to be a solid protection regime to avoid unwanted exposure of data and liability issues [81]. It can be said that 6G communication envisages a tech-savvy environment that has the potential to blur the understanding between human-to-machine and machine-to-machine interactions. We speculate that 6G itself combined with the groundbreaking concept of Internet of Everything (IoE) is likely to be labyrinthine in nature and is expected to contain hidden layers of communication that may require countermeasures to protect the data decision framework as well as the necessary building blocks for smooth user interface. However, until the introduction of 6G and IoE, engineers and policy makers need to establish a settled discourse of data integrity in maritime and ocean domain by observing the current IoRT architecture.

In reality, a sound data governance approach goes beyond just the protection factor simply because the data decision dimension and building blocks secure a "trustworthy" environment. A trustworthy business model entails trust in the product that is likely to have a positive repercussion among the stakeholders that are a part of the business model of non-personal data [82,83]. The current system is characterized as supervised autonomy (see Table 1). Detecting inherent surreptitious vices is a pre-condition in order to help engineers and manufactures of maritime RAS pass the design bottleneck and to ensure market success and subsequent successful integration by flag states and classification societies into mandatory survey processes. The key action as envisaged by authors is to flag out data-related liability provisions in international standards, and when doing so, consider the theoretical constructs of a sound data governance framework before harmonizing the international RAS data management system with other available best practices. Should the action materialize, the benefits are likely to be reaped by the actors involved in the business model, thus creating an environment where each and all are fully aware of the responsibilities and liabilities, whether strict, absolute, or vicarious

Here, collaboration among different international stakeholders of the maritime RAS ecosystem is climacteric. This could include discussions among all international bodies, including organizations that have RAS and maritime RAS mandate, e.g., IMO, IACS, ISO, engineers, policy makers, flag state authorities, manufacturers service suppliers, classification societies, and ship owners and operators to flesh-out solutions on this topic. All in all, what must be hindered is the development of maritime RAS technology-based laws, rules, and requirements in silo. Harmonization has always been at the epicenter of international efforts. Therefore, cultivating international harmonization through optimal solutions that answers the current burning questions leading to a regime that safeguards non-personal data is in order. After all, it is not only that the world contemplates a future where there exists maritime RAS-to-autonomous vessel communication, but also there is a silent aspiration that works to support safe and liability-free maritime RAS-to-autonomous vessel communication. Still much work lies ahead to keep the implications positive in mankind's epic era of combating to establish digital serenity and its unfortunately already inevitable impacts.

Author Contributions: T.M.J., as the WMU Principal Investigator of BUGWRIGHT2 was responsible for developing the main draft, which was based on raw data provided by A.P. Significant revisions were made by D.D. in the development of this article. All authors have read and agreed to the published version of the manuscript.

Funding: This paper is derived from research conducted under the European Union (EU) Horizon 2020 funded project titled Autonomous Robotic Inspection and Maintenance on Ship Hulls (BUGWRIGHT2) under grant agreement No. 871260.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to thank Ronán Long and Clive Schofield of the World Maritime University–Sasakawa Global Ocean Institute and the Nippon Foundation for their generous support. The authors are grateful to Anastasios Tsalavoutas and David Knukkel for providing first-hand information incorporated in the section titled "RAS and the Internet of Robotic Things: Through the Prism of Data".

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Tabular Amalgamation of Published Literature and Primary Sources Based on Selection Criteria

Selection Criteria: Literature on Data and Information	
Author(s)	**Title (Year of Publication)**
Zins, C.	What is the meaning of "data", "information", and "knowledge"?
Selection Criteria: Literature on Data and Asset	
Author(s)	**Title (Year of Publication)**
Lake, P.; Crowther, P.	Data an Organizational Asset. In *Concise Guide to Databases* (2013)
Selection Criteria: Literature on Big Data	
Author(s)	**Title (Year of Publication)**
Boyd, D.; Crawford, K.	Critical Questions for Big Data: Critical Questions for Big Data (2012)
Zhang, S.; Gao, H.; Yang, L. and Song, J.	Research on big data governance based on actor-network theory and Petri nets. In IEEE 21st International Conference on Computer Supported Cooperative Work in Design (CSCWD) (2017)
Johansson, T.; Long, R.; Dalaklis, D.	The Role of WMU-Sasakawa Global Ocean Institute in the Era of Big Data (2019)

Selection Criteria: Data Governance	
Author(s)	**Title (Year of Publication)**
McGilvray, D.	Data governance: The Missing Link for Data Quality Success. San Francisco Bay Area (2006)
Khatri, V.; Brown, C.V.	Designing data governance. *Communications of the ACM* (2010)
Al-Badi, A; Tarhini, A.; Khan, A.I.	Exploring Big Data Governance Frameworks (2018)
Al-Ruithe, M.; Benkhelifa, E.; Hameed, K.	Data Governance Taxonomy: Cloud versus Non-Cloud. *MDPI, Open Access Journal* (2018)
Al-Ruithe, M.; Benkhelifa, E.; Hameed, K.	A systematic literature review of data governance and cloud data governance. Personal and Ubiquitous Computing (2019)
Benfeldt, O.; Persson, J.S.; Madsen, S;	Data Governance as a Collective Action Problem. *Information Systems Frontier* (2020)
Janssen, M.; Brous, P.; Estevez, E., Barbosa, L. S and Janowski, T.	Data governance: Organizing data for trustworthy Artificial Intelligence (2020)
Chakravorty, R.	Common challenges of data governance (2020)
Thuraisingham, B.	Cloud Governance. In *IEEE 13th International Conference on Cloud Computing (CLOUD)* (2020)
Selection Criteria: Data Privacy and User Rights	
Author(s)	**Title (Year of Publication)**
Mattoo A.; Meltzer, J. P.	International data flows and privacy: the conflict and its resolution. *Journal of International Economic Law* (2018)
Chatzimichali, A.; Chrysostomou, D.	Human-data interaction and user rights at the personal robot era. In 4th International Conference on Robot Ethics and Standards: ICRES 2019, (2019)
Selection Criteria: Personal and Non-Personal Data	
Author(s)	**Title (Year of Publication)**
Finck, M.; Pallas F.	They who must not be identified-distinguishing personal from non-personal data under the GDPR (2020)
Somaini, L.	Regulating the Dynamic Concept of Non-Personal Data in the EU: From Ownership to Portability (2020)
Selection Criteria: Actor–Network Theory	
Author(s)	**Title (Year of Publication)**
Montenegro, L. M.; Bulgacov, S.	Reflections on actor-network theory, governance networks, and strategic outcomes (2004)
Latour, B.	*Reassembling the Social: An Introduction to Actor-Network Theory* (2005)
Dincer, D.	The Act-Shifts Between Humans and Nonhumans in Architecture: A Reading of Bruno Latour's Actor-Network Theory (2020)
Selection Criteria: Internet of Robotic Things	
Author(s)	**Title (Year of Publication)**
Ray, P.P.	Internet of Robotic Things: Concept, Technologies and Challenges (2017)
Yousif, R.	A Practical Approach of an Internet of Robotic Things Platform, Master of Science Thesis, KTH Royal Institute of Technology (2018)
Selection Criteria: IACS Primary Sources	
The International Association of Classification Societies	UR Z17, Procedural Requirements for Service Suppliers (1997)
The International Association of Classification Societies	Guidelines for Surveys, Assessment and Repair of Hull Structure–Corr. 1 (Recommendation 76) (2008)

Selection Criteria: Class Society Primary Sources on Drones, Crawlers, and ROV	
Author(s)	**Title (Year of Publication)**
Lloyds Register	Guidance Notes for Inspection Using Unmanned Aircraft Systems (2016)
Lloyds Register	Remote Inspection Technique Systems (RITS): Assessment Standard for Use on LR Class Surveys of Steel Structure (2018)
American Bureau of Shipping	Guidance Notes on the Use of Remote Inspection (2019)
Bureau Veritas	Approval of Service Suppliers (2020)
China Classification Society	Guidelines for Use of Unmanned Aerial Vehicles (2018)
China Classification Society	Rules for Classification of Sea-going Steel Ships (2015)
Det Norske Veritas	Approval of Service Supplier Scheme (2016)
Korean Register	Rules for the Classification of Steel Ships (2017)
Nippon Kaiji Kyokai	Rules for Approval of Manufacturers and Service Suppliers (2020) (Part 1 Chapter 1)
Registro Italiano Navale	Rules for the Certification of Service Suppliers (2020)
Russian Maritime Register of Shipping	RIT Requirements: Annex 39 (Guidelines for the Use of Remote Inspection Techniques for a Survey of Ships and Marine Structures)
Russian Maritime Register of Shipping	ROV Requirements: Annex I (Procedure for In-water Survey of Ships and Offshore Installations) of Guidelines on Technical Supervision of Ships in Service, Russian Maritime Register of Shipping
Selection Criteria: Data Management	
Authors(s)	**Title (Year of Publication)**
Loshin, D.	*Master data management* (2008)
Vilminko-Heikkinen, P.; Pekkola, S.	Changes in roles, responsibilities and ownership in organizing master data management (2019)
Earley, S.; Henderson, D.; Data Management Association	*DAMA-DMBOK: Data Management Body of Knowledge* (2017)
Brous P.; Janssen M.; Vilminko-Heikkinen R.	Coordinating Decision-Making in Data Management Activities: A Systematic Review of Data Governance Principles (2016)

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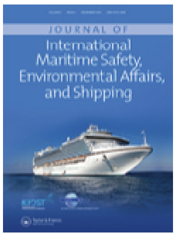

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Journal of International Maritime Safety, Environmental Affairs, and Shipping

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsea20

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To cite this article: Vera Alexandropoulou, Tafsir Johansson, Klimanthia Kontaxaki, Aspasia Pastra & Dimitrios Dalaklis (2021) Maritime remote inspection technology in hull survey & inspection: A synopsis of liability issues from a European Union context, Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5:4, 184-195, DOI: 10.1080/25725084.2021.2006463

To link to this article: https://doi.org/10.1080/25725084.2021.2006463

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Published online: 15 Dec 2021.

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JOURNAL OF INTERNATIONAL MARITIME SAFETY, ENVIRONMENTAL AFFAIRS, AND SHIPPING
2021, VOL. 5, NO. 4, 184–195
https://doi.org/10.1080/25725084.2021.2006463

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Maritime remote inspection technology in hull survey & inspection: A synopsis of liability issues from a European Union context

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ABSTRACT

Vessel hull inspection is a regulatory obligation. Adherence to procedural requirements forged by classification societies helps avoid numerous adverse consequences. In this era of technological innovation, drones, crawlers and underwater submersibles, aptly known as Remote Inspection Technologies, represent emerging technologies, and are being tested to conduct surveys and inspections that will gradually replace human presence on board ships and in-water. However, counter arguments have also emerged against the usage of these AI-based alternatives. Liability is one crucial drawback that could potentially discourage innovation and market growth, especially at the European Union level. Ship owners require a "safety net" as they are a part and parcel of global commerce. Then again, survey and inspection via technologies require the involvement of multiple actors, which makes it difficult to apportion liability. Solutions are required, especially at the European Union level, so that member states could move forward in a spirit of partnership, and nurture and foster technological innovation through partnership. Against the foregoing, this article delves into the European Union liability landscape and outlines some of the critical challenges and strategic ways forward for consideration.

ARTICLE HISTORY
Received 25 August 2021
Accepted 10 November 2021

KEYWORDS
European Union; liability; remote inspection technologies

Introduction

The ongoing improvement and enhanced capabilities of artificial intelligence (AI) applications, along with their integration with robotics, are creating a rather expanded portfolio of Robotic and Autonomous Systems (RAS) that offers cutting-edge solutions to industries engaged in maritime activities and especially shipping. The progressive nature of innovation upholds RAS as a remarkable catalyst that continuously maintains the motion of the "autonomy" agenda. Present efforts seek to autonomize the traditional "manned" concept with a view to introducing autonomous vessel to the global maritime industry. In tandem, by dint of technological evolution and adaptation, the maritime robotic industry is surfacing as one of the fastest growing markets (Jan Rødseth 2017). This growth is marked by the emergence of niche technologies often referred to as Remote Inspection Technology (RIT) that enables " … a Remote inspection Vehicle (RIV) with no pilot on board to provide access for the inspection of structures" (American Bureau of Shipping 2019).

Capable of operating in air or underwater, RITs are viewed as a viable option for surveying a ship and its structures for identifying corrosion, fracture and design-related damages during annual survey, intermediate survey, special survey, bottom survey and damage and repair survey where applicable (IACS Recommendation 76 1994). Other than acting as an alternative to human presence that could encounter risks when entering certain areas of a ship for inspection, RITs complement the global shipping agenda that conducts business in a just-in-time fashion. Generally speaking, annual surveys require around 1–2 days, intermediate surveys take around 3–4 days, and specials surveys take around 1–2 weeks (Johansson, Dalaklis, and Pastra 2021). In addition, the ship owners need to factor in post-inspection actions to repair and mitigate corrosion and other defects and deterioration. Operators confirm that reduced survey-time is an implied promise that comes with RIT deployment (Johansson 2021).

The effective integration and further improvement of the capabilities offered by RIT, as a result of advanced and clearly innovative technical applications, has the potential to fundamentally change certain aspects of operations within the maritime sector. Service robots remain the nucleus of RIT and showcase a revolutionary milestone in remote inspection, survey and maintenance. The advantages of utilizing RIT are

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manifold, especially when considering the numerous crucial mandatory statutory and classification tasks that are carried out on major carriers of the world fleet that are currently between the age range of 0 to +25 years with (approximately) 9,734 large ships and (approximately) 4,759 very large ships over the age of 5 years (UNCTAD/RMT/2019/Corr.1, Review of Maritime Transport 2019; European Maritime Safety Agency 2019). From a maritime standpoint, state-of-the-art RIT has the potential to conduct close-up surveys and thickness measurements in a timely manner and contribute to the mitigation of hull fouling or biofouling that could increase vessels' energy efficiency altogether reducing the level of fuel consumption (McClay et al. 2015).

Numerous factors (as well as an number of subfactors) are said to affect hull performance. Evidently, hull fouling or biofouling contributes to increased emissions – presently viewed as a phenomenon that is troubling the wider shipping industry (Deligiannis 2017). Mitigation measures typically involve direct human interventions, which are steadily shifting to an RIT mode with "human-in-the-loop," and potentially towards full-autonomy in the not-so-distant-future. Patently, classification societies, shipowners, manufacturers and service providers assert that RIT indeed has the potential to achieve the above effectively and efficiently by replacing the current rudimentary inspection system that is time-consuming to say the least (Official homepage of Seadrone 2020). There are clear indicators that the paradigm shift has already begun: National flag State authorities, classification societies and ship owners are gradually adapting to RIT applications that will, in turn, have vital regulatory applications in the context of control, enforcement and compliance, as well as assist in meeting requirements under environmental, climate and shipping regulation.

The International Association of Classification Societies (IACS), a non-governmental organization composed of 12 leading individual member societies that class 90 percent of total commercial tonnage has outlined the basic principles, as well as procedural guidelines in relation to operations concerning the usage of RIT in Recommendation 42 and Unified Requirement (UR) Z17 on Procedural Requirements (International Association of Classification Societies Information Paper 2020). Carefully inserted within the texts of international standards promulgated by IACS are specific types of RITs in remote inspection and survey operations. It is important to note that IACS enters the scene of ongoing discussions by virtue of two independent roles: a "public role" which is assumed as an international Maritime Organization (IMO) endorsed recognized organization, and a "private role," which is assumed when conducting inspections on behalf of the ship owner (International Association of Classification Societies Information Paper 2020).

IACS Recommendation 42 is bearing the title *Guidelines for Use of Remote Inspection Techniques for Surveys* and succinctly sets the stage for remote inspection techniques via RAS platforms that include: unmanned robot arm, Remote Operated Vehicles (ROV), Climbers and Drones (IACS Recommendation 42 1996). This list under discussion is kept open ended by adding the sentence "[o]ther means acceptable to the society," which is a prudent move given that innovation will influence the scope for the development of new types and varieties of RITs that might have greater role in the immediate future (IACS Recommendation 42 1996). In retrospect, RIT has garnered attention in international regulatory and policy communities, especially considering the novel aspect of their application that corresponds to optimum performance along with climate change mitigation benefits derived from hulls with a better environmental footprint (Johansson 2021).

Quite recently, the European Union (EU) has taken the lead in developing tailor-made standards for products operated by RAS. Examples of this are ripe in the work of European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI) (Johansson 2021). Parallel to these initiatives is the work of the *European Union High-Level Expert Group on Artificial Intelligence* that envisions the development of a horizontal foundation for AI through the establishment of trust between the producer/manufacturer and end-user (High-Level Expert Group on Artificial Intelligence 2019). However, from a European Union (EU) RIT horizontal policy perspective, there are aspects that remain shrouded with grey areas. "Liability" is one such important area that could impede the seamless integration of RIT within the EU maritime domain. A stark emphasis on safety and liability implications of RAS can be found in the 2020 report that states:

> At Union level, product safety and product liability provisions are two complementary mechanisms to pursue the same policy goal of a functioning single market for goods that ensures high levels of safety, i.e. minimise the risk of harm to users and provides for compensation for damages resulting from defective goods (European Commission 2020)

Against the above backdrop, this article provides a synoptic discussion on EU liability aspects relating to RIT. The discussion commences with an overview of international (RIT) procedural requirements, forming the current regulatory framework. This provides the vital building blocks of the framework, with a focus on gaps bearing "liability" in mind. Discussions then segue into an expository overview of potential liability challenges from an EU setting. Subsequently, the focus is shifted towards certain thorny issues corresponding to liability for hull inspection using RIT that sets the scene for a discussion on ship owner/carrier liability. This is followed by a critical synthesis on how ship owners could limit liability under existing international rules. Finally, alternatives are explored and recommendations provided before drawing concluding remarks.

RIT International Governance Framework: a synoptic overview

In response to the evolving RIT landscape, RIT Procedural Requirements embedded in IACS UR Z17 have undergone the fourteenth revision in March 2019. IACS also submitted a paper to the 7th session of IMO Sub-Committee on Ship Design and Construction (SDC) in February 2020 on the use of RITs during Enhanced Survey Programme Surveys (SDC 7/10 "Use of Remote Inspection Techniques (RITs)"). However, those suggestions were conditional on the surveyor being on board. All in all, as it stands today, IACS UR Z17 includes nine relevant sections with sections 3 and 16 of Annex I covering provisions on ROV for in-water survey and RIT as a tool for close-up survey of ship's structure and mobile offshore units respectively (IACS UR Z17 1997).

Pursuant to IACS UR Z17 procedural requirements, the extent to which firms or service suppliers can operate ROVs is limited to in-water survey and/or internal hull survey of compartments filled with water (ICAS UR Z17, 1997). Self-explanatory from the title of s. 3 of Annex I, ROVs can be deployed as an alternative to diver conducted surveys subject to the approval of the shipowner. On the other hand, provisions pertaining to the usage of RITs in close-up surveys, "where the details of structural components are within the close visual inspection range of the surveyor," rests in a separate section under Annex I of IACS UR Z17 (ICAS UR Z17, 1997). Close-up surveys may be performed in conjunction with thickness measurement, if required, and is traditionally included in the planning document alongside other mandatory specifics (IACS Recommendation 76 1994).

For better comprehension of the procedural requirements and integral elements that come into play, the following tables provide a structured and categorized overview of the integral elements at play during various phases of ROV and RIT deployment as found within the texts of IACS UR Z17. The structure takes from the three-part conceptual framework, i.e., actors, tools and mechanisms, as proposed by Markell and Glicksman (2016) in a 2016 publication with a view to assisting "policymakers seeking to design regulatory structures likely to produce effective governance in dynamic circumstances" (Markell and Glicksman 2016). Table 1 contains the general provisions,

Table 1. Breakdown of IACS UR Z17 elements integral to survey and inspection general provisions using ROVs and RITs pursuant to IACS UR Z17 sections 3 and 16 of Annex I.

IACS UR Z17: General Provisions		
Element	*Section*	*Summary*
Actors in Operation	S. 3	Manufacturers, Service Providers, Agent, Subsidiary, Subcontractor: Section 3 provides definition of the specific entities governed by IACS UR Z17.
Application of Mechanisms (in Preliminaries)	S. 4	Permissible in Statutory Services and Classification Services except non-ESP ships <500 Gross tonnage (GT) and all Fishing vessels.
Tools Involved in Preliminaries	S. 4.1.3	Verification and Accountability of Work Done by Third Party.
	S. 4.2	Approval of Service Provider by the Concerned Society.
	S. 4.3	Approval of Service Provider by the Concerned Society where the Society is Authorized by Flag Administration.
	S. 5.1	Procedures for Approval and Certification.
	S. 5.2.1 to S. 5.2.10	Training of Personnel (s. 5.2.2); Supervision (s. 5.2.3); Personnel Records (s. 5.2.4); Equipment and facilities (s.5.2.5); Control of Data (s. 5.2.6); Servicing Stations (s. 5.2.7); Documented Work Procedure (s. 5.2.8); Information of Agreements and Arrangements to-be Provided by Supplier if any Parts of Services are Subcontracted (s., 5.2.9); Verification of Service Providers by Supplier (s. 5.2.10).
	S. 5.3	Society to audit the Supplier
	S. 5.4	Obtaining a certification is conditional on demonstration of performance in relation to the specific service as well as completion of satisfactory reporting.
	S. 5.5.1	Supplier to Demonstrate Documented System Pertaining to Quality Management in accordance with ISO 9000 Series.
	S. 5.5.3	Application by Manufacturers' Endorsing Agents or Subsidiaries.
	S. 5.6.1	Service Suppliers Relations with the Equipment Manufacturer.
	S. 6.1	Conditions for Issuance of Certificate of Approval to Supplier and Content of Certificate.
	S. 8.1 to S. 8.4	Cancellation of Approval.
Tools Involved During Conduct of Task	S. 5.2.12	Documented Procedures and Instructions on Recordings by Suppliers.
Tools Involved after Completion of Task	S. 5.2.12	Documented Procedures and instructions to-be available for the Recording of Damages and Defects found during inspection.

Source: ICAS UR Z17, 1997

Table 2. Breakdown of IACS UR Z17 elements integral to survey and inspection procedural requirements for ROVs pursuant to section 3 of Annex I.

IACS UR Z17: Section 3 of Annex I (Firms carrying out an in-water survey on ships and mobile offshore units by diver or ROV)

Element	*Section*	*Summary*
Actors Involved in Preliminaries	S. 3.1	Training of Personnel (divers, ROV operators and supervisors) by supplier.
	S. 3.4.1	Diving supervisor must be qualified in accordance with supplier's general requirements and shall have a minimum of two years' experience as a diver carrying out inspection.
	S. 3.4.2	ROV supervisor shall have a minimum of two (2) years of experience of conducting inspections using ROVs.
	S. 3.5.1	The diver conducting shall have had at least one year's experience as an assistant diver carrying out inspections (including minimum 10 participation in different assignments).
	S. 3.5.2	ROV operators shall have at least one year of experience with conducting inspections using ROVs.
Actors Involved after Completion of Task	S. 3.8	Supplier to obtain verification from surveyor for each separate job followed by the surveyor's signature.
Application of Mechanisms during Conduct of Tasks	S. 3.1	In-water survey in lieu of a docking survey and/or the internal hull survey of compartments filled with water.
	S. 3-7-1 to S. 3.7.2	Suppliers should have documented operational procedures and guidelines including "guidance for the operation of the ROV, if applicable"; as well as "methods and equipment to ensure the ROV operator can determine the ROV's location and orientation in relation to the vessel."
Tools involved in the Preliminaries	S. 3.3	A plan (developed by supplier) for training of personnel,
Tools Involved after Completion of Task:	S. 3.8	Verification is an important tool that confirms approval by surveyor for each job completed.

Source: ICAS UR Z17, 1997

Table 3. Breakdown of IACS UR Z17 elements integral to survey and inspection procedural requirements for RITs pursuant to section 16 of Annex I.

IACS UR Z17: Section 16 of Annex I (Firms engaged in survey using Remote Inspection Techniques (RIT) as an alternative means for Close-up Survey of the structure of ships and mobile offshore units)

Elements	*Tools*	*Summary*
Actors Involved in Preliminaries	S. 16.3	The supplier will assume responsibility for the training and qualification of its operators operating RIT. UAV Pilots should be qualified and licensed under applicable national requirements or an equivalent industrial standard acceptable to the society.
	S. 16.5	The supervisor must be certified according to the recognized national requirements or an equivalent industrial standard coupled with a minimum of two years' experience in the inspection of ship's and/or MOU's structure.
	S. 16.6	The operator must be certified according to the recognized national requirements or an equivalent industrial standard coupled with a minimum of one years' experience in the inspection of ship's and/or MOU's structure.
Actors Involved after Completion of Task	S.16.10	Supplier to obtain verification from surveyor for each separate job followed by the surveyor's signature.
Mechanisms involved in the Preliminaries	S. 16.4	Training Plan for Personnel
Mechanisms involved During Conduct of Task	S. 16.2	Close-up Survey of ships' structure and mobile offshore units' structure by deploying RIT
Tools involved in the Preliminaries	S. 16.4	A plan (developed by supplier) for training of personnel
	S. 16.8	The supplier shall ensure the following operational procedures and guidelines well document:- Requirements for preparation of inspection plans when UAV are part of the equipment flight plans shall be included;- Operation of the remotely operated platforms;- Operation of lighting;- Calibration of the data collection equipment;- Operation of the data collection equipment;- Two-way communication between the operator, platform, Surveyor, other personnel such as support staff and ships officers and crew;- Guidance of the operator to provide complete coverage of the structure to be inspected;- Guidance for the maintenance of the remotely operated platforms, data capture and storage devices and display screens, as applicable;- Requirements for the collection and validation of data;- If data is to be stored, then requirements for location attribution (geo-tagging);- validation and storage of data;- Requirements for the reporting of inspections, including the recording of damages and defects found during inspection and repair work; and
	S. 16.9	The supplier is under an obligation to maintain he following:- Records of training;- Operator statutory and regulatory certificates and licenses;- Equipment register for UAVs, Robots, data collection devices, data analysis devices and any associated equipment necessary to perform inspections;- Equipment maintenance manuals and records/logbook;- Records of calibration; and- UAV/Robot operation logbook.
Tools involved in the Preliminaries	S. 16.7	High-definition display screen with live high-definition feed from inspection cameras as an integral part of the RIT.
Tools Involved after Completion of Task	S. 16.10	Verification is an important tool that confirms approval by surveyor for each job completed

Source: ICAS UR Z17, 1997

Table 2 is ROV-specific and Table 3 relates to provisions that govern the usage of RITs for remote inspection and survey.

The summary of contents in relation to the elements covered under this three-part framework depicts IACS as a pioneer of regulatory standards in the maritime domain (Johansson 2021). Notwithstanding, however, when conducting a detailed observation of IACS UR Z17 standard requirements (see Tables 1, 2 and 3) against requirements developed by individual Classification Society rules (namely, Lloyds Register, Bureau Veritas, American bureau of Shipping and China Classification Society), there appear to be a number of crucial shortcoming limitations in the IACS-developed international common minimum standards that govern the usage of RIT. Certain sources assert that while the basic instructive building blocks for using ROVs in in-water surveys and RIT for close-up surveys are logically stacked; it seems neither s. 3 nor s. 16 of Annex I adequately covers the important safety details concerning risk management system, safety assurance and third-party liability (Johansson 2021). According to certain views that are being put forward, all the above are important considerations that require adequate coverage within the texts of IACS UR Z17 in so far as RIT deployment and operations are concerned (Johansson 2021). Those considerations also require an investigation into the complex and challenging world of "liability" given that it is an important facet that has existed in varying forms as far as the functioning of the shipping industry is concerned. Therefore, liability challenges associated with RIT usage from an EU context is speared through in the next section.

(R)IT Associated Liability Challenges in a European Union Context

Developments in IT Technologies, in particular RIT, the learning ability and connectivity, cause the emergence of new risks or implications in the control of existing risks whereby new value chains imply the entry of new actors, such as data suppliers, operators or machine trainers. Moreover, Robotics may damage physical legal assets without intermediate human intervention while the learning ability of digital systems is certainly a developing field of unknown risks whereby the increasing connectivity leads to additional new challenges in terms of both safety and security.

The findings of the European added value assessment (EAVA) "Civil liability regime for artificial intelligence conducted by the European Parliamentary Research Service (EPRS)to accompany the European Parliament's draft report on a legislative initiative proposal on a civil liability regime for artificial intelligence delineate that the current EU civil liability regime is based on the partially harmonized product liability system accompanied by a fragmented civil liability framework (European Parliament resolution of 20 october with recommendations to the Commission on a civil liability regime for artificial intelligence (2020/2014 (INL)). The comparative legal analysis of the national liability systems of 19 Member States has indicated great divergence between member states (MS) in terms of their current rules and their degree of flexibility to adjust to the new challenges related to IT Technologies. Hence, in the absence of a common EU action, it is very likely that dissimilar divergent practices might emerge among MS, giving rise to obstacles hindering the functioning of the EU internal market.

Liability policies have major economic and social implications when explaining the substantial added value that could potentially be generated as a result of EU common action on AI liability. Apart from direct impacts on the reduction of risks and increase in safety, liability policies have dynamic effects on innovation, investment in research and development and ultimately business competitiveness while maintaining considerable social impact. This is due to the fact that rules on the distribution of risks and mechanisms for compensation of damages determine the acceptance and trust of technologies by consumers.

Turning to the *status quo* EU product liability regime, it is noted that this regime relies on the EU Product Liability Directive 85/374/EEC and applies in the context of IT Technologies as well, revised though and in some instances with reversed "burden of proof" since it is currently based on a *de facto* negligence liability system where the injured person is required to prove the damage, the defect and the causal relationship between defect and damage. It is also highlighted that the European Parliament proposed a "Regulation on liability for the operation of Artificial Intelligence-systems" containing a strict liability for operators, but suggested only (arguably) minor amendments to the existing product liability (software as a product, reversal of burden of proof in certain cases) (European Parliament Resolution of 20 October 2020 with recommendations to the Commission on a civil liability regime for artificial intelligence, 2020) in paragraph 8 as follows:

> "[The European Parliament] urges the Commission to assess whether the Product Liability Directive should be transformed into a regulation, to clarify the definition of 'products' by determining whether digital content and digital services fall under its scope and to consider adapting concepts such as 'damage', 'defect' and 'producer'; is of the opinion that, for the purpose of legal certainty throughout the Union, following the review of the Directive 85/374/EEC, the concept of 'producer' should incorporate manufacturers, developers, programmers, service providers as well as backend operators; calls on the Commission to consider reversing the rules governing the burden of proof for harm caused by emerging digital technologies in clearly defined cases and after a proper assessment [. . .]" (European Parliament Resolution of 20 October 2020 with recommendations to the Commission on a civil liability regime for artificial intelligence, 2020).

As far as the most conducive liable party is concerned, the shift in risk control has to be taken into account. Provided that "risk control is a result of causation, risk knowledge and the ability to change the causative behavior, thereby choosing the level of activity and the level of care, with regard to IT systems, risk control is increasingly shifted from the user to the producer as a result of automation whereby the end user, apart from the decision to use a system or not, has no further options to influence the risk" (Zech 2021). In this regard, it has been suggested that all human input, i.e., the persons that create, maintain or control the risk associated with the IT-systems shall attract liability while different liability rules will apply as to different risks (Zech 2021). Also, depending on the degree of high risk control a distinction between backend and frontend operators of IT systems has been proposed, thereto attributing a strict, joint and several liability regimes accompanied by a mandatory liability insurance.

RIT hull inspection liability

In the contemporary era, technology has improved considerably: to the point where marketed RIT are now considered as viable leading performers of surveys without surveyors physically attending ships. Current practices involve Classification Societies and Shipping Companies testing the application and success factors of ROVs and real-time RIT sensing devices. In this regard, some classification socieities consider that these new techniques offer greater efficiency, higher flexibility, and increased reliability in the day-to-day activities of survey and inspection without impairing the result of the outcome of such niche-area surveys. Furthermore, the Covid-19 pandemic has also drawn attention to the need for remote survey approaches (without requiring a surveyor to be on board), as in many cases surveyors cannot physically access ships to conduct surveys. This situation has also underlined the importance of developing common requirements for the implementation of remote survey approach as an acceptable form of intervention in some circumstances for overcoming the challenges of surveys in person. It is very likely that there will be progressive developments and adoption of remote surveys beyond the Covid-19 emergency situation as there are apparent benefits of advanced technology and greater flexibility in conducting surveys by deploying specialist surveyors, and flexibility for dealing with simple issues – while ensuring comparable quality and safety standards – are realized. In response to these trends, IACS established a Project Team in 2020 to develop common requirements for remote survey approach (Ko 2020). The Project Team will consider diverse aspects such as the equivalency between remote and traditional survey with surveyor attendance and impediments in existing IMO instruments and IACS Resolutions to remote survey and any inconsistencies which may exist.

In line with the aforementioned in Section I, the legal challenges that arise with regard to RIT orchestrated hull survey and inspection is that new actors are brought into the forefront such as data suppliers, data technicians, IT experts, machine learning experts or machine trainers, operators as well as, under an extended definition, manufacturers (producers) on whom different liability regimes will apply according to the risk-control measures they exercise. In case the maritime sector witnesses mass deployment of fully autonomous RIT, producer liability will be invoked since the probability of defectiveness is difficult to discharge on the part of the injured party as well as determine the causal link between the defect of the product and the damage while the extent of damages is still yet unknown. The latter is likely to be combined with a third-party liability insurance regime in order for the risks to be fairly distributed. The liability regime as to IT technologies and in particular with respect to RIT in relation to hull inspection remains unappraised both at the international and the EU level.

It should be emphasized that intended surveys and inspections on the hull relate to and aim at ensuring the seaworthiness of the vessel, as enshrined Article 94 of the United Nations Convention on the Law of the Sea of 1982 (UNCLOS 1982). Consequently, Article 94 of UNCLOS constitutes an overarching obligation and non-delegable duty on the part of the shipowner. In the absence of an RIT liability regime, chances are the aforementioned actors could attract liability when damage or loss has occurred due to unseaworthiness depending on the facts of each particular case and only in the event where the shipowner has exercised due diligence to make the ship seaworthy, thereby excluding his liability, by way of example in the case of latent defects on the hull which could not have been discovered even with the exercise of reasonable care on the part of the shipowner. If this is the case, then the leading authority on cases involving the liability of classification societies in tort for negligence in relation to third parties, i.e., *The Nicholas H* where the judgment of Lord Steyn exposes the policy issues which advocate against imposing liability on classification societies, might no longer be deemed as relevant henceforth (*Marc Rich & Co. A. G. v Bishop Rock Marine Co Ltd* 1995). Similarly, then, it should also be considered whether the limitation of liability regime of the Convention on Limitation of Liability for Maritime Claims (LLMC 1976/96), which is available to the shipowner and his agents/servants should be extended to the abovementioned actors in their capacity as independent contractors. To this effect, in the following Sections, an analysis of the non-delegable duty of the shipowner to make the ship seaworthy and the limitation regime under LLMC 1976/96 are discussed.

The liability of the shipowner/carrier

In maritime law, seaworthiness of a vessel is the overriding duty on the part of shipowner/carrier. Where there is no express provision in the charterparty as to seaworthiness, there is an implied obligation of seaworthiness at common law. In *Hongkong Fir Shipping v Kawasaki Kisen Kaisha* it was held that the obligation of seaworthiness embraces every part of the hull and machinery, stores and equipment and the crew itself (Hong Kong Fir Shipping Co Ltd v Kawasaki Kisen Kaisha Ltd 1961). Hence, the requirement for the shipowner to provide a seaworthy vessel comprises a twofold obligation, namely that the vessel must be suitably manned and equipped to meet the ordinary perils likely to be encountered while performing the services required of it, while at the same time it must be cargo worthy in the sense that it is in a fit state to receive the specified cargo. As far as the first aspect of the seaworthiness concept is concerned, the implied undertaking at common law covers not only the physical condition of the vessel and its equipment, but also extends to the competence of the crew and the adequacy of stores and documentation (Wilson 2010).

At common law, the obligation of providing a seaworthy vessel is "absolute" — signifying that in the event of breach, the shipowner will be liable irrespective of fault. This was particularly elucidated by Lord Blackburn in *Steel v State Line Steamship Co* stating that "there is a duty on the part of the person who furnishes or supplies the ship … that the ship shall be fit for its purpose … not merely that they should do their best to make the ship fit but that the ship should really be fit" (Steel v State Line Steamship Co. 1877). Moreover, the Court in *McFadden* held that the question whether a ship is seaworthy or not, is a question of fact which must be determined by the standard of an ordinary careful and prudent owner (*McFadden v Blue Star Line* 1905). Where the Hague-Visby Rules, incorporated into English law by The Carriage of Goods by Sea Act 1971, apply whether by the express incorporation in a charterparty via a paramount clause or in respect of a Bill of Lading governed by the respective Rules, the common law absolute undertaking of the shipowner is by virtue of Article III rule 1(a) of the Hague-Visby Rules replaced by the undertaking of the obligation on the part of the shipowner/carrier to exercise due diligence to make the ship seaworthy before and at the beginning of the voyage (Hague-Visby Rules). The test appears to be objective in that "the vessel must have that degree of fitness that an ordinary careful and prudent owner would require his vessel to have at the commencement of her voyage having regard to all the possible circumstances of it" (*McFadden v Blue Star Line* 1905).

In the case of a voyage charter, the obligation to provide a seaworthy vessel attaches at the time of sailing on the charter voyage (Wilson 2010). On the other hand, in respect of time charter the obligation attaches only at the time of delivery of the vessel under the charterparty (Eder, B. et. al. 2015). The initial seaworthiness undertaking is normally supplemented by some form of maintenance clause under which the shipowner is required to "keep the vessel in a thoroughly efficient state in hull, machinery and equipment for and during the service" (NYPE Form 2015). The obligation of the shipowner/carrier to exercise due diligence to "make the ship seaworthy before and at the beginning of the voyage" as per Article III rule 1(a) is viewed as a personal, overriding duty that cannot be delegated and any attempt by the carrier further to reduce or exclude responsibility under the rules to provide a seaworthy ship is invalidated (Art III rule 8) (The Hague-Visby Rules 1968). Accordingly, the shipowner/carrier will be liable not only for own negligence but also for the negligence of any party, including an independent contractor, to whom the performance of his obligation to make the vessel seaworthy was delegated (The Hague-Visby Rules 1968). This was principally established in *The Muncaster Castle*, where the House of Lords was called to decide whether the shipowners were liable for failure to exercise due diligence to make the vessel seaworthy, whereby unseaworthiness was due to the negligence of the fitter employed by competent ship repairers engaged by the shipowners (*Riverstone Meat Co Pty Ltd v Lancashire Shipping Co Ltd* 1961). On appeal by the cargo owners, the Court held that the carriers were liable unless due diligence in the work has been shown by every person to whom any part of the necessary work had been entrusted, no matter whether he was the carrier's servant, agent or independent contractor.

The Hague-Visby Rules in Art IV (2) defers to a list of specific instances and perils in which the shipowner's/carrier's liability for damage or loss to goods will be excluded, even where such loss or damage is caused by the act, neglect, or default of the master, mariner, pilot, or the servants of the carrier in the navigation or in the management of the ship. Finally, a general exculpatory provision provides for any other cause arising without the actual fault or privity of the shipowner/carrier, or without the fault or neglect of the agents or servants of the latter. In order for the shipowner/carrier to avoid liability, it must be shown that such loss or damage is covered by an exception. If the shipowner/carrier fails to establish the proximate cause of the loss, then he will be unable to rely on the exception (Hamilton v Pandorf 1887; *The Popi M* 1985). With regard to a defective, i.e., either ineffective or disastrous hull inspection by RIT, the most relevant exceptions potentially invoked in The Hague-Visby Rules under Art IV 2 are the following: "[n]either the carrier nor the ship shall be responsible for loss or damage arising or resulting from (p) Latent defects not discoverable by due diligence or, the exception (b) of Fire, unless caused by the actual fault or privity of the carrier" (The Hague-Visby Rules – The Hague Rules as Amended by the Brussels Protocol 1968). Additionally, the shipowner/carrier may avail himself of the general exclusion clause of Art IV 2(q) any other cause arising without the actual fault or privity of the carrier, or without the fault or neglect of the agents or servants of the carrier, but the burden of proof shall be on the person claiming the benefit of this exception to show that neither the actual fault or privity of the carrier nor the fault or neglect of the agents or servants of the carrier contributed to the loss or damage (The Hague-Visby Rules – The Hague Rules as Amended by the Brussels Protocol 1968).

However, the exceptions "only exclude the absolute liability of a carrier, and do not discharge him from the consequences of the want of reasonable skill, diligence and care" (*Notara v Henderson* 1872). The exceptions do not operate if such occurrence could have been avoided by the exercise of reasonable care. Accordingly, a shipowner or carrier cannot avail himself of an exception where the cargo owner is able to establish that the immediate cause of the damage was not the excepted peril but the unseaworthiness of the vessel. Whenever loss or damage has resulted from unseaworthiness the burden of proving the exercise of due diligence shall be on the carrier or other person claiming the exemptions of Art IV (Art IV (1) (The Hague-Visby Rules – The Hague Rules as Amended by the Brussels Protocol 1968). Similarly the benefit of limiting shipowner's/carrier's liability under Art IV (5) of the said Convention applies in any action against the carrier or the agent/servant of the carrier (but not being independent contractor of the carrier) in respect of loss or damage to goods covered by a contract of carriage whether the action be founded in contract or in tort is not available if it is proved that the damage resulted from an act or omission of the carrier (agent/servant) done with intent to cause damage, or recklessly and with knowledge that damage would probably result (see Article IV (e), Art IV bis 1 & 2) (The Hague-Visby Rules – The Hague Rules as Amended by the Brussels Protocol 1968).

Limitation of liability under the LLMC 1976/96

One of the unique features of maritime law is the shipowner's right to limit liability by bringing an increased range of claims within the ambit of a limitation fund, for loss or damage resulting from negligent navigation or management of vessel under the provisions of the 1976 International Convention on Limitation of Liability for Maritime Claims (LLMC 1976/96). The limitation rule is just one example of protectionism in the form of state support for the shipping industry by providing the shipowner with a calculable risk before embarking on a marine venture. If the maximum liability of the shipowner can be assessed in advance, then it should be easier and more cost-effective to obtain insurance cover – a factor also important to the injured party if he can thus be certain of recovery in the event of loss.

The 1976 LLMC Convention sets specified limits of liability for certain types of claims against shipowners (including salvors and insurers), whereby the term "shipowner" shall mean the owner, charterer, manager and operator of a seagoing ship in accordance with the rules of this Convention for claims set out in Art 2 containing:

(a) claims in respect of loss of life or personal injury or loss of or damage to property (including damage to harbor works, basins and waterways and aids to navigation), occurring on board or in direct connection with the operation of the ship (or with salvage operations), and consequential loss resulting therefrom;
(b) Claims in respect of loss resulting from delay in the carriage by sea of cargo, passengers or their luggage;
(c) Claims in respect of other loss resulting from infringement of rights other than contractual rights, occurring in direct connection with the operation of the ship;
(d) Claims in respect of the raising, removal, destruction or the rendering harmless of a ship which is sunk, wrecked, stranded or abandoned, including anything that is or has been on board such ship;
(e) Claims in respect of the removal, destruction or the rendering harmless of the cargo of the ship;
(f) Claims of a person other than the person liable in respect of measures taken in order to avert or minimize loss for which the person liable may

> limit his liability in accordance with this Convention, and further loss caused by such measures (LLMC 1976/96).

The claims set out in the foregoing paragraph shall be subject to limitation of liability even if brought by way of recourse or for indemnity under a contract or otherwise (Art 2 (2)) (LLMC 1976/96 1976).

The Convention allows for shipowners to limit their liability except if "it is proved that the loss resulted from his personal act or omission, committed with the intent to cause such loss, or recklessly and with knowledge that such loss would probably result" (LLMC 1976/96 1976). Furthermore, under Article 3(e) Claims by servants of the shipowner whose duties are connected with the ship, including claims of their heirs, dependents or other persons entitled to make such claims, if under the law governing the contract of service between the shipowner and such servants, the shipowner is not entitled to limit his liability in respect of such claims, or if he is by such law only permitted to limit his liability to an amount greater than that provided for in Article 6 (LLMC 1976/96 1976). Additionally, if any claims set out in Article 2 are made against any person for whose act, neglect or default the shipowner is responsible, such person shall be entitled to avail himself of the limitation of liability provided for in the Convention as well (Article 1 (4), LLMC 1976/96 1976). However, Article 4 stipulates that a person shall not be entitled to limit his liability if it is proved that the loss resulted from his personal act or omission, committed with the intent to cause such loss, or recklessly and with knowledge that such loss would probably result (LLMC 1976/96 1976).

Exploring suitable alternatives: fault-based liability, strict liability or vicarious liability?

There is no gainsaying that the terms "due diligence" and "reasonable care" are subject to objective interpretation. RITs are at present semi-autonomous guided by the notion of "human-in-the-loop." The associated international rules (See Tables 1, 2 and 3) comprise a structured business model in which a plethora of actors come into play. Here, determining fault-based liability can be challenging due to the involvement of multiple actors that are dependent on technology manufactured by a third part not involved in the business model and main operations. The core of this principle revolves around the establishment of casual nexus. In other words, application of the above principle depends on the determination of "sufficiently close causal connection" with reference to "cause-and-effect-relationship-factual link coupled with an inquiry "into whether this factual link was proximate rather than remote" (Owen 2007). Ozturk (2021) views the concept of foreseeability as the bedrock of "proximate" cause, and cites Karnow (2016) to argue that foreseeability on the part of actors-in-the-loop operating technology, especially fully autonomous, is likely to be highly uncertain per se (Karnow 2016; Ozturk 2021).

Literature dedicated to liability challenges in relation to RAS also explores strict liability that branches out into two categories, namely "strict product liability" and "liability for ultra-hazardous activities" (Ozturk 2021). Relevant to this discussion is the former category governed by the EU Product Liability Directive 85/374/EEC that, in the opinion of the authors, releases the ship owner from liability by holding the producer or manufacturer responsible for damages caused by products that are inherently defective in nature (EU Product Liability Directive 85/374/EEC 1985). Although the Directive does not explicitly cite "software" as a product per se, electricity is nevertheless coined as a product pursuant to Article 2 (EU Product Liability Directive 85/374/EEC 1985). Moreover, commentators view software as tangible products although the information embedded within the software medium is intangible (Alheit 2001; Ozturk 2021). Taking into account this view, authors assert that RIT indeed falls under the category of "product" in the context of Directive 85/374/EEC. Consequently, the manufacturer or producer will be held liable for damages caused by defective RIT invoked via Article 6 that states: "[. . .] it does not provide the safety which a person is entitled to expect, taking all circumstances into account, including (a) the presentation of the product; (b) the use to which it could reasonably be expected that the product would be put; (c) the time when the product was put into circulation" (EU Product Liability Directive 85/374/EEC 1985). The defense is, of course, readily available to the defendant under the exculpation clause, Article 7: "[. . .] having regard to the circumstances, it is probable that the defect which caused the damage did not exist at the time when the product was put into circulation by him or that this defect came into being afterwards; or [. . .] that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered [. . .]" (EU Product Liability Directive 85/374/EEC 1985).

Relevant to the discussion on ship owner liability is "vicarious liability" – a liability that is "premised on fault, albeit with a reversed burden of proof (*Entlastungsbeweis*) (Gilliker 2021; German Ministry of Justice). A sound example of this principle is provided by McMahon and Binchy (2013): "[t]he law may hold the employer liable for the wrongs of an employee, the principal liable for the wrongs of an agent, or the firm liable for the wrongs of its partner, in spite of the fact that the employer, the principal, or the firm may not have been at fault in any way. When the law imposes liability in these circumstances we speak of the employer, principal, or firm being "vicariously liable" (Binchy and McMahon 2013). When observing the RIT procedural landscape, it seems that the task of approval of service provider lies with the concerned Classification Society authorized by relevant flag administration (ICAS UR Z17, 1997). In the process of executing responsibility (see Table 1), the Classification Society is under an obligation to first and foremost, verify the performance of the third party (the service supplier) and subsequently, approve, verify and certify as seen fit for the purpose of conduct of classification and statutory surveys (ICAS UR Z17, 1997). What is also noteworthy is that the attending surveyor representing the Classification Society must verify each and individual tasks completed by the supplier. Based on this chain of command, the authors submit that when applying the principle of "vicarious liability" considering the roles mentioned above, the burden of proof in a liability case for damage will rest on the Classification Society.

An array of novel liability applications has emerged in tandem with RAS, as discussed above. Considering that RITs are characterized as objects under fault-based and strict liability and apply with certain restrictions, the application of vicarious liability, on the other hand, appears to operate with less restriction, in a manner of speaking, and therefore, better suited to determine liability in a befitting manner. In sharp contrast with the above proposition is the proposal tabled by Bertolini (2016) that favors the risk-management approach (Bertolini 2016). As opposed to fault-based liability that features time-consuming complex litigation for determining defendant's liability, a risk-management-based approach, according to Bertolini (2016) proceeds to hold the producer/manufacturer as absolutely liable whereby the defendant is able to acquire insurance, in a strategic manner to cover damages caused and provide for prompt compensation without being subjected to court proceedings (Bertolini 2016).

Recommendations

Based on the discussions and all the issues identified in the preceding sections, the following recommendations are being put forward:

- ***RIT Standards***: It is important to consider the notion/feasibility of establishing an EU RIT Agency that could contribute to developing RIT standards by taking into account EU wants and needs – until a state-of-the-art regulatory code is developed at the international level. Developing effective and detailed regulatory standards could serve as a stepping stone in developing the much-needed liability regime for RITs;
- ***Stakeholder Consultation***: The EU RIT stakeholders in consultation with IMO and IACS should carve out pertinent items that could be placed within an overarching tailor-made RIT regulatory Code of Conduct framework. While critical aspects, e.g., definitions including a refinement of IMO's definition of close-up survey as found in Harmonized System of Survey and Certification (HSSC), data governance and data protection, trust and ethics, should receive the much-needed consideration; filling out the current void in relation to liability is in order (Johansson 2021);
- ***Opting for a Clear* Pathway**: Develop a methodology that could guide the projection of the direction "liability" could take from RIT deployment, and simultaneously ensure that Tort law and Product Liability Regulations do not overlap as a result of human-RIT interactions. The methodology should be robust enough to provide guidance not only in the semi-autonomy/ "human-in-the-loop" phase, but also once RIT autonomy reaches its peak;
- ***Determining Types of RIT Liability & Developing a Safety Net***: As part of future research activities, exploring in detail all categories of liability with respect to actions by ship owners, producers/ manufacturers and any other entities involved should follow swiftly. This would also entail highlighting aspects that could exempt the entity involved in RIT operations from liability. Whether or not an RIT/smart insurance system should be initiated – is a matter to be determined jointly by producer/manufacturer, service suppliers and insurance companies. The notion that that an RIT/smart insurance system safety-net could serve as an important incentive which would allow innovation to grow without being stalled by incidental issues is also expressed here.

Conclusion

It is a self-explanatory fact that RITs hold a wealth of advantages. Beyond the general services, RITs play a critical role in bolstering support to the notion of "digital maritime" in this era of increased connectivity, with the new paradigm of 5 G that is currently being rolled out. The opening of opportunities is on the other hand hampered by threats in the form of liability that could inhibit the widespread usage of RIT services. This will, not only slow the market growth of technology, but also leave ship owners and surveyors with no other option but to revert back to hull survey and inspection through physical presence that is deemed as risky and onerous (Johansson, Dalaklis, and Pastra 2021). Liability will certainly have an important bearing on emerging technology applications and their effective use, since the fear of moving into "uncharted waters" could have a devastating effect. As the future rolls towards full autonomy, those liability aspects need to be identified and effectively addressed at the outset, not only for ensuring that all actors involved can play their part with utmost duty of care observing due diligence, but also for confirming that producers/manufacturers have the proper incentives to present new technologies for expediting the survey and inspection process.

An implied criteria of the EU Digital Single Market rests upon a holistic environment through which technology can grow and prosper. This environment comprises the landscape within which stakeholders of technology could maneuver at ease and carry out designated roles and responsibilities. Regulating that environment entails mitigating possible grey areas for discharging the full potential of the innovation at hand (Bertolini 2016). The maritime sector, in that aspect, is no different from the land-based sector in which efforts are persistent in removing barriers that could hinder the market growth of autonomous vehicles. Liability, in that sector, is already an issue that is being dealt proactively by practitioners, academics and experts (Bertolini 2016). EU Maritime stakeholders engaged with RIT operations need to proceed with the same level of diligence and integrity, and help push the "liability" agenda forward before individual EU member states developing their own rules. It is certainly worthwhile to explore the development of an EU RIT Code of Conduct in which liability rests alongside other provisions so as ensure a harmonized management system that is precautionary in essence.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This article derives from research conducted under the European Union (EU) Horizon 2020 funded project titled *Autonomous Robotic Inspection and Maintenance on Ship Hulls* (BUGWRIGHT2). This project has received funding form the European Union's Horizon 2020 research and innovation programme under grant agreement No 871260.

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Building a Trust Ecosystem for Remote Inspection Technologies in Ship Hull Inspections

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Abstract

The article contributes to the discussion concerning the role of trust in robotic and autonomous systems (RAS), with a sharp focus on remote inspection technologies (RITs) for vessel inspection, survey and maintenance. To this end, the article provides a first-hand insight into one of the major findings from BUGWRIGHT2* --- a collaborative project co-funded by the European Union's Horizon 2020 Research and Innovation programme that aims to change the European vessel-structure maintenance landscape. In doing so, this article explores trust from a psychological perspective, reflecting on its characteristics and predictors, followed by a discussion on the AI-trust ecosystem as envisaged by the European Commission. Structured interviews with thirty-three subject matter experts guide the main analysis revealing that trust is an essential precondition for integrating RITs into the current manual-driven inspection system. A synoptic overview of the vital trust-elements is provided before carving out the ways forward for developing a trustworthy environment governed by Human-Robot Interaction.

Keywords: trust; trustworthiness; human-robot interaction; human-robot teams; remote inspection technologies; unmanned aerial vehicles; crawlers, ROVs.

*This project has received funding form the European Union's Horizon 2020 research and innovation programme under grant agreement No 871260

1. Introduction

Autonomous Systems (AS) is an accepted term both in academia and the artificial intelligence community. The term is best described as the physical (robotic) and/or cognitive (autonomous) aspects of a system.[1] Today robotic and autonomous systems (RAS) derived from artificial intelligence (AI) cover a wide range of interconnected technologies, known as remote inspection technologies (RITs) operating on ground, air and underwater. The new epoch of robotics characterized by a substantial reduction of human and cognitive workloads through the integration of autonomous and semi-autonomous systems is anticipated to have a multifarious effect on the maritime sector.

In retrospect, the notion of autonomy has revolutionized the vessel design and operation ladscape. The paradigm shift has begun. Within the scope of this shift, both innovators and researchers seek to bridge the gap between current and desired capabilities through proper coordination of the three types of human agency, i.e., individual agency, proxy agency and collective agency, with autonomous systems at play. Coordinating-efforts continue in order to materialize a positive and sustainable effect on safety and marine environmental protection. In this process, innovators and researchers spear through elements of "trust" for establishing seamless interaction between natural persons and artificial intelligence. The objective is twofold: ensuring safety in accordance with the International Safety Management Code (ISM Code) and international relevant conventions, and widening public acceptance of vessels that are unmanned.[2] On a continuum of possible policy outcomes, various concerns are noted in literature relevant to distrust and overtrust in automation and the negative implications of vessels controlled and supervised by autonomous systems.[3]

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[1] US Joint Chiefs of Staff, Joint Concept for Robotic and Autonomous Systems, 19 Oct 2016.
[2] Jon Arne Glomsrud and others 'Trustworthy versus Explainable AI in Autonomous Vessels' In The International Seminar on Safety and Security of Autonomous Vessels, Helsinki [2019]. <https://library.oapen.org/handle/20.500.12657/41230> accessed 11 November 2021.
[3] Hannu Karvonen and Jussi Martio, 'Human Factors Issues in Maritime Autonomous Surface Ship Systems Development. In The Proceedings of the 1st International Conference on Maritime Autonomous Surface Ships, Busan, Korea, [2018] https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2599019/5-

To propel the digital-maritime revolution, the International Maritime Organization in 2017 approved guidelines on Maritime Autonomous Surface Ships' (MASS) trials that resulted in the deployment of pilot projects for testing autonomous vessels in major maritime nations: Norway, Singapore, Finland, Japan and the Netherlands. Subsequently, in 2021, IMO completed its regulatory scoping exercise with the objective to assess the maritime treaty instruments for integrating emerging technologies in the regulatory framework, and balancing the benefits derived from automation against safety and security concerns.[4] Today, four degrees of autonomy --- ranging from crewed ship with automated processes to fully autonomous and unmanned vessels with automated control systems that could render decisions without human intervention --- remain at the epicenter of the scoping exercise.

Although refinements are progressing in an expeditious manner, moving to a strict human-out-of-the-loop system in a movable asset containing valuable shipments requires more than just an effective and efficient machine-learning based technical infrastructure. A constructive balance between "human agency" and "autonomous modes" is required as it could very well enhance the level of trust in autonomous vessels. This balance is a pre-requisite given that shipping is by and large a hierarchical permission-based mobile system comprised of interested parties, e.g, charterers, shippers, consignees and container suppliers, and central actors, i.e., ship owner and master.

The pursuit of vessel autonomy has also called attention to multifarious smart-systems that could potentially improve vessels' safety and environmental performance and reduce human-based errors. RITs, distinguished from vessels, comprise an integral part of the sector for reducing carbon emissions and fulfilling IMO's targets to reduce emissions by 50% by 2050 compared to

HUMAN%20FACTORS%20ISSUES%20IN%20MARITIME%20AUTONOMOUS.pdf?sequence=1 accessed 11 November 2021. See also Andrzej Felski and Karolina Zwolak 'The Ocean-Going Autonomous Ship-Challenges and Threats' 2020 8(1) Journal of Marine Science and Engineering < https://doi.org/10.3390/jmse8010041> accessed 10 November 2021.

[4] The International Maritime Organisation (IMO), 'Autonomous Shipping' accessed 09 November 2021 (https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx).

2008 emissions. Different forms of RITs, such as micro aerial vehicles (MAVs) or drones, magnetic-wheeled crawlers (crawlers), and remotely operated vehicles (ROVs) are said to revolutionize ship inspection and maintenance with minimal user intervention. As of recent, manufacturers are focused on deploying semi-autonomous RITs for hull cleaning and enclosed-space inspection. Such deployment is likely to enhance surveyor's and owner's employee's safety and reduce the carbon footprint associated with a reduction in fuel consumption.[5]

RITs are based on what is perceived as a human–autonomy teaming where two parties (i.e., human and autonomous digital agents) work interdependently towards a common goal.[6] During a remote inspection process, the expectation is that the operator (of the robotic technology) and the semi-autonomous system will actively cooperate to perform the survey of the vessel. As such, this interdependency invokes the need for a well-calibrated level of trust and avoidance of mistrust and overtrust in RITs. It is submitted that the above requirements serve as a foundation for effective and efficient interaction between humans and robots and a critical prognosticator of technology acceptance and use.[7]

[5] Tafsir M. Johansson: International Standards for Hull Inspection and Maintenance of Robotics and Autonomous Systems (in "Emerging Technology and the Law of the Sea", James Kraska and Young-Kil Park, eds., Cambridge University Press, 2021). See also Vera Alexandropoulou, Tafsir Johansson, Vinia Kontaxaki, Aspasia Pastra and Dimitrios Dalaklis, 'Maritime Remote Inspection Technology in Hull Survey & Inspection: A Synopsis of Liability Issues from a European Union Context' (2021 in press) Journal of International Maritime Safety, Environmental Affairs and Shipping (Taylor & Francis).

[6] Thomas O'Neill and others, 'Human–autonomy teaming: A review and analysis of the empirical literature' [2020] Human Factors <https://journals.sagepub.com/doi/10.1177/0018720820960865> accessed 27 July 2021 (forthcoming).

[7] D. Harrison Mcknight and others, 'Trust in a specific technology' [2011] 2(2) ACM Transactions on Management Information Systems <https://dl.acm.org/doi/10.1145/1985347.1985353> accessed 27 July 2021; Sangseok You and Lionel Robert, 'Teaming up with robots: An IMOI (inputs-mediators-outputs-inputs) framework of human-robot teamwork' [2017] 2(1) International Journal of Robotic Engineering https://www.vibgyorpublishers.org/content/ijre/fulltext.php?aid=ijre-2-003 accessed 27 July 2021; Michael Lewis, Katia Sycara and Phillip Walker, 'The Role of Trust in Human-Robot Interaction' in Hussein A. Abbass, Jason Scholz and Darryn J. Reid (eds), Studies in systems, decision and control: Vol. 117 Foundations of trusted autonomy (Springer 2018)/ Kewen Wu and others, 'A meta-analysis of the impact of trust on technology acceptance model: Investigation of moderating influence of subject and context type' [2011] 31(6) International Journal of Information Management 572.

Rooted in psychological research on interpersonal relations, trust in robotic technologies is viewed as a complex and multi-layered research topic, especially in the context of its conceptualization, manifestation as well as trust dynamics and trust calibration.[8] RIT-associated trust complexity is seemingly evident in real-world applications. Trust in RITs relate to a complex interplay among specific work tasks, technological solutions, human dispositions, situative organizational/team settings, stakeholder needs, regulations, and policies. Consequently, a thorough understanding of the trust ecosystem is a prerequisite to the successful integration of RITs into the current manual-driven human-presence-dominated hull survey and inspection. Authors raise three questions --- the answers to which should pave the way for a clear understanding of the trust ecosystem: Which psychological insights need to be considered when reflecting on trust in RITs? Do normative guidelines for a trust ecosystem already exist? What aspects make RITs trustworthy for ship hull inspection?

To answer the preceding questions, this article starts with an overview of the psychological concept of trust, reflecting on its characteristics and predictors, illustrating psychological insights against the backdrop of the EU Horizon 2020 funded Project BugWright2.[9] A normative view on an AI-trust ecosystem by the European Commission,[10] drawing references to the psychological insights, follows. The findings from thirty-three interviews with service robotics experts are presented to underline concrete aspects that should be considered for developing an ecosystem of trust for vessel hull inspection.

[8] Dale E. Zand, 'Trust and managerial problem solving' [1972] Administrative Science Quarterly 17; Daniel J. McAllister, 'Affect- and cognition-based trust formations for interpersonal cooperation in organizations' [1995] 38(1) Academy of Management Journal 24. See also Peter A. Hancock and others, 'A meta-analysis of factors affecting trust in human-robot interaction' [2011] 53(5) Human Factors 517; Kristin E. Schaefer and others, 'A meta-analysis of factors influencing the development of trust in automation: Implications for understanding autonomy in future systems' [2016] 58(3) Human Factors 377. See also Mcknight (n 4) see also Stephan Lewandowsky, Michael Mundy and Gerald P.A. Tan, 'The dynamics of trust: Comparing humans to automation' [2000] 6(2) Journal of Experimental Psychology: Applied 104; Ning Wang; David V. Pynadath and Susan G. Hill 'Trust calibration within a human-robot team: Comparing automatically generated explanations' In The Eleventh ACMIEEE International Conference on Human Robot Interaction [2016] <https://ieeexplore.ieee.org/document/7451741/authors#authors> accessed 30 July 2021.
[9] The European Union's Horizon 2020 funded Bugwright2 project, which aims at changing the European regime for service robotics utilized for infrastructure inspection and maintenance (project page: www.bugwright2.eu).
[10] Commission, 'Building Trust in Human-Centric Artificial Intelligence' (Communication) COM(2019) 168 final

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2. A Psychological Perspective on Human Trust in Work Systems

2.1 Characteristics and Predictors of Trust: Theoretical and Empirical Evidence

Decades of psychological research unveiled that trust is a multifaceted convoluted construct.[11] As is commonly understood, trust describes the willingness to depend on another party in situations characterized by uncertainty, the possibility of undesirable outcomes and risk.[12] In an RIT-setting, the "other party," referring to the object of interdependence (i.e., trustee), is diverse, ranging from qualitatively different RITs to human stakeholders involved in the inspection process.[13] For example, a surveyor (trustor) during a hull inspection via semi-autonomy RITs may trust the data of the underwater drone (trustee 1), the magnetic-wheeled crawler (trustee 2), the aerial drone (trustee 3), or the technical operators of the RITs (trustee 4-x). Trust, in short, is linked to specific expectations the trustor has toward a trustee. From human trustees, trustors contemplate a) competence (i.e., ability to keep a promise) b) benevolence (i.e., caring, considerate, and willing to help) and c) predictability (i.e., consistent ability and benevolence). Expectations for non-human trustees are related to functionality (i.e., included features to fulfill a required task), helpfulness (i.e., adequate and responsive help), and reliability (i.e., reliable operation without failing).[14] Thereby, it is submitted that trust is not static but a dynamic

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[11] Zand (n 6); McAllister (n 6); Kevin Anthony Hoff and Masooda Bashir, 'Trust in automation: Integrating empirical evidence on factors that influence trust' [2015] 57(3) Human Factors 407.

[12] Mcknight (n 4); Meinald T. Thielsch, Sarah M. Meeßen and Guido Hertel 'Trust and distrust in information systems at the workplace' [2018] PeerJ < https://peerj.com/articles/5483/> accessed 30 July 2021

[13] Comparing humans and RITs as objects of dependence, human trustees have volition (i.e., choice power) and moral agency (i.e., differentiate between right and wrong), whereas a technological system is usually lacking these characteristics (i.e., amoral and non-volitional). This qualitative difference in the object of dependence addresses a central criticism of researchers, claiming, "people trust people, not technology" (p. 36) because trustees must have volition and moral agency (Friedman et al., 2000). However, advanced technologies including AI and a high level of automation may have the power to choose and decide (Endsley, 2017). In addition, ambitions to include morality into robotic AI decision-making is an ongoing research field (Kallioinen et al., 2019). Therefore, it is plausible to examine trust in technology, here in RITs in specific. See also: Batya Friedman, Peter H. Khan and Daniel C. Howe 'Trust online'. [2000] 43(12) Communications of the ACM 34; Mica R. Endsley 'From here to autonomy: lessons learned from human-automation research' [2017] 59(1) Human Factors 5; Noa Kallioinen and others 'Moral Judgements on the Actions of Self-driving Cars and Human Drivers in Dilemma Situations from Different Perspectives' [2019] 10 Frontiers in psychology 2415.

[14] Mcknight (n 4).

construct that does not necessarily increase over time.[15] Regarding the optimal level of trust, no maximal but a well-calibrated level of trust is most advantageous. Mistrust (too low) and overtrust (too high) both correspond to undesirable performance-related outcomes.[16]

The introduction of RITs shifts work processes from teams comprised of humans to human-robot teams, in which humans and autonomous agents collaborate interdependently towards achieving common objectives. Trust is critical to effective teamwork in traditional human teams and human-robot teams.[17] Consequently, research on predictors that make a technology trustworthy[18] or not (i.e., trust predictors) is highly relevant to describe, predict, and design effective human-robot teams in the field.

[15] D. Harrison Mcknight and others, 'Initial trust formation in new organizational relationships // Initial Trust Formation in New Organizational Relationships' [1998] 23(3) Academy of Management Review 473.
[16] Raja Parasuraman and Dietrich H. Manzey, 'Complacency and bias in human use of automation: An attentional integration' [2010] 52(3) Human Factors 381; Kate Goddard, Abdul Roudsari and Jeremy C. Wyatt, 'Automation bias: A systematic review of frequency, effect mediators, and mitigators' [2012] 19(1) JAMIA 121; Wang (n 9).
[17] In scientific discourse, heterogeneous terminology exists, such as hybrid teams (Straube & Schwartz, 2016), human-agent teams (Chen et al., 2011), human-autonomy teaming (O'Neill et al., 2020), human-robot-collaboration (Chen et al., 2020), socio-digital teams (Ellwart & Kluge, 2019), human-robot teams (You & Robert, 2017). As their underlying definitions are highly comparable, in this article we use the term human-robot teams consistently throughout this article/ see also O'Neill (n 3) / see also Daniel R. Ilgen and others, 'Teams in organizations: From input-process-output models to IMOI models' [2005] Annual Review of Psychology <https://www.annualreviews.org/doi/10.1146/annurev.psych.56.091103.070250> accessed 28 July 2021; John Mathieu and others, 'Team effectiveness 1997-2007: A review of recent advancements and a glimpse into the future' [2008] 34(3) Journal of Management 410/ see also You (n 4); Sangseok You and Lionel Robert, 'Trusting robots in teams: Examining the impacts of trusting robots on team performance and satisfaction' In T. Bui (Ed.), Proceedings of the Annual Hawaii International Conference on System Sciences, Proceedings of the 52nd Hawaii International Conference on System Sciences [2019] <https://scholarspace.manoa.hawaii.edu/handle/10125/59465> accessed 29 July 2021. See also: Sirko Straube and Tim Schwartz 'Hybride Teams in der digitalen Vernetzung der Zukunft: Mensch-Roboter-Kollaboration' [2016] 32 Industrie 4.0 Management 41; Jessie Y. C. Chen, Michael J. Barnes and Michelle Harper-Sciarini 'Supervisory control of multiple robots: Human-performance issues and user-interface design' [2011] 41(4) IEEE Transactions on Systems, Man, and Cybernetics - Part C: Applications and Reviews 435; Min Chen and others 'Trust-aware decision making for human-robot collaboration: Model learning and planning' [2020] 9(2) ACM Transactions on Human-Robot Interaction 1; Thomas Ellwart and Annette Kluge 'Psychological perspectives on intentional forgetting: An overview of concepts and literature' [2019] 33(1) KI - Künstliche Intelligenz 79; You (n 4).
[18] Naming advanced technology such as robotic AI as "trustworthy" is controversial in the scientific community. Ryan (2020) claims that seeing AI as trustworthy may weaken the value of interpersonal trust, further anthropomorphizes AI, and distracts responsibility from AI developers and users. We encourage readers to keep the mentioned legitimate concerns regarding the wording "trustworthy" in mind that in particular addresses the ethical and societal consequences. See also: Mark Ryan 'In AI We Trust: Ethics, Artificial Intelligence, and Reliability' [2020] 26(5) Science and Engineering Ethics 2749.

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Psychological research on trust in technologies like robots or AI systems demonstrates that trust predictors are diverse.[19] The trust predictors range from technology-related features (e.g., reliability) to human characteristics (e.g., disposition to trust), work task characteristics (e.g., task type), and social aspects (e.g., mental models) with varying degrees of impact depending on the trust stages (e.g., initial or after interaction) and application contexts.[20] As is seen below, Table 1 summarizes central psychological trust predictors within the four interdependent subsystems, namely work task, technology, human and social (i.e., organization and team).

Firstly, work task characteristics are vital in predicting trust because the work task specifies the area of dependence linking the human, technological, and organizational subsystems.[21] Work tasks differ in central characteristics, such as task type and roles, novelty, complexity, and interdependency. Trust in AI is higher in technical or analytical tasks compared to tasks that require social intelligence.[22] Work tasks can be further classified into monitoring and information tasks, idea-generating, decision-making, or action implementation tasks.[23] Considering that humans manage multiple qualitatively distinct work tasks in the same human-robot team, it appears that a human may trust a teammate (either human or robotic) in one task (e.g., idea generating), but consider the same trustee as untrustworthy in another task (e.g., decision-making).

Secondly, technology-related factors (e.g., robot characteristics) determine trust in Human-Robot Interaction (HRI). Thereby, technology-related factors empirically evidence the strongest impact on trust when compared to other factors.[24] The robot's reliability (i.e., performance-related feature) is vital. Here, especially robot failures early in implementation lower the level of

[19] Peter A. Hancock and others, 'A meta-analysis of factors affecting trust in human-robot interaction' [2011] 53(5) Human Factors 517; Hoff, (n 11); Schaefer (n 7).
[20] This systemic perspective on the predictors of trust within the subsystems of work task, human, technology, and organization and team is coherent with general design approaches of humane work (cf. Karltun et al., 2017).
[21] Eberhard Ulich, Arbeitspsychologie (Schöffer-Poeschel Verlag 2011].
[22] Ella Glikson and Anita Williams Woolley, 'Human trust in artificial intelligence: Review of empirical research' [2020] 14(2) Academy of Management Annuals 627.
[23] Parasuraman (n 16); Mica R. Endsley, 'From here to autonomy: lessons learned from human-automation research' [2017] 59(1) Human Factors 5.
[24] Hancock (n 22).

trust.[25] Besides, attribute-related features such as anthropomorphism, robot type and size, are deemed to impact trust. The work task is equally important since human-like robots for social tasks and machine-like agents for analytical tasks are trusted more.[26] Regarding interaction-related features, research shows that the level of autonomy (LoA) determines trust and use intention in multi-robot systems and robot swarms.[27] Depending on the specific work task (e.g., idea generation, decision making), a higher LoA (e.g., full automation, no human intervention possible) or lower LoA (e.g., manual control, human performs all task aspects) might be adequate for well-calibrated trust. Further research reveals that well-calibrated trust is strongly connected to safety issues. The term "automation conundrum" signals severe challenge in the sense that "the more automation is added to a system, and the more reliable and robust that automation is the less likely that human operations overseeing the automation will be aware of critical information and able to take over manual control when needed".[28] Integrating existing research, Hoff and Bashir[29] summarized multiple design features to promote well-calibrated trust in HRI. An adaptive or mixed level of autonomy is likely to guarantee a situational-appropriate level of human control. Accurate and polite robot feedback improves human-robot communication and simplifies user interfaces eases HRI.

Thirdly, human-related factors play a rather minor role in predicting trust compared to technology-related features.[30] However, the impact of human-related predictors differs depending on the timing of trust measurement.[31] Initial trust (e.g. trust in an unfamiliar party) is strongly formed through "second-hand information" like a human's experience with similar trustees, or trustor's personal opinions or dispositions excluding "first-hand knowledge" and

[25] Munjal Desai and others, 'Impact of robot failures and feedback on real-time trust' In HRI 2013 Proceedings [2013].
[26] Melissa A. Smith, M. Mowafak Allaham and Eva Wiese, 'Trust in automated agents is modulated by the combined influence of agent and task type' [2016] 60(1) Proceedings of the Human Factors and Ergonomics Society Annual Meeting 206.
[27] Huao Li, 'A computational model of human trust in supervisory control of robotic swarms' (Master's Thesis, University of Pittsburgh 2019) / Anna-Sophie Ulfert, Conny H. Antoni and Thomas Ellwart, 'The role of agent autonomy in using decision support systems at work' [2021] Computers in Human Behavior (forthcoming).
[28] Endsley (n 26) 8.
[29] Hoff (n 11).
[30] Hancock (n 22).
[31] Hoff (n 11).

direct interaction experience in a given task.[32] Growing experience with a specific technology makes human dispositions less important in trust assessments and subsequently changes personal attitude towards technology.

The fourth interdependent subsystem entails social aspects, including teams or organizations. Team cognitions (e.g., mental models) and co-contextual factors (e.g., culture, context) impact team collaboration and, in turn, trust in RITs.[33] Mental models of RITs include the mental representation of the knowledge about the RITs' functionalities and their proper use. For HRI and well-calibrated trust, mental models should be complete, accurate, and shared among team members (e.g. shared MM). This ensures that all parties involved have a clear understanding of RITs' abilities and limitations. Further, trust and its predictors (e.g., implicit or explicit communication) vary by culture and the voluntariness of the HRI. [34] Research shows that trust is powerful in forced-technology-use situations.[35]

Table 1. Predictors of trust in RITs

Subsystem	Selected predictors
Work Task	• Task type • Roles • Complexity • Interdependency
Technology	• Performance-based (e.g., false alarms, reliability) • Attribute-based (e.g., anthrophormization) • Interaction-based (e.g., level of autonomy, transparency, communication style)
Human	• Trust disposition • Knowledge, skills and attitudes • Robot experience

[32] Ibid 41; Xin Li, Traci J. Hess and Joseph S. Valacich 'Why do we trust new technology? A study of initial trust formation with organizational information systems' [2008] 17(1) The Journal of Strategic Information Systems 39
[33] Hancock (n 22).
[34] Dingjun Li, P. L. Patrick Rau and Ye Li, 'A cross-cultural study: Effect of robot appearance and task' [2010] 2(2) International Journal of Social Robotics 175; Lin Wang and others 'When in Rome: The role of culture & context in adherence to robot recommendations' (5th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Osaka, March 2010).
[35] Nathalie Schauffel and Thomas Ellwart, 'Forced virtuality during COVID-19: A multi-group perspective on technology acceptance of public digital services' [2021] 65(4) Zeitschrift für Arbeits- und Organisationspsychologie A&O 244.

Social (Teams and Organization)	•	Team cognition (e.g., mental models)
	•	Context (e.g., volutnariness)
	•	Regulations (e.g., written manuals)

Source: Table by the authors

2.2 Psychological Insights when Reflecting on Trust in RITs

On an abstract level, psychological findings reveal that trust is a complex and dynamic construct coupled with the fact that trust predictors are diverse ranging from technology-related features and work task aspects to human elements and social setting parameters, as summarized in Table 1. The following section specifies the insights derived from this when reflecting on trust in RITs.

2.2.1 Insight #1: Focus on a Task-specific Trust Evaluation

When reflecting on trust in RITs - one should focus on a task-specific trust evaluation since trust may differ across tasks, and thus trust and mistrust towards a trustee may occur in tandem.[36] RITs are used on a set of infrastructure for inspection purposes with varying aims, demands, and interdependencies during the ship hull survey and inspection process. Moreover, different inspection phases differ in terms of task type, such as planning the inspection based on former inspection reports or first drone videos, monitoring the robotic-supported survey and inspection, or decision-support to classify detected corrosion. Interpersonal tasks are also relevant (e.g., communication, and coordination between stakeholders) when using RITs. To specify the trust ecosystem, it is primarily essential to define the specific work task and identify the relevant subsystems (i.e., who, when, where, why, what). Authors notice that a hierarchical and process perspective on work tasks is helpful to subdivide an overarching task (e.g., hull inspection) in its

[36] McAllister (n 6); Dale E. Zand, 'Reflections on trust and trust research: Then and now' [2016] 6(1) Journal of Trust Research 63; Jens Emborg, Steven E. Daniels and Gregg B. Walker, 'A framework for exploring trust and distrust in natural resource management' [2020] Frontiers in Communication <https://www.frontiersin.org/articles/10.3389/fcomm.2020.00013/full> accessed 30 July 2021.

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subtasks (e.g., prepare access to the ship, mission planning, close-up survey, analyzing, reporting) and consider task characteristics as well as roles.[37]

2.2.2 Insight #2: Apply a Technology-specific Trust Focus.

Beyond a task-specific trust evaluation, reflections on trust in RITs apply a technology-specific focus of analysis given that a mix of RITs might co-exist that differ in technological features (e.g., reliability, speed, level of autonomy) with varying implications on trust. In a complex application case such as hull survey and inspection, different RITs could be used, including swarm intelligence, AI software, and a VR interface. These RITs differ in terms of operation and goals (e.g., thickness measurement, cleaning) as well as technical features and developmental statuses (e.g., reliability, speed, level of autonomy). Exemplarily, whereas aerial drones inspect the upper part of a ship hull cable-free, state-of-the-art underwater drones require a tether to guarantee sophisticated video streaming below water. Furthermore, within a specific task (e.g., thickness measurement of plate thickness), one might choose between different RITs that impact the level of trust (e.g., differences in speed, weight, color).

2.2.3 Insight #3: Consider Human-related Experience, Cognition, and Emotion, especially, in the Early Phases of RIT Use

Because trust is a dynamic construct and trust predictors vary in their relevance depending on the timing of trust assessment, it is essential to monitor trust dynamics and their predictors in the complex context of RITs. Especially in the early phases of RIT implementation, human-related experience, cognition, and emotions indeed matter. If a new RIT is used for the first time (i.e., initial trust), the trustor's (i.e., service supplier) dispositions and opinions remain critical. Positivity biases or skepticism towards robotic AI may exist and impact the trust ecosystem. Available "second-hand information" of trustors, including experiences of related industries and

[37] Paul Salmon and others, 'Hierarchical task analysis vs. Cognitive work analysis: Comparison of theory, methodology and contribution to system design' [2010] 11(6) Theoretical Issues in Ergonomics Science 504.

companies, contribute to the formation of initial trust. Consequently, negative recommendations might lower trust in RITs. After interaction with RITs, trust is viewed as being more strongly dependent on the direct interaction experience. This signifies that with interaction experience, controllable robot-related features are highly pertinent to well-calibrated trust. Active end-user participation, thus, can prevent unpredictable trust fluctuations due to person-related characteristics.

2.2.4 Insight #4: Take into Account that (Shared) Representations Impact RIT Trust

As heterogeneous stakeholders are involved in a hull inspection process, (shared) representation of roles, goals, legal regulations and policies impact trust in RITs. Complete, accurate, and shared mental models of robotic capabilities are essential for well-calibrated trust in RITs. Written manuals, user guidelines, and policy regulations act as the externalization of mental models.[38] Thereby, a trust ecosystem of RITs requests a focus on both strengths and weaknesses to make an informed decision on “when to trust technology” and “when to manually control it”. In a mandatory setting where maritime policy organizations publicly recommend the use of RITs, trust is noted as a powerful guide to human action (e.g., reinsurance behavior, technology use).

2.2.5 Insight #5: Aim at a Well-calibrated, Not a Maximal Level of Trust

An ecosystem of trust in RITs should aim at a well-calibrated level of trust because miscalibrations of overtrust (i.e., too much) and mistrust (i.e, too low) are dysfunctional. This means that low levels of trust can be both functional and dysfunctional depending on the given work task (insight #1) and technology used (insight #2). Exemplarily, a task-specific and technology-specific evaluation of trust in an RIT setting may uncover that trust is high in the missing planning stage (i.e., specification of survey plan) but relatively low in the approval of the inspection results (i.e.,

[38] Stephen M. Fiore and Travis J. Wiltshire, ‘Technology as Teammate: Examining the Role of External Cognition in Support of Team Cognitive Processes’ [2016] Frontiers in psychology <https://www.frontiersin.org/articles/10.3389/fpsyg.2016.01531/full> accessed 30 July 2021.

seaworthiness certificate). The mission planning task is very complex and cognitively demanding. It encompasses information gathering and integration (e.g., former inspection reports, ship drawings, results of first visual inspection, requirements classification society) and idea-generating tasks (task type). The task is also rather technical and analytical instead of emotional. In addition, it is noted that mission planning is a recurring task, following a rather standardized procedure. In contrast, robotic AI approving the inspection represents decision-making on the part of AI. Low trust scores might be appropriate (i.e., well-calibrated low trust), indicating that RITs cannot make this approval reliably and validly. However, a low trust score might also be inappropriate (i.e., mistrust), indicating that expectations in the system's functionality, reliability, and helpfulness are too low, revealing starting points for improving HRI (i.e., human-, technology-, or organizational-related trust predictors).

In conclusion, the five psychological insights indicate that when reflecting on trust in RITs, the focus is on technical components and task-specificities, human cognition, and changes over time in a dynamic and social environment. However, the insights specify a frame of analysis when reflecting on trust in RITs on-site, rather than a normative guideline, action-guiding for policy and society. Besides, they do not provide concrete trust components vital in ship hull survey and inspection processes --- aspects investigated in the following sections.

3. A Normative Approach to Trust and Artificial Intelligence. The EU White Paper

The European Commission has adopted a human-centered approach to trustworthiness.[39] Trustworthy AI, according to the European Commission, has the following three components, which should work in harmony throughout the system's entire life cycle: (1) it should be lawful, complying with all applicable laws and regulations; (2) it should be ethical, ensuring adherence to ethical principles and values; and (3) it should be robust, both from a technical and social perspective.[40]

[39] Commission (n 10).
[40] Ibid.

For the lawful dimension, AI applications should comply with national, regional and international instruments. For example, AI applications should be compatible with EU primary law, such as the Treaties of the European Union and its Charter of Fundamental Rights and EU secondary law, which includes the General Data Protection Regulation (GDPR) and the Product Liability Directive. In addition, compliance is required with the different national laws of each member state and industry-specific rules in force. Regulation could safeguard people against risks, boost legal certainty, and contribute to advancing countries' competitiveness in the race to achieve full autonomy using AI.[41]

Accordingly, AI should be in line with four ethical norms: respect for human autonomy, prevention of harm, fairness, and explicability.[42] The European Commission supports that most of these parameters are reflected in existing mandatory legal instruments. Ergo, this satisfies the first component of trustworthy AI.

EU pays special attention to safe, secure, and reliable operation of AI applications, creating safeguards to prevent adverse impacts. For the development of AI, the EU supports that a system's technical and social robustness should be ensured. Therefore, the following seven non-exhaustive requirements are specified in the Guidelines of the High-Level Expert Group:

1. Human agency and oversight: Systems should not undermine human autonomy and should support individuals in effective decision-making;
2. Technical robustness and safety: A preventative approach to risks should be taken that will minimize unintentional harm. Software systems to be protected against security vulnerabilities such as hacking;
3. Privacy and data governance: Effective data governance, emphasizing quality, integrity and privacy data parameters;
4. Transparency: Algorithms and AI decisions should be understandable by human beings;
5. Diversity, non-discrimination, and fairness: Data sets used by AI systems should not lead to prejudice and discrimination against certain groups or individuals. Stakeholders who are affected by AI systems should participate in the development and deployment of AI;

[41] Nathalie A. Smuha, 'From a "race to AI" to a "race to AI regulation": regulatory competition for artificial intelligence' [2021] Law, Innovation & Technology 13(1) 57.
[42] Commission (n 10).

6. Societal and environmental wellbeing: AI systems and their entire supply chain should act based on sustainability and ecological responsibility, considering their effect on institutions, democracy and society; and,
7. Accountability: Systems should enable the valuation of their algorithms, data and design processes.[43]

Markedly, the EU White Paper emphasizes complexities associated with trust and its predictors before applying AI into the work system. Apart from technology-related features, the human and social subsystems are underlined in the EU's normative approach. While the work task and trust dynamics play a rather minor role in the EU white paper, the psychological insights, however, are observed as being integrated into the ethical, regulatory, and legal dimensions in an implied manner. The following section dives into practical perspectives and identifies the specific components that stress on the terms "lawful", "ethical", and "robust".

4. Practical Perspective: Components of trust in RITs for Ship Hull Inspections

4.1 Methods

A national comparative study has been conducted considering the regulatory state-of-play in six leading maritime nations: the United States of America, the Netherlands, Canada, Norway, China and Singapore. The study evaluates how the above jurisdictions are in the process of governing autonomous operations in the domain of vessel survey and inspection. To satisfy the objectives, thirty-three (33) interviews were conducted between March and June 2021 with high-level operational experts, policymakers, industry experts and academics that are engaged with semi-autonomous operations. The number of participants and their professional fields are presented in Figure 1.

[43] Commission, 'On Artificial Intelligence - A European approach to excellence and trust' (White paper) COM(2020) 65 final.

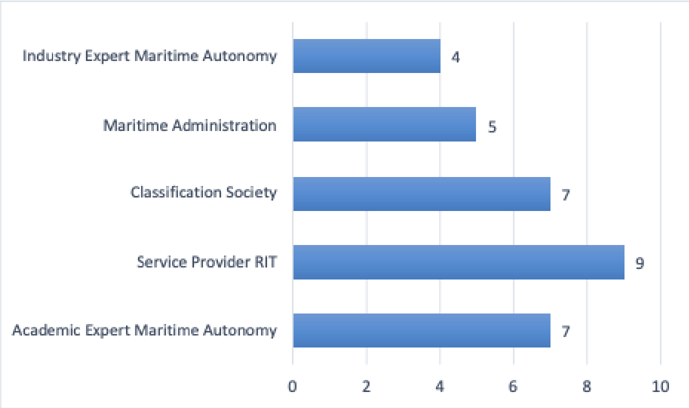

Figure 1: Number of participants per professional field

The respondents were invited to take part in a semi-structured interview on remote inspection technologies. The following two principal questions were posed to the respondents:

1. Based on your current knowledge (and professional perspective), would you say that Remote Inspection Technologies (Multi Aerial Vehicles/MAVs or Drones, Magnetic-wheeled Crawlers and Remotely Operated Vehicles/ROVs) for Hull Inspection are trustworthy? Please indicate your response on a scale from 1 to 5 with: (1) No, not at all. (2) Rather no. (3) Neutral (4) Rather yes. (5) Yes, absolutely.
2. What aspects make RITs trustworthy and what aspects do not?

4.2 Results and Discussion

As shown in Figure 2, the majority of the participants (40%) remained *neutral* when commenting on the trustworthiness of these systems, whereas 39% consider the use of RITs as *rather trustworthy.* Responses show that 18 % of the respondents find the systems *fully trustworthy* and only 3% consider them as *rather not trustworthy.* From the varying responses, authors note that classification societies deem these systems as moderately trustworthy, while service providers show a higher level of trust. While noting foreseeable and unforeseeable challenges that need to be addressed, all parties concur that remote technologies will be utilized in the maritime domain in the not-so-distant future.

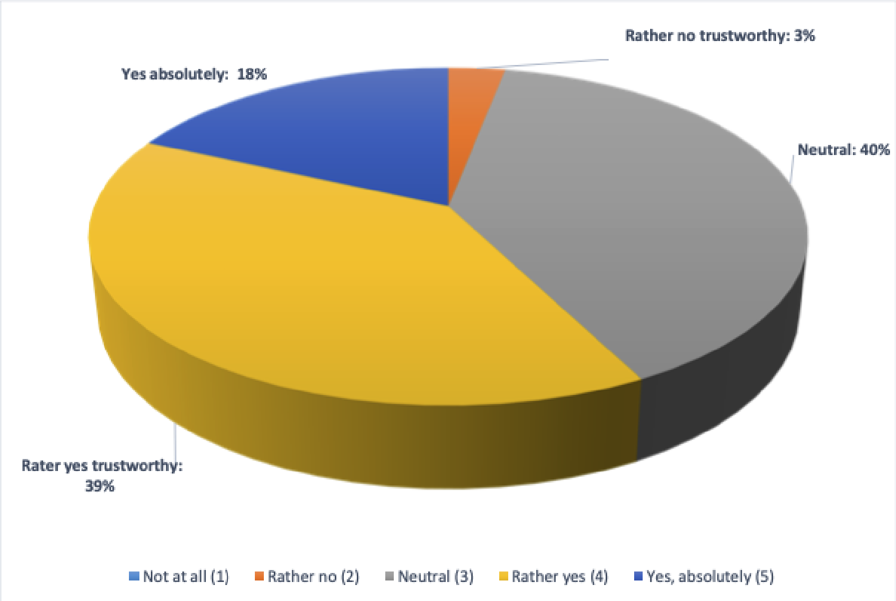

Figure 2: Level of Trustworthiness in RITs, n=33

With regard to the question on what makes RIT trustworthy, respondents' noted two elements, namely robustness and lawfulness (Figure 3). In this scenario, respondents stressed on a system that does not undermine human autonomy and supports individuals in effective decision-making. Respondents marked that even though the software integrates an extensible set of autonomous functions --- the current stage is semi-autonomy with the operator and surveyor-in-the-loop. Semi-autonomous RITs, such as Unmanned Aerial Vehicle (UAV), are fitted with cameras and live stream capabilities allowing human oversight and intervention. The operator or pilot is in charge of the unmanned aircraft/drone, which can operate out-of-sight and at a distance. During the process, the surveyor can assess the data either offline or by looking at live images and streaming videos transmitted by the operator of the service robot. In this instance, the surveyor is placed

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in the role of the ultimate decision-maker when it comes to acceptance or rejection of data collected by the UAV.

4.2.1 Robust Systems

Robustness of systems underscore two strategic dimensions: a) technical robustness; and, b) data governance. For technical robustness, the system's integrity is of paramount importance since RITs should be reliable and able to operate to the best of their capacity when required. Reproducibility of results is also crucial whereby the system should produce consistent results if the operation is repeated. Besides, the system's usability is a factor for consideration since it has to prove that it takes less time and is less costly than a traditional mode of survey.

Patently, the localization of drones and ROVs is an important concern since surveyors need to be aware of the robot's location in relation to its surroundings during the inspection process. Localization can be achieved either through onboard sensors that enable operators to observe its environment and its motion or with the help of a receiver that provides an estimate of its location based on a Global Positioning System (GPS). For drones flying in a confined space and storage tanks, a GPS signal may not be a viable option; therefore, the trustworthiness of those RITs can be enhanced with GPS-denied drone technology which includes: a) advanced visual sensors that enable the stabilization of a drone and obstacle avoidance sensors that can provide a drone with reference points, or b) a SLAM system (Simultaneous Localization and Mapping) that comprises of multiple sensors devising algorithms to map its surroundings in real-time. GPS positioning systems do not work underwater for ROVs as they can travel only a couple of inches through the water. One potential solution is to utilize technology such as the Underwater Positioning System (USBL) that detects the position of the ROV using acoustic positioning. USBL consists of a transceiver mounted on the vessel, and a transponder mounted on the ROV, which jointly cooperates to communicate the ROV's position relative to the vessel. However, there are cases that USBL on its own does not work well because the vessel is an obstacle for acoustics to communicate from the dunking transducer to the ROV's transponder.

Data governance and management are topics of great concern since a number of individual entities, namely, ship owners, service providers, and classification societies are involved in the inspection process. Data quality, including video and images, is one of the most crucial factors upon which trustworthiness in RITs rest. The quality of data is affected by various parameters, including lighting conditions, distance to the object and vehicle motion. High-definition cameras, artificial lighting and high precision sensors on UAVs and ROVs are paramount for detecting defects in the vessel's structure. Advanced image and data processing can be achieved with data localization, defect recognition and 3D scene reconstruction. 3D scene reconstruction of particular damages, via the use of high resolution visual, thermal, LIDAR and SONAR images, facilitates the identification of crack or damage localization and thicknesses in the hull structure.

For ROVS, three main concerns need to be taken into account for increasing data-trustworthiness: a) live stream connectivity; b) in-water visibility; and, c) weather conditions. For connectivity, past experience shows that satellite connections tend to be poor or average and, in turn, optimum quality video footage cannot be achieved. It is recognized that in-water visibility must be at least 2 meters, otherwise, the operator cannot identify the object under examination. Moreover, the sea environment (e.g., strong waves) should be monitored as currents more than 1.5 knots may force ROVs to float away from the vessel.

On the other hand, extremely windy conditions can prove to be dangerous for UAVs. This is due to the fact that UAVs must stabilize themselves to enable measurement accuracy. The problem differs in confined spaces because poor GPS connectivity leads to fuzzy data. 3D modeling that enables collision avoidance, quality dataset compilation and accurate 3D models of hull structure is one of the solutions to the above concern that will allow asset owners, service providers and classification societies to make highly informed decisions.

To achieve the desired robustness, RIT systems need to be secure given that the data retrieved is transmitted and supported by a wifi network. The growing interest in commercial UAV usage endangers the cyber domain and the security of generated data. A secure platform that will enable communication, data storage and data sharing between the different stakeholders is crucial.

To overcome this barrier more test-based statistics and data comparison is required to prove that the new technology is adequately safe and reliable, which is a precondition to mass deployment. A way forward could be to carry out trial inspections on the same vessel first using an ROV and subsequently cross-checking the data gathered against that obtained by a diver. Cracks identified by airborne or underwater images should be compared to traditional counterparts.

4.2.2 Lawful Systems

A lawful system is the third tool that has the potential to boost trustworthiness in RITs given that reliance on law is important to certain stakeholders involved in the RIT business model, such as policymakers and flag state officials that are not familiar with the system technicalities. Emphasis should be given on the development of standards and guidelines for technical specification and certification of these service robots to fulfill certain demands of the end-user. Thereafter, IACS and IMO techno-regulatory instruments should be updated at regular intervals. Accountability via governance frameworks and communication channels should be ensured with industry and/or public oversight groups, with a view to sharing best practices. Based on the responses provided by respondents, the following elements could be taken into account with a view to making the system "lawful":

- Regulation: IMO harmonized System aligned with IACS Unified Requirements;
- A separate Codes of Conduct: IACS rules and procedures;
- Standardization: ISO Standards or the IEEE P7000 standards series for maritime remote technology;
- Certification: Certificate standards for service providers and RITs operators
- National legislation for UAVs: a) for their operation in Visual Line of Sight (VLOS), Extended Visual Line of Sight (EVLOS) and Beyond Visual Line of Sight (BVLOS) and b) the certification of operators.

4.2.3 Other Important Factors

Many of the respondents highlighted three other incidental factors in addition to those described in the previous sections: a) the skills and expertise of the surveyor; and b) the lifecycle of the vessel. A number of respondents, especially from the maritime administration and classification societies, highlighted that experience, skills and training of the surveyors should not be underestimated. The surveyor's professional judgment that he/she exercises should not be different from existing physical/manual survey procedures. Even if the future systems hold a fully autonomous and energy-efficient operating system, humans should, nevertheless, be able to intercept an unwanted situation to ensure the safety of operations. Therefore, in light of the aforementioned, it is best to retain a human-in-the-loop.

In terms of the vessel's lifecycle, respondents noted that the decisions of maritime administration on the deployment of RITs are impacted by the type and age of the ship. Aging affects the structural integrity of the vessel via corrosion and fatigue cracks. RITs can easily be deployed on ships that are in their early lifecycle.

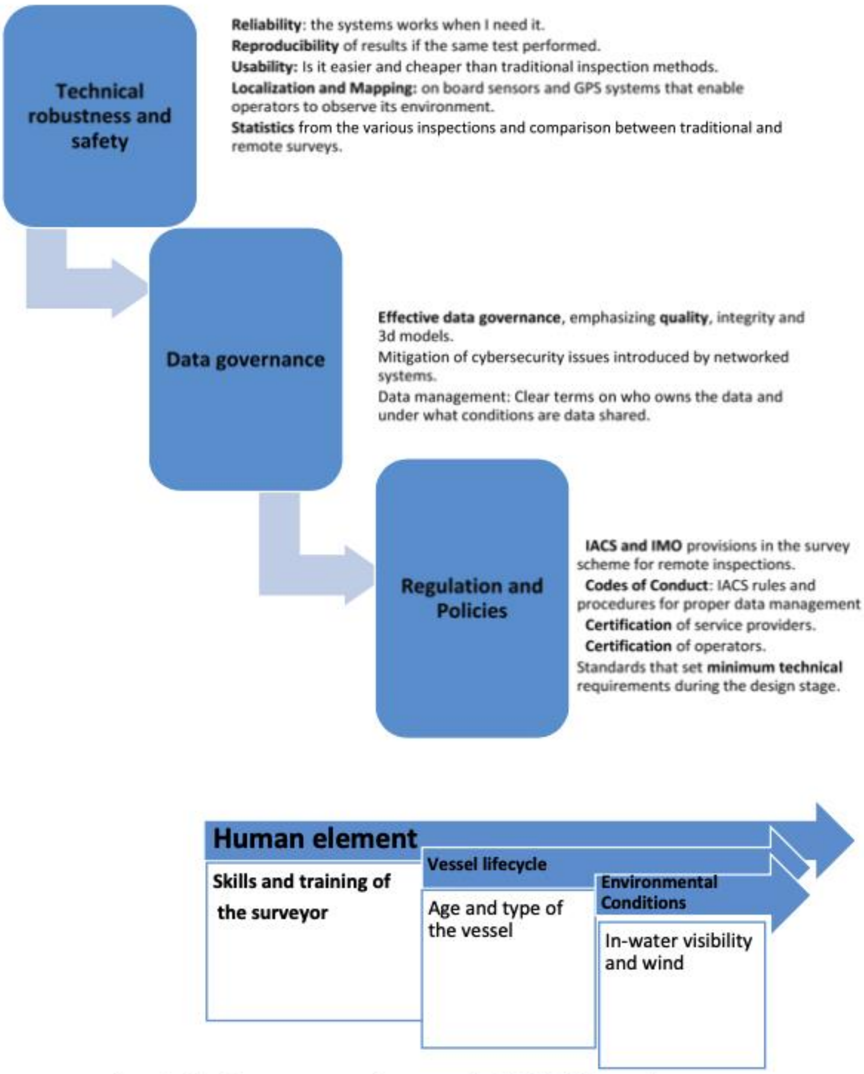

Figure 3: Most important aspects for trustworthy RITs for hull inspection

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5 The Way Forward for a Trustworthy Ecosystem: Stakeholders, Trust components, and Implementation

The European Commission stipulates that individuals should be able to trust technology with trustworthiness as a prerequisite for RITs uptake.[44] Notably, focusing on the three elements endorsed by the European Commission, respondents of this study emphasized on technical robustness, data governance and legal parameters in a system with human-in-the-loop. For technical robustness, the respondents noted that the system's integrity, usability and reproducibility of the results are central elements for a trustworthy ecosystem. Localization of these semi-autonomous systems is another area of concern since the surveyors should be able to locate the RIT immediately after deployment.

In terms of data parameters, findings from this study are consistent with conclusions drawn by Johansson et al:[45] data security and the effectiveness of data collection, data processing, and distribution of analysis outputs need to be demonstrated if RAS platforms are to achieve trustworthiness among the stakeholders of the business model.

The acquisition of more quantitative data for post-processing and analysis could certainly improve the robustness of these systems and assist in making assessments/decisions more objective. More data is needed in order to assess if RIT-based operations result in equivalent outcomes to a physical survey carried out by a surveyor. Results gathered by authors support previous psychological findings that technology-related features are most important for trust in a specific technology.[46] Thus, a technology-specific trust evaluation is vital when establishing a trust ecosystem. As indicated in multiple research on user acceptance, users evaluate

[44] Commission (n 48).
[45] Tafsir M. Johansson, Dimitrios Dalaklis, and Aspasia Pastra, 'Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers' 2021 9(6) Journal of Marine Science and Engineering < https://doi.org/10.3390/jmse9060594 > accessed 18 September 2021. See also Tafsir Johansson, Ronan Long & Dimitrios Dalaklis, 'The Role of WMU-Sasakawa Global Ocean Institute in the Era of Big Data', 2019 (14) The Journal of Ocean Technology 22.
[46] Hancock (n 22).

performance and necessary efforts (compared to a physical ship hull inspection) to fulfill the given work tasks.[47]

What is also noted from this study is the fact that the lack of clear regulatory guidance remains a significant concern. Currently, there exist a plethora of guidance notes prepared by individual classification societies, such as American Bureau of Shipping (ABS), Det Norske Veritas (DNV), Lloyds Register (LR), and China Classification Society (CCS). However, what is currently missing is guidance in the form of a Code of Conduct detailing limitations, apportionment of liability and other relevant matters that could instill confidence in flag administration and relevant stakeholders to assess the suitability of RITs. With the development of comprehensive guidance from IACS and experiences gained by ship owners/managers on RITs, a global framework to adopt the use of RIT promulgated under the auspices of IMO would be a befitting way forward to achieve uniform application of RITs by IMO Member States and the maritime industry. Concurring with the European Commission's vision, there is indeed a need for governance tools since trust is a policy objective that provides end-users with the confidence to take up AI applications. From a psychological perspective, policies and regulations act as externalizations of common representations.[48] They provide a framework for action that can give stakeholders guidance and confidence in the use of new robotic systems.

In that vein, it is also important to be cognizant that technologies should achieve at least the same quality of information as a human in relation to structural assessments and in a format easy to elaborate either automatically or by engineering judgment.[49] When employing efforts to identify procedures for assessing RITs performances objectively --- the human element as a part of HRI must remain within the scope of all current evaluations. Supervised or semi-autonomous, RITs enable the operator to control the device, even though the robot may operate from a

[47] Viswanath Venkatesh, James Y. L. Thong and Xin Xu, 'Unified Theory of Acceptance and Use of Technology: A synthesis and the road ahead' [2016] 17(5) Journal of the Association for Information Systems 328.
[48] Fiore (n. 44).
[49] Laura Poggi and others, 'Assessment of ship robotic inspections' (25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), September 2020).

distance through low-level decision-making software capabilities. The survey inspection procedures, and most importantly, the training schemes of surveyors must be adequately aligned to match the level of sophistication required to carry out services using respective RITs. This is broadly owing to the fact that not all RITs operate in the same environment.

As stated in IACS Rec. 42: "the results of the surveys by remote inspection techniques, when being used towards the crediting of surveys, are to be acceptable to the attending surveyor." The surveyor must exercise professional judgment and be satisfied with the quality and outcome when RIT is considered as an alternative to a physical survey. The surveyor's professional judgment cannot be any different from the judgment exercised in a survey that is conducted through physical presence. These findings underpin the psychological insight that a task-specific evaluation of trust is highly relevant when analyzing the trust ecosystem in RIT. In the analysis of trust or mistrust, it is necessary to identify the subtasks where the professional judgment of the surveyor is not supported by RITs or RITs outcomes are not satisfying for the surveyor. These subtasks must be carefully reviewed (i.e., trusting/mistrusting behavior) because the final responsibility for the inspection results still lies within the human surveyor.

Combining all the elements for developing a trust ecosystem identified in existing psychological trust literature, normative EU normative guidelines and the application-specific results of this study, the authors submit that an ecosystem of trust has multiple facets that relate to the governance scheme, social system, and technology itself. For trustworthy RITs, a holistic approach should be adopted since a trustworthy business model entails trust in the product that is likely to have a positive repercussion among the different stakeholders that are a part of the business model of non-personal data'[50] (See Figure 4).

[50] Johansson (n 50).

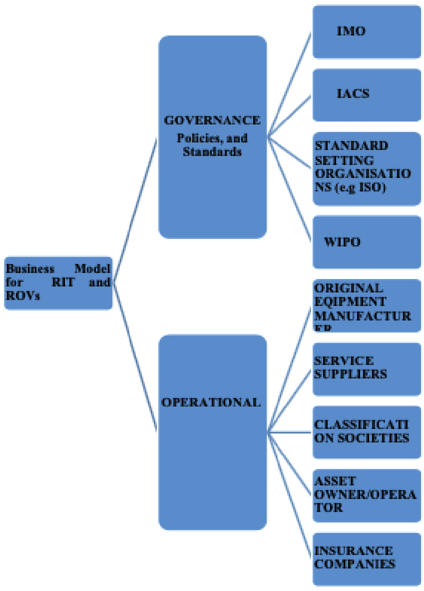

Figure 4: Stakeholder's ecosystem for the use of RITs
Source: Johansson, Dalaklis and Pastra, 2021

6 Concluding Remarks

Our findings contribute to the fragmented literature on trust in Artificial Intelligence. Although the definition of trust remains elusive, authors support that trust is primarily a psychological state with foundation dependent upon reciprocity, cooperation, and mutual concern for each other.[51] Trust in remote inspection technologies is a multi-faceted field that corresponds to a complex interplay among specific work tasks, human dispositions, organizational and team settings, stakeholder needs and policies. The above is further substantiated by respondents interviewed.

[51] Aspasia Pastra and others 'Exploring trust in the boardroom: the case of Nordic region' [2021] 27(3/4) Team Performance Management 278. See also Anil Ozturk: Lessons Learned from Robotics and AI in a Liability Context: A Sustainability Perspective (in "Sustainability in the Maritime Domain: Towards Ocean Governance and Beyond"), Angela Carpenter, Tafsir Johansson and Jon Skinner, eds., Springer, 2021).

The synthesis of all responses gathered indicate that for the adoption of RITs --- trust is certainly an invaluable precondition. Consequently, the notion of trust in RITs branch out into trust in the robustness of systems, data quality, reliability of data and security of databases. This is where a holistic Code of Conduct for RITs could be developed. What needs to be made clear is: when does the role of a human end and when does the role of RITs begin? A Code of Conduct, to this end, if developed bearing in mind the specific elements that constitute "trustworthiness" --- then it has the potential to solidify HRI-based operations increasing the level of trust within the ecosystem. Findings align with the literature and underscore that technology, law and trust are intrinsically linked and affect each other.[52] On the one hand, technology can improve the safety of life and safeguard the elimination of safety and liability risks. On the other hand, the law can strengthen trust in technologically advanced techniques and thus facilitate their adoption.[53]

As psychological findings clearly show, trustworthy AI is not a static process; rather a continuous evaluation of the relevant systems through technical and non-technical methods.[54] For the technical methods, various issues ought to be considered even from the architectural phase of AI. For example, the systems should be developed following white-list specific rules, procedures and "blacklist" restrictions. Non-technical methods, such as work tasks, human-related experience, organizational and team settings, regulations, Codes of Conduct, certification, accountability and an ethical mindset should be assessed on a regular basis and in a manner that is continuous.

Findings from the discussion on RIT trust ecosystem may provide invaluable insights when spearing through the notion of "trustworthiness" in generic technologies deployed as a human-proxy in other operations where permissible. To take but one example, MAVs used for payload carriage, delivery, agriculture, outer-space exploration, emergency rescue etc., are built on the

[52] Anton Vedder, Colette Cuijpers, Petroula Vantsiouri & Mariana Zuleta Ferrari 'The Law as a 'Catalyst and Facilitator' for Trust in E-Health: Challenges and Opportunities'[2014] 6(2) Law, Innovation and Technology, <https://doi.org/10.5235/17579961.6.2.305 > accessed 10 October 2021.
[53] Ibid.
[54] Hancock (n 22); Hoff (n 11); Schaefer (n 7) see also Commission (n 10).

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same technical formula but configured to achieve different pre-set objectives that go beyond survey and maintenance of specific objects for determining durability (as discussed in this article). For a sound comprehension of how the trust ecosystem operates in other technologies, one may need to fathom the technical, operational and objective-based differences that distinguish one technology from another. This is due to the fact that autonomous vehicles will trigger risks, impacts and issues different from autonomous vessels or autonomous RITs. Therefore, it will be important to identify/project those risks, impacts and incidental issues with respect to individual classes of technology before exploring the trust ecosystem. Not every technology is deployed for extracting vessel structure data calling for strict data governance management plans. Then again, not every technology unleashed in the maritime domain is configured to protect the environment or save the human element from work that is onerous, risky and time consuming.[55] Tasks, responsibilities and outcomes differ. Moreover, the *modus operandi* of transport-technologies differs from other technologies, such as, information technology, biotechnology, communication technology, medical technology etc. Despite the inherent difference, human presence is the common denominator in all existing technologies. In other words, until innovation unlocks the "full autonomy" frontier, human intervention or HRI will remain as an element of the operational system. "Trust" between humans in RAS or RITs will therefore, have an important bearing on respective operations whether land, air or underwater regardless of the level of risks attached to those operations. An appreciation of the RIT trust ecosystem could certainly be a stepping stone in unveiling the grey areas and help dissipate some of the thorny issues dormant in the operation of other technologies bound by a complex relationship between a natural person and a product.

[55] Especially in the maritime domain. Further insight can be gathered from the following publications: Neil Belelfontaine and Tafsir Johansson: Effective and Efficient Maritime Administration & Corporate Social Responsibility (in "CSR in the Maritime Industry, Lisa Froholdt, ed., Springer,, 2018); Lawrence Hildebrand, Neil Belelfontaine and Tafsir Johansson: The International Maritime Organization and Oil Pollution in the Mediterranean Sea (in "Oil Pollution in the Mediterranean Sea" (The Handbook of Environmental Chemistry), Angela Carpenter, ed., Springer Berlin Heidelberg, 2016); Neil Belelfontaine and Tafsir Johansson: The Role of the International Maritime Organization in the Prevention of Illegal Oil pollution from Ships: North Sea Special Status Area (in "Oil Pollution in the North Sea" (The Handbook of Environmental Chemistry), Angela Carpenter (ed.), Springer Berlin Heidelberg, 2016).

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THE INTERNATIONAL JOURNAL OF MARINE AND COASTAL LAW 37 (2022) 1–23

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Inspecting Ships Autonomously under Port State Jurisdiction: Towards Sustainability and Biodiversity in the EU

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Abstract

This article examines the possibility of autonomous inspection robots being used to undertake inspection tasks conducted on the basis of port State jurisdiction in European Union (EU) Member States' ports. A brief overview of technical research concerning such robots is offered. The article then outlines the EU legal framework concerning port State jurisdiction, and contextualises this legal landscape by recalling the history of attempts at the EU and international level to regulate in response to maritime disasters since the 1980s. Based on a close reading of the Port State Control Directive, alongside analysis of the aims pursued and policy options proposed in the context of the European Commission's significant ongoing work on a review of this instrument, it is clear that the adoption of autonomous inspection technologies could offer significant benefits, permitting more efficient completion of existing inspection tasks and potentially changing what is and is not considered feasible in inspection scenarios.

Keywords

port State jurisdiction – autonomous – European Union – sustainability – port State control – biodiversity – substandard shipping

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Introduction[1]

Robotic systems capable of visually inspecting, measuring for corrosion and thickness, and cleaning the hulls and structures of large ships are currently the object of growing technological development and investment. These systems can be composed of multiple individual robots of different kinds – for example micro aerial vehicles (drones), underwater vehicles and crawlers that magnetically attach to a metal surface – potentially operating to varying extents autonomously and making decisions based on artificial intelligence capabilities. While these technologies are still under development, it seems likely that they will become more widely used in situations where the structures, and especially the outer hulls, of large ships are inspected and/or cleaned. By potentially facilitating more frequent and detailed inspections of the outer hulls and structures of ships by States asserting port State jurisdiction these technologies could contribute to the reduction of substandard shipping and to the protection of the marine environment. By inspecting for and subsequently removing accumulated organic matter (biofouling) on ship hulls, these robotic systems could support significant fuel savings through the greater fuel efficiency created by smooth hulls, leading to lower greenhouse gas (GHG) emissions. More rigorous monitoring and removal of biofouling could also protect marine biodiversity from threats posed by alien invasive species introduced to a new ecosystem having been carried there on a ship's hull. This article addresses the question of how we can build these technologies into legal regimes that contribute to the enforcement of standards relating to the safety and maintenance standards of ships, the protection of the marine environment, and climate change mitigation. This perspective views these new technologies, not as posing new problems for European Union (EU) or International Maritime Organization (IMO) regulators, but as offering new possibilities.

This article outlines the legal framework applicable to the use of such autonomous robotic inspection systems by EU Member States asserting port State jurisdiction over ships entering their ports. Thus, by examining the EU's harmonisation of the way its Member States fulfil their responsibilities as port States, the article focuses on a point of intersection between EU law and the

1 The research that resulted in this publication was conducted under the European Union Horizon 2020 funded project 'Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks' (BugWright2), grant agreement No. 871260. The author would also like to acknowledge the generous funding of the World Maritime University (WMU)-Sasakawa Global Ocean Institute by The Nippon Foundation.

law of the sea.[2] The extent to which the aims pursued by EU legislation on port State jurisdiction – the improvement of 'maritime safety, security, [and] pollution prevention' – could be supported by the employment of autonomous inspection robots that are currently under development is analysed. This focus on EU port State jurisdiction as it relates to autonomous inspection technologies is useful for three main reasons. First, the European Commission is currently engaged in a process of revising the primary piece of EU legislation governing port State jurisdiction, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (the PSC Directive).[3] Through close analysis of the current version of the Directive alongside the Commission's assessment of its operation to date, this article examines how wider adoption of autonomous ship inspection robots could support the aims pursued by this significant legislative initiative.

Second, the EU has been particularly active in policy areas related to these technologies, especially on reducing substandard shipping, and on combatting climate change. On the topic of reducing substandard shipping, an interest can be perceived, especially among Members of the European Parliament (MEPs), to use EU legislation to prompt Member States to exercise their jurisdiction as flag, coastal or port States with more force and frequency with the aim of making shipping safer, cleaner and less polluting. It could be argued that this interest connects with a wider current impetus to expand regulatory powers of the State over maritime spaces in ways not limited to the flag and zonal architecture of the United Nations Convention on the Law of the Sea (LOSC). This impetus was well-captured by the observation made by Malcolm Evans when giving evidence before the International Relations and Defence Committee of the UK House of Lords in October 2021, that much room existed to 'ratchet up' assertions of State regulatory power within the existing LOSC framework.[4] With regard to climate change policies, the EU's increasingly strenuous efforts to reduce the contribution made by shipping to GHG emissions have taken the form of an argument with the IMO, conducted in a legal idiom but that is in substance a clash over the politics of climate change.

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2 For a conceptualisation of the concept of 'responsible Port state' see EJ Molenaar, 'Port State jurisdiction: Toward comprehensive, mandatory and global coverage' (2007) 38 *Ocean Development and International Law* 225–257.

3 Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L 131/57 [Directive 2009/16].

4 M Evans, 'Formal meeting (oral evidence session) of the International Relations and Defence Committee of the House of Lords: UNCLOS: Fit for purpose in the 21st century?' available at https://committees.parliament.uk/event/6011/formal-meeting-oral-evidence-session/. All websites accessed 10 March 2022, unless otherwise mentioned.

Third, this focus on the EU is merited because the EU's activity in these areas is of global systemic relevance. The EU has expressed a willingness to threaten to squeeze the IMO's position as prime regulator in the area of maritime policy. The EU's economic power and importance as a market for shipping makes this threat credible, with the consequence that EU law and policies are of interest internationally as they have the potential to both set standards and have effects beyond the EU.[5]

The article proceeds as follows. The first section explains what autonomous inspection robots are, and what kinds of inspection and cleaning tasks they can perform, or are likely to be able to perform in the near future. The second section outlines the EU legal framework concerning port State jurisdiction, its interaction with the prerogatives and obligations of States under the law of the sea, and with the Paris Memorandum of Understanding on Port State Control. The third section offers a truncated history of attempts to regulate and adequately enforce construction, safety and maintenance standards of merchant ships since the 1980s, focusing on EU acts and the specific problems associated with bulk carriers and oil tankers. The fourth section closely analyses provisions of EU legislation on port State jurisdiction that require the inner and outer structures of ships to be inspected, linking these requirements to capabilities of autonomous inspection robots. The fifth section examines the Commission's ongoing work on a review of the PSC Directive, examining how autonomous inspection robots could support the aims pursued by this initiative. The possibility of new EU legislation mandating that ships entering Member State ports comply with standards prescribing maximum acceptable levels of biofouling is examined, drawing a comparison with such initiatives in other jurisdictions. The fifth section briefly concludes.

What Are Autonomous Inspection Robots?

The autonomous inspection robots referred to in this article comprise a system of multiple different kinds of robots operating cooperatively to inspect and potentially clean a large structure composed of metal plates, such as the hull of a medium or large ship. There are three primary categories of such

5 S Kopela, 'Port-State jurisdiction, extraterritoriality, and the protection of global commons' (2016) 47(2) *Ocean Development and International Law* 89–130, at p. 90; on the EU's use of extraterritorial jurisdiction see J Scott, 'Extraterritoriality and territorial extension in EU law' (2013) 62(1) *American Journal of Comparative Law* 87–126 (cited in Kopela); see also J Leeuwen, 'The regionalization of maritime governance: Towards a polycentric governance system for sustainable shipping in the European Union' (2017) 117 *Ocean & Coastal Management* 23–31.

robot. Micro aerial vehicles are small multi-propeller drones that can systematically move around a large vessel, providing visual feedback to an operator. Autonomous underwater vehicles are small submersibles that can systematically visually map the portion of a ship's hull that is underwater. Finally, magnetic wheeled crawlers can attach to a steel plate surface and conduct acoustic based inspection of the surface above and below the waterline. By transmitting sound waves at the surface as they move slowly across it, these crawlers can measure the thickness of the steel, thus identifying points thinned by corrosion with significant accuracy. It is possible for all three categories of robot to work together, with several individual units of each kind transmitting data into a single augmented reality representation of a vessel, monitored by a human inspector. This vision, which is the object of the BugWright2 research project on which this article draws, is sketched in Fig. 1.

Drones, submersibles and crawlers of these kinds are currently most commonly operated remotely by a dedicated human operator, without making autonomous decisions about their own navigation or about the surfaces they inspect. However, significant research effort is currently being dedicated to developing inspection systems composed of robots that can navigate autonomously, while decisions about defects identified are taken by a human operator. It is not unrealistic to imagine that in the near future a greater level of autonomous operation may be attained, with teams of robots making independent decisions in order to synchronise their movements around a vessel, while using large stores of data from past inspections to make further decisions about defects identified on the vessel being inspected.

In the near future, the most holistic use of all three categories of inspection robot, represented in Figure 1, could permit ship surveys and inspections that

FIGURE 1 Drones, magnetic wheeled crawlers and submersibles working autonomously to visually and acoustically scan a ship while transmitting data to a human operator
SOURCE: C PRADALIER, 'AUTONOMOUS ROBOTIC INSPECTION AND MAINTENANCE ON SHIP HULLS AND STORAGE TANKS' (BUGWRIGHT2), DESCRIPTION OF THE ACTION, EU HORIZON 2020 GRANT AGREEMENT NO. 871260, USED WITH PERMISSION

would ordinarily take place in dry dock to be undertaken at the quay, potentially even while a vessel is unloading and loading cargo. Depending on the type of vessel and the level of inspection being undertaken, drones, crawlers or submersibles might also be used independently of each other. For example, submersibles could conduct a visual inspection of the underwater portion of the hull of a fishing vessel, while drones could be well suited to conducting a visual inspection of the massive sides of a cruise vessel, or the outer hull and inner cargo areas of a bulk carrier. Where hull cleaning is the aim, a team of crawlers fitted with brushes can be deployed to systematically sweep the hull clean of organic matter. The advantage offered by these technologies is that they can make it easier to quickly and effectively examine and clean difficult to access parts of a ship's outer and inner structure.

A Point of Intersection between EU Law and the Law of the Sea

This article focuses on ways such autonomous inspection robots could be used in the future by national authorities asserting port State jurisdiction in EU ports. Hence, the immediately applicable and overarching legal framework is provided by the PSC Directive, with its three implementing regulations.[6] With this Directive, the EU has sought to harmonise how its Member States exercise prerogatives they enjoy as port States under the law of the sea.

The ability of port States to prescribe and enforce legal standards with respect to ships choosing to enter their ports follows from a concurrent reading of several provisions of the LOSC.[7] Article 11 provides that outer parts of harbour works form part of the coast, making them part of the baseline and placing ports within internal waters; Article 8(1) specifies that waters landward of the baseline are internal waters; and, in stating that that the sovereignty of a State extends 'beyond its land territory and internal waters' to other specified

6 Directive 2009/16 (n 3). The Directive's three implementing regulations are: Commission Regulation (EU) No 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships, OJ L 125 [Commission Regulation No 428/2010]; Commission Regulation (EU) No 801/2010 of 13 September 2010 implementing Article 10(3) of Directive 2009/16/EC of the European Parliament and of the Council as regards the flag State criteria, OJ L 241; and Commission Regulation (EU) No 802/2010 of 13 September 2010 implementing Article 10(3) and Article 27 of Directive 2009/16/EC of the European Parliament and of the Council as regards company performance, OJ L 241.

7 R Churchill, 'Port State jurisdiction relating to the safety of shipping and pollution from ships: What degree of extra-territorialty?' (2016) 31(3) *International Journal of Marine and Coastal Law* (IJMCL) 442–469.

zones, Article 2(1) makes it clear that States enjoy territorial sovereignty over internal waters.[8] It follows from this pattern of provisions that States exercise prescriptive and enforcement jurisdiction that is territorial in nature over all ships, whether flying that State's flag or not, while they are in port, subject to any agreements with other States that may limit such jurisdiction. As noted by Robin Churchill, this is also the position under customary international law, binding States with maritime ports, but that have not ratified the LOSC.[9]

This article addresses the broader concept of port State jurisdiction, as opposed to port State control. Erik Jaap Molenaar usefully clarifies the distinction between these concepts by noting that port State control is best understood by reference to the terms of regional memoranda of understanding (examined below) defining voluntary commitments among States Parties to undertake control inspections of foreign ships calling at their ports with the aim of verifying compliance with internationally agreed standards, and to take enforcement action with respect to those standards that is largely corrective in nature.[10] Port State jurisdiction can be understood to encompass such control inspections, but to also include prescriptive and enforcement jurisdiction of port States over foreign flagged ships in their ports with respect to national or supranational legislation that may be more onerous than internationally agreed standards. A wider focus on port State jurisdiction is appropriate here because applications of autonomous inspection robots are envisaged that would support enforcement of international conventions, as well as applications that could support EU Member States exercising prescriptive jurisdiction over foreign flagged ships in their ports, for example, with regard to standards intended to safeguard marine biodiversity by prescribing minimum acceptable levels of biofouling.

Today, a consensus can be said to exist, in scholarship and as evidenced in State practice, that views port State jurisdiction as an increasingly important supplement to (though not a replacement of) flag State jurisdiction. It is a jurisdictional basis that is widely seen as supporting the assertion of relatively broad regulatory powers by port States over foreign flagged ships, and as an important tool with which to pursue the realisation of community interests

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8 United Nations Convention on the Law of the Sea (Montego Bay, 10 December 1982, in force 16 November 1994) 1833 *UNTS* 3; Churchill (n 7), at p. 444.

9 Churchill, *ibid.* Noting recognition of a State's wide discretion in exercising sovereignty over ports within its territory under customary international law, see Molenaar (n 2), at p. 227. This view was stated by the International Court of Justice in *Case concerning Military and Paramilitary Activities In and Against Nicaragua* (*Nicaragua/United States of America*) (*Merits*) [1986] ICJ Reports 14, at 111.

10 Molenaar (n 2), at p. 227.

such as the protection of the marine environment; the rigorous enforcement of construction, design, equipment and manning (CDEM) standards pertaining to ships; and measures relating to climate change mitigation.[11] With respect to port State control, the sixth recital to the PSC Directive evokes the current widespread emphasis of the role of port States in enforcing international standards neglected by flag States:

> [T]here has been a serious failure on the part of a number of flag States to implement and enforce international standards. Henceforth, as a second line of defence against substandard shipping, the monitoring of compliance with the international standards for safety, pollution prevention and on-board living and working conditions should also be ensured by the port State, while recognising that port State control inspection is not a survey and the relevant inspection forms are not seaworthiness certificates.[12]

11 On jurisdiction to prescribe and enforce CDEM standards see Churchill (n 7), at p. 445–458; For an overview of international law debate concerning port State jurisdiction see the 2016 special issue of the *International Journal of Marine and Coastal Law*: C Ryngaert and H Ringbom, 'Introduction: Port State jurisdiction: Challenges and potential' (2016) 31(3) *IJMCL* 379–394. The more contentious aspects of this debate tend to concern States asserting jurisdiction over ships in their ports on jurisdictional bases that are extra-territorial in nature (such as with regard to discharges alleged to have occurred outside maritime zones of the State in question), or in ways that have, or can be argued to have, extra-territorial effects. See Kopela (n 5). On discharges outside the port State's maritime zones, see Z Sun, 'The Role of East Asian Port States in Addressing Ship-Source Pollution in Arctic Shipping' (2022) *World Maritime University* [forthcoming publication]; Y Tanaka, 'Protection of community interests in international law: The case of the law of the sea' (2011) 15 *Max Planck Yearbook of United Nations Law* 329–375, at pp. 350–356. The territorial basis for assertions of port State jurisdiction addressed in this article can be considered sufficient, although some of these acts may be argued to have extra-territorial effects. Adopting a similar position see Molenaar (n 2), at p. 228. On this point, and considering the position of the European Court of Justice with regard to extra-territorial effects, see AN Honniball, 'The exclusive jurisdiction of flag States: A Limitation on pro-active port States?' (2016) 31(3) *IJMCL* 499–530.

12 Directive 2009/16 (n 3). This remained the view of the Commission as of its publication of an Inception Impact Assessment of the operation of the PSC Directive in October 2020: 'Port State Control is considered the third line of defence against sub-standard shipping, the primary responsibility laying with the shipowner and the flag state (the state of registration of the vessel). However as some owners and some flag states have shown an inability or an unwillingness to correctly discharge their responsibilities PSC is seen as a very important enforcement tool. Ensuring compliance with international rules and standards by vessels calling EU ports promotes a level playing field between shipowners. In addition, increasing the quality of shipping in EU waters helps preventing big maritime accidents and its associated financial and environmental costs'. Inception Impact

The PSC Directive and the Paris Memorandum of Understanding

The PSC Directive has the effect of making binding on EU Member States the particular system for coordinating inspections undertaken based on port State jurisdiction established by the Paris Memorandum of Understanding on Port State Control (the Paris MoU). The Paris MoU, like other regional agreements coordinating port States' undertaking of control inspections, is an agreement between States to coordinate inspections carried out by their national maritime authorities with the aim of enforcing international legal standards. First agreed to in 1982 between the then EU Member States and Norway, the Paris MoU now has twenty-seven Member States, including all EU Member States with seaports, the Russian Federation, Iceland, Canada and Norway.[13] Concretely, such regional MoUs on port State control entail the administration of databases recording results of past inspections and assigning risk profiles to individual ships based on those records; they outline procedures and parameters for how many inspections States Parties should undertake, how those inspections should be conducted and what should be inspected; and they facilitate the coordinated refusal of access to ports in the MoU region for ships failing to satisfy inspection standards or take remedial action. The regional system of MoUs has been criticised for failing to make consistent inspection practices between different MoU regions, and between States in the same MoU region, and for its non-binding character.[14]

As noted above, the EU would appear to have solved this problem, binding its Member States by layering its PSC Directive atop the arrangements made within the Paris MoU, and linking the practical operation of the Directive, for example with respect to the assignation of ship risk profiles, to the methods established by the Paris MoU.[15] With the international conventions enforced under the Paris MoU, the PSC Directive also coordinates Member States'

Assessment: 'Port State control - Strengthening safety, security and sustainability of maritime transport', DG MOVE.D2 – Maritime safety (2020) [Inception Impact Assessment].

13 Inception Impact Assessment (2020) (n 12). There are eight other regional MoUs: Asia and the Pacific –Tokyo MoU; Latin America – Acuerdo de Viña del Mar; Caribbean – Caribbean MoU; West and Central Africa – Abuja MoU; Black Sea region – Black Sea MoU; Mediterranean – Mediterranean MoU; Indian Ocean – Indian Ocean MoU; and Gulf region –Riyadh MoU. The United States Coast Guard maintain the tenth PSC regime. See IMO, 'Port State control' available at https://www.imo.org/en/OurWork/MSAS/Pages/PortStateControl.aspx.

14 A Graziano, MQ Mejia Jr. and J Schröder-Hinrichs, 'Achievements and challenges on the implementation of the European Directive on Port State Control' (2018) 72 *Transport Policy* 97–108, at p. 98, and criticism cited therein.

15 Directive 2009/16 (n 3), Recitals 9, 13, 14, 15.

enforcement of EU maritime legislation.[16] An exception made in the fortieth recital and in Article 3(1) of the Directive and related to MoU regions is addressed to France, permitting France's remaining colonies, the 'overseas departments' listed in Article 299(2) of the Treaty Establishing the European Community (TEC), now Article 349 of the Treaty on the Functioning of the European Union (TFEU), to be exempted from the port State control system applied pursuant to the PSC Directive, due partly to the fact that some of these territories are parties to different regional MoUs, as well as due to their geographical distance from Europe.[17]

Regulating in Response to Disasters

Briefly recalling the background to this contemporary legal landscape spanning multiple regimes is worthwhile because it contains salutary lessons for attempts to regulate shipping today. The 1980s and 1990s saw a series of significant disasters involving oil tankers and bulk carriers. Bulk carriers are used to carry huge quantities of loose dry cargo like grain, iron ore, or fertilizers. These vessels came into use in the post-war period, but in the early 1990s a large number of bulk carriers were wrecked after suffering catastrophic structural failures, in some cases simply breaking apart in heavy weather. Once these vessels failed, they were frequently flooded and lost extremely quickly, with the consequence that all crew died.[18] Research into the problem revealed that bulk carriers are subjected to particularly serious structural strains due to factors such as the loading and unloading of heavy, loose materials; the movement of unevenly distributed loose cargo; accelerated corrosion of metal plates composing the hull due to the chemical composition of these cargoes; design flaws; and the increased use of thinner, high-tensile steel plates.[19] Age was also a central causal factor, with most of the bulk carriers lost in the early 1990s being over 20 years old.

16 *Ibid.*, Article 1(a); Paris Memorandum of Understanding on Port State Control, Section 2, 'Relevant Instruments' [Paris MOU]; V Power, *EU Shipping Law* (3rd ed., Routledge, London, 2019) 1305.

17 Directive 2009/16 (n 3), Recital 40, Article 3(1); Consolidated version of the Treaty on the Functioning of the European Union, OJ C 326, Article 349 [TFEU].

18 'Bulk carrier - Improving cargo safety' [2007] United Nations Atlas of the Oceans available at https://web.archive.org/web/20070927063932/http:/www.oceansatlas.com/unatlas/issues/safety_at_sea/bulk_carrier/bulk_carrier.htm.

19 *Ibid.* High tensile steel can allow metal plates composing a ship's hull to be thinner than mild steel. This has the consequence that corrosion becomes a structural threat more quickly.

Since the 1980s oil tankers had also been involved with some regularity in massive disasters that caused catastrophic environmental pollution, making up a considerable portion of total worldwide losses of ships.[20] Concern in Europe at this trend had initially prompted the 1982 agreement to the Paris MoU. The 1999 breaking in two of the Maltese tanker *Erika* off the French coast and the 2002 wrecking of the Bahamian tanker *Prestige* off the Spanish coast prompted significant EU legislative packages focused on, among other topics, using inspections undertaken under port State jurisdiction to more vigorously enforce safety and maintenance standards with respect to foreign flagged vessels. Both the *Erika* and the *Prestige* had broken in two, were over twenty years old, and had been inadequately maintained and surveyed.[21] A particular contributing factor to disasters involving tankers was the use of tankers of a single, rather than double hulled design.[22] This prompted the EU to adopt a regulation accelerating the timetable specified by the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL) for the phasing out the use of single hulled oil tankers.[23]

This spate of shipping disasters from the 1980s through to the 2000s, involving especially but not only bulk carriers and tankers, catalysed efforts to impose more stringent legal standards for the construction, maintenance and inspection of merchant ships. One important outcome of these efforts, which is of particular relevance to the focus of this article, were the 1993 Guidelines on the Enhanced Programme of Inspections during Surveys of Bulk Carriers and Oil Tankers adopted by the IMO Assembly, on the basis of which amendments were made to the International Convention for the Safety of Life at Sea (SOLAS) that entered into force in 1996.[24] The Guidelines mandate enhanced survey procedures be applied to bulk carriers and tankers during the surveys prescribed by SOLAS, focusing on identifying corrosion, taking plate thickness measurements, how close-up surveys should be conducted, who is qualified to

20 MA Nesterowicz, 'European Union legal measures in response to the oil pollution of the sea' (2004) 29(1) *Tulane Maritime Law Journal* 29–44, at p. 31.

21 *Ibid.*, at pp. 32, 39.

22 Double hull tankers are designed with two layers of metal plates separating the oil they carry from the seawater. *Ibid.*, at p. 33, n 44.

23 International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997 (entered into force on 2 October 1983), 1340 *UNTS* 61 [MARPOL]; Nesterowicz (n 20), at pp. 33, 35.

24 Guidelines on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers, IMO Resolution A.744(18) adopted 4 November 1993; International Convention for the Safety of Life at Sea (SOLAS), 1974 (entered into force on 25 May 1980), 1184 *UNTS* 2.

conduct such surveys and what documents ships must carry to demonstrate compliance with these requirements.[25]

Responsibility for ensuring compliance on the part of ship owners and operators with these legal instruments lies primarily with flag States. Those States will in turn ordinarily follow the longstanding practice of privatising the responsibility of actually conducting the required surveys by contracting private companies to do so – classification societies.[26] However, the history of the development of these legal instruments shows that port States can also play a significant and at times crucial role in ensuring their enforcement. Australia's tightening of port State inspections in the early 1990s in response to disasters concerning ageing bulk carriers at first resulted in a large movement of bulk carriers from the Pacific to the Atlantic, apparently by owners seeking to protect their substandard vessels from Australia's more stringent inspection regime.[27] Subsequently, wider enforcement of standards concerning safety procedures, construction, design and maintenance of bulk carriers and tankers, alongside the agreement of IMO level guidelines, raised standards worldwide. When taken by port States in an economic and geographical position to do so, unilateral enforcement measures like those of Australia can contribute to raising standards more widely, including by prompting activity through the IMO.[28] The EU's speeding up of the phasing out of single hulled oil tankers in the early 2000s is another example of unilateral (in this case, on the part of a regional body) regulation that went beyond internationally agreed standards and had the effect of helping to lift global standards.[29]

Writing in 2004 of the EU's successive efforts to combat oil pollution resulting from disasters involving old, poorly maintained and surveyed oil tankers, Malgorzata Anna Nestorowicz summarised the situation in the following way:

25 Relatedly, the EU has legislated to harmonise procedures for the safe loading and unloading of bulk carriers: Directive 2001/96/EC of the European Parliament and of the Council of 4 December 2001 establishing harmonised requirements and procedures for the safe loading and unloading of bulk carriers, OJ L 13.

26 For analysis of the position of classification societies within the field of global maritime governance drawing on Bourdieusian sociological concepts, see R Lillillour and DB Fernandez, 'The balance of power in the governance of the global maritime safety: The role of classification societies from a habitus perspective' (2021) 22(3) *Supply Chain Forum: An International Journal* 268–280.

27 'Bulk carrier - Improving cargo safety' (n 18).

28 Molenaar (n 2), at p. 226.

29 The United States had previously taken unilateral action to phase out the use of single hull tankers: Oil Pollution Act of 1990, 104 Stat. 484.

> Even if the recent years have seen an important development in monitoring and control of the maritime traffic on the international level, they can hardly catch up with the potential dangers that shipping brings about. The mechanism established by the IMO granting a flag state major prerogatives over its ships is not effective anymore. The ownership of the registered tonnage is largely concentrated in new flag states where the IMO conventions are either not uniformly adopted or, if adopted, not properly enforced due to insufficient controls of ships by the flag state authorities. Moreover, many of the IMO resolutions are not legally binding. This allows many substandard ships to continue to operate under one of the flags of convenience where controls are not too strict. Employing an old, substandard ship constitutes for many importers a major reduction in fixed costs.[30]

The EU's efforts to harmonise how Member States assert port State jurisdiction, currently manifested in the PSC Directive, is yet another unilateral (regional) attempt to address this situation by better enforcing compliance with internationally agreed standards with respect to ships entering EU ports, as well as to enforce EU maritime legislation that goes beyond standards provided for in international conventions. This can be welcomed as a productive contribution to improving the safety of life at sea, the protection of community interests like the marine environment, and as a measure that reduces substandard shipping and removes a competitive advantage enjoyed by owners and operators that benefit from cutting costs by operating poorly maintained ships.[31]

From the truncated history of legal developments concerning ship construction, maintenance and inspection standards presented here, we can draw two significant lessons. First, as is often noted by commentators, an assertion of public regulatory power that may seem improbable today is often one disaster away from becoming an imperative and obvious priority of powerful actors keen to act and be seen to act. Second, these legal developments are often propelled through initial unilateral acts taken by powerful States or regional organisations. Departing from a perspective cognisant of these lessons, the following section examines the extent to which the employment of autonomous inspection robots could, or would, constitute an innovation in the operation of port State jurisdiction from the perspective of EU law.

30 Nesterowicz (n 20), at p. 44.
31 Molenaar (n 2), at p. 226; Directive 2009/16 (n 3), Recitals 7, 16.

Inspection of Ship Structures under Current EU Legislation on Port State Jurisdiction

The PSC Directive is the latest iteration of EU legislation on how Member States undertake inspections based on port State jurisdiction. In response to events, including those outlined in the previous section, it consolidates and moves the law further than previous legislation on the subject. As Vincent Power notes, the Directive embodies the fact that 'PSC is best seen as an evolutionary regime'.[32] The legal basis for the PSC Directive was Article 80(2) of the TEC, now Article 100(2) of the TFEU. Article 100(2) falls under Title VI, which sets out a framework for a common transport policy, and gives the European Parliament and Council the power to 'lay down appropriate provisions for sea and air transport'. [33] The stated purpose of the Directive is 'to help drastically reduce substandard shipping in the waters under the jurisdiction of the Member States', and in scope it applies to 'any ship and its crew calling at a port or anchorage of a Member State to engage in a ship/port interface', with the possible exception of ports of French colonies noted above.[34] Member States are required to 'take all necessary measures, in order to be legally entitled to carry out the inspections referred to in this Directive on board foreign ships, in accordance with international law', entailing national legislation be adopted by Member States to empower their competent authorities, and that those authorities be adequately staffed and equipped.[35] The Directive requires Member States to refuse access to ports and anchorages in their jurisdiction where a ship fails to satisfy inspection criteria on several occasions and after specified time periods, and to detain any ship exhibiting deficiencies 'clearly hazardous to safety, health or the environment' until the deficiencies are rectified.[36]

A number of provisions of the PSC Directive establish a framework within which Member States' competent authorities could choose to employ autonomous inspection robots when fulfilling their obligations to assert port State jurisdiction. The central point from the perspective of this article is that the Directive, and the Paris MoU on which it draws in significant respects, requires Member States' competent authorities to inspect the inner and outer structures of ships in specified circumstances. Under the terms of the PSC Directive

32 Power (n 16), at p. 1307.
33 TFEU (n 17).
34 Directive 2009/16 (n 3), Articles 1, 3(1).
35 *Ibid.*, Articles 4(1), 4(2).
36 *Ibid.*, Articles 16, 19.

and the Paris MoU ships are selected for 'periodic inspections' at intervals determined by a system of assigning risk profiles to individual vessels. This selection also takes into account past performance of a ship's flag State, the relevant recognised organisations ('a classification company or other private body, carrying out statutory tasks on behalf of a flag State administration'), and companies responsible for operating a ship.[37] Ships can also be subject to 'additional inspections' regardless of the time period since their last periodic inspection where 'overriding or unexpected factors arise'.[38] Such factors concerning ships include suspension or withdrawal from their class since their last inspection in the Paris MoU region; being the subject of a report or notification by another Member State; being involved in a collision on the way to port; or carrying certificates issued by a recognised organisation that is no longer recognised.

Having been selected for inspection, a ship may first be subject to an 'initial inspection', during which a Port State Control Officer (PSCO) verifies the ship is carrying documentation certifying compliance with international conventions relating to safety and security, as well as EU maritime legislation, checks whether deficiencies identified during a prior inspection have been rectified and assesses 'the overall condition of the ship'.[39] However, a 'more detailed inspection' may be conducted where there are 'clear grounds', after an initial inspection, to believe a ship does not meet the relevant requirements of a convention.[40] Among the examples of 'clear grounds' specified in Annex V to the PSC Directive is: 'Evidence from the inspector's general impression and observations that serious hull or structural deterioration or deficiencies exist that may place at risk the structural, watertight or weathertight integrity of the ship'.[41]

A focus on the inner and outer structure of ships is also a component of a further inspection category, that of 'expanded inspections'.[42] Expanded inspections are carried out on ships of certain types with certain risk profiles. Among other categories, 'passenger ships, oil tankers, gas or chemical tankers or bulk

37 Quoting *ibid.*, Article 2(19) regarding recognised organisations; on selecting ships, Article 12 and Annex I; on risk profiles and frequency of inspections, Article 10 and 11 respectively; the Directive draws language and procedures from Annex 7 (risk profiles) and Annex 8 (on selecting ships for inspection), Paris MOU (n 16).
38 Directive 2009/16 (n 3), Article 12, Annex I.
39 *Ibid.*, Article 13(1), Annex IV.
40 *Ibid.*, Article 13(3).
41 *Ibid.*, Annex V Part A(13).
42 *Ibid.*, Articles 2(11), 2(12), 2(13), 14.

carriers, older than 12 years of age' are prioritised for expanded inspections.[43] Annex VII to the Directive specifies risk areas to be given particular attention, including a ship's 'structural condition', 'weathertight condition' and 'pollution prevention'.[44] Commission Regulation No. 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships offers yet further detail concerning specific items that should be verified during an expanded inspection. The annex to this implementing regulation specifies that with regard to appraising a ship's structural condition, the specific items to be verified during an expanded inspection referred to under Article 14(4) of the Directive include: for all ships, the condition of the hull and deck; and for bulk carriers and oil tankers, the verification of documentation certifying compliance with the Enhanced Survey Programme (discussed above), and examination of the condition of bulkheads, coamings and ballast tanks within the cargo area, with the possibility that at least one ballast tank may need to be inspected from the inside.[45]

Finally, a focus on inspecting the inner and outer structure of ships is also evident in the criteria on the basis of which a PSCO is required to make a professional judgment as to whether a ship should be detained. These criteria are referred to in Article 19(3) and listed (non-exhaustively) in Annex X, grouped by reference to the international conventions to which they relate. Alongside broadly delineated 'main criteria' concerning the general safety and ability of a vessel to proceed to sea, criteria of particular relevance for the purposes of this article include: under SOLAS, failure to carry out the ESP, which in turn could be a ground for a more detailed inspection as per Article 13(3) and Annex V; and under the 1966 International Convention on Load Lines, 'significant areas of damage or corrosion, or pitting of plating and associated stiffening in decks and hull affecting seaworthiness or strength to take local loads'.[46]

The provisions of the PSC Directive highlighted here all require a PSCO to undertake some level of visual inspection of the outer and inner structure of vessels of all types. With regard to bulk carriers and tankers, visual inspection for structural defects is given added priority due to the particular risks associated with these vessels and their history of involvement in significant disasters, as outlined in the previous section. Drones or submersibles operating

43 *Ibid.*, Article 14(1).
44 *Ibid.*, Annex VII.
45 Commission Regulation No 428/2010 (n 6), Annex Part A(a) and (b), Part B(b), Part E(a) and (b).
46 Directive 2009/16 (n 3), Article 19, Annex X, Points 3.2, 3.5.

autonomously to identify structural defects could offer significant advantages in such scenarios. Submersibles offer the possibility of visually inspecting underwater parts of a ship's hull with relative speed and without the use of divers. Drones also offer the possibility of inspecting difficult to access parts of massive vessels. The autonomous navigational capabilities of drones currently under development enable the systematic visual appraisal of enormous areas of steel plating in a way that a human eye would be unable to replicate. This level of methodical, systematic inspection conducted at relative speed would increase the likelihood of areas of plate corrosion, pitting and cracking being identified. Drones are also well suited to inspection tasks within the large internal compartments of vessel hulls, for example, the inspection of bulkheads in a bulk carrier.

One conclusion that can be drawn from the above analysis is that it would be possible for national competent authorities to use autonomous inspection robots to conduct inspections based on port State jurisdiction within the legal framework provided by the PSC Directive as it stands. Judgment as to how and in what scenarios such technologies may be useful would be a matter for the national competent authorities, and at the most immediate operational level for the PSCO undertaking a particular inspection, depending on the procedures established at national level. The professional judgment of the PSCO with respect to the best way to appraise whether a ship satisfies standards of relevant EU maritime legislation and international conventions is emphasised in the Directive.[47] From a technical and operational perspective, the European Maritime Safety Agency (EMSA) could offer support and coordinate Member States' adoption of autonomous inspection technologies. EMSA has the responsibility of supporting Member States' with the aim of ensuring 'the convergent and effective implementation of the port State control system' by, among other tasks, assessing the port State control procedures established by individual Member States and managing the THETIS and SafeSeaNet databases, which record ships prioritised for inspection and the results of those inspections, and collate information on vessel movements to and from EU ports respectively.[48]

These new technologies can be viewed simply as new tools that can allow old inspection tasks to be completed in new, quicker and (it is hoped) more effective ways. However, they can also be viewed as technologies that alter the character of old tasks by making it possible to inspect in ways not

47 E.g., *ibid.*, Annex X, Point 1.
48 *Ibid.*, Recital 10; Power (n 16), at pp. 1305–1306; Regulation (EC) No 1406/2002 of the European Parliament and of the Council of 27 June 2002 establishing a European Maritime Safety Agency, OJ L 208.

considered feasible previously. The PSC Directive caveats the scope of detailed or expanded inspections on the basis of 'practical feasibility or any constraints relating to the safety of persons, the ship or the port'.[49] It may prove to be the case that the employment of autonomous inspection robots will change what is and is not considered safe and feasible in the context of inspections conducted under port State jurisdiction. With respect to feasibility, the speed offered by autonomous inspection robots may simply permit inspections to include more extensive and rigorous examination of ship structures than is currently possible through human, visual inspection. With respect to safety, one concrete example that may be noted concerns expanded inspections of oil tankers and bulk carriers. Notwithstanding the requirement under Article 14 of the PSC Directive read together with the annex to its implementing Regulation No. 428/2010 (examined above) that as part of an expanded inspection, the condition of bulkheads be examined in the case of bulk carriers and that ballast tanks within the cargo area be examined and possibly entered in the case of both bulk carriers and oil tankers, feedback from PSCOs suggests that in practice it is rare for a PSCO to enter cargo holds or tanks.[50] The use of inspection drones could help to reduce this discrepancy between law and practice. As noted above, drones are well suited to inspection tasks within the large internal compartments of vessel hulls, for example, the inspection of bulkheads in a bulk carrier or of ballast tanks.

Possible Changes to EU Legislation on Port State Jurisdiction

At the time of writing in May 2022, a number of EU legislative proposals that could support the possible increased use of autonomous ship inspection robots under port State jurisdiction are at various stages of development. The most significant of these are the Commission's plan to review and potentially revise the PSC Directive, and the 'Fit for 55' legislative package, so called because it aims to reduce EU net greenhouse gas emissions by at least 55 percent by 2030 compared to 1990 levels. The implications of each of these significant initiatives merit brief examination.

In October 2020, the Commission announced its intention to review the PSC Directive, after which a public consultation took place. The Commission

49 Directive 2009/16 (n 3), Annex VII; a similar caveat is found in Commission Regulation No 428/2010 (n 6), Recital 1.

50 I am grateful to the members of the BugWright2 'Senior Advisory Group' for this observation.

is expected to publish a legislative proposal in the summer of 2022. Upon announcing its intention to review the Directive, the Commission published an Inception Impact Assessment outlining problems and policy options, on the basis of which it intends to develop a legislative proposal. One set of policy options, proposed on the basis of perceived problems with the functioning of the PSC Directive, envisaged requiring Member States to conduct 'more substantive, ship based inspections', concentrating 'on operational issues rather than being just a document check'; charging EMSA with training PSCOs to be 'more pro-active' in their approach to safety, security and pollution prevention; supporting Member States that have difficulty fulfilling their inspection commitments due to limited resources, including with respect to staffing; and encouraging Member States' to digitalise their inspection procedures, including by making provision for the acceptance of electronic certificates of compliance with international standards and preparing port State control procedures to accommodate autonomous shipping.[51]

From these proposed policy options, an impetus can be discerned in favour of moving towards more substantive inspection procedures, carried out in a uniform way by all Member States, which instrumentalise and adapt to greater levels of automation, of ships themselves and of their associated technologies. Review of the Directive aims to incorporate 'new tools and political priorities' into this legal framework.[52] The autonomous inspection robots discussed here fit comfortably with this impetus and could contribute to the achievement of aims sought by revising the Directive, including the improvement of 'maritime safety, security, [and] pollution prevention'.[53]

A second leitmotif of the Commission's proposed policy options with respect to the PSC Directive is a focus on mitigating the shipping industry's contribution to GHG emissions. The Inception Impact Assessment identifies as a problem the fact that the current inspection targeting system does not allow for emphasis to be placed on environmental aspects aimed at rewarding 'greener' vessels, and notes that environmental issues connected to decarbonising maritime transport 'will have to be looked at from the enforcement perspective'.[54] Review of the Directive is framed in part as a response to the European Council Conclusions endorsing the 'Opatija Declaration' of March

51 Inception Impact Assessment (n 12), Part A and B; European Parliament, 'Legislative Train Schedule: Review of the Port State Control Directive' available at https://www.europarl.europa.eu/legislative-train/theme-promoting-our-european-way-of-life/file-port-state-control-directive-review.

52 Inception Impact Assessment (n 12), at Part 2.

53 *Ibid.*, at Part A.

54 *Ibid.*

2020, the 'EU Waterborne Sector – Future Outlook: Towards a carbon-neutral, zero accidents, automated and competitive EU Waterborne Transport Sector', a declaration that instantiates a belief that digitalisation and automation, climate sustainability and the EU's economic competitiveness are intertwined.[55] This focus on 'greener' shipping is shaped by the broader context of the EU's assumption of an increasingly active role with respect to regulating GHG emissions from ships and its vying with the IMO on this topic, as noted at the outset of this article. The 'Fit for 55' legislative package announced in July 2021 fits into the 'European Green Deal', the overarching initiative that aims to make the EU the first climate neutral continent by 2050, and contains a number of much commented upon proposals of relevance to shipping, including its inclusion in the European Emissions Trading System (ETS), a proposed FuelEU Maritime Regulation and the proposed Alternative Fuels Infrastructure Regulation.[56]

While at this stage the Commission's vision of how a legislative proposal based on its review of the PSC Directive should practically connect to environmental goals pertaining to shipping is not clear, it could be suggested that one possible connection concerns biofouling. As noted above, accumulated organic matter on a ship's hull significantly reduces fuel efficiency by increasing friction between the surface of the hull and the water. Cleaning such biofouling from a ship's hull can result in a reduction in fuel consumption of 10 to 30 percent. This could be visualised as approximately half a swimming pool of heavy fuel being saved on a return trip across the Atlantic.[57] The lower energy density of non-fossil alternative fuels means that maximising fuel efficiency will remain an important concern for non-fossil fuel burning vessels. Biofouling also risks the introduction to new habitats of alien invasive species. This is widely recognised as a serious threat to biological diversity, and the EU has adopted legislation (not limited to the maritime sphere) on alien invasive

55 Council Conclusions on 'EU Waterborne Transport Sector – Future outlook: Towards a carbon-neutral, zero accidents, automated and competitive EU Waterborne Transport Sector' 2020.

56 Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2015/757 in order to take appropriate account of the global data collection system for ship fuel oil consumption data COM/2019/38; Proposal for a Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC COM/2021/562; Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council COM/2021/559.

57 C Pradalier. 'Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks' (BugWright2), Description of the Action, EU Horizon 2020 grant agreement No. 871260.

species, as well as a series of instruments focused on improving and protecting the quality of EU waters and marine habitats.[58]

One way to combat biofouling is by painting ship hulls with anti-fouling paints, although it is recognised that such paints do not completely prevent the accumulation of biofouling.[59] Another option is to physically clean hulls, brushing them free of organic matter. While the EU has adopted legislation prohibiting the use of anti-fouling paints harmful to the environment, no EU legislation currently exists that prescribes acceptable levels of biofouling for ships entering Member State ports, or requiring national authorities to address biofouling in the context of inspections under port State jurisdiction.[60] Such legislation can be found in jurisdictions outside the EU, for example in Australia, New Zealand, and in some US states.[61] In certain Australian ports, for example, biofouling is an object of inspection, while the state of California has recently developed an inspection programme that will use remotely operated underwater vehicles to examine the hulls and difficult to access areas of vessels entering port to ascertain their compliance with state level mandatory biofouling regulations.[62]

In the context of revising the PSC Directive, the EU could address biofouling in a similar way, requiring Member States to inspect for acceptable levels

58 Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species, OJ L 317; Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), OJ L 164; on implementation of the MSFD Directive see R Derrig, 'Report on Irish State practice on the law of the sea 2020' (2020) XV *Irish Yearbook of International Law* (forthcoming publication).

59 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species, IMO Resolution MEPC.207(62) adopted on 15 July 2011.

60 Previously, anti-fouling paints frequently contained organotin compounds, active biocides intended to prevent organisms from attaching to the hull, which had significant negative effects on the marine environment. In 2003, the EU legislated to prohibit ships bearing such anti-fouling paints from entering Member State ports, a unilateral regulatory act that is considered to have prompted enough States to ratify the International Convention on the Control of Harmful Anti-fouling Systems on Ships to ensure its coming into force in 2008: Regulation (EC) No 782/2003 of the European Parliament and of the Council of 14 April 2003 on the prohibition of organotin compounds on ships, OJ L 115 [Regulation No 782/2003]. On this see L Gipperth, 'The legal design of the international and European Union ban on tributyltin antifouling paint: Direct and indirect effects' (2009) 90 *Journal of Environmental Management* S86–S95

61 CJ Zabin *et al.*, 'How will vessels be inspected to meet emerging biofouling regulations for the prevention of marine invasions?' (2018) 9(3) *Management of Biological Invasions* 195–208.

62 *Ibid.*, at p. 199.

of biofouling on ships entering their ports. Alongside inspection, cleaning hulls of biofouling can also be undertaken robotically. The magnetic wheeled crawlers described in the second section above can be fitted with brushes and can navigate autonomously across the entire surface of a large hull, brushing organic matter free above and below water. It is worth noting that if ships were cleaned in this way with sufficient frequency, biofouling could be eliminated completely and only gentle brushing would be required during each cleaning. This reduces the possibility that anti-fouling paints are brushed free along with organic matter and released into the marine environment. Given the EU's focus on investing in port infrastructure to support decarbonisation aims under the 'Fit for 55' legislative package, resources could be committed to making such robotic cleaning systems available in ports.

Conclusion

This article has analysed the extent to which the aims pursued by EU legislation on port State jurisdiction – the improvement of 'maritime safety, security, [and] pollution prevention' – could be supported by the employment of autonomous inspection robots that are currently under development. Based on a close reading of the primary piece of EU legislation governing port State jurisdiction, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control, alongside the problems and policy options identified in the context of the Commission's significant ongoing work on the revision of this Directive, these technologies could support the completion of inspection tasks conducted under the current version of the Directive in significant ways.

One conclusion that has been drawn from this analysis is that it would be possible for national competent authorities to use autonomous inspection robots to conduct inspections based on port State jurisdiction within the legal framework provided by the PSC Directive as it stands. The analysis undertaken here also suggests that autonomous inspection technologies could prove even more useful to Member States implementing a revised version of the Directive focused on more proactive, substantive inspection procedures that incorporate both automated technologies and sustainability and environmental protection aims to a greater extent than is currently the case. From the perspective of EU law, an appropriate way for the Commission to ensure Member States employ autonomous inspection robots would be through a new regulation implementing provisions of a revised PSC Directive that require physical inspection of ship structures, or through a revised version of Regulation

No. 428/2010 implementing Article 14 of the PSC Directive.[63] The purpose of such a regulation, directly effective in national law, would be to specify what means Member States should use to implement a particular requirement of the Directive. In this case, those means would be autonomous inspection robots.

As suggested above, mandatory minimum biofouling standards offer a logical point of intersection between sustainability and biodiversity protection aims, and ship inspection practices, which might profitably be addressed by the Commission's revision of the PSC Directive. Mandatory minimum biofouling standards could also be laid down by means of a regulation, similar to the manner in which the EU prohibited the use of organotin compounds in antifouling paints used on ship hulls.[64]

The intersection between the construction and maintenance quality of ships and sustainability and biodiversity aims is significant. This will only become more so as regulators seek to pressure older fossil fuel burning ships out of the global fleet through more stringent enforcement of existing legal instruments, and potentially the introduction of new, higher standards. Increasingly automated enforcement procedures may play a significant role in this effort.

63 Commission Regulation No 428/2010 (n 6).
64 Regulation No 782/2003 (n 60).

Harmonizing the Maritime Service Robotics Techno-regulatory Regime: Six Blocks of Influence for Good Environmental Stewardship

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Abstract:

This submission* discusses Remote Inspection Techniques (RIT), their deployment in biofouling survey and maintenance, their harmonization with international requirements for semi-autonomous platforms, as well as highlights positive implications of internationally harmonized RIT standards with the European Union (EU) vessel hull inspection regime. RIT, in this context, represent systems based on machine learning that offer time-efficient and perhaps cost-effective alternatives to existing manual-driven survey and maintenance operations. These Artificial Intelligence (AI)-based alternatives are projected to save ship's operation time that make up a significant portion of running costs. Most recently, COVID-19 provided an impetus to test RIT for conducting statutory and classification surveys remotely. However, the integration of RIT raises concern for the viability of common minimum standards developed by international organizations, especially from an environmental perspective. The initial findings unveiled at COP26 stressed the need to mitigate biofouling build-up which explicitly contributes to increased greenhouse gas emissions. Therefore, niche sources and technological tools for environmental excellence cannot be overlooked. Moving forward, efforts to maintain good environmental stewardship at the EU level will not only require the seamless integration of RIT, but also a guarantee that all techno-regulatory elements vital to the semi-autonomous platform are streamlined into policy through international multi-stakeholder consultation.

1. Introduction

Breakthrough innovation followed and enhanced by revolutionary technology has brought the maritime regulatory community the transformative promise of "Robotic and Autonomous Systems (RAS)" --- but what is needed to allow RAS best be embraced?[1] One of the unique

*This article derives from the findings of project BUGWRIGHT2: Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks (Task 1.4) --- funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 871260.

[1] *T. Johansson*, International Standards for Hull Inspection and Maintenance of Robotics and Autonomous Systems, in J. Kraska & Y. Park (eds.), Emerging Technology and the Law, Cambridge University Press, 2022 in press. See also *D. Dalaklis* et al. (2022), The port of Gothenburg under the influence of the fourth stage of the

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aspects of applying RAS configured service robots is the potential to acquire unique data and information on the ocean and marine environment to enhance current research in remote exploration. Like other dynamic robotic developments, these RAS service robots have advanced from single applications, like remote exploration and data gathering, to a wide range of more holistic services. Within the maritime domain, technological innovations have led to effective integration of RAS, gradually transforming, and in niche areas, replacing human-presence-based operations. Dubbed as a byproduct of the fourth industrial revolution, RIT, utilizing RAS-oriented service robotics, are now being tested and deployed to survey critical areas, such as enclosed spaces of commercial vessels, that are prone to damage and deterioration and are otherwise difficult to access and monitor.

On the external front, outer hull inspections require upkeep through annual surveys, intermediate surveys and special (or renewal surveys), and enhanced surveys that are unavoidable obligations for ship owners and operators under international law. The principal regulations for outer hull survey and maintenance are covered in the 2011 International Maritime Organization (IMO) Guidelines for the Control and Management of Ship's Biofouling to Minimize the Transfer of Invasive Aquatic Species. The Guidelines calls for two specific actions; the monitoring of biofouling status of a vessel and the mitigation of both imminent and potential threats to vessel safety and the marine environment. Traditionally, these surveys have been human-centric, requiring much time and effort. Classification societies, licensed by flag states to survey, classify ships and issue certificates, have laid down a significant, and at times onerous conditions, which must be met at the preliminary, inspection and post-inspection stages. Since inception, RIT have been a preferred alternative to human-centric regulatory tasks that also pose a risk to human life.

The novel aspect of the application of RIT to climate change mitigation benefits derived from hulls with a better environmental footprint has garnered widespread attention in the maritime regulatory and policy communities and there are clear indicators that the paradigm shift has begun.[2] National flag state authorities, classification societies and ship

industrial revolution: Implementing a wide portfolio of digital tools to optimize the conduct of operations, *Maritime Technology and Research (MTR),* 4(3), 2022.
[2] Remote Survey, Det Norske Veritas: https://www.dnv.com/oilgas/remote-survey/index.html (last visited 27 December 2021); Survey by Remote Inspection Techniques – Use of Approved Service Suppliers, Det Norske Veritas: https://www.dnv.com/news/survey-by-remote-inspection-techniques-use-of-approved-service-suppliers-144572 (last visited 27 December 2021); Remote Technology Points to Cost Efficiency and Quality

owners are steadily adapting to RIT-based solutions, especially during the COVID-19 pandemic and the special challenges and limitations of human-presence on board ships. But though the market growth of new service robotic solutions is promising, the non-standardized assortment of RIT, built with varying technical specifications, designed to perform the very same inspection and maintenance tasks --- will likely slow market growth and ultimately hinder mass deployment. Standardization is an international concern. It is clear: service robots should not be developed in isolation.[3] Unfortunately, manufacturers initially moved from developing industrial robots with a single-use to polyfunctional RIT without clearly established common standards. As we move forward though, all stakeholders would benefit by embracing and adhering to critical safety, quality, performance, and efficiency standards developed in a cooperative and common effort; and the earlier in the life cycle the better. Otherwise, achieving good environmental stewardship may prove unnecessarily slow, cumbersome, and costly.

Good environmental stewardship is intrinsically linked to the responsible use and protection of the environment through sustainable and resilience-based conservation practices.[4] Those practices consist of interlocked "approaches, activities, behaviors, and technologies to protect, restore, or sustainably use, the environment".[5] Specifically, innovation has provided us with the opportunity to apply emerging technologies or new applications to achieve positive results across the marine transport domain which also requires good environmental governance.

The current reality is that the international maritime RIT governance framework is fragmented and shrouded with both grey areas that impede the integration of RIT alternatives at both the regional and national levels. Harmonization efforts are at an embryonic stage and is so acknowledged at the EU level. Noteworthy in this context, is a 2021 working document issued by the General Secretariat of the Council of the EU which focuses on harmonizing

Gains, Det Norske Veritas: https://www.dnv.com/oilgas/perspectives/remote-technology-points-to-cost-efficiency-and-quality-gains.html (last visited 27 December 2021).
[3] *G. S. Virk* et. al., ISO Standards for Service Robots, Advances in Mobile Robotics - The Eleventh International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, 2008, 1-6, pp. 1, 2.
[4] *F. S. Chapin* et al, Ecosystem Stewardship: Sustainability Strategies for a Rapidly Changing Planet, Trends in Ecology & Evolution, 2010, 25 (4):241-249.
[5] *N. J. Bennett* et al., Environmental Stewardship: A Conceptual Review and Analytical Framework. Environmental Management 61, 2018, 597–614.

international guidance for remote survey.[6] Authors assert that there are outstanding issues that call for the need to revisit the common minimum standards developed by the International Association of Classification Societies (IACS) with a view to harmonizing the core steering mechanisms for effective and efficient operation of RIT on a global scale. This working paper embraces and underlines the need to bring consistency among the different Classification Societies techno-regulatory provisions and practices. This needed harmonization is reinforced by the unique proposition tabled by the EU High-Level Expert Group on Artificial Intelligence (AI) that calls attention to a number of elements that constitute lawful, ethical and trustworthy AI through the creation of a robust horizontal regulatory foundation (See Figure).[7]

It is also worth noting that underwater hull cleaning via RAS is likely to primarily be introduced to comply with the requirements necessary for issuance of mandatory IMO Anti-Fouling Systems (AFS) certification by flag States. However, with the adoption of the new MARPOL, Annex VI, Regulation 28 requirement for a Carbon Intensity Indicator (CII) rating to be calculated and assigned to a ship each year (beginning in 2023), coupled with increasingly stricter CII values, underwater hull cleaning using RAS may well emerge as the new CII standard replacing current AFS certification. Also projected, under stricter environmental requirements, is that RAS will become a central component of a ship's underwater hull maintenance and environmental optimization. An inherent benefit of complying with these requirements is reduced fuel consumption which renders a financial incentive for shipowners/operators. RAS and related RIT stand to benefit shipowners/operators, as well as its manufacturers and developers, inspection companies, classification societies and other RAS and RIT stakeholders, and most importantly --- the environment and society at large.

In the context of good environmental stewardship, and with EU practices as a focus, the use of progressive technologies in the surveying and maintenance of vessels' outer hull will be assessed. Discussed will be the underlying importance of RIT for shipping, as well as its implications for the United Nations Convention on the Law of the Sea, 1982 (UNCLOS)

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[6] *Council of the European Union*, Working Document: Non-paper from the Commission drafted to Facilitate EU Coordination, 1178/20, ADD 1, Annex, Brussels, 29 October 2020 (OR. en): https://data.consilium.europa.eu/doc/document/ST-11781-2020-ADD-1/en/pdf (last visited 27 September 2021).
[7] Report of the High-Level Expert Group on Artificial Intelligence, 2019, COM, pp. 1-36.

as a governance framework pertaining to safety, and especially, environmental protection. Subsequently, RIT common minimum standards will be delineated, followed by a first-hand insight into the building blocks for a RIT regulatory blueprint (developed under the World Maritime University's BUGWRIGHT2 project). Finally, concluding remarks will highlight the need for policy harmonization to allow for seamless integration of RIT to foster good environmental stewardship.

2. Why Remote Inspection Technologies in Shipping?

Considering that the maintenance executed through required statutory and classification tasks performed by major carriers of a world fleet comprised of nearly 10,000 "large ships" (between the age-range of 0 to +25 years) and nearly 5,000 "very large ships" (over the age of 5 years), the advantages of utilizing RIT is manifold.[8] The principal types of ships involved in this commercial shipping include tankers, bulk carriers, containerized traders and residual general cargo ships. On the increase are the number of bulk trade shipments.[9] Dry bulk commodities account for 40 percent of total dry cargo shipments (as of 2018).[10] In its 2019 statistics report, the European Maritime Safety Agency (EMSA) estimated a total of nearly 12,000 bulk carriers trading internationally in 2018.[11] According to the EMSA-estimates for the same year, that there were a total of 16,250 general cargo ships with a gross tonnage a 59,206, and 13,757 oil and chemical tankers with a gross tonnage 345,545 .[12]

Shipping performance at the highest level of efficiency is the principle that drives the world fleet's operation. But constraints highlighted by researchers indicate "hull resistance" negatively impacts hull performance which hinders a ship's optimal performance.[13] Among many sub-factors affecting hull performance; hull fouling or biofouling most significantly

[8] UNCTAD/RMT/2019/Corr.1, Review of Maritime Transport: 2019, United Nations, Geneva, 1-132 (31 January 2020) p. 4 (ships by age and size). See also Electronic Quality Shipping Information System, *The World Fleet in 2018: Statistics from Equasis*, European Maritime Safety Agency (2019): http://www.emsa.europa.eu/equasis-statistics/items.html?cid=95&id=472 (last visited 27 September 2021) p. 9, table 3.
[9] Id. UNCTAD/RMT/2019/Corr.1, p. 5, see Figure 1.1.
[10] Id. at 5, see Figure 1.1. See also Electronic Quality Shipping Information System, supra note 8, at 6.
[11] Id. Electronic Quality Shipping Information System, p. 8, table 1 (ships by type and size) and table 2 (ships by gross tonnage). See also Statistica, *Number of Ships in the World Merchant Fleet as of January 1, 2019, by type*: https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type/ (last visited 27 December 2021).
[12] Id. Electronic Quality Shipping Information System, p. 8, table 1 (ships by type and size) and table 2 (ships by gross tonnage).
[13] *P. Deligiannis*, Ship Performance Indicator, Marine Policy 75, 204-209 (2017), p. 205 et seq.

contributes to increased global shipping emissions.[14] In technical terms, hull fouling increases water resistance and in so doing also increases energy usage, a very significant concern for the shipping industry, while also impacting scheduling and maintenance costs.[15] Preliminary findings from a Global Industry Alliance (GIA) report stressed the importance of "maintaining a smooth and clean hull free from biofouling" to avoid increase in Greenhouse Gas (GHG) emissions.[16]

Service providers specializing in niche areas are reaping the benefits of RAS, which is changing the traditional image of inspection and maintenance. A noteworthy expanded application involves close-up survey, thickness measurements measurement of structures, and biofouling cleaning of commercial vessels using micro aerial vehicles (MAVs), magnetic crawlers and remotely operated vehicles (ROVs). This introduction of the above types into survey and maintenance practices "… alleviate[s] the need for humans to work in … dangerous or dirty environments but also improve its image into one with productive and cost saving elements requiring the need for highly skilled, tech-savvy engineers".[17]

3. RIT Implications on the Law of the Sea?

Implications on UNCLOS brought by RIT are best assessed in this context by reviewing the legal status of RIT, and secondly and distinctly, the impact harmonized standards governing new technology will have on UNCLOS.

To assess the first strand, Part XIII of UNCLOS that regulates marine scientific research-related activities is the key section.[18] Although the term "marine scientific research"

[14] Id., p. 204. See *R. Adland* et. al., The Energy Efficiency Effects of Periodic Hull Cleaning, Journal of Cleaner Production 2008 (178), 1-13, p. 2.
[15] *T. McClay* et. al., Vessel Biofouling Prevention and Management Options Report, UNCLAS//Public, CG-926 R&DC 2015, 1-54, p. (v). See *M. P. Schultz* et. al., Economic Impact of Biofouling on a Naval Surface Ship, Biofouling, 27: 1, 87-98, First published on: 14 December 2010 (iFirst) (2011), pp. 87, 88, 89 et seq.; *H. Wang and N. Lutsey*, Long-Term Potential for Increased Shipping Efficiency Through the Adoption of Industry-Leading Practices, Washington: International Council on Clean Transportation, 2013, White Paper, 1-26, pp. 3, 4, 5, 6, 7, 8.
[16] *Global Industry* Alliance, Preliminary Results: Impact of Ship's Biofouling on Greenhouse Gas Emissions, 2021, GEF-UNDP-IMO GloFouling Partnerships project: https://wwwcdn.imo.org/localresources/en/MediaCentre/Documents/Biofouling%20report.pdf (last visited 27 September 2021).
[17] *M. J. Farnsworth* et. al., Autonomous Maintenance for Through-Life Engineering, in L. Redding & R. Roy (eds.), Through-life Engineering Services, Springer International Publishing, 2014, 395-419, p. 397.
[18] United Nations Convention on the Law of the Sea, adopted 10 December 1982, UNTS 1833 (entered into force 16 November 1994) (UNCLOS), Part XIII. An authoritative definition is found in *A. H.A Soons*, Marine Scientific Research and the Law of the Sea, 1982, The Hague: TMC Asser Instituut, p 6: "any study or related experimental work designed to increase man's knowledge of the marine environment".

remains undefined in the texts of Part XIII, the term itself is central to all work related to preservation of the marine environment.[19] Both the scale and extent of marine scientific research is grounded not only on an in-depth assessment of the detrimental effects of ocean pollutants, but also on the exploration of science-based solutions.[20] Assessment of datasets gathered through surveys acquired via technology are now common practice in the world of marine scientific research. Ocean exploration, ocean floor mapping, and aggregation of oceanographic data using floaters, drifters and underwater gliders or Autonomous Underwater Vehicles (AUVs) are examples of this trend. However, the deployment of those technologies has not always been free from debate. Questions have been raised by policy analysts as to whether the legal status of gliders and floaters constitutes "operational oceanography" due to the fact that they are tied to the geographic territory, which invokes the labyrinthine principle of "consent regime".[21]

In the current context, debate can be set aside on the ground that RIT, although bearing a subtle connection to marine scientific research, are fundamentally, and primarily, for a different purpose: to provide both statutory and classification alternatives to human-centric surveys on vessels that are berthed, anchored, moored within internal waters, or dry-docked in a structured area. Notwithstanding the absence of a point of reference that determines the legal status of professional RIT; complacency with regards to UNCLOS's "safety at sea" provisions are applicable. Taking the necessary measures under UNCLOS for ensuring "safety at sea" is a vital responsibility of the flag state. Explicitly covered under the "safety at sea" Article 94 are provisions for both vessel "construction" and "seaworthiness" with an expectation that flag States conduct services on vessel structures in support of good operation and performance. In this context "intention" is a nuance critical to understanding the applicability of RIT. Specifically, *intentionality* in the modern technological environment occurs when operational objectives are aligned with international objectives obliging service suppliers and end-users of innovative equipment to remain compliant. To determine whether this can be termed "improved compliance" can be ascertained by comparing vessel

[19] *T. Davenport*, Submarine Communications Cables and Science: A New Frontier in Ocean Governance? in H. N. Scheiber, J. Kraska and M. Kwon (eds.), 2015, Science, Technology and New Challenges to Ocean Law, p. 226. This statement is based on Id., A. H.A Soons, p. 14.
[20] Id., T. Davenport
[21] *T. Hofman and A. Proelss*, The Operation of Gliders under the International Law of the Sea, 46:3 Ocean Development and International Law, 2015, 167-187, p. 168. See also *K. Bork*, *Johannes Karstensen, M. Visbeck & A. Zimmermann*, The Legal Regulation of Floats and Gliders—In Quest of a New Regime? 39:3 Ocean Development & International Law, 2008, 298 -328, pp. 307, 311.

performance and energy efficiency levels between two different bulk carriers; one that has been surveyed manually vs one that has benefitted from RIT.

Indicators of "intention" or "intentionality" include *writing*, *sensing* and *shaping* --- subsets that combine to structure and regulate the objectives of an anticipated environment.[22] Techno-regulatory standards mirror the *writing* sub-set that defines the dynamics of "environing technology".[23] Published techno-regulatory standards developed by international organizations are objective-specific and impact the modern technological environment. In many ways, regional and national objectives are deeply ingrained in the environmental objectives of UNCLOS, which in turn, endorses harmonized international standards; the next discussion.

Part XII of UNCLOS highlights *good environmental stewardship*, and requests Member States (MS) to undertake "individually or jointly as appropriate, all measures … that are necessary to prevent, reduce and control pollution of the marine environment from any source, using … the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavor to harmonize their policies in this connection".[24] Here, strong emphasis is placed on mitigating vessel-source pollution by regulating vessel design, construction and equipment.[25] Furthermore, Part XII lays the foundation for a global and regional cooperative regime with reference to "competent international organizations" to establish "international rules, standards and recommended practices and procedures" on vessel-source pollution.[26]

UNCLOS views General Accepted International Rules and Standards (GAIRS) as a pathway for symbiotic, compatible and a reciprocal nexus for existing international treaties.[27] Markedly, GAIRS allows for "new concepts, such as precaution and biodiversity to become

[22] *S. Sörlin and N. Wombs*, Environing Technologies: A Theory of Making Environment, 34 History and Technology, 2018, 101–125, pp. 5, 6, 7 and 8.
[23] Id., p. 7: "As indicated by scholars Sörlin and Wombs: "often these technologies are also connected to writing, as documenting is intrinsic to many activities, especially those which are circulated in society and over time. The United Nations Convention on the Law of the Sea, UNCLOS, or the IPCC Fifth Assessment Report are examples of writing (documents) that environ".
[24] Supra note 18, UNCLOS, Part XII, Article 194; See also Code for the Implementation of Mandatory IMO Instruments, IMO Resolution A. 973(24), Adopted on 1 December 2005, at s. 4 (General).
[25] Supra note 18, UNCLOS, Part XII, Article 194(3).
[26] Id., Part XII, Article 197.
[27] Id.

part of UNCLOS normative structure", and helps move the trajectory of the cooperation regime towards good environmental stewardship.[28] To that end, GAIRS endorses competent international organization developed standards provided that the standards so developed resonate with the central objectives of UNCLOS.[29] Openness and complementarity to other regimes tied to good environmental stewardship stands as the crux of Article 211and Article 237 and that both bolster support to this rule of reference.[30] In that vein, GAIRS not only regulates consistency with International Maritime Organization (IMO) promulgated instruments, but also elucidates a broad scope for accommodating IMO Recognized Organizations (RO) and their rules and requirements.

4. RIT Class Survey: Common Minimum Standards

IACS is the key international body that comes into play in all discussions related to RIT international rules and requirements. Serving in the capacity as an RO on behalf of maritime administrations, IACS is composed of twelve members that set international classification standards covering "90% of the world's cargo-carrying ship tonnage".[31] Taken together, IACS rules and requirements apply to both *statutory* (subject to the flag States agreement) and *classification* surveys --- the successful completion of which results in the issuance of statutory and classification certificates, respectively. Suffice to note that, the same *statutory* survey and certification procedures that were attached to a plethora of IMO instruments are now harmonized through IMO's *Harmonized System of Survey and Certification* (HSSC) with the objective of standardizing survey procedures and timelines.[32] Within the harmonized

[28] *R. A. Barnes*, The Continuing Validity of UNCLOS, in J. Barrett and R. A. Barnes (eds.), The United Nations Convention on the Law of the Sea: A Living Instrument, British Institute of International and Comparative Law, 2016, 459 – 489, p. 472, citing *D. Freestone*, International Fisheries Law Since Rio: The Continued Rise of the Precautionary Principle, in A. Boyle and D. Freestone (eds.). International Law and Sustainable Development: Past Achievements and Future Challenges, 1999, Oxford University Press, p. 135.
[29] Supra note 18, UNCLOS, 21(2), (4); 39(2)(a)-(b); 41(3); 53(8); 60(3),(5), and (6); 94(2)(a); 94(5); 211(2), (5), and (6)(c); 226(1)(a); and 271.
[30] Supra note 18, UNCLOS arts. 22; 39; 41(4)-(5); 53(9); 60(3), (5); 61(2), (5); 119(2); 197-202; 204-205; 207(4); 208(5); 210(3); 211(1)-(6); 212-214; 216; 217(1), (4), (7); 218(1); 220(7); 222-223; 238-239; 242-244(2); 246(3), (5), (5)(d); 248-249; 251-253(1)(b), (4), (5); 254(1)-(4); 256-257; 262-263(3); 265; 266(1); 268-273; 275(1)-(2); 276(1); 278; 297(1)(c); 319(2)(a). See also see also Report of the Secretariate of the International Maritime Organization, Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization, U.N. Doc. LEG/MICS.8, p. 8
[31] *International Association of Classification Societies*, About IACS – Introduction: https://www.iacs.org.uk/about/ (last visited 27 September 2021).
[32] Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), 2017, A 30/Res. 1120, adopted on 18 December 2017. *N.B.* the 2017 HSSC was amended and updated in 2019 to reflect amendments to BWM Convention, MARPOL and 1974 SOLAS. No survey-specific changes were made during the amendment. The amendments are set out in Annex XX to IMO Document III 6/15.

texts, HSSC provides direct reference to classification society standards to strengthen uniformity that would enhance MS compliance with good environmental status.[33]

Significantly, IACS advocates for the integration of RIT platforms under specified conditions. Those conditions are detailed in Recommendation 42 titled *Guidelines for Use of Remote Inspection* (Recommendation 42). At the outset, Recommendation 42 stipulates that unmanned robot arm, ROV climbers, drones and other acceptable means may be deployed to "facilitate the required external and internal examinations, including close-up surveys and gauging" subject to approval and consultation among RIT technician, the owner's representative and the attending surveyor.[34] Restrictions on RIT platform usage are also in place in the likelihood where severe damages and deterioration are observed in structures, in which case manual close-up surveys and thickness measurements may be initiated.[35]

IACS Unified Requirement (UR) Z17 titled *Procedural Requirements for Service Suppliers* embodies a theoretical extension of Recommendation 42.[36] Composed of RIT-led standards, UR Z17 is aimed at firms providing *statutory* survey (where flag States reserve the right to conduct their own assessment and approval of service suppliers for statutory surveys) and *classification* survey. It in this document there are detailed procedural as well as special requirements to be followed for the use of; ROVs to carry out in-water survey on ships and mobile offshore units by ROVs (s. 3), as well as RITs as an alternative means for Close-up Survey of the structure of ships and mobile offshore units (s. 4) (see Table, below).[37]

Noticeably, while Recommendation 42 notes ROV as a division of RIT, ROV has nevertheless received specific attention through the formulation of a separate section under UR Z17. If this placement is guided by the rationale that ROVs operate underwater or on water surfaces, which is different than navigating RITs on air or on steel hulls then perhaps the methodology as well as external disruption factors (strong water current, ice-infestation during winter etc.) should have been highlighted. Moreover, the deployment of ROVs by

[33] Supra note 1, T. Johansson.
[34] Recommendation 42 Guidelines for Use of Remote Inspection Techniques for surveys - Rev.2 June 2016 (Recommendation 42), downloaded from the official homepage of IACS: http://www.iacs.org.uk/publications/recommendations/41-60/rec-42-rev2-cln/ (last visited 20 September 2021).
[35] Id., s. 2.1.
[36] IACS UR Z17, Procedural Requirements for Service Suppliers: http://www.iacs.org.uk/publications/unified-requirements/ur-z/?page=2 (last visited 29 December 2021).
[37] Id.

service providers in in-water cleaning operations invoke the question whether s. 3 of IACS UR Z17 should enshrine a caveat within the texts referring to precautionary measures when removing heavy metal and coating flakes from vessels' hull (for environmental benefits). Turning to s. 16 which covers requirements, specifically, only when RITs serve as an alternative means for close-up surveys, it is noteworthy that s. 16.1 has adopted two terms: Unmanned Aerial Vehicles (UAV); and Drones --- under two distinct bullet-points. But what are the differences between the two, if any? Several other questions also remain unanswered, leaving the task of building beyond minimum standards to individual classification society members.

Table: Tabular Overview of IACS UR Z17 Procedural and Special Requirements

<table>
<tr><th colspan="6">Procedural Requirements for Service Suppliers</th></tr>
<tr><th colspan="4">Principal Building Blocks</th><th>Principal Focus</th><th>Governing the Scope of Suppliers that Provide RIT Services</th></tr>
<tr><td>Procedures for Approval and Certification</td><td>Conditions for Issuance of Certificate</td><td>Cancellation of Approval</td><td rowspan="3">Approval of Service Providers by the Concerned Authority Where the Society is Authorized by Flag Administration</td><td>Actors</td><td>S. 3: Manufacturers, Service Providers, Agent, Subsidiary and Subcontractor</td></tr>
<tr><td rowspan="2">Application by Manufacturers Endorsing Agents or Subsidiaries</td><td>ISO 9000 Quality System</td><td>Conditions for Certification</td><td>Mechanisms</td><td>S. 4: Permissible in Statutory Services and Classification Services except non-ESP ships <500 Gross tonnage (GT) and all Fishing vessels</td></tr>
<tr><td>Auditing the Supplier</td><td>Service Suppliers Relation with Equipment Manufacturer</td><td>Tools</td><td>S. 4.1.3: Verification and Accountability of Work Done by Third Party; S. 4.2: Approval of Service Provider by the Concerned Society; S. 4.3: Approval of Service Provider by the Concerned Society where the Society is Authorized by Flag Administration; S. 5.1: Procedures for Approval and Certification; S. 5.2.1 to S. 5.2.10: General Requirements for Suppliers; S. 5.3: Auditing the Supplier; S. 5.4: Conditions for Certification; S. 5.5.1: Supplier to Demonstrate Documented System Pertaining to Quality Management in accordance with ISO 9000 Series; S. 5.5.3: Application by Manufacturers' Endorsing Agents or Subsidiaries; S. 5.6.1: Service Suppliers Relations with the Equipment Manufacturer; S. 6.1: Conditions for Issuance of Certificate of Approval to Supplier and Content of Certificate; S. 8.1 to S. 8.4: Cancellation of Approval; S. 5.2.11: Reporting by Suppliers; S. 5.2.12: Documented Procedures and Instructions on Recordings by Suppliers</td></tr>
<tr><th colspan="6">Special Requirements (for …): Annex 1</th></tr>
<tr><th colspan="4">Firms Engaged in Statutory and Classification Surveys</th><th colspan="2">ROV Special Requirements Pursuant to S. 4</th></tr>
<tr><td colspan="4">S. 3: Firms carrying out an in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV).</td><td>The Human Element</td><td>Supervisor: qualified according to national or international industrial NDT standard
Operator: qualified according to national or international industrial NDT standard
Training of Personnel: Supplier is responsible for training of operator, supervisor with respect to training on handling equipment. Must have knowledge on: -Ship’s underwater structure and appendages, propeller shaft, propeller, rudder and its bearings, etc.; -Non-destructive testing in accordance with a recognized national or international industrial NDT standard; -Certification as a thickness measurement firm when conducting thickness measurements under water; -Bearing clearance measurements on rudders and propeller shaft; -Under-water video monitoring with TV-monitors on deck, as well as still picture work; -Operation of under-water communication system; -Any special equipment necessary for the work carried out.
Verification: The supplier must have the Surveyor’s verification of each separate job, documented in the report by the attending Surveyor(s) signature.</td></tr>
</table>

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<table>
<tr><td rowspan="2"></td><td>Reporting System</td><td>A plan for training of personnel in the reporting system, minimum Rule requirements for relevant ship or unit types, ship’s or unit’s underwater structure, measuring of bearing clearances, the recognition of corrosion damage, buckling and deteriorated coatings, etc. shall be included.</td></tr>
<tr><td>Procedures & Guidelines</td><td>Operational procedures and guidelines for firms carrying out in-water survey by ROV shall also include: -Guidance for the operation and maintenance of the Remotely Operated Vehicle, if applicable; and -Methods and equipment to ensure the ROV operator can determine the ROV’s location and orientation in relation to the vessel.</td></tr>
<tr><td rowspan="5">S. 16: Firms engaged in survey using Remote Inspection Techniques (RIT) as an alternative means for Close-up Survey of the structure of ships and mobile offshore units</td><th colspan="2">RIT Special Requirements Pursuant to S. 16</th></tr>
<tr><td>The Human Element</td><td>Supervisor & Operator: Similar to the former
Training of Personnel:
-Marine and/or offshore nomenclatures.
-The structural configuration of relevant ships types and MOUs, including internal structure.
-The remote inspection equipment and its operation.
-Survey plans for examination of hull spaces of various configurations, including appropriate flight plans if using a UAV.
-Thickness measurement (TM) and non-destructive examination (NDE) in accordance with a recognized National or International Industrial NDE Standard when these are part of the service.</td></tr>
<tr><td>Training Plan</td><td>Same as s. 4 (except the title here is training plan)</td></tr>
<tr><td>Documentation & Records</td><td>The supplier shall maintain: -Records of training; -Operator statutory and regulatory licences
-Equipment register for UAVs, Robots, data collection devices, data analysis devices etc.; -Equipment maintenance manuals and records/logbook; -Records of calibration; and -UAV/Robot operation logbook</td></tr>
<tr><td>Verification</td><td>The supplier must have the Surveyor’s verification of each separate job, documented in the report by the attending Surveyor(s) signature.</td></tr>
</table>

Source: IACS UR Z17, Procedural Requirements for Service Suppliers (Rev. 15 October 2020)

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5. The Case for Harmonizing through International Guidelines

The difficult task of achieving environmental compliance excellence is complex and even further exacerbated by the plurality of classification rules. Presently, there are more than fifty classification societies that have specific procedural standards. For example, rules and requirements developed by the American Bureau of Shipping (ABS), China Classification Society (CCS), Bureau Veritas (BV), Det Norske Veritas (DNV) and Lloyd's Register (LR), to name just a few, indicates that much effort has been placed on the outlining of rules and requirements in order to keep pace with maritime innovation. However, not all societies have advanced relevant operational and technical standards. IACS's ability to establish common minimum standards with the needed degree of regulatory symmetry has been hindered by the unfortunate development of multiple sets rules governing the same technology.

Conceiving sound and effective regulations at the EU level requires that specific methods and principles be embedded across all classification societies that promulgate rules. Recalling Articles 42, 43(2), 91(1), 100(2), 173(3), 175, 188, 192(1), 194(2), 195(2) of the Treaty on the Functioning of the European Union, the European Association of Classification Societies (EurACS) notes that: "[a]n "all embracing" maritime policy where synergy between the various fields of expertise is exploited will strengthen the competitiveness of the EU maritime sector …". In reality, what is absent is an EU integrated RAS policy that delineates the basic elements or principles which could serve as a foundation for attaining RIT regulatory symmetry.

To illuminate the elements that would best constitute a harmonized RIT regulatory blueprint, authors of this article have delved into *de lege lata* (the law as it exists) taking into account the rules of major classification societies (both members and non-members of IACS and EurACS). The findings from these analyses indicate inconsistencies. On a positive note, there also emerges a unique outline of six building blocks that could help facilitate the harmonization process. Additionally, the initial findings were explored in detail by the authors during semi-structured interviews of thirty-two officials based in the United States of America (US), the Netherlands, Canada, Norway, China and Singapore. The respondents represented national administrations (5), classification societies (7), service suppliers or agents (9), industry stakeholders (4), and academia (7) in their official capacity.[38] It is important to note that some respondents (about 10%) voiced concerns regarding the integration of service robotics to satisfy regulatory obligations, and noted the fallacy of regulatory symmetry. Others confirmed that achieving alignment through a top-down approach, led by IMO and IACS in consultation with the International Organization for Standardization, as well as industry and academia (collectively known as the triple helix), a crucial ingredient to achieving global environmental and other objectives within the maritime domain. All in all, the expository responses helped carve out ways forward considering the six building blocks that will have important bearing on the rules that will emerge should an international guidance be developed in response to MS request (*de lege ferenda*: the basis of new law) (see Diagram, below).

Diagram: Six Building Blocks of Influence

4.1. First Block: Remote Inspection Technology v Remote Survey

[38] Interviews were conducted between March and June 2021 as a part of the research-methodology under project BUGWRIGHT2 work package 1.4.2 titled *National Comparative Analysis*,

To set the scene, it will help to start with a general observation: the inherent difference between the terms *RIT* and *remote survey* cannot be determined from the texts of IACS common minimum standards as it does not reference remote surveys. The former (RITs) comes with reference to acceptable technologies or techniques that could be used when carrying out prescribed surveys either in situ or off site. Remote surveys, on the other hand, denotes a survey conducted via remote technology off-site, and does not require the physical presence of the concerned surveyor. This difference must be preserved so as to refrain from using the two terms interchangeably.

4.2. Second Block: Developing Definitions

IACS makes an effort with s. 1.1 of Recommendation 42 to list equipment types that currently serves as the minimum standard definition of RIT. Considering the evolving nature of innovation, those types will inevitably branch out into other expeditious complex systems, necessitating the development of unified definitions for each and every type of permissible techniques. The authors of this article further assert that the procedural rules and requirements ought to be founded on concrete product-definitions.

No two techniques are built following a standard pattern, although certain tangible components may be the same. It is also observed that different types of techniques maneuver in different environments. Techniques also differ in terms of tasks and outcomes. However, for all types, the trait shared in common is incorporating innovation towards full-autonomy. Depending on how innovation progresses in relation to each individual acceptable techniques; technological and other differences will stay discernable despite the amalgamated placement of all types under the common term "Remote Inspection Techniques".

Notable template definitions already exist, and can be found in sections 1.1, 1.3 and 1.5 of Guidance Notes developed by the American Bureau of Shipping (ABS):

> **1.1 Unmanned Aerial Vehicles (UAVs)**
> An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot onboard. The UAV can be remotely controlled or programmed to fly a predetermined route using information on a specific asset's condition to target known areas of concern. It can collect visual data (such as still images, live-stream and recorded video) from difficult-to-reach structures and areas.
>
> **1.3 Remotely Operated Underwater Vehicles (ROVs)**

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An ROV is an unmanned unit designed for underwater observation, survey, inspection, construction, intervention or other tasks. Similar to UAVs, an ROV can be remotely controlled or programmed to travel a predetermined route using information on a specific asset's condition to target known areas of concern. It can collect visual data, perform Nondestructive Testing (NDT), and measure plate thickness in difficult-to reach areas.

1.5 Robotic Crawlers

A Robotic Crawler, commonly referred to as a "crawler", is a tethered or wireless vehicle designed to "crawl" along a structure by means of wheels or tracks. Crawlers are often equipped with magnets which allow them to operate on a vertical surface or hull structures in air or underwater.[39]

4.3. Third Block: Operational & Technical Standards Based on Variety

As discussed earlier, individual RIT are marked by operational and technical differences. Therefore, this requires the introduction of operational and technical standards that complement mandatory procedural requirements. Operational and technical standards are beyond the purview of IACS, hence their exclusion from the scope of UR Z17.[40] Such standards, however, are important for setting a baseline for determining operational limitations, to establish timelines for the initiation of "confirmatory surveys" (where surveyors proceed to examine abnormal damage and deterioration manually pursuant to s. 1.3 of IACS Recommendation 42). Fortunately, however, classification societies, such as ABS for example, have developed operational standards for UAV, ROV and Robotic Crawlers (which are termed as Remote Inspection Vehicle (RIV) as opposed to the common minimum standard term RIT that is used widely at the EU level).

Given an inherent vulnerability to risk, "risk assessment" is an important feature of operational standards. It is worth noting that surveys using aerial drones, unlike crawler and ROVs, can easily be compromised due to humidity, lighting, and air turbulence. Furthermore, hybrid RITs that have the potential to conduct biofouling cleaning, in addition to survey operations, require limiting all possible risks prior to deployment. The ABS promulgated *Guidance Notes* also include sound methodologically construed categories of risk-assessments, founded on operational standards, for the three preferred types of RITs; explosion risks in hazardous areas, dropped object risks, collision risks (e.g., with other

[39] American Bureau of Shipping, Guidance Notes on the Use of Remote Inspection: https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/other/242-gn-remote-inspection-tech/rit-gn-feb19.pdf (last visited 29 December 2021).
[40] Supra note 34, Recommendation 42.

RIVs), lost link risks (e.g., network compromise), and other risks consisting of high-risk working areas, risk associated with other parallel operations and emergency situations.

The China Classification Society (CCS) in its document titled *Guidelines for Use of unmanned Aerial Vehicles,* describes in detail the technical standards for UAVs.[41] These standards focus on safety performance, operation performance, enduring capacity, data transmission and communication, data storage (e.g., video and image resolutions and video and photo formats), and requirements for airborne cameras.[42] Technical standards, according to the authors, close the circle of procedural rules and requirements in so far as they ensure safety and reliability, and enable interoperability by providing a common language to evaluate performance.

4.4. Fourth Block: Determining the Degree of Autonomy

Vocabularies found in the document titled *ISO 8373: 2012 (en) Robots and Robotic Devices – Vocabulary* developed by the Technical Committee ISO/TC 184 sets a number of useful definitions relevant to both industrial and service robots. In defining the term "robots", ISO keeps the performance facet open-ended appreciating "the degree of autonomy", loosely translated as the level of a systems' reliance on human intervention in the execution of pre-determined tasks when operating within the programmed pathway.[43] Important to note here is that while the definition of *operator* acknowledges the integration of human intervention to "start, monitor and stop the intended operation"; it does not proffer any further clarification on what the term "monitor" entails.[44]

Professional service robots, or RITs, have built-in image sensors that convert photons into electrical signals that are then viewed and analyzed by operators engaged in commercial inspection activities. Therefore, according to s. 2.12 (professional service robot) when read together with s. 2.17 (operator) - monitoring intended operations could be viewed as pertaining to "inspection function" being undertaken, or "inspected," through the service

[41] China Classification Society. Guidelines for Use of Unmanned Aerial Vehicles for Surveys, 2018: https://www.ccs.org.cn/ccswzen/articleDetail?id=201910000000003817 (last visited 31 December 2021).
[42] Id., s. 2.6.
[43] ISO 8373: 2012 (en) Robots and Robotic Devices – Vocabulary (2012), International Organization for Standardization: https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-2:v1:en (last visited 15 September 2020) at s. 2.6.
[44] Id. at s. 2.17.

robot's image sensors. In other words, the current system portrays a model built on semi-autonomy or supervised-autonomy. Bearing in mind the aims of realizing full-autonomy, the RIT systems today could undergo strategic re-categorization in a fashion similar to what has been accomplished in relation to Maritime Autonomous Surface Ships (MASS).[45] It is necessary to emphasize that such a categorization from the get-go could help keep track of many graduations toward-autonomy and thereby assist classification societies with future revisions:

Table: Categorization of RIT Based on MASS Degree of Autonomy

Degree/Level of Autonomy	MASS	RIT
First Degree	Ship with automated processes and decision support with seafarers on board to operate and control the systems. Systems are partially automated, unsupervised with seafarers on board ready to assume control.	RIT-survey conducted in the presence of the attending surveyor. This degree aligns explicitly with IACS Recommendation 42 and IACS UR Z17.
Second Degree	Remotely controlled ship with seafarers on board.	Remote survey with the possibility of surveyor to intervene, if necessary.
Third Degree	Remotely controlled ships without seafarers on board.	Remote survey without attending surveyor.
Fourth Degree	Fully autonomous ship.	RIT with automated processes and Artificial Intelligence-based machine learning operating systems to support decision-making.

Source: IMO Doc. MSC 100/20/Add. 1, Annex 2

4.5. Fifth Block: Data Management & Security

Data acquisition is the heart of all RIT-interventions.[46] Stakeholders involved in this process include non-human actors, e.g., technological tools and infrastructure, and human actors, i.e.,

[45] IMO Doc. MSC 100/20/Add. 1, Annex 2, Framework for the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS), Dec. 7, 2018, ¶ 1 and IMO, MSC 99th Briefing (2018): http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx (last visited 31 December 2021).
[46] *T. Johansson*, D. Dalaklis and *A. Pastra*, Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers, 9(6) Journal of Marine Science and Engineering 594, 2021; See also *T. Johansson, T., R. Long, R., & D. Dalaklis*, The Role of WMU-Sasakawa Global Ocean Institute in the Era of Big Data. The Journal of Ocean Technology, 14(4), 2019, 22-29

service providers, classification societies and ship owners (end-users).[47] The latter is aptly known as "human-in-the-loop" with supervisors, operators and surveyors remaining engaged during data storage and verification of data collected through RIT-based visual inspection and close-up surveys. In essence, the RIT infrastructure communicates data to "human-in-the-loop" via five independent layers: hardware, network, internet, infrastructure and application.[48]

Within the RIT multi-stakeholder landscape, "control of data" has received due attention in s. 5.2.6 of IACS UR Z17, which, unfortunately, dwells only on service suppliers' duty to confirm computer software's ability to acquire, record, report, store, measure and monitor data, and does not do justice to the title.[49] Corroborated by interview respondents, the *status quo* inadequacy does not create any privacy contentions for EU Member States since non-personal data, such as ones that are acquired by RIT, fall outside the scope of EU's Regulation 2016/679 on the General Data Protection Regulation (GDRP).[50] That being said, RIT acquired data is attached to the vessel-history as it informs surveyors (conducting periodical surveys) about maintenance tasks previously completed. As such, asset-related information in shipping has been traditionally met with utmost confidentiality to protect ship owners from unforeseen threats caused from reaches in cyber security.

Individual efforts to govern non-personal data management and data security are noted in various guidelines articulated by individual classification society members. For example, data calibration and analytics has received attention in the RIT-specific document titled *Remote Inspection Technique Systems (RITS) Assessment Standard for use on LR Class Surveys of Steel Structure* issued by LR.[51] Issued by the same society, data capture and treatment considerations have also been prioritized in *Guidance Notes for Inspection using Unmanned Aircraft Systems*.[52] In this document, key provisions on data encapsulated in s. 8 entitled "Inspection Data" covers important recommendations on "data security principles,

[47] *D. Loshin*, Master Data Management, 1st ed.; Kaufmann: Burlington, MA, USA, 2008.
[48] Supra note 47, T. Johansson. See P. *P. Ray*, Internet of Robotic Things: Concept, Technologies and Challenges. IEEE Access 2017, 4, 9489–9500.
[49] Supra note 36, IACS UR Z17, s. 5.2.6.
[50] European Union. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC (General Data Protection Regulation).
[51] Lloyd's Register, Remote Inspection Technique Systems (RITS) Assessment Standard for Use on LR Class Surveys of Steel Structure, 2018.
[52] Lloyd's Register, Guidance Notes for Inspection Using Unmanned Aircraft Systems, 2016.

standards and methods" against "manipulation or unwanted distribution".[53] DNV has also advanced rules and requirements that are found in the document titled *Approval of Service Supplier Scheme* illustrates concrete effort to regulate RIT-data storage.[54] Section 16.1.4 of Appendix A obliges service suppliers to store data in an orderly fashion whereby the files should be made available upon request for a duration of five years.[55] This provision is quite unique as common minimum standards do not address questions, such as: who should be responsible for data and image preservation, and how long does individual survey data and image need to be preserved?

A striking feature of the *Guidance Notes on the Use of Remote Inspection Technologies* developed by the ABS, are criteria for RIV post-operation data review and processing tasks.[56] Also in this document, RIT data governance criteria is infused in sections 4.9 and 4.11 as well as all essential elements integral to the data decision domain. A strong emphasis on "data security policies and procedures" can be found in section 4.11.1.1(h).[57] On the Asian front, CCS has provided similar emphasis on data acquisition, data processing, and data security in in section 3 of their *Guidelines for Use of Unmanned Aerial Vehicles for Surveys*.[58] Collectively, all of the provisions briefly discussed above provides a settled discourse on non-personal data integrity for a semi-autonomous system.

4.6. Sixth Block: Reference to the National Liability Regime

Legal scholars dealing with RAS issues have concluded that there are no philosophical or legal grounds to refer to technology as a "subject" or a "being" from an ontological context.[59] From a producer standpoint, both industrial robots or service robots are manufactured through an action or a process and refined for sale. Focusing on the keyword "manufacture", it is posited that all RAS, whether autonomous vessels, autonomous vehicles or RIT, are merely "products" that are offshoots of a cascade of applied science-related innovations. The

[53] Id., Lloyd's Register.
[54] Det Norske Veritas-Germanischer Lloyd, Approval of Service Supplier Scheme, 2019: http://rules.dnvgl.com/docs/pdf/DNVGL/CP/2019-02/DNVGL-CP-0484.pdf (last visited 1 January 2022).
[55] Id., Det Norske Veritas-Germanischer Lloyd, s. 16.1.4.
[56] Supra note 40, American Bureau of Shipping.
[57] Id.
[58] China Classification Society, Guidelines for Ship Remote Surveys, 2019.
[59] *A. Bertolini*, Robotic Prostheses as Products Enhancing the Rights of People with Disabilities: Reconsidering the Structure of Liability Rules, International Review of Law, Computers & Technology, 2015, 29:2-3, 116-136, p. 117.

functional approach is to apply a legal framework to govern the usage of products.[60] This is perhaps because service robots need to possess a high degree of autonomy because their *modus operandi* takes place in an "unconstrained, human-centered environment".[61]

Safety and liability are interrelated concepts. As noted by the European Commission, higher levels of safety symbolize minimal risk of harm while ensuring adequate compensation for damages.[62] Existing and emerging applications of complex varieties of RIT (as discussed earlier) will demand a concrete safety-net that could protect end-users from third party liability. Consequently, authors do not consider it feasible to include a new RIT liability provision within common minimum standards, rather submit the proposition that a reference, in brief, be made to the national liability regime within the scope of the MS requested international guidelines. Off-site remote surveys bear risks of damage to physical assets. Risks ranging from dropped object, collision or lost link, and defective products, *inter alia*, call the need to solve RIT-induced liability issues through existing regional or national policies so as to remove a major barrier that could potentially inhibit the market growth of RIT.

The above nexus would prove to be advantageous for EU MS given that the proposition would allow liability incurred from the usage of RIT to be governed by EU Product Liability Directive 85/374/EEC.[63] RIT used in remote surveys are operated using (battery-produced) "electricity" --- that is viewed as a product pursuant to Article 2 of Directive 85/374/EEC. The producer or manufacturer can resort to the defense mechanism found in Article 7: "[…] having regard to the circumstances, it is probable that the defect which caused the damage did not exist at the time when the product was put into circulation

[60] *V. Alexandropoulou* et al., Maritime remote inspection technology in hull survey & inspection: A synopsis of liability issues from a European Union context, Journal of International Maritime Safety, Environmental Affairs, and Shipping, 2021, 5:4, 184-195. See also A. Pasta et al. (in press: September 2022: Autumn 14.2 volume) Building a Trust Ecosystem for Remote Technologies in Ship Hull Inspection, Journal of Law, Innovation and Technology, Vol. 14 (2), 2022 in press.
[61] *T. Haidegger* et al., Applied Ontologies and Standards for Service Robots, Robotics and Autonomous Systems, 2013, 61(11): 1215-1223.
[62] European Commission, 2020 Report on the Safety and Liability Implications of Artificial Intelligence, the Internet of Things and Robotics. Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee.
[63] EU Product Liability Directive 85/374/EEC, 1985, Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, OJ L 210, 7.8.1985, 29–33. See also *A. Ozturk*, (2021). Lessons Learned from Robotics and AI in a Liability Context: A Sustainability Perspective, A. Carpenter, T. Johansson and J. Skinner (eds.), Sustainability in the Maritime Domain: Towards Ocean Governance and Beyond, 2021, Springer Sustainability Series

by him or that this defect came into being afterwards; or […] that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered […]".[64] Alternatively, in the case of strict product liability, the manufacturing company will most likely acquire insurance, and manage to exploit the economies of scale by distributing costs along the value chain.[65] The liability circle for RIT will be closed.

5. Conclusions

RAS service robots are now being effectively integrated to survey critical areas, which are difficult to access and monitor providing a safe to human-centric tasks. Furthermore, the application of RIT allows for ship hulls with a better environmental footprint.[66]. Though new service robotic solutions are promising, RIT built with non-standardized technical specifications will likely hamper mass deployment. Unfortunately, the current RIT governance framework also impedes integration across all levels of the maritime community. On a positive note, efforts are underway, particularly within the EU, to harmonize international guidance for remote surveys. There is a clear need to review and update common minimum standards to effectively integrate RIT in the global maritime sector.

The surge of RIT deployment in the maritime world embodies a visionary memorandum: enhanced performance in ocean affairs and maintaining good environmental stewardship. Whatever the merits of this vision, state-of-the-art equipment governing class rules and requirements do little beyond lightweight standards. Common minimum standards have resulted in duplication of efforts, to say the least.

Recent years have seen unique developments at the international level, such as the introduction of the Goal-Based Standards (GBS) into IMO initiatives. GBS is a clear and feasible way forward for a regulatory framework covering RAS and RIT. Notably, IMO applied the GBS concept through IMO Resolution MSC.287(87), titled Adoption of the

[64] Id., Article 7.
[65] *M. C. Rodríguez-Villalobos* et al., Economies of Scale and Minimization of the Cost: Evidence from a Manufacturing Company, Journal of Eastern Europe Research in Business and Economics, 2018, 1-16.
[66] Remote Survey, Det Norske Veritas: https://www.dnv.com/oilgas/remote-survey/index.html (last visited 27 December 2021); Survey by Remote Inspection Techniques – Use of Approved Service Suppliers, Det Norske Veritas: https://www.dnv.com/news/survey-by-remote-inspection-techniques-use-of-approved-service-suppliers-144572 (last visited 27 December 2021); Remote Technology Points to Cost Efficiency and Quality Gains, Det Norske Veritas: https://www.dnv.com/oilgas/perspectives/remote-technology-points-to-cost-efficiency-and-quality-gains.html (last visited 27 December 2021).

International Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers (2010). Subsequently, IMO's audit and verification process was finalized and approved in July 2016, demonstrating that IACS' Common Structural Rules have been successfully implemented into each of the twelve IACS member classification societies' rules and requirements in accordance with the GBS concept for bulk carriers and oil tankers. GBS is now being implemented into a variety of other IMO instruments to include the International Convention for the Safety of Life at Sea (SOLAS) and the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code). The GBS concept would also be highly suitable for a common global regulatory framework covering RAS and RIT.

Finally, the IMO is cognizant that strategies and standards need to be aligned through the development of a common methodology by internationally harmonized guidelines. This has become even more evident during the pandemic as ship owners have turned to RIT-mode for remote surveys. In light of these challenges, six strategic blocks have been proposed which can enable national regulators to sustain a regulatory regime shared with other stakeholders to best keep pace with a technological environment in flux. Crafting these fundamental blocks is a task that is well overdue from members of EurACS. Regardless of the eventual direction international guidance takes, members of EurACS will need to coordinate their efforts for uniformity to ensure that the EU RIT stakeholders can thrive in this paradigm shift. Both EU and non-EU classification societies need to stay synchronized and adhere to international guidance to come. Much work lies ahead to keep innovation coordinated for the common good in mankind's epic battle with negative impacts of our climate's change.

C. ANNEX: Principal Research Report (2020 – 2022) for Task 1.4

This section contains the original texts produced by the World Maritime University based on raw data and information. In other words, this section contains foundation-research imbricated with desktop research findings, raw data, raw-data analysis, results from primary and secondary source examination, and findings from inquiry and strategic exploration. It is important to note that the World Maritime University has finalized this report (May-August 2022) taking into account all general and specific comments provided by the following members of the Senior Advisory Group (report shared with members on 12 March 2022; feedback received 5 April 2022):

1. Mr. Thomas Klenum; Executive, Vice President, Liberian Registry, Washington, Germany;
2. Ms. Mona Swoboda; Program Manager, Inter-American Committee on Ports (CIP) Organization of American States;
3. Ms. Vera Alexandropoulou; Lawyer & Solicitor and Vice President, Thalassa Foundation;
4. Ms. Marina Papaiouanou; Training Manager, Det norske Veritas;
5. Captain Yoss LeClerc; President & CEO at Logistro Consulting International Inc.; President, International Harbour Masters Association;
6. Mr. Aron Frank Sørensen; Head of Marine Environment, Baltic and International Maritime Council;
7. Dr. Miguel Núñez Sánchez; Spanish Civil servant (Special Services) at Ministerio de Transportes, Movilidad y Agenda Urbana
8. Mr. Andrew Baskin; Vice President, Global Policy and Trade, General Counsel, HudsonAnalytix, Inc.;
9. Mr. David Knukkel; CEO at GDI and RIMS BV, Global Drone Inspection (GDI) of Robotics in Maintenance Strategies (RIMS), the Netherlands;
10. Mr. George Giazlas; Operations Manager DIVING STATUS Underwater Services;
11. Mr. Thomas Aschert; Senior Principal Surveyor, Lloyd's Register, Netherlands;
12. Mr. Frans van Ette; Programme Directeur AI, TNO, South Holland Province, the Netherlands;
13. Mr. Andreas Åberg; Senior Surveyor, Department of Inspections, Remote Survey Center; and
14. Mr. Fernando Pou Feliu; Senior Assessor of Safety and Security, European Maritime Safety Agency.

1. INTRODUCTION

1.1 Setting the Scene: Technology, Standards and International Guidance in Profile[1]

The complex operation of the world of technology is undoubtedly standard-reliant (Hatto, 2010(a)). Standards are deemed "voluntary and consensus" - based and integral to international infrastructures, economies and trade (Hatto, 2010(b), p. 2). While standards provide manifold advantages; the primary objective of standards is to provide concrete support/basis/means with regards to ongoing developments that will simultaneously help maintain the level of progress in relation to future developments (Hatto, 2010(b), p. 3)).

Today, Stakeholders involved in the field of technological developments primarily rely on standards published by organizations that have the mandate to implement four distinct categories of standards: national, regional, international and informal (Hatto, 2010(b), p. 4). Of the three international organizations working on setting technological standards, i.e., International Organization for Standardization (ISO), International Electrotechnical Commission (IEC) and International Telecommunication Union (ITU); ISO, founded in 1947, has had significant impact with over 17,000 standards published to date (Hatto, 2010(b), p. 4).

The definition of "standard" that is widely accepted and adhered-to can be found in one of the earliest publications by ISO titled *The Aims and Principles of Standardization* dates back to 1972 (ISO, 1972, p. 18). The term standard has been defined in the above ISO publication as "[t]he results of a particular standardization effort, approved by a recognized authority. It may take the form of: (1) a document containing a set of conditions to be fulfilled (in French "norme"); and (2) a fundamental unit or physical constant, for example, ampere, metre, absolute zero (Kelvin) (in French "étalon")". The same definition is incorporated verbatim by the American National Standard Institute, and is adhered to by standards-writing organizations in the United States of America (US) (NBS Special Publication, 1977, p. 74). IEC, on the other hand, refers to "standard" as "... document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities, or their results, aimed at the achievement of optimum degree order in a given context" (Official homepage of IEC). This definition has been implemented verbatim by the British Standardisation Organisation (BSO). Finally, in the United Nations (UN) affiliated ITU agency that comprises the Radiocommunication Sector, Telecommunication Standardization Sector and Telecommunication Development Sector --- the work on standardization is primarily private sector driven (Kawamori, M., and Moreno, M. F., 2010).

"Standard" and other associated terms, e.g., specification, specialization, are a part of an overarching term titled "standardization", defined as: "the process of formulating and applying rules for an orderly approach to a specific activity for the benefit and with the cooperation of all concerned, in particular for the promotion of optimum overall economy taking due account of functional conditions and safety requirements'' (ISO, 1972, pp. 17-18). A clear distinction is made in the 1972 ISO publication where It is further stated that the specific applications of "standardization" include: (1) units of measurement; (2) terminology and symbolic representation; (3) products and processes, and (4) safety of persons and goods"

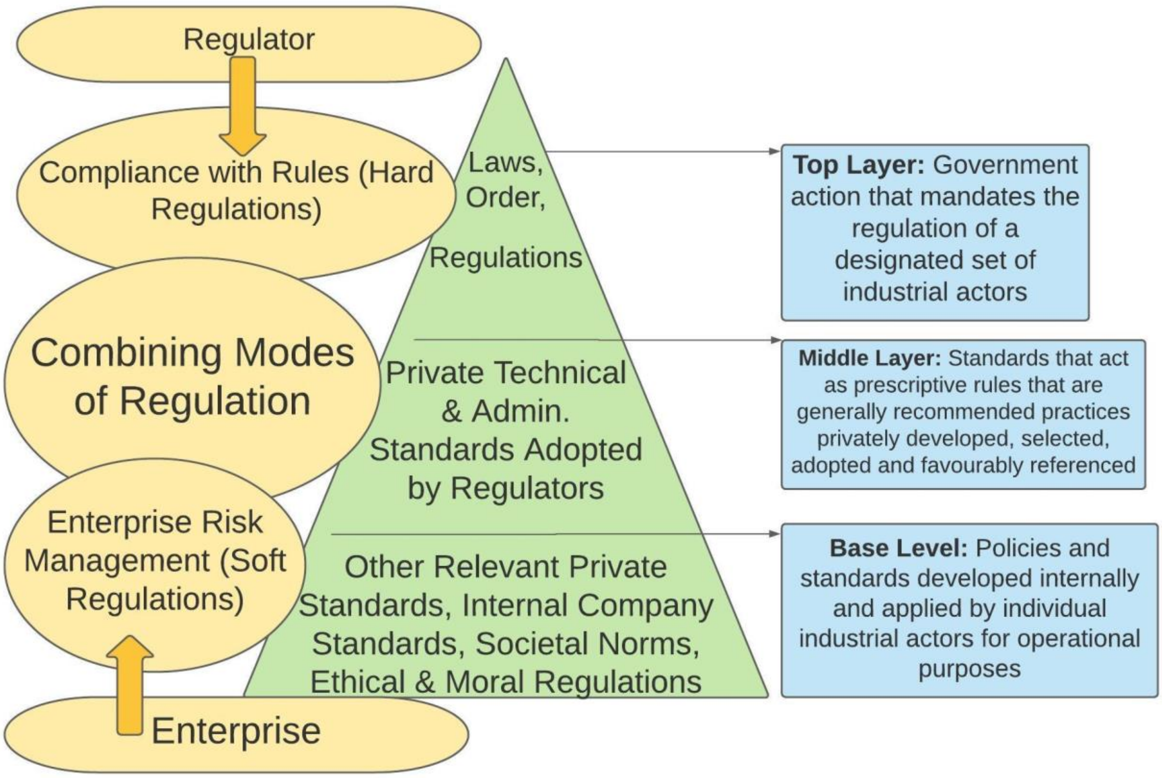
[1] A summary of this section has been inserted in the forthcoming publication: Johansson, T. (2021 in press) Advances in Robotics and Autonomous Systems for Hull Inspection and Maintenance (2022) in "Emerging Technology and the Law of the Sea" (James Kraska and Young-Kil Park, (eds.)), Cambridge University Press, © Cambridge University Press.

(ISO, 1972, pp. 17-18). In short, “standardization” determines not only the basis for the present but also for future development and therefore, assists in keeping pace with progress whereby “standard” is the result of a particular standardization effort, approved by a recognized authority.

The commencing point of any discussion related to legal insight on standards requires an insight into the nexus between standards and regulations. The principal difference between regulations and standards is that while the former is legally binding in nature and subject to sanctions, the latter is voluntary in nature with no legal obligations for compliance (Hatto, 2010(b), p. 4). Despite this dichotomy, the overall landscape of “standards” is composed of an entangled web of voluntary standards and regulatory standards. To explain this theory further, Lindøe and Baram developed a pyramidal structure to show the position of both standards in the regulatory regime. This pyramidal structure contains three distinct layers with relevant private standards, and methodological and behavioral guidelines embedded into the bottom layer (Lindøe and Baram, 2020, p. 236). The middle layer is composed of private technical and administrative “standards” and form a part of the compliance regime, and as such considered as regulatory standards (Lindøe and Baram, 2020, p. 236). A sharp distinction can be drawn between the middle-layer regulatory “standards” from the bottom-layer voluntary “standards” on the ground that “they have been adopted by or favourably referenced by regulators” and “considered authoritative and therefore, constitute *de jure* or *de facto* requirements that must be heeded by the targeted set of private actors” (Ayres and Braithwater, 1992; Lindøe and Baram, 2020, pp. 236-237). Finally, the top layer determines whether the regulatory regime in question will enact hard law or soft law on the subject matter, and depending on that decision, the main outcome from the bottom-layer is composed of enacted laws, orders and regulations (Lindøe and Baram, 2020, p. 236).

According to Lindøe and Baram, placing “soft law”-based standards and voluntary guidelines, whose application is left to the discretion of the entity, in a separate distinct layer leads to debate given that “hard” laws in reality could contain both “soft” and “hard” elements (Sinclair, 1997, pp. 529-559; Lindøe and Baram, 2020, p. 237). A blend of both “hard” and “soft” elements already exists in regulatory regimes --- a noteworthy example of which is the US “hard” law on offshore oil and gas operation (Lindøe and Baram, 2020, p. 237). Section 12(d) of the 15 USC 3701 Act on “Standards Conformity” only confirms this view held by Lindøe and Baram regarding blended usage in so far as it states that: “[a]ll Federal agencies and departments shall use technical standards (defined as ‘performance-based or design-specific technical specifications and related management systems practices’) that are developed and adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments” (Lindøe and Baram, 2020, p. 242). The interplay and interconnectedness of laws, rules, norms, guidelines, and voluntary standards widely accepted by enterprises without adoption by regulators is conclusive and well-established (Lindøe and Baram, 2020, p. 246).

Figure 1: Regulatory Regime Structure Explained by Lindøe and Baram



Source: Adapted from Lindøe, Preben H. and Baram, Michael, S. (2020) "The role of standards in hard and soft approaches to safety regulation" In: Odd Einar Olsen, Kirsten Voigt Juhl, Preben H. Lindøe and Ole Andreas Engen, Standardization and Risk Governance: A Multi-Disciplinary Approach, Routledge, (p. 236).

The technology-industry, similar to other private industries, is evaluated based on performance and safety and risk management systems. Today, safety and management systems, and standards are intertwined into a horizontal topic and as such, necessitate the interaction between public and non-public norms (Lindøe and Baram, 2020, p. 250). Private and industry prompted standards, guidelines and norms serve as external sources of the regulatory regime (Lindøe and Baram, 2020, p. 239). Adherence and compliance are in order to boost the economic value of those industries while ensuring public purposes (Lindøe and Baram, 2020, p. 250). The latter is deemed as one of the principal mandates of the government that encourage regulators to orchestrate the use of industrial standards with a view to striking a balance between "hard" and "soft" elements embedded in the subject-specific regulatory regime creating a blended environment. Capitalizing on industry-based standards help national regulators maintain a robust regulatory regime and manoeuvre in a landscape shared with other stakeholders to keep pace in a changing technological environment (Lindøe and Baram, 2020, p. 250).

Central in the vein of the modern technological environment is intentionality. Reaching the desired goals and objectives with minimum effort while maintaining the highest safety standards in all aspects is what makes the modern technological environment unique. A growing trend is observed among technological scholars that support the notion that technology is a terraforming practice that shapes and structures the environment (Sörlin and Wombs, 2018, p. 1). From the seventeenth century up until the mid-nineteenth century the term "technology" was used in the English language in a confined context, i.e., knowledge on technology --- a strict translation of the original Greek words "techne" and "logos" (Sörlin and Wombs, 2018, p. 5). It is safe to assume that mankind has surpassed this confined meaning given that technology has evolved and is continuously reshaping the environment. Sörlin and Wombs (2018) has relied on an integrated subset containing three specific technologies, i.e., writing, sensing and shaping to explain "environing technology" of which "environment" is the principal product (Sörlin and Wombs, 2018, pp. 5-8). Those three overarching "environing technologies" are composed of individual technologies, tools and practices with the tightly coupled "writing" and "sensing" elements that has helped "shape" standards that exist today (Sörlin and Wombs, 2018, pp. 7).

"Writing" in the context of "environ technology" is a topic closely associated with "standards" and "customary practices" given that documenting is intrinsic to activities related to the regulatory regime. A sound example forwarded by Sörlin and Wombs (2018) is the United Nations Convention on the Law of the Sea, 1982 (UNCLOS) and its dependence "on previous portrayals of the open seas as contentious and not clearly defined (2018, p. 7). It is therefore deduced that texts on standards whether "hard law" or "soft law" clearly belong to the domain of "environing technology" under the category of the "writing" element. This placement is crucial broadly owing to the fact that international documents, both normative and informative, contain technical and operational texts on standards developed by experts that help observe and ascertain progress-relevant milestones on sensor-based technological performance. Texts on standards and safety are indeed horizontal topics. Because achieving those milestones, in turn, contributes to progress and helps improve overall "safety, health and protection of life" ---- one of the four principal aims of standards and standardization (ISO, 1972, p. 5). Important to note that the "safety" aspect has been highlighted by international organizations including ISO and stressed in various research and development projects at the European level. In this setting, authors Fosh-Villaronga and Golia (2019) note that:

> "[w]hile ISO 13482:2014 is concerned with (physical) safety requirements, the legislative system includes many other fundamental rights to be protected. The euRobotics projects on the legal and ethical aspects since 2010, and the European Robolaw project, have repeat- edly highlighted five legal themes that any robot regulation should concern: (1) health, safety, consumer and environmental regulation; (2) liability; (3) intellectual property rights; (4) privacy and data protection; and (5) capacity to perform legal transactions." (Fosh-Villaronga and Golia (2019), p. 14).

From a benchmarking perspective, the definition of technological "standard" found today has a narrowed definition compared to the 1972 ISO definition. The narrowed definition of "standard" considered by modern-day technological experts refers only to documents developed by means of consensus embodied in rules, guidelines or characteristics in the conduct of area -specific activities with a view to achieving highest positive results (Pirlet, 2019, p. 1). This definition is followed by a recommendation that places emphasis on the importance of drafting technology-related "written" performance standards for stakeholders so as to allow evolution, progress and innovation (Pirlet, 2019, p. 1). The "written" aspect, as emphasized by Pirlet (2019, p. 1), should ideally build on unambiguous requirements to form a standardization-framework containing management, rules and procedures. Literature also notes that an important motivation behind the development of standardization framework composed of International, national or regional rules and procedures for sector-specific product is to keep the product itself up-to-date simply because robotics, electro-mechanics and Information of Things (IoT) belong to the fourth industrial paradigm, also known as Industry 4.0 Paradigm (Pirlet, 2019, p. 1; Vermesan and Bacquet, 2017,

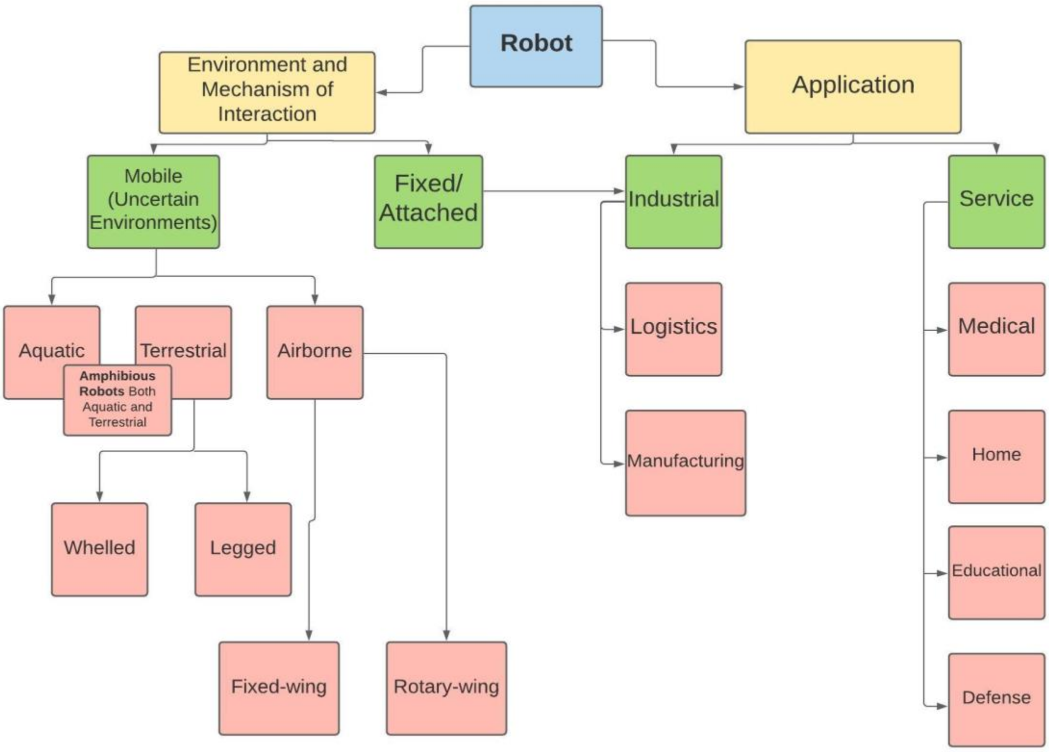
p. 310). This importance stems from the conceptual approach of the state-of-the-art Industry 4.0 Paradigm that strongly emphasizes on developing fundamental standards by legitimate organizations for consistency in products in order to boost efficiency (Gorecky et. al., 2014; Lapp Group AG, 2014).

When turning to the maritime and ocean domain, it is observed that the physical world is witnessing an era of digital advancement. The technology industry, more specifically, the maritime robotic industry is surfacing as one of the fastest growing markets. This growth is marked by the emergence of technologies often referred to as Robotic and Autonomous Systems (RAS). In the continuum of technological development, RAS has reached a stage where they are able to achieve desired goals. At this juncture, it is important to mention that the word “autonomous” embedded in the term RAS is not applied in a strict sense given that the work pertaining to the development of “fully autonomous” RAS is still an ongoing process.

Currently, RAS requires a certain degree of human intervention because unmanned RAS, such as Unmanned Aerial Vehicles (UAVs), has not reached the “acceptance” stage by respective authorities. It is also noteworthy that despite the high usage of the term RAS, especially by Technical Committees (TC) of non-formal standard developing bodies, such as the Institute of Electrical and Electronics Engineers (IEEE); the definition of RAS itself is currently non-existent. It is observed that the term RAS diffused today among those bodies is often used interchangeably with the term “robot” - the definition of which is considered as being “influenced by literary depictions” (Bertolini, 2013, p. 216). As noted by Bertolini (2013) with reference to the literary influenced definition found in *Merriam Webster* dictionary is questionable (Bertolini, 2013, p. 218). While the quest for an ideal definition continues; academics rely on a simple classification of “robots” based on operations and the environment they operate in (Ben-Ari and Mondada, 2018).

Despite the existing deficiency, RAS, today, is commonly composed of niche-products otherwise known as techniques, such as; drones, magnetic crawlers and Remotely operated Vehicles (RoVs). As we segue into the maritime survey and inspection regime, an important observation is conspicuous. The development-cycle of those products has led-to the creation of a multi-disciplinary environment bringing experts, policy-makers, academics, engineers, industry-folks. Tools to facilitate communication, definition, measurement, Key Performance Indicators (KPI), commerce and manufacturing are integral to this multi-disciplinary environment, which again, places importance on the development of “standards”.

Figure 2: Robots Classified According to Operation and Environment



Source: Adapted from Ben-Ari, M. and Mondada, F. (2018) *Elements of Robotics*, Springer, pp. 2-3.

Shipping has been enormously influential in the growth of the global economy. The shipping industry continues to play a vital role in the maritime and ocean domain. The manner in which goods transported by the shipping industry are considered more efficient than any other industries existing in the physical world. Fuel demand, fuel prices, fuel usage and global warming have sparked the interest to seek alternative options that would not only reduce energy consumption, but also enable the shipping industry to remain competitive in the global market. Efficient shipping means improved energy management whereby alternative fuels will inevitably shape the industry's future. This begs the question: how could remote techniques promote efficient shipping and ultimately play a constructive role in improved energy management? The connection explored is one that relates to the potential role played by emerging technologies to ameliorate the detrimental effects caused due to "biofouling".

A concrete definition of "biofouling" can be found in the International Maritime Organization's (IMO) 2011 Guidelines and has been defined at as: "... the accumulation of aquatic organisms such as micro-organisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling can include microfouling and macrofouling" (2011 Guidelines, IMO, p. 2). The detrimental effects caused by the accumulation of aquatic organisms resulting in biofouling and its connection to fuel usage by industry has been explained in light of increased frictional resistance demanding increased fuel usage by vessel operators (Schultz et. al., 2011, pp. 87-89; Molland et. al., 2014, pp. 175-188; Wang and Lutsey, 2013; Molland et. al., 2017, p. 7). In precise words, biofouling or hull fouling increases water resistance that have profound consequences on energy usage, hitherto perceived to be a concern for the industry and the maritime and ocean domain, at large.

The way forward is found in evidence-based literature noting the importance of hull cleaning by vessel operators to reduce effects of resistance. For example, Molland et. al. (2017) highlights the importance of inspection and cleaning activities by stating that "[t]he easiest method to reduce the effect of viscous resistance is to keep the hull clean and free of barnacles and underwater grasses … frictional resistance is a function of surface roughness. Fouling of the hull can increase fuel consumption up to 15 percent. Keeping the underwater hull clean will reduce surface roughness and help minimize the effects of viscous resistance and conserve fuel. Ships are also periodically dry-docked and their bottoms are stripped and repainted to return the ship's hull to a smooth condition (emphasis added)" (Molland et. al., 2017, p. 22). On the external front, outer hull inspections require upkeep through annual surveys, intermediate surveys and special (or renewal surveys), and enhanced surveys that are unavoidable obligations for ship owners and operators under international law.

The novel aspect of the application of RIT to climate change mitigation benefits derived from hulls with a better environmental footprint has garnered widespread attention in the maritime regulatory and policy communities. There are clear indicators that the paradigm shift has begun. This is evident from the online documents titled "Remote Survey"; "Survey by Remote Inspection Techniques – Use of Approved Service Suppliers"; "Remote Technology Points to Cost Efficiency and Quality Gains" published by Det Norske Veritas.

Evidently, national flag state authorities, classification societies and ship owners are steadily adopting RIT-based solutions, especially during the COVID-19 pandemic and the special challenges and limitations of human-presence on board ships. Although the market growth of new service robotic solutions is promising, the non-standardized assortment of remote inspection techniques (RIT), built with varying technical specifications, designed to perform the very same inspection and maintenance tasks --- will likely slow market growth and ultimately hinder mass deployment. Standardization in the form of international guidance resolving all incidental issues is emerging as an international concern. It is clear: neither service robots nor standards guiding the usage should be developed in isolation.

RIT is a big leap from the traditional ways of conducting hull inspection and maintenance. That being said, investigating reliability of RAS and different maintenance techniques are not only important for manufacturers, but also for service providers. For international provisions on safety and performance standards, it is a common practice to turn to the work of the intergovernmental organization known as IMO. International conventions are enforced by flag States directly or through recognized organization (RO), such as classification societies, acting on their behalf. Today, classification societies operate in tandem with ISO and other international organizations serving in the capacity of RO. In the maritime domain, the procedural rules in the form of common minimum standards developed by the International Association of Classification Societies (IACS) are invaluable to ship owners and operators in that they assist integrating RIT in mandatory surveys under international law. Similar to land-based technologies, the functionality of technologies applied in the ocean domain are evaluated on the basis of the so-called standardized safety and performance provisions encapsulated in the many IMO promulgated conventions.

While it is important to understand the implications of new service emerging technologies on the Law of the Sea governance framework, there is also a growing need to observe how other international governmental and non-governmental organizations with a standard mandate are addressing the core issues to help manufacturers pass the design bottleneck to enable the joint production of mutually valued outcomes that could create a positive impact on innovation, safety and environment. Harmonization of rules and requirements that govern procedures, and then identification of emerging incidental issues, especially those that emanate from the usage of RIT by service providers is key from an international horizontal policy perspective. The former has been, to a great extent, accomplished by IACS in a befitting manner. The latter, however, requires the attention of all stakeholders lest those issues should create barriers that detract from the main objectives of RIT deployment.

When observing literature on state-of-the-art, it also appears that the development of *de jure* standards by Standard Setting Organizations (SSO) gives rise to intellectual property challenges. Intellectual property differentiates products and services, thus maintaining their exclusivity, whereas standards harmonize products and impose uniform obedience (Pires de Carvalho, 2015). Intellectual property (IP) is about "the creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce" (WIPO, 2020a). The main intellectual property categories are patents, trademarks, copyrights/data ownership issues and trade secrets. For the first three categories, the government grants monopolistic property rights and the rights at issue can be registered (Brady, 2015). The IP protection's economic and social gains comprise a great driver of consumer welfare that allows firms to produce the same output with fewer scarce resources (Padilla et al., 2019). Through intellectual property rights, software and hardware companies restrict competition and bound consumer choices by isolating competitors from the market or raising their entrance costs (Lemley, 2002; Mair, 2016).

The most relevant segment of IP that is relevant to the current discussion on standards is "patents". The term itself denotes the exclusive right granted for technological inventions to an inventor for a specific timeframe (generally 20 years) in exchange for public disclosure (WIPO, 2020a). After the completion of this period, the knowledge-object can be used free of charge. Patents that protect the technologies to operate the standard become Standard Essential Patents (SEPs) and their inclusion in the standard-framework lead to the exclusion of alternative technologies (Padilla et al., 2019).

SSOs have developed intellectual property rights (IPR) policies for the inclusion of patents in standards that safeguard the licensing of SEP. SEP owners are entitled to royalty rates in their licensing agreements or have the option to refuse to license their IP altogether. SSOs request standard-setting participants to disclose potential SEPs and declare if the grant implementers' licenses under Fair, Reasonable and Non-Discriminatory (FRAND) licensing principles (Contreras et al., 2019; Li and Wang, 2017). FRAND commitments take the legal form of a contract between the relevant parties in the standard-setting process, and proceeds to strike a balance with the need for standardization of products for public use and the rights of the owners of IPRs (ETSI Intellectual Property Rights Policy, 2020). There is little guidance to help parties conceptualize FRAND terms. Their explicit content is agreeable to negotiations between the relevant parties, whether there are cases that necessitate a softening of IP law's hard-edges (Mair, 2016).

After the development of standards, the standard-technology is made accessible to potential users. However, several SEP disputes have been noted globally between technological companies and SSOs on the FRAND terms. Li and Wang (2017) noted two main reasons for these disputes: a) injunctive relief in cases where patent holders believe that, after the commercialization of the standard, they are still entitled to pursue this legal remedy b) FRAND term disagreements about royalty rates for licensing SEPs as what seems to be "reasonable" for one party may be "unreasonable" for the other party. Therefore, a good practice for SSOs is to ensure that their IP policies include explicit provisions about SEP holders who seek injunctive relief against a willing licensee, as well as guidelines for defining reasonable royalties.

IP protection is also crucial to the promotion of environmentally sound technologies and their dissemination, where needed. The United Nations Framework Convention on Climate Change (UNFCCC, 1994) sets the basis for technology transfer between developed and developing countries. UNFCCC intends to tackle “dangerous” human interference with the climate system and stabilize greenhouse gas concentrations. The Parties to the Convention are requested to cooperate and exchange scientific, technological, technical and legal information. According to Article 4, all Parties should cooperate in the development and transfer of technologies that reduce anthropogenic emissions of greenhouse gases in all relevant sectors, including the transport industry (UNFCCC, 1994). The Paris Agreement that aims to maintain a global temperature rise in this century to well below 2 degrees Celsius above pre-industrial levels also underlines the need for implementation of collaborative technology development and transfer from developed to developing countries (UNFCCC Secretariat, 2016). Despite the need to transfer these technologies on an international scale, intellectual property rights could pose a barrier for climate negotiations and actions (Zhou, 2019).

The IP system affects various elements of the technology transfer process, ranging from the protection of the ownership of climate-friendly technologies to the transfer of IP (Zhang, and Wang, 2014). The World Trade Organization (WTO) and the World Intellectual Property Organization (WIPO) are the two major international bodies that regulate IPR. WIPO, a UN specialized agency, provides capacity building and fact-based information to assist with international policy dialogue and effective technology transfer. WTO’s Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS, 1994) comprises the static legal framework that regulates the trade of climate-friendly technologies and sets minimum standards of protection to be provided by each Member for copyright, trademarks, designs, patents, and trade secrets. TRIPS is an essential element of the multilateral trading system that encompasses provisions of the two key treaties of WIPO, which is the Paris Convention on industrial property and the Berne Convention on copyright. Member States are invited to adopt intellectual property measures to prevent the abuse of intellectual property rights.

Article 7 of the WTO Agreement, entitled “objectives,” states that the protection of intellectual property rights should facilitate the promotion and transfer of technological innovation for mutual benefits between producers and users, contributing to social and economic welfare (TRIPS, 1994). Article 10.1 of the Agreement includes provisions about computer programs that shall be protected under copyright according to the provisions of the Berne Convention (1971). Databases should also receive copyright protection as per Article 10.2 should their contents constitute intellectual creations. Provisions exist on patent protection and information disclosure requirement once an invention is patented and associated flexibilities like compulsory licensing is in place. Accordingly, member States should ensure that patents are available for any inventions in all fields of technology subject to the normal requirements for novelty. Article 66.2 requires developed countries to provide incentives to enterprises under their jurisdiction to promote technology transfer to least-developed country Members.

Nonetheless, various discussions under the framework of UNFCCC have been raised to understand whether there are cases where IP impedes the transfer of climate-friendly technology to developing countries (Zhang, and Wang, 2014). Inaccuracies and inefficiencies have been noted in the current international regime since different patent laws in different jurisdictions do not affect the sale or usage of the patented technology in another country. The key stakeholders have conflicting opinions on the IPRs of the relevant technologies whereby different national systems create obstacles in compulsory licensing in the international transfer of climate technologies (Harper, 1997). Given that out of the seventy-three articles of TRIPS only a minor part is relevant to environmental issues (Harper, 1997), the researchers note that the current regime needs to be revisited. Zhou (2019) calls for a new mind-set of cooperation between UNFCCC, WTO, and WIPO, through which UNFCCC will be the central authority to interpret the TRIPS technology transfer provisions. All three organizations could jointly attempt to strike a balance between private interest and national governments. While the above aspects concerning IP, IPR, FRAND Term and TRIPS do not create any immediate contentions with regards to RIT deployment, they are nevertheless, worth consideration respecting the subtle connection between IPR framework and data.

Within the IPR framework, the data shared among the different stakeholders (in the post-inspection process) should be safeguarded against disclosure as a part of intellectual property rights or trade secrets. Data governance and management is closely linked to RIT and ROV applications. Data governance concerns the upper-level planning and the decisions about allocating responsibilities, access and control to data, whereas data management is associated with the implementation and monitoring of these decisions (Khatri and Brown, 2010). Patently, data governance - an overarching term, sets distinct rules on data ownership in various data life-cycle stages. The data management process encompasses the sequence of the following activities: collection, storage, processing, using, sharing and destroying of data (Janssen et al., 2020). Manufacturers, service suppliers, classification societies and shipping companies should take every effort to clarify data ownership, access and usage rights during a remote survey. This, according to the researchers, is just one out of several incidental issues that require the attention of ship-owners as well as concerned end-users.

The current reality is that the international maritime RIT governance framework is somewhat fragmented and shrouded with grey areas that impede the integration of RIT alternatives at both the regional and national levels. Harmonization efforts are at an embryonic stage and is so acknowledged at the EU level. Noteworthy in this context, is a 2021 working document issued by the General Secretariat of the Council of the EU which focuses on harmonizing international guidance for remote survey (Council of the European Union, 2020). Authors assert that there are outstanding incidental issues that call for the need to revisit the common minimum standards and the standards developed by respective classification societies with a view to harmonizing the core steering mechanisms for effective and efficient operation of RIT on a global scale. This needed harmonization is reinforced by the unique proposition tabled by the EU High-Level Expert Group on Artificial Intelligence (AI) that calls attention to a number of elements that constitute lawful, ethical and trustworthy AI through the creation of a robust horizontal regulatory foundation.

In retrospect, AI has turned into a strategic priority for governments leading to global competition for the development of AI applications and policies (Smuha 2021). In 2017, Canada became the first country to establish a national plan for AI titled “Pan-Canadian Artificial Intelligence Strategy” to foster a collaborative AI ecosystem by establishing interconnected nodes of scientific excellence in three major centres for AI: Edmonton, Montreal, and Toronto. In 2019, the US, through Executive Order 13859, promised to sustain and enhance the scientific, technological, and economic leadership position in AI research and deployment through a coordinated Federal Government strategy (Center for Homeland Defense and Security, 2019). The same year, Singapore launched the “National AI Strategy” that spells out plans to deepen the use of AI technologies and re-think business models by 2030. With its ambitious "Next Generation Artificial Intelligence Development Plan," China has set out a top-level design blueprint charting its approach to developing AI technology by 2030. At the European Union level, the European AI strategy (2018) specifies the EU's goal to "lead the way in developing and using AI for good and for all, building on its values and its strengths."

From the above mentioned, researchers note that Governments acknowledge the necessity to adopt policies that could stimulate beneficial innovation while safeguarding their citizens from potential risks from AI applications. Safety, responsibility, and product liability aspects of AI, including negligence, design defects, and manufacturing defects, usually fall into a legal and regulatory vacuum. At the same time, participants in regulatory debates hold diverging views of autonomy. Promoting uniformity in approaches that relate to safety and liability is vital to mitigate AI-related negative externalities and ensure that AI is "trustworthy", namely legal, ethical and robust.

The different AI national plans set specific targets for the ocean and maritime sectors, including research and development of autonomous vessels and autonomous onboard systems. In this context, autonomous and semi-autonomous RIT for vessel inspection have triggered the attention of relevant stakeholders. Breakthrough innovation followed and enhanced by revolutionary technology has brought the maritime regulatory community the transformative promise of "Robotic and Autonomous Systems (RAS)" --- but what is needed to allow RIT best be embraced? The question is answered by evaluating specific blocks of influence that comprise the regulatory blueprint for consideration when developing international guidance on the topic. Researchers assert that, although discussion centres around hull classification surveys for bulk carriers using RIT --- the regulatory blueprint could serve as a foundation for future techno-regulatory developments pertaining to survey and inspection of other specific areas for other types of vessels.

1.2 Objectives

The objectives of this report are aligned with the objectives found in s. 2.1.3 (pp. 28-29) of the Grant Agreement entitled "regulatory barriers and policy framework inputs".

Objectives: Review of international Arrangements

The objectives of this part of the review are fourfold:

Objective 1 – Analyse emerging technologies from the context of United Nations Convention on the Law of the Sea, the UN Framework Convention on Climate Change, and the Paris Agreement;

Objective 2 – Review IMO treaty regime related to safety, efficiency and the environmental control of pollution; intellectual property rights further to WIPO and related standards, along with the certification requirements and standards pursuant to ISO framework as well as Bulk Carrier Certification Schemes; and

Objective 3 – Conduct preliminary cross-comparative analysis of selected member classification societies with a view to extracting elements for the Regulatory Blueprint; and

Objective 4 – Amalgamate individual take-aways from examination of selected international organizations, and findings that serve as ways forward **Regulatory Blueprint from International Legal Insight.**

Objectives: Review of National Arrangements

The national analysis conducted under this research aims to contribute to the reform and the progressive development of uniform norms for autonomous robotics regulation and standards. To ensure consistency followed by a satisfactory outcome, the national comparative study has the following five principal objectives:

Objective 1: Review status of national norms, regulations, standards, and initiatives related to autonomous robotics, artificial intelligence, autonomous ships, and remote inspections;

Objective 2: Advance understanding of the regulatory and self-regulation national approaches for robot-technologies and remote inspections;

Objective 3: Exemplify the existing usage of different regulatory tools in the aviation and automotive sectors;

Objective 4: Identify the national strengths and weaknesses of the country and the opportunities and threats to which it is exposed; and

Objective 5: Identify best practices that could be utilized to produce a distinctive and state-of-the-art regulatory and policy blueprint.

Objectives: Review of European Union Arrangements

The article outlines the EU legal framework concerning port State jurisdiction, and contextualises this legal landscape by recalling the history of attempts at EU and international level to regulate in response to maritime disasters since the 1980s.

1.3 Methodology

Methodology Used to Review international Arrangements

To reach the aims and objectives of this part of the report, the research methodology used is a combination of the doctrinal and comparative methods. The doctrinal methodology, sometimes simply referred to as the “legal” method so to distinguish it from non-legal disciplines, is basically concerned with doctrinal research which, in turn, is a combination of “legal theory research” and “expository research” (Chynoweth, 2009). To this end, the report utilizes only the “expository research” method given that the task does not include critical analysis and incisive examination of relevant legal doctrines and principles. This form of research comprises detailed examination of legal texts including legislative material and international legal instruments, also often referred to as “black-letter law”. Exposition of legal texts in the research process includes, as well, international instruments, relevant scholarly literature such as textbooks, academic and professional journals containing legal opinions and expert commentaries, industry standards, procedures and requirements and the likes.

Expository research is an essential component of the doctrinal methodology discussed above. This is the primary methodology employed in the research leading to this report. It is used to analyse the extant law (*de lege lata)* pointing out its drawbacks and deficiencies. It must be thoroughly understood to determine what the law should be in the future (*de lege ferenda*). Needless to say, this approach highlights the continuum of past, present and future in terms of the progress of the law.

Findings from expository research have been confirmed with respondents (consisting of service providers from two companies and selected classification societies) interviewed during 2020-2021.

Methodology Used to Review National Arrangements

The methodology deployed for reviewing selected national arrangements include analysis of data collected through primary and secondary sources of information. Secondary sources included scholarly materials written by legal experts, governmental publicly available documents, legal directories and policy documents provided by maritime administrations. Primary data was collected through in-depth semi-structured interviews (between March and July 2021) with the following entities:

United States of America
US Coast Guard (USCG), Holland & Knight LLP, HudsonAnalytix, Inc, Inter-American Committee on Ports (CIP), Association for Unmanned Vehicle Systems International, MG Marine Consulting LLC, University of Florida Levin College of Law, DNV USA and TMA BlueTech.

The Netherlands
Ministry of Infrastructure and Water Management, Global Drone Inspection, TNO Netherlands, Netherlands AI Coalition, RINA Netherlands, Lloyd's Register North Europe, Lloyds Register Deutschland, Airborne Composites Automation, Tilburg Law School and Captain AI.

Canada
Transport Canada (TC) (government of Canada), Logistro Consulting International Inc, Deep Trekker Inc and Avestec.

Norway
Norwegian Maritime Authority, Norwegian University of Science and Technology (NTNU), VUVI AS, University of Stavanger, University of South-Eastern Norway, Kongsberg Maritime, Blueye Robotics, Jotun A/S, Nordic Unmanned and Zeabuz.

China
China Classification Society and Bureau Veritas.

Singapore
Bureau Veritas Singapore, DNV Singapore, Performance Rotor, Madfly and Red Dot Analytics. Email communications with a team of Senior Advisers from the Maritime and Port Authority of Singapore (MPA).

The above respondents offered strategic and critical views pertaining to how selected jurisdictions are paving the way to autonomous operations, more specifically hull inspections and cleaning, through technological advancements. The information so gathered helped mark out strategic actions for the regulatory and policy blueprint considering the state-of-the-art as well as gaps and drawbacks, which can be used by the concerned regulatory bodies when developing new regulations or reforming existing laws and policies.

METHODOLOGY USED TO REVIEW EUROPEAN UNION ARRANGEMENTS

The examination proceeds as follows. The first section explains what autonomous inspection robots are, and what kinds of inspection and cleaning tasks they can perform, or are likely to be able to perform in the near future. The second section outlines the EU legal framework concerning port State jurisdiction, its interaction with the prerogatives and obligations of States under the law of the sea, and with the Paris Memorandum of Understanding on Port State Control. The third section offers a truncated history of attempts to regulate and adequately enforce construction, safety and maintenance standards of merchant ships since the 1980s, focusing on EU acts and the specific problems associated with bulk carriers and oil tankers. The fourth section closely analyses provisions of EU legislation on port State jurisdiction that require the inner and outer structures of ships to be inspected, linking these requirements to capabilities of autonomous inspection robots. The fifth section examines the Commission's ongoing work on a review of the PSC Directive, examining how autonomous inspection robots could support the aims pursued by this initiative. The possibility of new EU legislation mandating that ships entering Member State ports comply with standards prescribing maximum acceptable levels of biofouling is examined, drawing a comparison with such initiatives in other jurisdictions. The fifth section briefly concludes.

2. REVIEW OF INTERNATIONAL ARRANGEMENTS

ABBREVIATION

2011 ESP Code	International Code on the enhanced programme of inspections during surveys of Bulk carriers and Oil tankers, 2011
2011 Guidelines	The 2011 Guidelines for the Control and Management of Ships' Biofouling to minimize the Transfer of Invasive Aquatic Species
ABS	American Bureau of Shipping
AFS Convention	International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001
AI	Artificial Intelligence
AUV	Autonomous Underwater Vehicles (used interchangeably with ROV)
BCH	Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as amended
BIMCO	The Baltic and International Maritime Council
BSO	British Standardization Organization
BWM	International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, as amended
CCS	China Classification Society
CEN	The European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
COP	Conference of the Parties
CTCN	Climate Technology Centre and Network
DNV	Det Norske Veritas

DoA	Description of Actions
EEXI	Energy Efficiency eXisting Index
ESTs	Environmentally Sound Technologies
ETSI	European Telecommunications Standards Institute
EU	European Union
FRAND	Fair, Reasonable and Non-discriminatory
GDPR	The General Data Protection Regulation (EU)
GHG	Greenhouse Gas
GL	Germanischer Lloyd
HSSC	Harmonized System of Survey and Certification
HSSC, 2021	The Survey Guidelines under the Harmonized System of Survey and Certification, 2021
IACS	International Association of Classification Societies
IACS Recommendation 42	Guidelines for Use of Remote Inspection Techniques for Surveys Recommendation 42
IACS Recommendation 76	Guidelines for Surveys, Assessment and Report of Hull Structure - Bulk Carriers Recommendation 76
IBC	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as amended
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended
IP	Intellectual Property
IPRs	Intellectual Property Rights
IRS	Indian Register of Shipping
ISO	International Organization for Standardization
IMO	International Maritime Organization
IoT	Information of Things
ITU	International Telecommunication Union
KR	Korean Register
KPI	Key Performance Indicators
LDCs	Least Developing States
LR	Lloyds Register
LLC 66/88	International Convention on Load Lines, 1966 as modified by the Protocol of 1988 relating thereto, as amended
NK	Nippon Kaiji Kyokai
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, and as further amended by the Protocol of 1997, as amended

MC	Magnetic-wheeled Crawlers
MAV	Micro Aerial Vehicles
NDCs	Nationally Determined Contributions
P&I Clubs	Protection and Indemnity Clubs
Polar Code	International Code for Ships Operating in Polar Waters
RAS	Robotic and Autonomous Systems
RIT	Remote Inspection Techniques
RINA	Registro Italiano Navale
RO	Recognized Organization
ROVs	Remotely Operated Underwater Vehicles
RS	Russian Maritime Register of Shipping
SEEMP	Guidance for the Development of a Ship Energy Efficiency Management Plan
SEPs	Standard Essential Patents
SOLAS, 1974	International Convention for the Safety of Life at Sea, 1974
SSOs	Standard-setting organizations
TC	Technical Committees
TEC	Technology Executive Committee
TNAs	Technology Needs Assessments
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
UAVs	Unmanned Aerial Vehicles
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
UR (with reference to IACS)	Unified Requirements
US	United States
UNFCCC	United Nations Framework Convention on Climate Change
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

2.1 Technology & Developments under the United Nations

With a view to setting the scene, the main focus of this section revolves around the work of the United Nations (UN). At the outset, this section highlights the measures outlined in the umbrella convention, known as the United Nations Convention on the Law of the Seas (UNCLOS), with regards to protection of the marine environment (UNCLOS, 1982). Subsequently, the discussion shifts to the *UN Convention Framework on Climate Change* highlighting the need for technological innovation to deal with some of the thorny issues in relation to shipping, as well as the impacts of Artificial Intelligence (AI) on sustainable development initiatives.

2.1.1 United Nations Convention on the Law of the Sea[2]

UNCLOS has been characterized as the "constitution for the oceans" that provides a comprehensive regime of rules governing all uses of the oceans and their resources. Robotic technology and unmanned systems include a shift from physical access to remote human involvement, shaking the foundation of proximity-based provisions (Petrig, 2020). Evolutionary interpretation of UNCLOS has been proposed as a proper method to keep this living instrument aligned with transformative technology (Boyle, 2005; Petrig, 2020; Woker et al., 2020) since the amendment procedure is considered as a lengthy and demanding task. Even if the simplified procedure pursuant to Article 313 is to be followed, the amendment will be rejected if one State Party objects to it; therefore, interpretation seems to be the only solution to preserve the treaty from becoming obsolete. Although there are commentators that support an interpretive approach that cannot be applied to all the provisions, UNCLOS has been characterized as "a framework convention" subject to a process of continuing refinements (Macdonald, 1999). Constitutions like UNCLOS, encompass fundamental norms that provide the legal framework for the entire life of a community for an unspecified period of time (Fassbender, 1998).

Implications on UNCLOS brought by RIT are best assessed in this context by reviewing the legal status of RIT, and secondly and distinctly, the impact harmonized standards governing new technology will have on UNCLOS.

To assess the first strand, Part XIII of UNCLOS that regulates marine scientific research-related activities is the key section. Although the term "marine scientific research" remains undefined in the texts of Part XIII, the term itself is central to all work related to preservation of the marine environment. Both the scale and extent of marine scientific research is grounded not only on an in-depth assessment of the detrimental effects of ocean pollutants, but also on the exploration of science-based solutions. Assessment of datasets gathered through surveys acquired via technology are now common practice in the world of marine scientific research. Ocean exploration, ocean floor mapping, and aggregation of oceanographic data using floaters, drifters and underwater gliders or Autonomous Underwater Vehicles (AUVs) are examples of this trend. However, the deployment of those technologies has not always been free from debate. Questions have been raised by policy analysts as to whether the legal status of gliders and floaters constitutes "operational oceanography" due to the fact that they are tied to the geographic territory, which invokes the labyrinthine principle of "consent regime" (Hofman and Proels, 2015).

In the current context, debate can be set aside on the ground that RIT, although bearing a subtle connection to marine scientific research, are fundamentally, and primarily, for a different purpose: to provide alternatives to both statutory and classification alternatives to human-centric surveys on vessels that are berthed, anchored, moored within internal waters, or dry-docked. Notwithstanding the absence of a point of reference that determines (and protects) the legal status of professional RIT; complacency with regards to UNCLOS's "safety at sea" provisions are applicable. Taking the necessary measures under UNCLOS for ensuring "safety at sea" is a vital responsibility of the flag state. Explicitly covered under the "safety at sea", Article 94 are provisions for both vessel "construction" and "seaworthiness" with an expectation that flag States conduct services on vessel structures in support of good operation and performance. In this context

[2] This section has been used verbatim in the forthcoming publication: Johansson, T. (2021 in press) Advances in Robotics and Autonomous Systems for Hull Inspection and Maintenance (2022) in "Emerging Technology and the Law of the Sea" (James Kraska and Young-Kil Park, (eds.)), Cambridge University Press, ©Cambridge University Press.

"intention" is a nuance critical to understanding the applicability of RIT. Specifically, intentionality in the modern technological environment occurs when operational objectives are aligned with international objectives obliging service suppliers and end-users of innovative equipment to remain compliant. To determine whether this can be termed "improved compliance" can be ascertained by comparing vessel performance and energy efficiency levels between two different bulk carriers; one that has been surveyed manually vs one that has benefitted from RIT.

Indicators of "intention" or "intentionality" include writing, sensing and shaping --- subsets that combine to structure and regulate the objectives of an anticipated environment (Sörlin and Wombs, 2018). Techno-regulatory standards mirror the writing sub-set that defines the dynamics of "environing technology" (Sörlin and Wombs, 2018). Published techno-regulatory standards developed by international organizations are objective-specific and impact the modern technological environment. In many ways, regional and national objectives are deeply ingrained in the environmental objectives of UNCLOS, which in turn, endorses harmonized international standards; the next discussion.

To analyze the second strand, heavy reliance is made on part XII that deals with protection and preservation of the marine environment. Part XII is seen as being closely related to the aims of BUGWRIGHT2 in so far as Article 194 states that measures should be taken to prevent pollution of the marine environment from vessels, ensuring the safety of operations at sea, and regulating the design, construction, equipment, operation and manning of vessels and devices operating in the marine environment (UNCLOS, Part XII, Article 194). In short, part XII of UNCLOS highlights good environmental stewardship, and requests Member States (MS) to undertake "individually or jointly as appropriate, all measures … that are necessary to prevent, reduce and control pollution of the marine environment from any source, using … the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavour to harmonize their policies in this connection" (UNCLOS, Part XII, Article 194). According to Article 196, States shall take all the essential measures to prevent pollution of the marine environment resulting from the use of technologies or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment (UNCLOS, Part XII, Article 196.1). Here, strong emphasis is placed on mitigating vessel-source pollution by regulating vessel design, construction and equipment. Furthermore, Part XII lays the foundation for a global and regional cooperative regime with reference to "competent international organizations" to establish "international rules, standards and recommended practices and procedures" on vessel-source pollution (UNCLOS, Part XII, Article 197).

UNCLOS views General Accepted International Rules and Standards (GAIRS) as a pathway for symbiotic, compatible and a reciprocal nexus for existing international treaties. Markedly, GAIRS allows for "new concepts, such as precaution and biodiversity to become part of UNCLOS normative structure", and helps move the trajectory of the cooperation regime towards good environmental stewardship. To that end, GAIRS endorses competent international organization developed standards provided that the standards so developed resonate with the central objectives of UNCLOS. Openness and complementarity to other regimes tied to good environmental stewardship stands as the crux of Article 211and Article 237 and that both bolster support to this rule of reference. In that vein, GAIRS not only regulates consistency with International Maritime Organization (IMO) promulgated instruments, but also elucidates a broad scope for accommodating IMO Recognized Organizations (RO) and their rules and requirements.

2.1.2 UN Framework Convention on Climate Change: From UNFCCC to Paris Agreement and SDGs

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force in 1994 with the aim to tackle "dangerous" human interference with the climate system and stabilize greenhouse gas concentrations. The Parties to the Convention are requested to: cooperate to promote sustainable economic development, communicate regularly, update national and, where appropriate, regional programs. Exchange of scientific, technological, technical and legal information is required by Signatory parties. Article 4 addresses climate technology and specifies that all Parties should cooperate in the development and transfer of technologies that reduce anthropogenic emissions of greenhouse gases in all relevant sectors, including the transport industry (UNFCCC, 1994).

For the period 1997 to 2001, countries cooperated on climate technology development and transfer through a series of Regional Workshops (UNFCCC, 2016). In 1997, Parties to the Convention addressed climate technology development and transfer in Article 10 (c) of the *Kyoto Protocol*, which operationalizes UNFCCC and creates a burden to developed countries by setting binding emission reduction targets.

The Protocol's first commitment period lasted from 2008 till 2012 and a maximum assigned amount of the six main greenhouse gases (CO2; CH4; N2O; HFCs; PFCs; and SF6) was set by Parties. After the completion of the first commitment period, the Doha Amendment of Kyoto protocol – United Nations Framework Convention on Climate Change (UNFCCC) (2012) - established the second commitment period 2013-2020 and sets new targets for a reduction of GHG emissions by at least 18% below 1990 levels (UNFCCC, 2012). As of 28 October 2020, 147 Parties have signed and achieved the required threshold for its entry into force. This implies that Kyoto's second commitment period has been established and the reduction commitments of the countries specified in Annex I of the Amendment have become legally binding.

Since the period of applicability for Kyoto was from 2008 to 2012 and for Doha between 2013 and 2020, a new climate agreement was required to protect international climate after 2020. The Paris Agreement (UNFCCC Secretariat, 2016) entered into force on 4 November 2016 to strengthen the UNFCCC adopted in 1992. Article 2 of the Paris Agreement specifies that a global temperature rise should be kept this century well below 2 degrees Celsius above pre-industrial levels. Measures should be sought to limit the temperature increase even further to 1.5 degrees Celsius. Parties to the Agreement are required to prepare, maintain and communicate nationally determined contributions (NDCs) and formulate long-term low greenhouse gas emission development strategies.

The fundamental force that connects outer hull inspection cleaning and maintenance with the Paris Agreement is related to the vision of fully realizing technology development and transfer for reducing GHG emissions and enhancing climate resilience. Technological innovation is considered as an essential accelerator of the efforts to implement national climate action, and Article 10 of the Paris Agreement addresses issues relating to technological development and innovation.

Based on article 10.1 it is asserted that "[p]arties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions". Cooperative actions between the Parties are needed for technology development and transfer. Article 10, paragraph 4, of the Paris Agreement, establishes the Technology Framework, which will serve as the guiding tool for the work of the Technology Mechanism in facilitating enhanced action on technology development and implementing the Paris Agreement.

Technology development and transfer has been a major objective of the UNFCCC since 2010 when the Conference of the Parties (COP) established the Technology Mechanism to facilitate nations to develop and transfer climate technologies to reduce greenhouse gas emissions and adapt to the adverse effects of the changing climate (Conference of the Parties (COP)|UNFCCC, 2010). The Technology Mechanism within the Paris Agreement is a crucial element in implementing the Agreement.

The Technology Mechanism consists of two complementary bodies that work together – the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). TEC, with a panel of 20 technology experts, analyses policy-related issues to climate technology development and serves as the policy arm of the UNFCCC Technology Mechanism, whereas CTCN is the operational arm of the UNFCCC Technology Mechanism, transferring these technologies to developing countries. The European Union and its Member States are primary supporters of the CTCN.

The focused areas of action to be undertaken under the framework are: (a) innovation (b) implementation; (c) enabling environment and capacity-building; (d) collaboration and stakeholder engagement; and (e) support (Framework Conversion on Climate Change, 2018).

Regarding innovation, as stipulated in Article 10 paragraph 5 of the Paris Agreement, there is a pressing need to accelerate and encourage innovation to achieve a long-term global response to climate change and promote economic growth and sustainable development. Technological innovation should deliver environmentally and socially sound climate technologies on a widespread scale.

Under the prime implementation theme, the Paris Agreement highlights the importance of technology and all actions taken should facilitate the implementation of collaborative technology development and transfer, taking into consideration the role of North-South, South-South, triangular and regional collaboration in fostering implementation. The tools to be utilized include nationally determined contributions, long-term low greenhouse gas emission development strategies and technology needs assessments (TNAs).

Regarding the theme of Capacity-building for technology development and transfer, measures are required to strengthen countries' capabilities to take climate action in the context of the Paris Agreement. Enhancing public awareness on climate change and facilitating an investment-friendly national environment is of paramount importance. Governments should be helped in playing a key role in fostering private sector's involvement by designing and implementing policies, regulations and standards that boost favourable market conditions for climate technologies.

Collaboration, the fourth area of action, will enable the engagement of all the relevant stakeholders, ranging from local communities, national planners, the private sector and civil society organizations in the planning and implementation of Technology Mechanism activities. As for the fifth area of action, that of Support, includes innovative finance and investment at different stages of the technology cycle- will be provided to developing country Parties.

2.1.3 AI & the UN 2030 Agenda for Sustainable Development

United Nations 2030 Agenda for Sustainable Development includes 17 Sustainable Development Goals, three of which are related to the environmental dimensions of development.

1. SDG 13: Take urgent action to combat climate change and its impacts;

2. SDG 14: Life below water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development; and

3. SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Each country has the flexibility to set-up its own institutional architecture for implementing the United Nations 2030 Agenda through National Sustainable Development Strategies (NSDS's). Although the UNFCCC remains the basic global forum for negotiating the global response to climate change, environmental related SDGs are an essential step in incorporating climate change measures into national policies. Collective action and investments in technology can play a crucial role in limiting the increase in global mean temperature to two degrees Celsius above pre-industrial levels. The European Strategic Energy Technology Plan (SET Plan) is a good example of a cooperative initiative that could help in satisfying the various targets under Goal 13 as it facilitates the transition towards a climate-neutral energy system via the utilization of low-carbon technologies.

In furtherance of the foregoing, it is noted that Artificial Intelligence (AI) could act as an enabler in twenty-five environmental targets of the three SDGs (93%) through the analysis of large-scale interconnected databases and development of joint environmental actions (Vinusea et. al., 2020). AI could support: a) the understanding of climate change b) low-carbon energy systems with high integration of renewable energy c) the health of ecosystems d) automatic identification of possible oil spills and e) restoration of degraded land and soil (Vinuesa et. al., 2020). Table 1 depicts the positive (green color) or hybrid impact (orange color) of Artificial Intelligence on the SDGs 13, 14, and 15. For example, in terms of SDG Goal 14, AI can significantly reduce marine pollution of all kinds with the utilization of algorithms for automatic identification of possible oil spills, minimize and address the impacts of ocean acidification through scientific cooperation and develop research capacity and transfer marine technology. However, for targets 14.2 and 14.5 and 14.7, AI can have hybrid effects and act both as enabler and inhibitor since access to AI-related information of ecosystems could lead for example to overexploitation of marine resources.

Table 1: AI as an Enabler or Inhibitor for the SDGs 13, 14 and 15

SDG 13	SDG 14	SDG 15
13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements
13.2 Integrate climate change measures into national policies, strategies and planning	14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in	15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase

	order to achieve healthy and productive oceans	afforestation and reforestation globally
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought
13.A Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible	14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development
13.B Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species
	14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed
	14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products
	14.A Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine	15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

	biodiversity to the development of developing countries, in particular small island developing States and least developed countries	
	14.B Provide access for small-scale artisanal fishers to marine resources and markets	15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts
	14.C Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want	15.A Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems
		15.B Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation
		15.C Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities

Source: Vinuesa et. al. (2020): Green Color denotes that AI acts as Enabler and Orange that AI acts as both Enabler and Inhibitor. The absence of highlighting indicates the absence of identified evidence.

2.1.4 Take-away from Technology & Developments under the United nations

The key take-aways from this part of the discussion are summarized in the following:

Extracted from s. 2.1.1 (United Nations Convention on the Law of the Sea)

Safety Aspects: Taking the necessary measures under UNCLOS for ensuring “safety at sea” remains a vital responsibility of the flag state. Article 94 of UNCLOS provides a detailed but non-exhaustive list of safety issues to be addressed by the flag State. Explicitly covered under the “safety at sea” Article 94 are provisions for both vessel “construction” and “seaworthiness” with an expectation that flag States conduct services on vessel structures in support of good operation and performance. The integration of RIT into the survey and maintenance aspects of Article 94 are subject to the same, if not higher, expectations.

Environmental Aspects: As a bedrock principle, UNCLOS views the role of the General Accepted International Rules and Standards (GAIRS) as a legal mechanism for safeguarding the marine environment. Self-explanatory from the title, GAIRS embraces “standards” developed by “competent international organizations” which are acceptable to the extent that they remain compatible with the scope, intent and objectives of UNCLOS. This rule of reference is spread across a number of Articles throughout UNCLOS, including Article 211 titled "pollution from vessels", which is considered an implicit reference for cooperation through the IMO (UNCLOS, Article 211). Moreover, article 237 is said to "adopt an approach of openness and complementarity" to all other regimes with respect to protection of the marine environment (UNCLOS, Article 237). Thereby, the rules of reference via GAIRS not only offers consistency with IMO regulatory instruments but also elucidates a broad scope for considering IMO ROs and their rules and requirements. Conversely, through their respective functions, Classification Society standards complement the rules of IMO, which in turn ensures the effective and efficient implementation of environmental provisions of UNCLOS.

Extracted from s. 2.1.2 (UN Framework Convention on Climate Change: From UNFCCC to Paris Agreement and SDGs)

Technology Accelerates Sustainable Actions: The vessel hull inspection regime is integrally connected with the mission and vision of SDG 13 that calls for the need to take urgent action to combat climate change and its impacts.

The survey and inspection regime also has a subtle nexus with the Paris Agreement in so far as technological development and transfer for reducing GHG emissions and enhancing climate resilience is concerned. International arrangements confirm that technological innovation indeed accelerates the implementation of national climate action.

2.2 International Organization for Standardization (ISO)

ISO currently operates on the basis of six interlinked strategic directions over the period 2016-2020 (ISO Strategy: 2016-2020, 2015). The strategies range from developing high-quality standards for effective use of technology to engaging stakeholders and partners (ISO Strategy: 2016-2020, 2015, p. 2). At the outset, it is important to note that marine technologies and development of those technological standards fall under the mandate of Technical Committee ISO/TC 8 titled "Ships and Marine Technology" (Standards ISO/TC 8) (see table 2). The scope of the work of ISO TC/8 currently revolves around standards that are technical in nature including design, construction, structural elements, outfitting parts, equipment, methods and technology *inter alia*.

Table 2: Overview of ISO "Ships and Marine Technology Standards" (table: verbatim)

SUBCOMMITTEE	SUBCOMMITTEE TITLE	PUBLISHED STANDARDS	STANDARDS UNDER DEVELOPMENT
ISO TC 8/SC 1	Maritime Safety	50	12
ISO TC 8/SC 2	Marine Environment Protection	25	14
ISO TC 8/SC 3	Piping and Machinery	56	7
ISO TC 8/SC 4	Outfitting and deck machinery	61	18
ISO TC 8/SC 6	Navigation and ship operations	45	7
ISO TC 8/SC 7	Inland navigation vessels	33	0
ISO TC 8/SC 8	Ship design	56	7

ISO TC 8/SC 11	Intermodal and Short Sea Shipping	5	9
ISO TC 8/SC 12	Ships and marine technology - Large yachts	9	9
ISO TC 8/SC 13	Marine technology	3	11

Source: Official Homepage of ISO (https://www.iso.org/committee/45776/x/catalogue/)

Considering the keywords, i.e., inspection, maintenance and cleaning derived from the objective of BUGWRIGHT2; the standards published by the two noteworthy ISO subcommittees have been extracted in the following tabular overview (see table 3).

Table 3: ISO Sub-Committee Published Standards Potentially Linked to BUGWRIGHT2

Subcommittees Considered Relevant to RAS Associated with BUGWRIGHT2	**Subcommittee**	**Standards Potentially Relevant to BUGWRIGHT2 Technology and/or Project under the Direct Responsibility of ISO/TC 8/SC 13 Secretariat**
ISO TC 8/SC 2	Marine Environmental Protection	25 published (standards under development: 14)
ISO TC 8/SC 13	Marine Technology	3 published (standards under development: 11)

Source: Official Homepage of ISO (https://www.iso.org/committee/45776/x/catalogue/)

A further look at the keywords of the titles of the 28 published standards reveals 28 standards published by the Marine Environmental Protection and the Marine Technology Committees do not cover the procedural standards in relation to the topic at hand. Although most of the published standards cover risk assessment and marine technology, the ISO standards neither directly nor indirectly address the legal/regulatory standards sought to be explored and examined by WMU under BUGWRIGHT2, i.e., RAS technologies covering vessel hull inspection, maintenance and cleaning (see table 4).

Table 4: Titles of ISO Marine Environmental Protection and Marine Technology Sub-Committee Published Standards

SUB-COMMITTEE "MARINE ENVIRONMENTAL PROTECTION" PUBLISHED STANDARDS	**SUB-COMMITTEE "MARINE TECHNOLOGY" PUBLISHED STANDARDS**
ISO 13073-1:2012 Ships and marine technology - Risk assessment on anti-fouling systems on ships — Part 1: Marine environmental risk assessment method of biocidally active substances used for anti-fouling systems on ships	**ISO 21173:2019** Submersibles — Hydrostatic pressure test — Pressure hull and buoyancy materials
ISO 13073-2:2013 Ships and marine technology — Risk assessment on anti-fouling systems on ships — Part 2: Marine environmental risk assessment method for anti-fouling systems on ships using biocidally active substances	**ISO 21851:2020** Marine technology — Ocean observation systems — Design criteria of ocean hydro-meteorological observation systems reuse and interaction
ISO 13073-3:2016 Ships and marine technology — Risk assessment on anti-fouling systems on ships — Part 3: Human health risk assessment method of biocidally active substances used in	**ISO 22252:2020** Manned submersibles — Breathing air supply and CO2 adsorption systems — Performance requirements and recommendations

anti-fouling paints on ships during the application and removal processes	
ISO 13617:2019 Ships and marine technology — Shipboard incinerators — Requirements	
ISO 16165:2020 Ships and marine technology — Marine environment protection — Vocabulary relating to oil spill response	
ISO 16304:2018 Ships and marine technology — Marine environment protection — Arrangement and management of port waste reception facilities	
ISO 16446:2013 Ships and marine technology — Marine environment protection — Adapter for joining dissimilar boom connectors	
ISO 17325-1:2014 Ships and marine technology — Marine environment protection — Oil booms — Part 1: Design requirements	
ISO 17325-1:2014 Ships and marine technology — Marine environment protection — Oil booms — Part 1: Design requirements	
ISO 17325-2:2014 Ships and marine technology — Marine environment protection — Oil booms — Part 2: Strength and performance requirements	
ISO 17325-3:2018 Ships and marine technology — Marine environment protection — Oil booms — Part 3: End connectors	
ISO 17325-4:2018 Ships and marine technology — Marine environment protection — Oil booms — Part 4: Auxiliary equipment	
ISO 18309:2014 Ships and marine technology — Incinerator sizing and selection — Guidelines	
ISO 18611-1:2014 Ships and marine technology — Marine NOx reduction agent AUS 40 — Part 1: Quality requirements	
ISO 18611-2:2014 Ships and marine technology — Marine NOx reduction agent AUS 40 — Part 2: Test methods	
ISO 18611-3:2014 Ships and marine technology — Marine NOx reduction agent AUS 40 — Part 3: Handling, transportation and storage	
ISO 19030-1:2016 Ships and marine technology — Measurement of changes in hull and propeller performance — Part 1: General principles	

ISO 20053:2017 Ships and marine technology — Marine environment protection — Specifications on design and selection of sorbents	
ISO 20083-2:2019 Ships and marine technology — Determination of the shaft power of ship propulsion systems by measuring the shaft distortion — Part 2: Optical reflection method	
ISO 20083-3:2019 Ships and marine technology — Determination of the shaft power of ship propulsion systems by measuring the shaft distortion — Part 3: Elastic vibration method	
ISO 21070:2017 Ships and marine technology — Marine environment protection — Management and handling of shipboard garbage	
ISO 21072-2:2020 Ships and marine technology — Marine environment protection: performance testing of oil skimmers — Part 2: Light and medium viscosity oil	
ISO 21072-3:2010 Ships and marine technology — Marine environment protection: performance testing of oil skimmers — Part 3: High viscosity oil	
ISO 23048:2018 Ships and marine technology — Verification method for portable power measurement using a strain gauge	

Source: Official Homepage of ISO

2.2.1 Standard Definitions: Robots, Robotic Devices and Mobile Robots

The common vocabularies or definitions pertaining to robots and robotic devices are found in the second revised edition of *ISO 8373:2012 Robots and Robotic Devices – Vocabulary* (ISO 8374:2012). What is noteworthy about ISO 8373:2012 is the way it has set the definitions for industrial robots and service robots creating a strategic dichotomy for comprehending the two types. “Industrial automation application” is the point of distinction between the two. In other words, “industrial robots”, whether fixed or mobile, are used for industrial application while “services robots” that “perform useful tasks” for the humans are those that exclude such applications (see table 5).

Table 5: Important Definitions (extracted) from Robots and Robotic Devices-Vocabulary as Found in ISO 8373:2012

Section from ISO 8374:2012	Definition
S. 2.2: **Autonomy**	“Ability to perform intended tasks based on current state and sensing, without human intervention”
S. 2.6 read in conjunction with s. 4.3 and 2.2: **Robot**	“Actuated mechanism programmable in two or more axes (4.3) with a degree of autonomy (2.2), moving within its environment, to perform intended tasks:
S. 2.9 read in conjunction with s. 2.4 s. 2.5, s. 2.1, s. 4.3, s. 3.1. and s.	“Industrial robot automatically controlled, reprogrammable (2.4), multipurpose (2.5) manipulator (2.1), programmable in three or more axes (4.3), which can be

5.8: **Industrial Robot**	either fixed in place or mobile for use in industrial automation applications Note 1 to entry: The industrial robot includes: — the manipulator, including actuators (3.1); — the controller, including teach pendant (5.8) and any communication interface (hardware and software).
S. 2.10 read in conjunction with s. 2., s. 3.15.5, 2.9 and 2.10: **Service Robot**	"Robot (2.6) that performs useful tasks for humans or equipment excluding industrial automation applications"
S. 2.17 read in conjunction with s. 2.6 and s. 2.14: **Operator**	"Person designated to start, monitor and stop the intended operation of a robot (2.6) or robot system (2.14)"
S. 2.20 read in conjunction with s. 2.6: **Installation**	"Operation consisting of setting the robot (2.6) on its site, connecting it to its power supply and adding infrastructure components where necessary"
S. 2.25 read in conjunction with s. 2.6: **Collaborative Operation**	"State in which purposely designed robots (2.6) work in direct cooperation with a human within a defined workspace"
S. 2.29 read in conjunction with s. 2.6 ands. 5.12: Human-Robot Interaction (HRI)	"Information and action exchanges between human and robot (2.6) to perform a task by means of a user interface (5.12) EXAMPLE: Exchanges through vocal, visual and tactile means.
S. 2.30: **Validation**	"Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use have been fulfilled
S. 2.31: **Verification**	"Confirmation by examination and provision of objective evidence that the requirements have been fulfilled"

Source: Official Homepage of ISO

The standard definitions on "mobile robots" prepared by ISO Technical Committee ISO/TC 299 (ISO 19649:2017, 2017) (see table 6), appear to be in high usage for BUGWRIGHT2 Consortium Members that are dealing with RAS technical aspects.

Table 6: Important Definitions (extracted) from Mobile Robots-Vocabulary as found in ISO 19649:2017

Section from ISO 19649:2017	Definition
S. 3.1.1 read in conjunction with s. 3.1.2: **Mobile Robot**	"robot able to travel under its own control
S. 3.1.2 read in conjunction with s. 3.3.6 and s. 3.3.7: **Mobility**	"ability of the mobile platform (3.1.2) to travel within its environment
S. 3.1.7: **Travel Surface**	"terrain on which the mobile robot (3.1.1) travels"
S. 3.1.10 read in conjunction with s. 3.1.2: **Locomotion**	"self-propelled travel of the mobile platform (3.1.2)"
S. 3.3.1: **Steer Wheel/Steered Wheel**	"Wheel whose orientation is controlled to change the direction of travel"
S. 3.5.5 read in conjunction with s. 3.1.2: **Mobile Platform Coordinate System**	"coordinate system referenced to one of the components of a **mobile platform** (3.1.2)
S. 3.5.6 read in conjunction with s. 3.3.1, s. 3.1.2 and s. 3.5.5: **Steer Angle**	"Angular displacement of the axle of a steer wheel (3.3.1) about the $+Z_p$ axis
S. 3.5.7 read in conjunction with s. 3.1.2 and s. 3.5.5: **Forward Travel**	"Movement of the mobile platform (3.1.2) along its $+X_p$ axis"

S. 3.5.8 read in conjunction with s. 3.5.5 and s. 3.1.2: **Reverse Travel/Backward Travel**	"Movement of the mobile platform (3.1.2) along its $-X_p$ axis
S. 3.5.9 read in conjunction with s. 3.1.2 and s. 3.5.9: **Traverse/Lateral Traverse**	"Movement of the mobile platform (3.1.2) along its Y_p axis
S. 3.5.10 read in conjunction with s. 3.1.2, s. 3.5.7, s. 3.5.8 and s. 3.5.9: **Diagonal Travel**	"Movement of the mobile platform (3.1.2) as a combination of forward travel (3.5.7)/reverse travel (3.5.8) and traverse (3.5.9)"
S. 3.5.11 read in conjunction with s. 3.1.2 and s. 3.3.6: **Omni-directional Travel**	"Movement of the mobile platform (3.1.2) whose direction of travel can be changed instantaneously and arbitrarily by means of an omni-directional mobile mechanism (3.3.6)"
S. 3.5.12 read in conjunction with s. 3.1.2 and s. 3.5.5: **Turning**	"movement of the mobile platform (3.1.2) causing a change of the orientation of the mobile platform coordinate system (3.5.5)"
S. 3.5.16 read in conjunction with s. 3.1.2 and s. 3.5.12: **Turning Width**	"Minimum width of the rectangular passage within which the mobile platform (3.1.2) can complete a specific type of turning (3.5.12)"
S. 3.5.17 read in conjunction with s. 3.1.1: **Cornering Force**	force exerted on the mobile robot (3.1.1) by centrifugal force when travelling".
S. 3.5.18 read in conjunction with s. 3.1.1: **Balance Control/Balance Management**	"Process of maintaining the static and dynamic stability of the mobile robot (3.1.1)"
S. 3.6.1 read in conjunction with s. 3.1.1 and s. 3.1.2: **Pose**	"Combination of position and orientation in space"
S. 3.6.2 read in conjunction with 3.6.1 and 3.1.1: **Simultaneous Localization and Mapping (SLAM)**	"Constructing and refining the environment map while using features of the partly constructed map for recognizing the pose (3.6.1) of the mobile robot (3.1.1) travelling within its environment"
S. 3.6.6 **Collision**	"Dynamic contact resulting in momentum exchange"
S. 3.6.7 read in conjunction with s. 3.6.5 and s. 3.6.6: **Obstacle Avoidance**	"Preventing interference, such as approaching, contacting or collision (3.6.6), with obstacles by detecting them with external state sensors and adjusting trajectory planning (3.6.5)
S. 3.6.8 read in conjunction with s. 3.6.6: **Collision Avoidance**	"preventing **collision** (3.6.6) using external state sensors and reacting accordingly".
S. 3.6.9 read in conjunction with s. 3.1.2: **Mobile Platform**	"process of reaching and/or connecting a station, facility or other **mobile platform** (3.1.2) in order to perform an intended task"

Source: Official Homepage of ISO

2.2.2 Quality Management System: ISO 9000 Series

ISO 9000 family of standards, preceded by its reputation, comprises international systems in relation to quality management (Selection and Use of the ISO 9000 Family of Standards, 2016, p. 1). In short, the ISO 9000 Series developed by ISO/TC 176 specifies the basic requirements, and serves as international standards with a view to establishing "effective and efficient" quality management system as well as continual improvement for achieving business excellence (Selection and Use of the ISO 9000 Family of Standards, 2016, p. 2). The ISO 9000 family of standards, often referred to ISO Series of Standards, contains four thematic strands of standards, including Fundamentals and Vocabularies (ISO 9000:2015); Requirements (ISO 9001:2015); Guidance for Organizations to Achieve Sustained Success (ISO 9004:2018) and Guidelines for Auditing Management Systems (ISO 19011:2018). The modalities of the above four have been summarized in the following:

ISO 9000:2015 covers definitions that are deemed important to comprehend the basics of ISO 9000 Series. All definitions and vocabularies provided in ISO 9000:2015 concentrate on seven fundamental concepts and principles of a quality management system that are accepted universally (IS0 9000:2015; 2015):

- Organisations seeking sustained success through the implementation of a quality management system;
- Customers seeking confidence in an organisation's ability to consistently provide products and services conforming to their requirements;
- Organizations seeking confidence in their supply chain that product and service requirements will be met;
- Organisations and interested parties seeking to improve communication through a common understanding of the vocabulary used in quality management;
- Organisations performing conformity assessments against the requirements of ISO 9001;
- Providers of training, assessment or advice in quality management;
- Developers of related standards (IS0 9000:2015; 2015)

So, what is *quality management*? Under ISO 9000:2015, a quality management is an amalgamation of "quality policies and quality objectives, and processes to achieve these quality objectives through quality planning, quality assurance, quality control, and quality improvement" (IS0 9000:2015; 2015). In other words, the achievement of "quality objectives" contained in a "quality policy" that spells out quality processes through planning, assurance, control and continuous improvement is what a management as a *quality management*.

Respondents confirmed that organizations tend to follow the ISO 9000 series in the implementation of a proper, clear, transparent and efficient structure based on information (and templates) readily available in documents laying down the procedures creating a "quality" communication system between and among the workers. Markedly, the term "quality" under s. 3.6.2 is defined as a "degree which a set of inherent characteristics of an object fulfils requirements" and could be associated with adjectives such as poor, good or excellent (IS0 9000:2015; 2015). In this context, "quality objective" could be determined via "objective evidence" gathered through data, and is closely associated with "audit" defined as: "systematic, independent and documented process for obtaining objective evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled" (IS0 9000:2015; 2015). "Audit criteria", in turn, is a milestone against which collected "audit evidence" is evaluated whereby the results of such evaluation is defined as "audit findings" that helps understand compliance and non-compliance. Here, it is noteworthy that "audit criteria" are selected from statutory or regulatory requirements covering both rules and regulations laid down at national and international levels (IS0 9000:2015; 2015).

The second strand of standards from the 9000 series outlines the requirements for a quality management system. Encapsulated in the title *ISO 9001: Quality Management Systems – Requirements*, the requirements apply to all types and sizes of organization that seeks continual improvement using strategic standards. Pursuant to clause 2, there are seven principal management principles governing the requirements: 1. customer focus; 2. leadership; 3. engagement of people; 4. process approach; 5. improvement; 6. evidence-based decision making; and 7. relationship management (ISO 9001:2015, 2015). Important to note that ISO 9001:2015 is a standard to which organizations could certify whereby certification holds the proof that the organization in question has successfully satisfied (demonstrated through audits) the crucial requirements of this specific strand of standard.

ISO 9004:2018 titled ISO 9004:2018 (en) titled *Quality management - Quality of an Organization - Guidance to achieve sustained success* provides significant insight as to how an organization continued improvement and sustained success (ISO 9004:2018, 2018). This third strand of standards of the ISO 9000 series. To this end, in the context of any given organization (clause 5), ISO 9004:2018 considers internal and external issues (clause 5) that take into account "mission, vision, values and culture" (clause 6); "leadership" comprised of policy and strategy, objectives and communication (clause 7); "process management" containing determination of processes, responsibilities and managing processes (clause 8); "resource management" with a sharp focus on people, organizational knowledge, technology (clause 9); "Performance analysis and evaluation" containing performance indicators, performance analysis, performance evaluation, internal audit, self-assessment and reviews (clause 10); and "improvement learning and innovation" (clause 11) (ISO 9004:2018, 2018). While infusing confidence in organization's ability to satisfy the expectations of customers; the consideration of the above internal and external issues guarantees continued improvement and subsequent success (ISO 9004:2018, 2018).

Finally, the fourth strand of standards titled *ISO 19011:2018: Guidelines for Auditing Management Systems* stresses on the important principles coupled with guidelines in relation to the management and conduct of audits (ISO 19011:2018; 2018). Within ISO 19011:2018, audits are classified into three types: first party audit (internal audit); second party audit (external provider audit and other external interested party audit) and third-party audit (certification/accreditation audit and statutory, regulatory and similar audit) (ISO 19011:2018; 2018). In doing so, ISO 19011:2018 stipulates the required qualifications against which the competence of auditors may be evaluated (ISO 19011:2018; 2018).

2.2.3 Take-aways from the Work of ISO

Notwithstanding the absence of BUGWRIGHT2-specific legal/regulatory standards; there are indeed important take-away points that are viewed as strong foundations to help set the legal/regulatory scene, and could assist in the development of future regulatory framework relevant to RIT. Those areas are highlighted in the following:

Extracted from s. 2.2.1 (Standard Definitions: Robot, Robotic Devices and Mobile Robots)

Strong Foundation in Place: ISO 8373:2012 covers a broad range of definitions from the context of maritime robotics. These definitions, as well as definitions found in ISO 19649:2017, could be taken into consideration during other future developments, for example, international guidance on remote survey.

Degree of Autonomy: A noteworthy finding when examining the definition of "service robots" is that the term itself has been developed taking into account the role of an operator. In other words, this is an indication of "supervised autonomy", which is how the RIT under BUGWRIGHT2 are operated and controlled. However, the words "able to perform tasks for humans" remains ambiguous, as "supervised autonomy" is only an indication that all tasks are completed via RIT. Researchers view the words "for human" as an enabler of "autonomy" defined as the "ability to perform intended tasks based on current state and sensing, without human interaction". An autonomous system, apparently, excludes the "operator" (defined as "person designated to start, monitor and stop the intended operation of a robot, s. 2.17, ISO 8374:2012, 2012) that is the human-element in the "supervised autonomy" system. Notwithstanding, a major finding from examining ISO standard definitions is the term "degree of autonomy", which is an important consideration in relation to understanding the human-robot dynamics.

Another major finding from ISO-developed vocabularies is with regards to the definitions of "mobile robot" and "mobility" found in sections 3.1.1 and 3.1.2 of ISO 19649:2017. It appears that the robots that are being referred to are ones that are governed by "full autonomy" (ref: s. 3.1.2: "robot able to travel under its own control"; ISO 19649:2017, 2017). Given the current "supervised autonomy" system, researchers assert that it is safe to opt for the term "remote inspection techniques" or "robot" when referring to the BUGWRIGHT2 technologies rather than "mobile robot" or "service robot" so as to avoid confusion as to the existing degree of autonomy.

Extracted from s. 2.2.2 (Quality Management System: ISO 9000 Series)

A Reference for Quality-system: Quality Management System that sets the pre-determined criteria for organization's management system utilizing RIT. These are well documented in international rules and requirements that deal with the usage of RIT.

2.3 The International Maritime Organization (IMO)

Transportation (land, air, sea and water) accounts for 23 percent of the global energy-related CO2 emissions with waterborne transport being more efficient in terms of gCO2/t-km compared to other freight transport modes (Sims et. al., 2014). The amount of GHG emissions in the sector is mainly due to the reliance of the sector on fossil fuels. The decarbonization of the transport industry is thus significant to the achievement of the goals set out in the Paris Agreement (UN Climate Action, 2017), despite the fact that the global governance of transport GHG emissions is rather fragmented. Although emissions from domestic modes of transport (rail, road, shipping and aviation) are included in the NDCs of countries under the Paris Agreement, international shipping is not addressed in the Agreement (Shi, 2018). Article 2.2. of the Kyoto Protocol states that Parties shall pursue control of emissions of greenhouse gases for marine bunker fuels through IMO.

IMO is the regulatory body which has mainly dealt with GHG emissions from international shipping while the UNFCCC is monitoring progress under its five-year Global Stock take, based on Article 14 of Paris Agreement. Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and its amendments is the primary instrument for the technical and operational measures of air emissions. Annex VI focuses on a phased reduction in Nitrogen Oxides (NOX), Sulphur Oxides (SOX) and Particulate Matter (PM) from marine engines. Chapter 4 to Annex VI on regulations on energy efficiency for ships contains provisions about the energy efficiency design index (EEDI) for new ships and the ship energy efficiency management plan (SEEMP) for all ships.

Specifically, in 2011, Resolution MEPC.203(62) on "Inclusion of regulations on energy efficiency for ships in MARPOL Annex VI" introduced obligatory technical and operational Ship Energy Efficiency Management Plan (SEEMP) initiatives for the energy efficiency of ships. Long-term technical measures are related to the

Energy Efficiency Design Index (EEDI); a performance-based mechanism that facilitates ship innovation and sets a minimum level of energy efficiency for the work undertaken for new ships of 400 GT and above. Regarding the short time measures introduced for the existing ships, IMO introduced the Energy Efficiency eXisting Index (EEXI). Ships need to calculate their EEXI following technical means to improve their energy efficiency compared to a baseline. According to the regulations, EEXI must be available on the first annual, intermediate or renewal IAPP survey or the initial International Energy Efficiency (IEE) survey after 1 January 2023. An International Energy Efficiency Certificate (IEEC) should be issued upon successful calculation of the EEXI.

For operational initiatives, SEEMP enables operators to monitor the performance of existing vessels of 400 GT and above engaging in international trade. Regulation 23 addresses the transfer of technology relating to the improvement of energy efficiency of ships.

The transfer of technology relating to the improvement of energy efficiency of ships is underlined in resolution MEPC.229 (65), with article 4 emphasizing that the transfer of technology needs to respect property rights, including intellectual property rights.

As stated in Article 1.4 of Resolution MEPC. 304(72) on the *Initial IMO Strategy on Ship GHG Emissions Reduction* of 2018, the Strategy remains alienated with law of the sea, the UNFCCC, Paris Agreement and United Nations 2030 Agenda for Sustainable Development. The Strategy in Section 3.1 specifies the levels of ambition for the international shipping sector noting that through technological innovation and the alternative fuels, the existing fleet and new ships aim to minimize: a) CO2 emissions by at least 40% by 2030 with an ambition of 70% by 2050, compared to the 2008 levels; and b) the total annual GHG emissions by at least 50% by 2050 compared to the levels of 2008. The Strategy lays out a multitude of short-, mid- and long-term measures. Article 4.7 notes that short term measures should include: a) research and development activities to address marine propulsion, alternative fuels, and innovative technologies that enhance the energy efficiency of ships; and b) incentives for first movers to develop new technologies.

In accordance with the IMO strategy on the reduction of GHG emissions from ships, the Marine Environment Protection Committee of the IMO adopted on 17 May 2019 the MEPC.323(74) Resolution inviting “[m]ember States to encourage voluntary cooperation between port and shipping sectors to contribute to reducing GHG emissions from ships”. Some of the measures that port authorities could implement to facilitate the decrease of GHG emissions from ships include Onshore Power Supply and bunkering of alternative low-carbon fuels and optimization of port calls' process.

2.3.1 Climate Change and Problems Associated with Non-indigenous Species

Non-indigenous species (NIS) threatens the ecological balance of the seas and can adversely affect the recipient communities through predation, parasitism, and habitat change. Non-indigenous species (NIS) can be transmitted through: a) ballast water tanks when untreated ballast water released at the ship's destination; and b) on the wetted surface of hulls as biofouling.

To address the issue of untreated ballast water, in 2004 the IMO adopted in *The International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM Convention). The Convention aims to control the transfer of potentially invasive species. Vessels should have a ballast water management plan and possess an international ballast water management certificate. A number of Guidelines have been released by IMO for the proper implementation of the Convention.

Apart from the risks associated with untreated ballast water, there are ports around the world with fragile ecosystems that are at high risk from biofouling. Biological fouling is dependent on many factors such as ship's loading condition, trade routes, proper anti-fouling coatings, ocean and environmental conditions. Despite the global efforts to tackle this issue, biological introduction risks are likely to persist due to climate change (Ware et. al., 2020). Non-indigenous species and climate change have been characterized as critical ecosystem stressors (Iacarella et. al., 2020) with warmer temperatures leading to NIS outbreaks (Walther et. al., 2009).

2.3.2 IMO'S STATUTORY FRAMEWORK: BIOFOULING IN FOCUS

Vessel biofouling, which is the accumulation of aquatic organisms on the wetted surfaces of vessels, raises dramatics concerns about the invasion of non-native species. Besides, biofouling or hull fouling diminishes vessel performance, increases weight, reduces speed and poses substantial operational costs, such as dry-docking and cleaning, for ship-owners. It has been estimated that the fuel cost of ships increases 10% for lightly fouled hulls and this amount may reach up to 35% when hulls are heavily fouled (Munk et al. 2009). Failure of marine coatings and biofouling affect the roughness of a ship's hull which in turns considerably escalates frictional resistance and hence fuel consumption and greenhouse gas emissions (Demirel et. al., 2017).

The International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS Convention, 2001) prohibits the use of harmful anti-fouling paints and anti-fouling systems that contain toxic substances. The Convention bans the use of TBT as a biocide on all vessels as it has been found to be highly toxic to the marine species. According to Article 10, Signatories parties shall ensure that their vessels of 400 gross tonnage and above that are engaged in international voyages are surveyed based on the regulations specified in Annex 4 to ensure compliance of the ship's anti-fouling system with the Convention.

In furtherance of the foregoing, the 2011 *Guidelines for the Control and Management of Ship's Biofouling to Minimize the Transfer of Invasive Aquatic Species* (2011 Guidelines) is a helpful tool for proper biofouling management practices that minimize the risks associated with biofouling. Patently, the 2011 Guidelines provides significant emphasis on procedures related to biofouling management pursuant to the BWM Convention and AFS Convention, 2001 in conjunction with Guidance for the Development of a Ship Energy Efficiency Management Plan (SEEMP). Recognizing the findings from evidence-based studies concluding that all ships contribute to some degree of biofouling after immersion in water, the 2011 Guidelines prescribes in-water cleaning management in addition to anti-fouling installation and maintenance (Resolution MEPC.207(62), 2011). According to s. 6.4 of the Guidelines, the five factors that have to be taken into consideration while choosing an anti-fouling system are: planned periods between dry-docking, ship speed, ship operation profile, ship type and legal requirements (IMO, 2011).

In short, the 2011 Guidelines provides significant emphasis on statutory procedures related to biofouling management pursuant to the BWM Convention, AFS Convention of 2011 in conjunction with Guidance for the Development of a Ship Energy Efficiency Management Plan (SEEMP). Recognizing the findings from evidence-based studies concluding that all ships contribute to some degree of biofouling after immersion in water, the 2011 Guidelines prescribes in-water cleaning management in addition to anti-fouling installation and maintenance (Resolution MEPC.207(62), 2011).

2.3.2.1 In-water Cleaning with ROVs

Under the 2011 Guidelines, in-water cleaning is seen as an important management tool for dealing with biofouling. The term "in water cleaning" under s. 2.1 has been defined as "… the physical removal of biofouling from a ship while in the water" (2011 Guidelines, s. 2.1). In this context, the 2011 Guidelines calls for the need to conduct in-water inspection "periodically" focusing on a number of areas outlined in s. 7.3:

- Propeller thrusters and propulsion units;
- Sea chests;
- Rudder stock and hinge;
- Stabilizer fin apertures;
- Rope guards, stern tube seals and propeller shafts;
- Cathodic protection anodes;
- Anchor chain and chain lockers;
- Free flood spaces inherent to the ships' design;
- Sea chest and thruster tunnel grates;
- Echo sounders and velocity probes;
- Overboard discharge outlets and sea inlets; and
- Areas prone to anti-fouling coating system damage or grounding (e.g., areas of the hull damaged by fenders when alongside, leading edges of bilge keels and propeller shaft "y" frames) (2011 Guidelines, s. 7.3).

What is noteworthy about the 2011 Guidelines, is that in terms of tools, s. 7.4 provides two procedural tools when conducting the periodic "in-water" survey as a part of the "inspection, cleaning and maintenance" procedure. Other than divers, the 2011 Guidelines allows the usage of ROVs that is viewed as one of the practical options for such operation.

Provisions on Remote Operated Vehicles (ROVs) can be found in s. 7.4, and has been framed in the following manner:

> **Dive and remotely operated vehicle (ROV) surveys** can be practical options for in-water inspections although they do have limitations regarding visibility and available dive time compared with the area to be inspected, and difficulties with effectively accessing many biofouling prone niches. Such surveys should be undertaken by persons who are suitably qualified and experienced and familiar with biofouling and associated invasive aquatic species risks and the safety risks relating to in-water surveys. Regulatory authorities may have recommended or accredited biofouling inspection divers (s. 7.4, 2011 Guidelines).

Based on the aforementioned, it is safe to assert that the use of ROVs can prove to be an effective tool that comes as an alternative to survey via diving in the effort to minimize non-indigenous marine species, sharp decrease of fuel consumption and reduction of air pollution. In addition, section 12 covers the importance of cooperation among States for conducting research for further development of technologies for "in-water cleaning that ensures effective management of the anti-fouling system, biofouling and other contaminants, including effective capture of biological material" [2011 Guidelines, s. 12.1.2].

2.3.2.2 IMO Harmonized System of Statutory Survey & Certification

Statutory rules developed by IMO details stipulations that are embedded into member State (flag State) national rules. Until the end of the twentieth century, surveys and certifications concerning safety and environmental pollution were diffused in a wide range of international instruments. To align those many survey and certification procedures, IMO has adopted a harmonized approach by introducing the *Harmonized System of Survey and Certification* (HSSC) in order to address survey procedural matters that have resulted in duplication of efforts by the industry. The *Survey Guidelines under the Harmonized System of Survey and Certification,* (HSSC 2021) (IMO Assembly Resolution A.1156(32) supersede the previous Guidelines and considers the harmonised system of survey and certification found a number of IMO instruments: *International Convention for the Safety of Life at Sea, 1974* (SOLAS, 1974); *International Convention on Load Lines, 1966* (1966 LL Convention, or LLC 66), as modified by the Protocol of 1988 relating thereto, as amended (LLC 66/88); *International Convention for the Prevention of Pollution from Ships*, 1973, as modified by the Protocol of 1978 relating thereto, and as further amended by the Protocol of 1997, as amended (MARPOL); *BWM Convention*; *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as amended* (IBC Code); *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended* (IGC Code); *Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as amended* (BCH Code); *and International Code for Ships Operating in Polar Waters* (Polar Code) (Resolution A. 1140(31), 2020).

Currently under the HSSC, the types of statutory surveys common in the above international Conventions have been harmonized. The conduct of those statutory surveys leads to the issuance of a statutory certificate, which is distinguished from class surveys that lead to the endorsement of a class certification although classification surveyors from classification societies are observed as carrying out those statutory surveys, often carried out by class surveyors on behalf of the flag of the ship. The types of ship surveys found in the HSSC, 2021 are the following:

S. 2.1: An **initial survey** is a complete inspection before a ship is put into service of all the items relating to a particular certificate, to ensure that the relevant requirements are complied with and that these items are satisfactory for the service for which the ship is intended;

S. 2.2: A **periodical survey** is an inspection of the items relating to the particular certificate to ensure that they are in a satisfactory condition and fit for the service for which the ship is intended;

S. 2.3: A **renewal survey** is the same as a periodical survey but also leads to the issue of a new certificate;

S. 2.4: An **intermediate survey** is an inspection of specified items relevant to the particular certificate to ensure that they are in a satisfactory condition and fit for the service for which the ship is intended;

S. 2.5: An **annual survey** is a general inspection of the items relating to the particular certificate to ensure that they have been maintained and remain satisfactory for the service for which the ship is intended;

S. 2.6: An inspection of the **outside of the ship's bottom** is an inspection of the underwater part of the ship and related items to ensure that they are in a satisfactory condition and fit for the service for which the ship is intended; and

S. 2.7: An **additional survey** is an inspection, either general or partial according to the circumstances, to be made after: .1 a repair resulting from investigations or whenever any important repairs or renewals are made; or, .2 change, replacement, or significant repair of the structure, equipment, systems, fittings, arrangements and material.

2.3.2.3 Examples from 2011 Enhanced Survey Programme Code

The survey programme of the *International Code on the enhanced programme of inspections during surveys of Bulk carriers and Oil tankers, 2011* (2011 ESP Code) developed pursuant to the recommendations made by the Maritime Safety Committee at its 98^{Th} session is applicable to bulk carriers and oil tankers (IMO, 2011 ESP). It is important to note that the surveys found under this Code do not form a separate survey, rather it outlines, for example, the "what" and "how" to inspect hulls and structures in the conduct of the given types of surveys (IMO, 2011 ESP). The following table highlights a few important provisions in relation to Bulk Carrier survey as found in the 2011 ESP, with a special focus on close-up survey and thickness measurement for: (i) Bulk Carriers 20,000 dwt and above and 10 years of age and above; and (ii) Bulk Carriers 100,000 dwt and above and between 10-15 years of age:

Table 1: Summary of Objective-based Provisions from IMO's 2011 ESP

Who?	Which?	When?	What?	How?	Reporting
Bulk Carriers	Bulk Carriers 20,000 dwt and above and 10 years of age and above	First Scheduled Renewal Survey and all subsequent Renewal and Intermediate Surveys (by two surveyors)	**(S. 4.4.3) Bulk Carriers >15 years:** inspection of the outside of the ship's bottom should be carried out with the ship in dry-dock. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and water ballast tanks should be carried out in accordance with the applicable requirements for intermediate surveys, if not already performed. **Bulk Carriers <15 years:** Inspection of ship's bottom not conducted during renewal survey may	**S. 7.1.2:** Thickness measurements of structures in areas where close-up surveys are required should be carried out simultaneously with close-up surveys **Inspection Types:** - Close-up survey of the structures such as Shell, frames, bulkheads etc. - Thickness measurement of hull - Inspecting and Testing of Cargo Tanks - Inspecting and Testing of Ballast Tanks - Inspection and Testing of Hatch Covers and Coamings - Inspecting and Testing fuel tanks, side and double bottom Tanks **Definitions:**	**Reporting (Annex 6 (1.2))** **1.** Evidence that prescribed surveys have been carried out in accordance with applicable requirements; **2.** Documentation of surveys carried out with findings, repairs carried out and condition of class (recommendation) imposed or deleted; **3.** Survey records, including actions taken, which should form an auditable documentary trail. Survey reports should be kept in the survey report file required to be on board;
Bulk Carriers	Bulk Carriers 100,000 dwt and above and between 10-15 years of age	Intermediate Survey (by two surveyors)			

			be carried out with the ship afloat **What to check?** - Ship's structural damage or deformation - Corrosion - Condition of Hull - Pitting - Condition of Coating Watertight Integrity of ship	**Overall Survey (s. 1.2.4)** Overall survey is a survey intended to report on the overall condition of the hull structure and determine the extent of additional close-up surveys. **Close-up Survey (s. 1.2.5)** Close-up survey is a survey where the details of structural components are within the close visual inspection range of the surveyor, i.e., normally within reach of hand.	**4.** Information for planning of future surveys; and **5.** Information which may be used as input for maintenance of classification rules and instructions.

Source: IMO's 2001 ESP (ref: https://themarinestudy.com/topic/1-2-definitions-2/?v=f003c44deab6)

2.3.2.4 Revisiting 2019 Proposed Amendments to the 2011 ESP Code to integrate RIT

This section serves as a reminder of efforts to integrate RIT into the 2011 ESP Code. Highlighting the importance of "safer surveys, decreased fault rate and reduction of costs of maintenance", IACS tabled the following three elements as additional updates to the *2011 ESP Code, as amended by resolution MSC.461(101)* (entered into force on 1 January, 2021) on 29 November 2019:

- Alignment with IACS Recommendation 42 through insertion of definition on RIT;
- Permit the usage of RIT for the conduct of close-up surveys; and
- Provide specific requirement for RIT, where deemed fit (Amendments to the 2011 ESP Code: Use of Remote Inspection Techniques (RITs), 2019)

Although the approval of proposed amendments is contingent on future discussions (that will likely take place during the Implementation of IMO Instruments (III) 8th Session), the Annex to the submission contains two noteworthy specific insertions and one replacement. Consequently, the first insertion concerns the following definition of RIT in the form of new sections (1.2.22 in part A of annex A; 1.2.22 in part B of annex A; 1.2.21 in part A of annex B; and 1.2.18 in part B of annex B):

> Remote inspection technique is a means of survey that enables examination of any part of the structure without the need for direct physical access of the surveyor (Amendments to the 2011 ESP Code: Use of Remote Inspection Techniques (RITs), 2019).

The second insertion comprises six specific elements to be inserted as new 1.6 in the above parts and annexes:

> 1.6 Remote inspection techniques (RIT)
>
> 1.6.1 The RIT shall provide the information normally obtained from a close-up survey. RIT surveys shall be carried out in accordance with the requirements given herein. * These considerations shall be included in the proposals for use of a RIT which shall be submitted in advance of the survey so that satisfactory arrangements can be agreed with the Administration.

* Refer to IACS recommendation 42 'Guidelines for Use of Remote Inspection Techniques for surveys'.

1.6.2 The equipment and procedure for observing and reporting the survey using a RIT shall be discussed and agreed with the parties involved prior to the RIT survey, and suitable time is to be allowed to set up, calibrate and test all equipment beforehand.

1.6.3 When using an RIT as an alternative to close-up survey, if not carried out by the Administration itself, it shall be conducted by a firm approved as a service supplier and shall be witnessed by an attending surveyor of the Administration.

1.6.4 The structure to be examined using an RIT shall be sufficiently clean to permit meaningful examination. Visibility shall be sufficient to allow for a meaningful examination. The Administration shall be satisfied with the methods of orientation on the structure. 1.6.5 The surveyor shall be satisfied with the method of data presentation including pictorial representation, and a good two-way communication between the surveyor and RIT operator shall be provided.

1.6.6 If the RIT reveals damage or deterioration that requires attention, the surveyor may require traditional survey to be undertaken without the use of an RIT."

Finally, the proposal requests the replacement of existing 1.5 in the following manner:

Original text:

1.5 Thickness measurements and close-up surveys

In any kind of survey, i.e., renewal, intermediate, annual or other surveys having the scope of the foregoing ones, for structures in areas where close-up surveys are required, thickness measurements, when required by annex 2, shall be carried out simultaneously with close-up surveys.

Amended text:

1.5 Thickness measurements and close-up surveys

1.5.1 In any kind of survey, i.e., renewal, intermediate, annual or other surveys having the scope of the foregoing ones, for structures in areas where close-up surveys are required, thickness measurements, when required by annex 2, shall be carried out simultaneously with close-up surveys.

1.5.2 Consideration may be given by the attending surveyor to allow use of remote inspection techniques (RIT) as an alternative to close-up survey. Surveys conducted using a RIT shall be completed to the satisfaction of the attending surveyor. When RIT is used for a close-up survey, temporary means of access for the corresponding thickness measurements as specified in this Part shall be provided unless such RIT is also able to carry out the required thickness measurements."

In short, the amendments proposed by IACS, is viewed by researchers as covering two important components: RIT and RIT-based close-up survey.

2.3.3 Take-aways from the Work of the International Maritime Organization[3]

The key take-aways from this part of the discussion are summarized in the following:

Flexibility in terms of Review and Amendment: IMO's Maritime Safety Committee and the Marine Environment Protection Committee are advised to keep the HSSC under review, and conduct amendments as necessary.

Extracted from s. 2.3.2.2 (IMO Harmonized System of Statutory Survey & Certification)

Reference to Schemes Developed by Classification Societies: Moving towards a harmonized way forward, IMO's Harmonized System of Survey and Certification (HSSC) has addressed important matters that have for a considerable period of time resulted in duplication of effort. Patently, the harmonization objective of the HSSC encapsulates the achievement of seamless procedural standards governing inspection and maintenance tasks through a set of uniform surveys that better address different Convention requirements.

About 100,000 commercial vessels of more than 100 tons constitute the so-called global maritime shipping industry, and to date, remains as the cornerstone of global trade and commerce (UNCTAD/RMT/2019/Corr.1, 2020). Data reveals that, the principal types of ships involved in commercial shipping consist of tankers, main bulks, minor bulks, containerized traders and residual general cargo ships (UNCTAD/RMT/2019/Corr.1, 2020). On the increase since 2000 are with the number of bulk trade shipments (an increase by more than half over the decade) (UNCTAD/RMT/2019/Corr.1, 2020). Dry bulk commodities today account for 40 percent of total dry cargo shipments as of 2018. This was confirmed by the European Maritime Safety Agency (EMSA) in its 2019 statistics report on the world fleet which further estimates that the total number of bulk carriers accounted for in 2018 stood at 11,929 with the highest gross tonnage of 457,648 out of the 116,857 merchant ships that trade internationally (Electronic Quality Shipping Information System, 2019). The total number of general cargo ships, and oil and chemical tankers for 2018 were estimated to be 16,250 with 59,206 gross tonnage and 13,757 with 345,545 gross tonnages respectively. Sizes of all major carriers of the world fleet vary from "small" to "very large" ships between the age range of 0 to +25 years (Electronic Quality Shipping Information System, 2019). It is important to note that approximately 9,734 large ships and 4,759 very large ships in operation are over the age of 5 years (Electronic Quality Shipping Information System, 2019). Maintaining structural integrity of ships as they age over time is indeed integral to the safety facet.

Considering the age of large and very large vessels in the current world fleet, harmonized statutory surveys (periodic survey, intermediate survey, annual survey, underwater inspection of ship's bottom and additional survey) are necessary for effective monitoring to ensure and enhance compliance with maritime safety and environmental regulations. It should be noted that these harmonized statutory surveys found in the HSSC, 2021 are accompanied by references to schemes developed by classification societies and are considered as the cutting edge of standards in the maritime world.

[3] This section has been used verbatim in the forthcoming publication: Johansson, T. (2021 in press) Advances in Robotics and Autonomous Systems for Hull Inspection and Maintenance (2022) in "Emerging Technology and the Law of the Sea" (James Kraska and Young-Kil Park, (eds.)), Cambridge University Press, © Cambridge University Press.

2.4 International Association of Classification Societies (IACS) & Common Minimum Standards

The role of classification societies (with reference to *recognised organisations*) is well noted in international law, for example, the International Convention for Safety of Life at Sea, 1974 (SOLAS 1974) and in the 1988 Protocol to the International Convention on Load Lines. Therefore, any attempt to narrow the role of classification society to just "survey assistance" is likely to undermine the positive and multifaceted influence of classification societies in maintaining the effectiveness of the world fleet's commercial vessels. *Classification* Rules developed by classification societies are of high importance with respect to design plans, construction, sea trials and other trials – all of which are key building blocks of the maritime environment and safety regime. In terms of class rules and requirements, IACS plays the leading role in so far as all stakeholders engaged in statutory and class-related processes adhere to the many requirements embodied in the Unified Requirements (UR). At the international level, IACS currently serves as the established principal technical advisor of the IMO, which forms a part of IACS's international engagement. At the outset, it is important to note that the *International Association of Classification Societies Information Paper* provides for a standard definition of a "classification society" - an organization which:

> "(i) Publishes its own classification Rules (including technical requirements) in relation to the design, construction and survey of ships, and has the capacity to (a) apply, (b) maintain and (c) update those Rules and Regulations with its own resources on a regular basis;
>
> (ii) verifies compliance with these Rules during construction and periodically during a classed ship's service life;
>
> (iii) publishes a register of classed ships;
>
> (iv) is not controlled by, and does not have interests in, ship-owners, shipbuilders or others engaged commercially in the manufacture, equipping, repair or operation of ships; and
>
> (v) is authorized by a Flag Administration as defined in SOLAS Chapter XI-1, Regulation 1 and listed accordingly in the IMO database, Global Integrated Shipping Information System (GISIS)" (IACS Information Paper).

As of today, IACS today is composed of eleven classification societies: Lloyds Register (LR), American Bureau of Shipping (ABS), Bureau Veritas (BV), China Classification Society (CCS), Croatian Register of Shipping (CRS), Det Norske Veritas-Germanischer Lloyd (DNV-GL) (*N.B.* DNV-GL will be DNV as of 1 March 2021), Korean Register (KR), Nippon Kaiji Kyokai (NK), Registro Italiano Navale (RINA), Polish Register of Shipping (PRS) and Indian Register of Shipping (IR Class). The IACS organizational structure is composed of:

> **IACS Council:** is the principal governing body and is composed of Chairman, Vice Chairman and a representative from each member society;
>
> **IACS General Policy Group:** is composed of management representatives from each member society. This group handles general policy matters, and five Panels, i.e., Hull Panel, Machinery Panel, Safety Panel, Environmental Panel and Survey Panel. The above five panels "are in charge of technical matters associated with the development and revision of Unified Requirements (UR) and Unified Interpretations (UI)". Each of the five panels have designated project teams containing a small number of members that address specific technical matters within a fixed period;
>
> **IACS Permanent Secretariat:** is composed of IACS Permanent Secretary and ten staff members that assist the Chairman in the conduct of daily activities, including communication with IMO, with a view to ensuring compliance of standards within the organizational setting; and
>
> **IACS Quality Committee:** manages the overall IACS quality system. This committee is composed of Small Groups (SG) containing a small number of members that have the responsibility to investigate and carry out specific tasks

> and report to Council or the General Policy Group, as well as Expert Groups (EG) composed of experts from each of the ten member societies. (Official homepage of Class NK).

From a BUGWRIGHT2 perspective, IACS-promulgated classification rules are important for a number of reasons. Rules collectively developed by IACS members class around 94% of commercial tonnage engaged in global maritime trade and therefore, important to assess structural strength of integral parts of ship's hulls and appendages, propulsion, steering systems, power generation and auxiliary systems built into the ship, with a view to maintaining essential services on board. Aptly known as "class requirements", IACS Unified Requirements (UR) provides a set of procedures covering class surveys.

2.4.1 Rational Behind Selection of Specific IACS Class Rules for Study

In order to determine the specific UR for further examination, the "use-case analysis" developed (by Consortium Members focusing on technical areas) at the initial stage of project BUGWRIGHT2 has been carefully observed. In other words, the tabular overview of the "use-case analysis" enables a clear understanding of which specific rules to target for further examination.

Table 2: BUGWRIGHT2 Use-case Analysis

	Use Case 1	**Use Case 2**	**Use Case 3**	**Use Case 4**
Ship Type	Bulk Carrier	Bulk Carrier	Bulk Carrier	Bulk Carrier
Ship Space	Underwater	Underwater	Berthed	Dry Docked
Operational Condition	Berthed	Anchorage	Berthed	Dry Docked
Inspection Type	Condition Survey	Class Survey	Damage Inspection	Class Survey
Robotic System	AUV	AUV	MAV, AUV and Crawler	MAV, Crawler

Based on the "inspection type" (see fifth row) outlined in Table 2, condition survey and damage inspection were the first categories that were explored. Research into "condition survey" revealed that they are a part of the non-periodic survey. Responses from respondents (interviewed in 2020) indicated that the "condition survey" protocol includes damage and repair survey, voyage repairs, conversion surveys and extraordinary surveys. Document analysis further indicated that condition surveys are a part of the Condition Assessment Scheme adopted by IMO in 2001 through MEPC Resolution 94(46). In retrospect, the Condition Assessment Scheme is aligned with the Annex B of the Enhanced Survey Programme adopted by IMO through Resolution A.744(18) as amended , and eventually replaced by the ESP Code (IMO, Resolution MEPC.94(46)). In addition, condition surveys may be conducted by Protection and Indemnity Clubs (P& Clubs). Insightful information on "condition survey" has also been gathered from the official homepage of GARD that states:

> P&I condition surveys are not intended to replace or compete with surveys performed by class societies, but they have, in a number of cases, proved to be a useful supplement. To a certain degree a P&I condition survey, like a port state inspection, may reveal weaknesses not only in the ship, but also in the surveys performed by class and flag states (Official homepage of GARD).

Subsequent research concentrated on use cases 2 and 4 with regards to "class survey". The key-headings, i.e., "ship type", "ship space", "operational condition", and "robotic system" as found in Table 2 played an instrumental role in narrowing down the types of UR documents that will be further examined from a three-part framework setting (see s. 2.5). The documents associated with the use-case analysis keywords have been limited to the following:

Key words (Columns 1-4): Bulk Carrier, Underwater, Berthed, Dry-docked, Class Survey

IACS UR Documents matching Keywords:

IACS Recommendation 76: Survey, Assessment and Repair of Hull Structure

IACS Unified Requirement (UR) Z3: Periodical Survey of the Outside of the Ship's Bottom and Related Items

IACS UR Z7: Hull Classification Survey

IACS UR Z10.2: Hull Surveys of Bulk Carriers

Key words (Column 5): AUV, MAV and Crawler

IACS UR Documents matching Keywords:

IACS Recommendation 42: Remote Inspection Techniques (RIT)

IACS UR Z17: Procedural Requirements for Service Suppliers

2.4.2 Setting the Theoretical Dimension for Examination of IACS Class Rules

Authors Markell and Glicksman (2016) proposes a three-part conceptual framework in a 2016 publication with a view to assisting "policymakers seeking to design regulatory structures likely to produce effective governance in dynamic circumstances" (Markell and Glicksman, 2016, p. 566). The three-part framework so proposed by the authors consists of; (1) "the **actors** who are or should be involved in different capacities in administering the governance regime"; (2) "the **mechanisms** (legal and otherwise) available to promote regulatory goals"; and (3) "the **tools** available to policymakers and other stakeholders to advance desired results" (Markell and Glicksman, 2016, p. 566). Markedly, the three-part proposition by the authors is viewed as instrumental in enabling policymakers to "structure and administer" regulatory programs when faced with institutional change or "dynamic change" (Markell and Glicksman, 2016, p. 565).

Attention to Markell and Glicksman's three-part framework for the examination of international standards developed by international organization, case-in-point, IACS, has been drawn for two explicit reasons. The first reason stems from the fact that is the standard rules developed by IACS, perceived as international standards, have been subject to numerous revisions and corrections in the past. In other words, the rules have been subject to "change" --- a constant "dynamic" that remains at the heart of the proposition by Markell and Glicksman. Considering the standard rules related to Hull cleaning, inspection and maintenance for Bulk Carriers, the following number of revisions/corrections have taken place in the development of IACS Unified Requirements (UR) as it exists today:

IACS UR Z3: Periodical Survey of the Outside of the Ship's Bottom and Related Items: 8 Revisions since 1996 and 1 Correction in 2002

IACS UR Z7: Hull Classification Surveys: 28 Revisions since 1990

IACS UR Z10.2: Hull Surveys of Bulk Carriers: 36 Revisions since 1994 and 1 Correction in 2006

IACS UR Z17: Procedural Requirements for Service Suppliers: 14 Revisions since 1999

The second reason for using the tripartite framework is one that relates to obtaining cohesive findings from conducting comparative analysis between IACS UR Z17 on *procedural requirements for service suppliers* and selected individual classification society rules covering the same subject matter. The three-part elements of the framework will serve as the three comparative stressors [Actors; Mechanisms and Tools] against which the individual classification society rules will be examined (in s. 2.5 of this report) with a view to highlighting the *unique additional provisions* (not covered by IACS) that require consideration to mitigate incidental issues.

2.4.3 Detailed Examination of IACS Class Rules through the Lens of Three-part Framework

This section contains the important take-aways from detailed examination of selected IACS class rules through the prism of the "actor-mechanism-tool" theoretical context. Note that analyses found in the following section is based on the "theoretical" three-part conceptual framework proposed by Authors Markell and Glicksman (2016). Utilizing the theoretical dimension has given the researchers a detailed understanding of the different complex layers coupled with the tasks and tools involved in both manual inspection and survey, inspection and survey using RIT. The results gathered serve as one of the important foundations for the regulatory blueprint. It is important to note that the following sections have been developing taking into account the provisions (verbatim) found in the various documents referred to in the headings.

2.4.3.1 IACS Recommendation 76: IACS Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers

As the title suggests, the *IACS Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers* intends to provide guidance to surveyors of IACS Member Societies and other interested parties involved in hull structure survey, assessment and repairs for Bulk Carriers (IACS Recommendation 76, 1994, p. 1). The *principal focus* of IACS Recommendation 76 is bulk carriers "constructed with a single deck, single skin, double bottom, hopper side tanks and topside tanks in cargo spaces, and is intended primarily to carry dry cargo, including ore, in bulk" (IACS Recommendation 76, 1994). IACS Recommendation 76 is divided into 5 segments covering class survey requirements, technical aspects, planning- preparation-execution and structural failures and repairs (IACS Recommendation 76). In short, the Manual is a body that not only touches upon class rules on survey preparation, but also provides detailed illustrations on "what to look for, possible cause, and recommended repair methods" in cases where there are structural deteriorations and damages (IACS Recommendation 76, 1994, p. 1).

2.4.3.1.1 IACS Recommendation 76: *Actors*

The *actors* that are explicitly involved in accordance with the different provisions at different stages (Preliminary-During Conduct of Task-After Completion of Task) IACS Recommendation 76 are identified in the following:

<u>Actors involved in the Preliminaries:</u>

S. 4.4.2 (Owner's General Obligation): The *owner* is primarily responsible for being aware of the scope of upcoming surveys. Under this obligation, the owner needs to instruct those that are responsible including

Master or the *Superintendent* to make the necessary arrangements. Should any doubt arise, the concerned *Classification Society* needs to be consulted;

S. 2.6.1 (Damage Survey): Damage Surveys are outside the scope of periodical surveys. The *owner or owner's representative* is under a duty to inform the classification society when "such damage or defect could impair the structural capability or watertight integrity of the hull";

S. 2.1.4 (Enhanced Survey Programme): Bulk carriers above 20,000 DWT belong to the Enhanced Survey Programme as of 1 July 2001. For those bulk carriers above 20,000 DWT, all special and intermediate hull classification surveys need to be carried out starting with the 3rd special survey and should be done by at least *two exclusive surveyors*. In addition, one exclusive surveyor should be on board for taking thickness measurements.

S. 4.4.1 (Surveyor's General Obligation): This section outlines the general obligation of *surveyor* with respect to comprehensive understanding of the ship's (to be surveyed) structural arrangements and survey history. The surveyor should prepare sketches of typical structural elements in advance with a view to record defects and/or ultrasonic thickness measurements rapidly and accurately;

S. 4.7.4 (Company's Involvement in Survey Planning Meeting): In cases where a *company is hired for thickness measurement*, then the company is under an obligation to be a part of the planning meeting; and

S. 4.2.1 (Survey Programme in Advance of Special Survey): Developed by the *Owner* in cooperation with Classification Society.

Actors Involved During Conduct of Task:

S. 2.3.3 (Thickness Measurement during Special Survey/Periodical Survey or Class Renewal Survey): Thickness measurements of hull structure in special surveys must be carried out in consultation with or agreement with *Classification Society*; and

S. 4.7.3 (Thickness measurement): This section opens up the opportunity for a certified and qualified *company* to conduct thickness measurement in lieu of class society. However, the section emphasizes on the importance of an on-board surveyor during thickness measurement, and the results need to be verified by the surveyor in charge.

Actors Involved after Completion of Task:

S. 2.6.1 (Damage Repairs): The duty of damage inspection and relevant repairs are to be performed by *Classification Society surveyors*. Classification Societies, upon inspection may defer permanent repairs to be made coinciding with planned periodic surveys.

2.4.3.1.2 IACS Recommendation 76: *Mechanisms (Intangibles)*

The *mechanisms* through which specific survey, assessment and repair related tasks are completed at different stages (**Preliminary**-**During Conduct of Task**-**After Completion of Task**) are amalgamated in the following:

Mechanisms at the Preliminary Stage:

S. 4.2.3, S. 4.3.1 and S. 4.3.4 (Planning Document): A *planning document* pursuant to s. 4.2.3 could augment the close-up survey and thickness measurement in the survey programme and should be developed in advance of the survey (s. 4.3.2). Such a planning document should be agreed with the relevant classification society. S. 4.3.1 section spells out the scope of a planning document: - Identify critical structural areas; - Stipulate the extent and locations for close-up survey and thickness measurements with respect to sections; and - Internal structures as well as nominated suspect areas. Finally, s. 4.3.4 containing information about particulars to be contained in the planning document: (a) Main particulars; (b) Main structural plans (scantling drawings), including information regarding use of high tensile steels; (c) Plan of tanks/holds; (d) List of tanks/holds with information on use, protection and condition of coating; (e) Conditions for survey (e.g. information regarding hold and tank cleaning, gas freeing, ventilation, lighting, etc.); (f) Provisions and methods for access; (g) Equipment for surveys; (h) Corrosion risk nomination of holds and tanks; (i) Design related damages on the particular ship, and similar vessels, where available; (j) Selected holds and tanks and areas for close-up survey; (k) Selected sections for thickness measurements; (l) Acceptable corrosion allowance; (m) Damage experience related to the ship in question.

Mechanisms during Conduct of Task:

S. 2.1.1 in conjunction with S. 2.4.1 (Periodic Surveys): *Periodic surveys* consist of special surveys or renewal surveys carried out at five-year intervals (Annual and intermediate surveys are carried out in between special surveys);

S. 2.2.1 (Annual Survey): The aim of *annual survey* is to confirm that the general condition of hull is maintained and remains at a satisfactory level;

S. 2.3.2 (Intermediate Survey): *Intermediate survey*, *inter alia*, entails re-examination of suspect areas as well as thickness measurements of suspect areas that have potentially corroded or are prone to rapid wastage;

S. 2.6.1 (Damage Survey and Repairs): *Damage surveys* fall outside the scope of periodic surveys. The ship owner is under an obligation to inform the concerned Classification Society should any such damage be observed that could compromise the structural integrity or watertight integrity of the hull.

S. 2.1.4 and S. 2.1.6 (Enhanced Survey Programme): Bulk carriers above 20,000 DWT belong to the *Enhanced Survey Programme* as of 1 July 2001. For those bulk carriers above 20,000 DWT, all special and intermediate hull classification surveys need to be carried out starting with the 3rd special survey and should be done by at least two exclusive surveyors. In addition, one exclusive surveyor should be on board for taking thickness measurements. S. 2.1.6 provides the principal criteria for ESP: 1. Coating: Poor condition referring to more than 20% breakdown of the coating or the formation of hard scale in 10 % more of the area; and 2. Structure Corrosion: A wastage between 75 % and 100 % of the allowable diminution for the structural member in question.

Mechanisms after Completion of Task:

S. 3.4.3 and S. 3.4.4: *Repair* in cases of structure deterioration and *temporary measures* in cases of Structure deterioration.

2.4.3.1.3 IACS Recommendation 76: Tools (Tangibles Excluding Technologies)

The *tools* used during survey, assessment and repair related tasks are completed at different stages (**Preliminary**-**During Conduct of Task**-**After Completion of Task**) are amalgamated in the following:

<u>Tools at the Preliminary Stage:</u>

S. 3.4.3 (Considerations for Repair in Cases of Structure Deterioration): *Doubler plates must not be used for the compensation of wasted plate*. *Repair work in tanks requires careful planning* in terms of accessibility;

S. 3.4.4 (Consideration for Temporary measures in Cases of Structure Deterioration): *Special consideration should be given to areas buckled under compression*. *A suitable condition of class should be imposed* when temporary measures are accepted.

<u>Tools during Conduct of Task:</u>

S. 2.4.2 (Close-up Examination in association with thickness measurement): Special surveys are composed of **close-up examinations** coupled with **thickness determination** for detecting fractures, buckling, substantial corrosion and other types of structural deterioration;

S. 2.3.2 (Intermediate Survey): Intermediate survey entails *re-examination of suspect areas* as well as *thickness measurements of suspect areas* that have potentially corroded or are prone to rapid wastage;

S. 2.1.4 (Enhanced Survey Programme): Bulk carriers above 20,000 DWT belong to the Enhanced Survey Programme as of 1 July 2001. For those bulk carriers above 20,000 DWT, all special and intermediate hull classification surveys need to be carried out starting with the 3rd special survey and should be done by at least two exclusive surveyors. In addition, one exclusive surveyor should be on board for *taking thickness measurements*; and

S. 4.7.1 (Thickness Measurement Compliance): This section stresses on compliance with Classification Society requirements with regards to *thickness measurement*. The measurements should adequately represent the nature and extent of any corrosion or wastage of the respective structure.

<u>Tools after Completion of Tasks (close-up and thickness measurement):</u>

S. 3.4.3 (Repair in Cases of Structure Deterioration): In cases where structure has deteriorated to the permissible minimum thickness, the *structure should be cropped and renewed instead of using doubler plates*; and

S. 3.4.4 (Temporary measures in Cases of Structure Deterioration): When postponing replacement of defective parts: *temporary measures* could be deployed including *sandblasting or painting* (in order to reduce corrosion), *applying doublers*; *applying stiffeners over affected areas*, and *applying cement box over affected areas*.

2.4.3.2 IACS UR Z3: Periodical Survey of the Outside of the Ship's Bottom and Related Items

Periodical Survey of the Outside of the Ship's Bottom and Related Items covered under IACS UR Z3 contains details on unified requirements pertaining to periodic survey conducted on outside of the ship's bottoms (IACS UR Z3, 1984, p. 1). IACS UR Z3 contains three segments with a special focus on in-water surveys in

Z3.3. At the outset, IACS UR Z3 establishes the important obligation, i.e., two examinations during every "five-year special survey (IACS UR Z3, 1984, s. Z3.1.2). One examination needs to be carried out in conjunction with special survey with an interval between the first and second survey not exceeding the time limit of 36 months (IACS UR Z3, 1984, s. Z3.1.2). Examination as such, should normally be carried out while the ship is dry-docked, with in-water survey as an alternative (IACS UR Z3, 1984, s. Z3.1.3). However, for ships (of 15 years and above) that fall under the ESP, examination should be carried out when the ship is in dry-docked condition (IACS UR Z3, 1984, s. Z3.1.3).

2.4.3.2.1 IACSUR Z3: *ACTORS*

The *actors* that are explicitly involved in accordance with the different provisions at different stages (Preliminary-During Conduct of Task-After Completion of Task) IACS Recommendation UR Z3 are identified in the following:

Actors involved in the Preliminaries:

S. 3.1.1 (Owner's general obligation before survey of ship's bottom): This section puts an obligation on the *owner to notify the Classification Society* when the ship's bottom can be examined in dry-dock or in a slipway; and

S. 3.3.3. (Discussions between ship owner and parties prior to In-water Survey): This section provides those adequate discussions be held *between ship owner and parties* with respect to equipment, procedure for observing and reporting. Adequate time should also be allowed to the company to test the equipment beforehand.

Actors Involved During Conduct of Task:

S. 3.3.3: *Ship owner and parties involved including company*

S. 3.3.4 (Surveillance by Surveyor during In-water Survey by Survey Firm Pursuant to IACS UR Z17): The In-water Survey is to be carried out under the surveillance of a *surveyor* by an *in-water survey firm* approved as a service supplier according to UR Z17.

Actors Involved after Completion of Task:

S. 3.3.5 (Satisfaction of Surveyor after in-water Survey): The *Surveyor is to be satisfied* with the method of pictorial representation, and a good two-way communication between the *Surveyor and divers* is to be provided.

2.4.3.2.2 IACS Z3: MECHANISMS (INTANGIBLES)

The *mechanisms* through which periodic survey of outside of the ship's bottom-related tasks are completed at different stages (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Mechanisms at the Preliminary Stage:

S. 3.3.1 (Operational Condition): This section provides that examination of the ship's bottom should normally be carried out in *dry-docked operational condition*. *Alternative operational conditions* are in-water survey when the *ship is afloat*; and *Ships >15 years* should be given special consideration before dry-docked or in-water surveys; and For *Enhanced Survey Programme for ships >15 years* all examinations should be conducted when ship is *dry-docked*;

S. 3.1.2 (Special Survey/Special Periodical Survey/ Class Renewal Survey): *Two surveys* in 5 years. The *first survey in conjunction with special survey*;

S. 3.3.1 (Information obtained from In-water Survey similar to dry-docking survey): The information obtained from *in-water survey* should be similar to the information (should it have been) gathered from survey conducted via dry-docking; and

S. 3.3.2 (Conditions for in-water survey): This section lays down the following rules for *in-water surveys*: 1. In-water Survey is to be carried out with the *ship in sheltered water and preferably with weak tidal streams and currents*.

2. *In-water visibility and the cleanliness* of the hull below the waterline is to be clear enough to permit a meaningful examination.

Mechanisms during Conduct of Task:

S. 3.2.2 to S. 3.2.6 (Examination when Ship is Dry-docked): Sections 3.2.2 to 3.2.6 deals with *examination* of specific areas including: - Excessive corrosion and deterioration in shell plating; Connection between the bilge strakes and the bilge keels; - Other elements that do not need immediate repair must be recorded; - Sea chests and their gratings; - Sea connections; - Overboard discharge valves; -Cocks and their fastenings to the hull or sea chests; - Visible parts of rudder; - Rudder pintles; - Rudder shafts; - Couplings; - Stern frame; - Visible parts of propeller; - Stern; - Visible parts of side thrusters; and Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units); and

S. 3.3.1 (In-water Survey): Special consideration should be given to: 1. *Ascertaining rudder bearing clearances*; 2. *Stern brush clearances of oil stern bearings based on review of operating history*; 3. *On board testing*; and 4. *Stern oil sample reports*.

Mechanisms after Completion of Task:

S. 3.3.6 (Dry-docking after Damage identified during in-water survey): If the in-water survey reveals damage and deterioration then the ship needs to be *dry-docked* for a more detailed survey and subsequently, actions should be taken to carry out repairs.

2.4.3.2.3 IACS UR Z3: Tools (Tangibles Excluding Technologies)

The *tools* used at different stages under IACS UR Z3 (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Tools at the Preliminary Stage:

S. 3.2.1 (Placement on Blocks for Dry-docked Survey): If the ship is in *dry-dock operational condition*, then the ship needs to be *placed on blocks of sufficient height* creating the necessary staging condition to allow examination; and the *necessary staging condition* should allow the examination of elements shell plating including bottom and bow plating, stern frame and rudder, sea chests and valves, propeller, etc.

Tools During Conduct of Task:

S. 3.2.1 (Placement on Blocks for Dry-docked Survey): The *necessary staging condition* should allow the *examination of elements shell plating including bottom and bow plating, stern frame and rudder, sea chests and valves, propeller, etc.*

Tools after Completion of Tasks:

S. 3.3.6 (Damage identified after in-water survey and Dry-docking for more detailed survey): If the in-water survey reveals damage and deterioration then *the ship needs to be dry-docked for a more detailed survey* and subsequently, actions should be taken *to carry out repairs*.

2.4.3.3 IACS UR Z7: Hull Classification Surveys

The requirements found in the document entitled *Hull Classification Surveys* pursuant to IACS UR Z7 applies to self-propelled vessels (IACS UR Z7, 1990). In short, IACS UR Z7 comprises five segments, four tables containing specific requirements and two Annexes containing specifics on recommended procedures (IACS UR Z7, 1990). Markedly, Z7 in its entirety applies to BUGWRIGHT2 and contains details concerning hull classification surveys spread across the 51-page document.

2.4.3.3.1 IACSUR Z7: *Actors*

The *actors* that are explicitly involved in accordance with the different provisions at different stages (Preliminary-During Conduct of Task-After Completion of Task) IACS Recommendation UR Z7 are identified in the following:

Actors involved in the Preliminaries:

S. 1.6.2 and S. 1.6.3 (Discussion among concerned parties involved in the RIT as an alternative to close-up survey; and approval of service suppliers in the witness of attending surveyors) [TAKE AWAY: REGULATORY BLUEPRINT]: Under s. 1.6.2, the equipment and procedure for observing and reporting the survey for gathering information generally obtained through close-up survey should be discussed among the *concerned parties* in advance of the RIT survey. Adequate time must be allowed to set-up, calibrate and test all equipment beforehand. In addition, s. 1.6.3 comes with a reference to *service suppliers and approval of firms* that conduct RIT-based close-up survey. If the *service supplier* receives approval to proceed, in which case the process needs to be done in the witness of the *attending surveyor* of the Society;

S. 5.1.1 (Owner's obligation): It is the obligation of the Owner to provide the necessary facilities for a safe execution of the survey;

S. 5.4.1 (Surveyor, Survey Party, Officer on Deck, Personnel in Charge of Ballast Pump Handling, Surveyors of Tanks and Personnel on board involved in Survey at Sea or Anchorage): Survey at sea or at anchorage under s. 5.4.1 may be accepted provided the *Surveyor* is given the necessary assistance from the *personnel onboard*. A communication system is to be arranged between the *survey party* in the tank or space and the responsible *officer on deck*. The above system must also include the *personnel in charge of ballast pump handling* if boats or rafts are used. Surveys of tanks by means of boats or rafts may only be undertaken at the sole discretion of the *Surveyor*.

Actors Involved During Conduct of Task:

S. 5.3.1 (Surveyor, Firm Approved by Society, Classification Society involved in thickness measurement): Thickness measurement to be carried out by means of ultrasonic test equipment whereby the accuracy of the equipment is to be proven to the *Surveyor* as required. Thickness measurements are to be carried out by a *firm approved* by the *society* in accordance with UR Z17 (except that in respect of measurements of non-ESP ships less than 500 gross tonnage and all fishing vessels, the firm need not be so approved); and

S. 5.2.1: Access to Structures Provided to *Surveyor* for examination of hull structure.

Actors Involved after Completion of Task:

S. 1.6.5 (Satisfying the Surveyor when Using RIT) [TAKE AWAY: REGULATORY BLUEPRINT]: The *Surveyor* is to be satisfied with the method of data presentation.

2.4.3.3.2 IACS Z7: Mechanisms (Intangibles Including Technologies)

The *mechanisms* through which hull classification survey-related tasks are completed at different stages (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Mechanisms at the Preliminary Stage:

S. 1.6.1 (Proposal for Usage of RIT as an Alternative to Close-up Survey): The use of RIT to obtain information generally gathered through a close-up survey must be included in the proposal and submitted in advance of the survey in order to develop satisfactory arrangements with the Classification Society;

S. 1.6.2 and S. 1.6.3 (Preconditions for using RIT as an alternative to close-up survey) [TAKE AWAY: REGULATORY BLUEPRINT]: Under s. 1.6.2, the equipment and procedure for observing and reporting the survey for gathering information generally obtained through close-up survey should be discussed in advance of the *RIT survey*. Adequate time must be allowed to set-up, calibrate and test all equipment beforehand. In addition, s. 1.6.3 comes with a reference to service suppliers and approval of firms that conduct *RIT-based close-up survey*. If the service supplier receives approval to proceed, in which case the process needs to be done in the witness of the attending surveyor of the Society;

Section 2.1.1 to Section 2.1.4: Specific schedules (similar to s. 2.4.1 of IACS Recommendation 76) in relation to *Special Survey/Special Periodical Survey/Class Renewal Survey*;

S. 2.1.5: *Survey Planning Meeting prior to Special Survey* (similar to s. 4.7.4 of IACS Recommendation 76)

S. 3.1: Specific schedule in relation to *Annual Survey*;

S. 4.1.1: Specific schedule in relation to *Intermediate Survey*;

S. 4.1.3: *Survey Planning Meeting prior to Intermediate Survey* (similar to s. 4.7.4 of IACS Recommendation 76)

Mechanisms During Conduct of Task:

S. 1.6.1 (Usage of RIT during Survey to Gather Information Similar to Close-up Survey in Annual, Intermediate or Special Surveys): The *use of RIT* to obtain information generally gathered through a close-up survey in *annual, intermediate or special surveys*;

S. 2.2.1 to S. 2.2.12 (Contents to be Examined During Special Survey (in Addition to Annual Survey): The *special survey* should include (in addition to the requirements of annual survey) the following: Checks of sufficient extent to ensure that the hull; Equipment and related piping, as required in 2.2.12, are in satisfactory condition and fit for the intended purpose for the new period of class of five years to be assigned, thickness measurements and testing during hull examination in accordance with S. 2.2.11 and 2.2.12. The underwater parts to be examined: Excessive corrosion and deterioration in shell plating; Connection between the bilge strakes and the bilge keels; Other elements that do not need immediate repair must be recorded; Sea chests and their gratings; Sea connections; Overboard discharge valves; Cocks and their fastenings to the hull or sea chests; Visible parts of rudder; Rudder pintles; Rudder shafts; Couplings; Stern frame; Visible parts of propeller; Stern; Visible parts of side thrusters; and Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units);

S. 3.2.3 to S. 3.2.5 (Contents to be Examined During Annual Survey): Examination of weather decks, ship side plating above water line, hatch covers and coamings during *Annual Survey*. Where mechanically operated steel covers are fitted, it is important to check the satisfactory conditions of a number of elements. The same applies to cases where portable covers, wooden or steel pontoons are fitted in relation to other elements (s. 3.2.3.2). In addition, there needs to be an examination of the weld connection between air pipes and deck plating (2. 3.2.3.5); external examination of air pipe heads installed on exposed decks (s. 3.2.3.6); examination of flame screens on vents to all bunker tanks (s. 3.2.3.7); examination of ventilators, including closing devices (s. 3.2.3.8); suspect areas in the previous survey need to be examined followed by thickness measurement of substantial corrosion (s. 3.2.4); and examination of ballast tanks when required as a consequence of the result of Special Survey and Intermediate Survey (s. 3.2.5.1); and

S. 4.2.1 to S. 4.2.6 (Contents to be Examined During Intermediate Survey): This section lays down the following important points that need to be considered during Intermediate Survey:

Ships between 5 and 10 years: A general internal examination of representative ballast tanks needs to be carried out. Should there be no hard protective coating, soft or semi-coating or poor coating, then the examination needs to be extended to other ballast tanks of same type;

For ships over 10 years: A general internal examination of ballast tanks needs to be carried out;

If no visible structural defects: Corrosion prevention system is effective.

Ballast tanks excluding double bottom ballast tanks: If there is no hard protective coating, soft or semi-coating or poor coating, and is not renewed, then then the tanks need to be internally examined at annual intervals. Double bottom ballast tanks: If there is no hard protective coating, soft or semi-coating or poor coating, and is not renewed, then then the tanks need to be internally examined at annual intervals.

<u>**Mechanisms after Completion of Task:**</u>

S. 2.1.6 (No concurrent crediting): This section stipulates that survey and thickness measurements to both Intermediate Survey and Special Survey *cannot be concurrently credited* and must be credited separately;

S. 4.1.4 (No concurrent crediting): Similar to s. 2.1.6 (above);

S. 1.6.6 (Traditional Survey Following RIT Close-up Surveys if Damage Detected): If the RIT survey reveals damage or deterioration, then the Surveyor may call for a traditional survey to be undertaken without the usage of RIT.

2.4.3.3.3 IACS UR Z7: Tools (Tangibles Including Technologies)

The *tools* prescribed for usage during different stages under IACS UR Z7 (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Tools at the Preliminary Stage:

S. 5.1.2 and S. 5.1.3 (Safe Access and Cleanliness as a Pre-condition to survey and thickness measurement): S. 5.1.2 emphasizes that tanks and spaces are to remain *safe for access* whereby s. 5.1.3 puts emphasis on *cleanliness* for survey and thickness measurements and requires spaces to be cleaned including removal of corrosion scale that are loosely accumulated;

S. 5.1.4 (Sufficient illumination as a Pre-condition to survey and thickness measurement): This section emphasizes on *sufficient illumination* to allow detection of corrosion, deformation, fractures, damages or other structural deterioration;

S. 5.1.5 (Safe access as a Pre-condition to assess and verify effectiveness of coating and conditions of internal structures: *Safe access* needs to be provided to the surveyor to verify coating and carry out *assessments* which might require spot *removal* in cases where soft or semi-hard coatings have been applied.

S. 5.1.6 (Items to-be removed for examination of plating and framing): For plating and framing examinations, the surveyor may require the *removal of casings, ceiling, linings and loose insulations*;

S. 5.2.1 and S. 5.2.2 (Different Means for Access to Structures (to Surveyor for Examination of Hull Structure): *Permanent staging and passages* through structures; *temporary staging and passages* through structures; *hydraulic arm vehicles* such as conventional cherry pickers, *lifts and movable platforms; boats or rafts*; and other equivalent means.

S. 5.2.3 (Access to Types of RIT (Subject to Acceptance by Surveyor) for Examination of Hull Structure) [TAKE AWAY: REGULATORY BLUEPRINT]: - *Unmanned robot arm; Remotely Operated Vehicles (ROV); Unmanned Aerial Vehicles / Drones; Other means* acceptable to the Classification Society.

Tools During Conduct of Task:

S. 1.4.1 (Thickness Measurement and Close-up Surveys for Wastage Above Permissible Limits and Structural Defects or Corrosion): During annual survey, intermediate survey or special survey, *thickness measurements and close-up surveys* of the following areas shall be done in tandem: side shell frames, their end attachments and adjacent shell plating; deck structure and deck plating; bottom structure and bottom plating; watertight or oil-tight bulkheads; hatch covers and hatch coamings; Examination of the weld connection between air pipes and deck plating; External examination of all air pipe heads installed on the exposed decks; and Examination of ventilators, including closing devices, if any;

S. 1.4.2: *Using RIT as an Alternative to Close-up surveys* for Wastage Above Permissible Limits and Structural Defects or Corrosion. In this process, temporary means of access for corresponding thickness measurement must be provided unless the RIT is able to carry out the required measurements;

S. 1.6.1 (Criteria Regarding Information Gathered from RIT: Similar to Close-up Survey Information): *Information from RIT* should be those that are obtained from a close-up survey and must be done in accordance with IACS Recommendation 42;

S. 1.6.5 (Two-way Communication when using RIT): There needs to be a two-way communication between Surveyor and RIT Operator and the Surveyor;

S. 3.2 (Examination during Annual Survey): Annual survey comprises an *examination* to ensure that the hull, hatch covers, hatch coamings, closing appliances, equipment and related piping are maintained in a satisfactory condition;

S. 5.1.7 (Examination of condition of coating behind insulation in refrigerated cargo spaces): Condition of coating behind the insulation needs to be *examined* in refrigerated cargo spaces. The e*xamination* could be limited to verifying that the protective coating is still effective and that there are no structural defects. If the coating is in poor condition, then the *examination* may be extended;

S. 5.3.1 (Equipment for Thickness measurement): This section provides emphasis on *ultrasonic testing equipment thickness measurement* and states that the accuracy of the equipment needs to be proven to the surveyor as required;

S. 5.3.2 (Fracture Detection Procedures and Equipment): This section outlines the four types of equipment for fracture detection in *fracture detection procedures*: radiographic equipment; ultrasonic equipment; magnetic particle equipment; and dye penetrant;

S. 5.4.2 and S. 5.4.3 (Communication System During Survey at Sea or Anchorage): A *communication system* is to be arranged between the survey party in the tank or space and the responsible officer on deck. The above system must also include the personnel in charge of ballast pump handling if boats or rafts are used;

Tools after Completion of Tasks:

S. 1.3.2 (Remedial Measures if Vessel Fitness is Compromised Due to Structural Defects or Corrosion): This section prescribes the need for *remedial actions* before vessel is allowed into operation should survey results indicate that vessel fitness has been compromised;

S. 1.3.1 (Damage Repair (Due to Wastage Over Allowable Limits) of Areas Post Survey): If areas observed indicate damage in association with wastage require *immediate repair*. These are areas according to this section include: side shell frames, their end attachments and adjacent shell plating; deck structure and deck plating; bottom structure and bottom plating; watertight or oil-tight bulkheads; hatch covers and hatch coamings; Examination of the weld connection between air pipes and deck plating; External examination of all air pipe heads installed on the exposed decks; and Examination of ventilators, including closing devices, if any.

S. 1.3.2 (Temporary Measures for Structures Isolated and Localized in Nature Due to Damage Caused by Wastage Over Allowable Limits): If the following structures are isolated and localized in nature which does not affect the structural integrity, then *temporary measures* may be taken: side shell frames, their end attachments and adjacent shell plating; deck structure and deck plating; bottom structure and bottom plating; watertight or oil tight bulkheads; hatch covers and hatch coamings; Examination of the weld connection between air pipes and deck plating; External examination of all air pipe heads installed on the exposed decks; and Examination of ventilators, including closing devices, if any.

2.4.3.4 IACS UR Z10.2: Hull Surveys of Bulk Carriers

IACS document titled *Hull Surveys of Bulk Carriers* under UR Z10.2 covers, in details, survey procedural standards in relation to bulk carriers, which touch upon the subject matter of BUGWRIGHT2 (Hull Surveys of Bulk Carriers, IACS URZ 10.2, 1992). The procedures are categorized into nine individual thematic strands including a separate and distinct segment on procedures for thickness measurement.

2.4.3.4.1 IACS UR Z10.2: *Actors*

The *actors* that are explicitly involved in accordance with the different provisions at different stages (Preliminary-During Conduct of Task-After Completion of Task) IACS UR Z10.2 are identified in the following:

Actors involved in the Preliminaries

S. 5.1.1 (Survey Programme Developed by Owner in Cooperation with Classification Society): This section emphasizes on the obligation for *owners* to cooperate with the *Classification Society* prior to any part of Special Survey and Intermediary Survey for bulk carriers above 10 years of age;

S. 5.1.4 (Classification Society Advising Owner of Maximum Acceptable Structural Corrosion Diminution Level): The *Classification Society* will advise the *Owner* of the maximum acceptable structural corrosion diminution levels applicable to the vessel;

S. 5.2.1 and S. 5.2.1.1: *Owner's General Obligation* to Provide Necessary Facilities for Survey upon Agreement with Classification Society;

S. 5.2.3 to S. 5.2.5: Cleanliness, safe access and sufficient illumination ensured by the *owner* for effective survey and thickness measurement by the *surveyor*;

S. 5.6.1: Survey at Sea or Anchorage if Accepted by Surveyor;

S. 5.4.1: Surveyor, Survey Party, Officer on Deck, Personnel in Charge of Ballast Pump Handling involved in Survey at Sea or Anchorage; and

S. 5.7.2: Survey Planning Meeting prior to commencement of any part of the renewal and intermediate survey is to be held among the attending *surveyor(s)*, *the owner's representative* in attendance, the *thickness measurement firm representative*, where involved, and the *master of the ship* or an appropriately qualified representative appointed by the master or Company.

Actors Involved During Conduct of Task:

S. 7.2.1 (Thickness Measurement by Qualified Firm Certified by Classification Society): This section stresses on the requirement that thickness measurements need to be carried out by a *qualified firm* that is certified by *Classification Society*; and

S. 7.1.1: *Society* and *Surveyor's Duties* During *Thickness Measurement Process*;

Actors Involved after Completion of Task:

S. 1.3.2: *Surveyor's opinion after obtaining survey results* in relation to *structural defects or corrosion.*

2.4.3.4.2 IACS UR Z10.2: *Mechanisms (Intangibles)*

The *mechanisms* through which periodic survey of outside of the ship's bottom-related tasks are completed at different stages (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Mechanisms at the Preliminary Stage:

S. 2.1.1 to S. 2.1.5 and S. 2.2.1.1 (Special Survey Schedule and Scope): The *Special Survey* schedule and scope is similar to IACS UR Z7 (see s. 2 for schedule and s. 2.2.1 for scope of Special Survey);

S. 3.3.1 and S. 3.2.1.1 (Annual Survey Schedule and Scope): The *Annual Survey* schedule and scope is similar to IACS UR Z7 (see s. 3.1 for scope of Special Survey);

S. 4.1.1 to S. 4.1.3 (Intermediate Survey Schedule and Scope): The *Intermediate Survey* schedule and scope is similar to IACS UR Z7 (see s. 4.1 for scope of Special Survey);

S. 5.1.3 (Survey Programme Needs to be Complacent with UR Z10.2 (Tables I, II and Paragraph 2.5) Requirements): The submitted *Survey Programme* is to *account for and comply*, as a minimum, with the requirements of Tables I, II and paragraph 2.5 for close-up survey, thickness measurement and tank testing, respectively, and is to include relevant information including at least: Basic ship information and particulars, - Main structural plans (scantling drawings), including information regarding use of high tensile steels (HTS); Plan of holds and tanks; List of holds and tanks with information on use, protection and condition of coating; Conditions for survey (e.g., information regarding hold and tank cleaning, gas freeing, ventilation, lighting, etc.); Provisions and methods for access to structures; Equipment for surveys; Nomination of holds and tanks and areas for close-up survey (per 2.3); Nominations of sections for thickness measurement (per 2.4); Nomination of tanks for tank testing (per 2.5); and Damage experience related to the ship in question; and

S. 5.1.5 (Reference to Technical Assessment in Conjunction with Planning for Enhanced Surveys of Bulk Carriers Special Survey – Hull (contained in Annex I) in the Planning of the Survey Programme): Considerations may be given to the *Guidelines for Technical Assessment* in Conjunction with *Planning for Enhanced Surveys of Bulk Carriers Special Survey - Hull, contained in Annex I*, which under UR Z10.2 are considered as "recommended tools", which may be invoked at the discretion of the Classification Society, when considered necessary and appropriate, in conjunction with the preparation of the required Survey Programme.

Mechanisms During Conduct of Task:

S. 7.3.2 (Number of Measurements (thickness measurement during annual, intermediate or special survey)): With reference to Table 1 and Figures 4-9 of IACS UR Z10.2 on the *locations of the points to be measured* are given for the most important items of the structure *considering the extent of thickness* *measurements* according to the different structural elements of the ship and *special, intermediate and annual surveys*; and

S. 7.3.3 (Locations of Measurements (thickness measurement during annual, intermediate or special survey)): With reference to Table 1 that covers *systematic thickness measurements* related to the calculation of global hull girder strength and specific measurements connected to close-up surveys during *annual, intermediate or special surveys*; and

Mechanisms after Completion of Task:

S. 1.3.1 to S. 1.3.3: Damage measures from survey and examination during *annual, intermediate or special survey.*

2.4.3.4.3 IACS UR Z10.2: Tools (Tangibles Excluding)

The *tools* used at different stages under IACS UR Z10.2 (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Tools at the Preliminary Stage:

S. 5.1.2 (List of Documents to be Collected for Selecting Tanks, holds, Areas and Structural Elements under the Survey Programme): The following *documentation is to be collected and consulted* with a view to selecting tanks, holds, areas, and structural elements to be examined: Survey status and basic ship information Documentation on-board; Main structural plans (scantlings drawings), including information regarding use of high tensile steels (HTS); Relevant previous survey and inspection reports from both Classification Society and the Owner; Information regarding the use of the ship's holds and tanks, typical cargoes and other relevant data; Information regarding corrosion prevention level on the newbuilding; and Information regarding the relevant maintenance level during operation;

S. 5.2.1.2: Details of means of access during survey is to be provided in the *Survey Questionnaire*;

S. 5.2.2: Cargo holds, tanks and spaces need to be to be *safe for access*, and *Cargo holds, tanks* and to be *gas free and properly ventilated*;

S. 5.2.3 (Cleanliness as a Condition to Survey and thickness measurement): In the preparatory phase (preliminary stage) for survey and thickness measurements and to allow for a thorough examination, *all spaces are to be cleaned* including removal from surfaces of all loose accumulated corrosion scale. In other words, spaces need to be sufficiently clean and free from water, scale, dirt, oil residues etc. to reveal corrosion, deformation, fractures, damages, or other structural deterioration as well as the condition of the coating.

S. 5.2.4: *Sufficient illumination* is to be provided with a view to revealing corrosion, deformation, fractures, damages or other structural deterioration as well as the condition of the coating;

S. 5.2.5: Providing *safe access* is important for surveyors to verify "the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating";

S. 5.3.1 (Means to-be Provided to Access Hull Structures for Close-up Surveys): The following means are to be provided for *close-up surveys on hull structures*: permanent staging and passages through structures;

temporary staging and passages through structures; hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms; portable ladders; boats or rafts; and other equivalent means;

S. 5.3.2 (Means to-be Provided to Access Hull Structures Other Than Cargo Holds for Close-up Surveys): The following means are to be provided for *close-up surveys on hull structures other than cargo holds*: permanent staging and passages through structures; temporary staging and passages through structures; hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms; portable ladders; boats or rafts; and other equivalent means;

S. 5.3.3 (Means to-be Provided to Access Cargo hold Shell Frames of Bulk Carriers <100,000 dwt for Close-up Surveys): The following means are to be provided to *access cargo hold shell frames of bulk carriers <100,000 dwt* for *close-up surveys*: permanent staging and passages through structures; temporary staging and passages through structures; portable ladder restricted to not more than 5 m in length may be accepted for surveys of lower section of a shell frame including bracket; hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms; boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water; and other equivalent means; and

S. 5.3.3 (Means to-be Provided to Access Cargo hold Shell Frames of Bulk Carriers >100,000 dwt for Close-up Surveys): *Use of portable ladders is not accepted*.

<u>**Tools During Conduct of Task:**</u>

S. 1.4: *Thickness Measurement* to-be Conducted *in Conjunction with Close-up Surveys* in any kind of surveys: special, intermediate or annual;

S. 2.5.1 to S. 2.5.6: These sections emphasize on *pressure testing* of all boundaries of *water ballast tanks, deep tanks and cargo holds* used for water ballast within the cargo length area;

S. 2.6.1 and S. 2.6.2: Sections 2.6.1 and 2.6.2 provide additional requirements to the *special survey requirements for bulk carriers* that need to be adhered to *after determining compliance with SOLAS XII/12 AND XII/13*;

S. 3.2.3: Sub-sections 3.2.3.1 to 3.2.3.10 describes in detail regarding *examination of weather decks, hatch covers and coamings during Annual Survey*;

S. 3.2.4.1 and S. 3.2.4.2: The two sub-sections spell out procedures for *examination of cargo holds for bulk carriers that are 10 to 15 years of age and* bulk carriers that are over *15 years of age during Annual Survey*;

S. 3.2.5: This section spells out procedures for *examination of cargo holds for bulk carriers* that are *10 to 15 years of age and bulk carriers* that are *over 15 years of age* during *Annual Survey*;

S. 3.3: Sub-sections 3.3.1 and 3.3.2 provide *additional requirements* for *Annual Surveys* on *cargo holds* of ships that are *subject to SOLAS XII/9.1* and additional requirements *after determining compliance with SOLAS XII/12 and XII/13*;

S. 4.2.2: The many sub-sections under s. 4.2.2 comprises of sub-sections for *intermediate survey* with a focus on *survey, examination and thickness measurements* of ballast tanks and cargo hold in bulk carriers of 5-10 years of age, bulk carriers that are 10-15 years of age and bulk carriers above 15 years of age;

S. 5.4.1 to S. 5.4.3 (Equipment for Thickness Measurement and Fracture Detection Procedures): The accuracy of the *ultrasonic test equipment* for thickness measurement needs to be proved by surveyor. *Four equipment for fracture detection procedures*: radiographic equipment; ultrasonic equipment; magnetic particle equipment; and dye penetrant – may be required by the surveyor. Finally, equipment, such as, explosimeter, oxygen-meter, breathing apparatus, lifelines, riding belts with rope and hook and whistles together with *instructions and guidance* on their use are to be made available during the survey;

S. 5.6.2 (Communication System During Survey at Sea or Anchorage): A *communication system* is to be arranged between the survey party in the spaces and the responsible officer on deck;

S. 5.6.4: Usage of Rafts and Boats for Close-up Surveys Observing a Number of Conditions; and

S. 2.4.1 to S. 2.4.5 (Extent of Thickness Measurement): This section provides provisions on the extent of thickness measurement with reference to Annexes 3 and 5 as well as Table VIII of UR Z10.2;

Tools after Completion of Tasks:

S. 1.3.1 (Damage Repairs after any survey): Damage repair options include: bottom structure and bottom plating; side structure and side plating; deck structure and deck plating; inner bottom structure and inner bottom plating; inner side structure and inner side plating; watertight or oil-tight bulkheads; hatch covers or hatch coamings; and items in 3.2.3.10 (Examination of bunker and vent piping systems, including ventilators); and

S. 1.3.3 (Temporary Repairs in Accordance with IACS PR 35 on Structures that are Isolated and Localized in Nature): Appropriate temporary repair to restore watertight or weather tight integrity and impose a condition of class in accordance with IACS PR 35.

2.4.4 Detailed Examination of IACS Class Rules on RIT Through the Lens of Three-part Framework

This section of the report examines two IACS documents that contain explicit reference to Remote Inspection Technologies. The two documents include IACS Recommendation 42: *Guidelines for Use of Remote Inspection Techniques for Surveys* and IACS UR Z17: *Procedural Requirements for Service Suppliers*.

2.4.4.1 IACS Recommendation No. 42: Guidelines for Use of RIT in Surveys

Guidelines for Use of Remote Inspection Techniques for Surveys, referred to as IACS Recommendation 42 stipulates guidance for the usage of remote techniques for class surveys in relation to:

- periodical survey of the outside of the ship's bottom and related items;
- hull classification survey, hull surveys for general dry cargo ships;
- hull surveys for Liquefied Gas Carriers;
- hull surveys of oil tankers, hull surveys of bulk carriers;
- hull surveys of chemical tankers;
- hull surveys of double hull oil tankers,
- hull surveys of double skin bulk carriers, periodical surveys of Cargo Installations on ships carrying liquefied gases in bulks;
- survey of machinery;

- surveys of propeller shafts and tube shafts;
- hull survey for new construction; and
- periodic survey of fuel installations on ships other than Liquefied Gas Carriers utilizing gas or other low flash point fuels (IACS Recommendation 42, 1996).

IACS Recommendation 42 is composed of three distinct segments titled *General*, *Conditions* and *Procedures*. The *General* part is further divided into three sections with 1.1 covering five techniques that are considered as Remote Inspection Techniques (RIT). These include: Divers, Unmanned Robot Arm, ROV, Climbers, and Drones (IACS Recommendation 42, 2016, s. 1.1). Within the same section the Guidelines has also included "other means acceptable to the society" and by doing so, embraced flexibility to include other types of innovations that may serve as a technique in remote inspections (IACS Recommendation 42, 1996, s. 1.1).

Section 1.2 of IACS Recommendation 42 provides that the types of technologies outlined in s 1.1 subject to approval "may be used to facilitate the required external and internal examinations, including close-up surveys and gauging" (IACS Recommendation 42, 2016, s. 1.2). In doing so, the methods applied in the process of remote inspection should be done in the presence of the surveyor using approved technology should "provide the survey results normally obtained for/by the Surveyor", and results so obtained "when being used towards the crediting of surveys are to be acceptable to the attending Surveyor" (IACS Recommendation 42, 1996, s. 1.2).

S. 1.3 provides an additional duty on surveyors to conduct "confirmatory surveys/close-up surveys at selected locations to verify the results of the remote inspection technique" (IACS Recommendation 42, 2016, s. 1.2). Thickness measurements from confirmatory surveys/close-up surveys may be requested as deemed appropriate by the attending surveyor (IACS Recommendation 42, 2016, s. 1.2). All plans corresponding to the inspection via RIT including confirmatory survey/close-up survey/thickness measurements need to be submitted "for review and acceptance in advance of the survey" (IACS Recommendation 42, 1996, s. 1.3).

S. 2.1 limits the usage of RIT in cases where:

- There is a record or indication of abnormal deterioration or damage to structure or to items to be inspected;
- There are recommendations for repairs;
- There are conditions found during the course of the inspection whereby such conditions affect the class of the vessel; and
- The remote inspection technique reveals damage or deterioration that requires attention. In such cases the Surveyor may require close-up survey/thickness measurements without the use of remote inspection technique to be undertaken (IACS Recommendation 42, 1996, s. 2.1).

Finally, part 3 of IACS Recommendation 42 details procedures with respect to the conduct of inspection of items or structures using RIT. This part starts with the stipulation that inspection needs to be carried out by a qualified technician (IACS Recommendation 42, 1996, s. 3.1). Prior to the inspection, a pre-meeting should take place among the qualified technician, ship owner representatives and the attending surveyor(s) confirming that all arrangements outlined in the "the inspection plan are in place, so as to ensure the safe and efficient conduct of the inspection work to be carried out" (IACS Recommendation 42, 1996, s. 3.1). The items selected for inspection using RIT need to be sufficiently cleaned before to "permit meaningful examination" and "visibility" (IACS Recommendation 42, 1996, s. 3.3 and s. 3.4). Other operations, i.e., means of thickness gauging and non-destructive testings could be used in tandem with RIT (IACS Recommendation 42, 1996, s. 3.2).

2.4.4.1.1 IACS Recommendation 42: *Actors*

The *actors* that are explicitly involved in accordance with the different provisions at different stages (Preliminary-During Conduct of Task-After Completion of Task) of IACS Recommendation 42 are identified in the following:

Actors involved in the Preliminaries

S. 3.1 (Qualified Technician): This section does not provide specific conditions that render a "technician" as a "qualified technician";

S. 3.1 (Pre-meeting among Technician, Ship owner Representatives and Surveyors): A meeting among *technician, ship owner representatives* and *surveyors* is a precondition to commencing the inspection process.

Actors Involved During Conduct of Task:

S. 1.2 (Surveys Must be Conducted in the Presence of a Surveyor): All inspections must be carried out in the presence of the surveyor;

Actors Involved after Completion of Task:

S. 1.2: Acceptance of Results from RIT by Surveyor

2.4.4.1.2 IACS Recommendation 42: *Mechanisms*

The *mechanisms* through which periodic survey of outside of the ship's bottom-related tasks are completed at different stages (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Mechanisms Involved During Conduct of Task:

S. 1.2 (Methods of RIT to Obtain Same Results for Surveyor): The methods applied for remote inspection technique are to provide the survey results normally obtained for/by the Surveyor;

2.4.4.1.3 IACS Recommendation 42: *Tools*

The *tools* used at different stages under IACS Recommendation 42 (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Tools involved in the Preliminaries:

S. 1.3 (Review of Inspection Plan): An inspection plan via RIT needs to be developed and submitted for *acceptance and review* prior to the inspection;

Tools Involved During Conduct of Task:

S. 2.1 (Restrictions in RIT Usage): Restriction in RIT usage if there is a record or indication of abnormal deterioration or damage to items or structure under inspection, and if there are existing recommendations for repair;

S. 1.2 (Close-up Surveys and Gauging): This section provides the scope of using RIT: *internal and external examinations/inspections*;

S 3.3 (Cleanliness of All Items Selected for Inspection): To conduct a meaningful examination using RIT under Recommendation 42 means that all items selected for inspection needs to be *sufficiently clean*;

S. 3.4 (Visibility of All Items Selected for Inspection): Sufficient visibility of the items or structures is important. Visibility is important to determine the condition of items and structures. However, this section does not provide any guidance on what constitutes sufficient visibility and what conditions the RIT needs to satisfy to render the visibility through the camera lens of RIT as sufficient; and

S. 3.2: Thickness Gauging and NDT in Tandem with RIT Inspections

Tools Involved after Completion of Task:

S. 1.2: Limiting Usage of RIT for Close-up and Thickness Measurements in Case of Damage or Deterioration

S. 1.3 (Confirmatory/Close-up Surveys to Verify Results of RIT): The surveyor has the option to carry out confirmatory surveys/close up surveys to verify results gathered from RIT. The attending surveyor may request confirmatory thickness measurement as deemed fit to verify the results gathered from RIT.

2.4.4.2 IACS UR Z 17: Procedural Requirements for Service Suppliers

Procedural Requirements for Service Suppliers published in 1997 comprises procedures to be followed when engaging the services of a supplier that is not directly employed by IACS (IACS UR Z17, 1997, p. 2). IACS UR Z17 is divided into nine segments whereby provisions related to in-water survey on ships by ROV can be found in the section 3 of Annex I. Subsequently, section 16 of Annex I covers the procedural requirements aimed at firms engaged in survey using RIT as an alternative to close-up survey of ships structural elements (and mobile offshore units). In short, section 3 and 16 of Annex denotes I the permissible limits of RAS usage in the context of Bulk Carrier survey and inspection. The two specific where RAS could be applied includes:

- In-water survey on ships using ROV; and

- Surveys using RIT only as an alternative to on close-up surveys (IACS UR Z17, 1997, Sections 3 and 16 of Annex I).

2.4.4.2.1 IACS UR Z17: Examining the General Scope

Before dealing with sections 3 and 16 of IACS UR Z17, it is important to observe the general facets that govern the procedural requirements. This has been done maintaining the tripartite textual setting used in the previous sections.

2.4.4.2.1.1 IACS UR Z17: *Actors*

The *actors* that are explicitly involved in accordance with the different provisions at different stages (Preliminary-During Conduct of Task-After Completion of Task) IACS Recommendation 17 are identified in the following:

Actors involved:

S. 3 (Manufacturers, Service Providers, Agent, Subsidiary, Subcontractor): Section 3 provides definition of the specific entities governed by IACS UR Z17.

2.4.4.2.1.2 IACS Recommendation 17: *Mechanisms*

Mechanisms Involved during Preliminaries:

S. 4: Approval is required for all ships (*Statutory Services* and *Classification Services*) except non-ESP ships <500 Gross tonnage (GT) and all Fishing vessels;

2.4.4.2.1.3 IACS Recommendation 17: *Tools*

The *tools* used at different stages under IACS Recommendation 17 (Preliminary-During Conduct of Task-After Completion of Task) are amalgamated in the following:

Tools involved in the Preliminaries:

S. 4.1.3 (Verification and Accountability of Work Done by Third Party): This section highlights that upon acceptance of work of a third party, the Society is under an obligation to *verify all services*. The entire process shall be governed by the Society's quality management system and the work of the third party shall be treated as the work of the Society and shall be governed by *RO Code IMO MSC.349 (92) and MEPC.237(65)*;

S. 4.2 (Approval of Service Provider by the Concerned Society): If the work of third party or service suppliers are used by a Surveyor from the Society in taking decisions then the third party or service supplier must be *approved and verified* by the Society. These services include in-water surveys on ships using ROV and close-up surveys using RIT;

S. 4.3 (Approval of Service Provider by the Concerned Society where the Society is Authorized by Flag Administration): *Approval of service provider* by Society prescribed in section 4.2 is contingent on approval/authorization by flag Administration, authorized organizations acting on behalf of flag Administration or other organizations acceptable to flag Administration;

S. 5.1 (Procedures for Approval and Certification): This section contains a *list of documents* that needs to be submitted by Service Provider to the concerned Society

S. 5.2.1 to S. 5.2.10 (General Requirements for Suppliers): Training of Personnel (s. 5.2.2); Supervision (s. 5.2.3); Personnel Records (s. 5.2.4); Equipment and facilities (s.5.2.5); Control of Data (s. 5.2.6); Servicing Stations (s. 5.2.7); Documented Work Procedure (s. 5.2.8); Information of Agreements and Arrangements to-be Provided by Supplier if any Parts of Services are Subcontracted (s., 5.2.9); Verification of Service Providers by Supplier (s. 5.2.10);

S. 5.3 (Auditing the Supplier): Upon submission and *review of documents* with satisfactory results, the Supplier or Service Provider will be audited by the Society;

S. 5.4 (Conditions for Certification): Obtaining a certification is conditional on *demonstration of performance* in relation to the specific service as well as completion of satisfactory reporting;

S. 5.5.1: Supplier to Demonstrate Documented System Pertaining to Quality Management in accordance with ISO 9000 Series;

S. 5.5.3: *Application by Manufacturers'* Endorsing Agents or Subsidiaries;

S. 5.6.1: *Service Suppliers Relations with the Equipment Manufacturer*;

S. 6.1 (Conditions for Issuance of Certificate of Approval to Supplier and Content of Certificate): For *obtaining a certificate of approval* by the Society, the supplier needs to complete both audit and demonstration tests in a satisfactory manner. The certificate of approval issued by the Society is evidence that the results of services performed in accordance with that system may be accepted and utilized by the Society's Surveyors in making decisions affecting classification or statutory certification. The certificate will state the type and scope of services as well as equipment limitations. After completion of audit and testing, the Supplier may be included in the Society's records of approved Service Suppliers;

S. 8.1 to S. 8.4 (Cancellation of Approval): Section 8.1 to S. 8.4 contains the specific grounds due to which the Society reserves the right to *cancel approval* granted to Service Suppliers.

Tools Involved During Conduct of Task:

S. 5.2.11 (Reporting by Suppliers): *Reporting by Supplier* in Format Acceptable to Society (s. 5.2.11)

Tools Involved after Completion of Task:

S. 5.2.12 (Documented Procedures and Instructions on Recordings by Suppliers): Documented Procedures and instructions to-be available for the *Recording of Damages and Defects* found during inspection (s. 5.2.12).

2.4.4.2.2 IACS UR Z17: *Section 3 of Annex I*

Annex 3 of IACS UR Z17 contains procedural requirements for *Firms carrying out an in-water survey on ships and mobile offshore units by diver or ROV*.

2.4.4.2.2.1 (IACS UR Z17) Section 3: Actors

The *actors* that are explicitly involved in accordance with the different provisions at different stages of Annex 3 of IACS UR Z17 are identified in the following:

Actors involved in the Preliminaries

S. 3.1: Training of Personnel (divers, ROV operators and supervisors) by supplier;

S. 3.4.1 Diving supervisor must be qualified in accordance with supplier's general requirements and shall have a minimum of two years' experience as a diver carrying out inspection;

S. 3.4.2: ROV supervisor shall have a minimum of two (2) years of experience of conducting inspections using ROVs;

S 3.5.1: The diver conducting shall have had at least one year's experience as an assistant diver carrying out inspections (including minimum 10 participation in different assignments); and

S. 3.5.2: ROV operators shall have at least one year of experience with conducting inspections using ROVs.

Actors Involved after Completion of Task:

S. 3.8: Supplier to obtain verification from surveyor for each separate job followed by the surveyor's signature.

2.4.4.2.2.2 (IACS UR Z17) Section 3: Mechanisms

The *mechanisms* stipulated under Annex 3 of IACS UR Z17 are identified in the following:

Mechanisms Involved During Conduct of Task:

S. 3.1: In-water survey in lieu of a docking survey and/or the internal hull survey of compartments filled with water; and

S. 3.7.1 to S. 3.7.2: Suppliers should have documented operational procedures and guidelines including "guidance for the operation of the ROV, if applicable"; as well as "methods and equipment to ensure the ROV operator can determine the ROV's location and orientation in relation to the vessel";

2.4.4.2.2.3 (IACS UR Z17) Section 3: Tools

The different *tools* recommended in Annex 3 of IACS UR Z17 are identified in the following:

Tools involved in the Preliminaries:

S. 3.3: A plan (developed by supplier) for training of personnel.

Tools Involved after Completion of Task:

S. 3.8: Verification is an important tool that confirms approval by surveyor for each job completed.

2.4.4.2.3 IACS UR Z17: *Section 16*

Annex 16 of IACS UR Z17 contains procedural requirements for *Firms engaged in survey using Remote Inspection Techniques (RIT) as an alternative means for Close-up Survey of the structure of ships and mobile offshore units*.

2.4.4.2.3.1 (IACS UR Z17) Section 16: Actors

The *actors* that are explicitly involved in accordance with the different provisions at different stages of Annex 16 of IACS UR Z17 are identified in the following:

Actors involved in the Preliminaries:

S. 16.3: The supplier will assume responsibility for the training and qualification of its operators operating RIT. UAV Pilots should be qualified and licensed under applicable national requirements or an equivalent industrial standard acceptable to the society;

S. 16.5: The supervisor must be certified according to the recognized national requirements or an equivalent industrial standard coupled with a minimum of two years' experience in the inspection of ship's and/or MOU's structure;

S. 16.6: The operator must be certified according to the recognized national requirements or an equivalent industrial standard coupled with a minimum of one years' experience in the inspection of ship's and/or MOU's structure;

Actors Involved after Completion of Task:

S. 16.10: Supplier to obtain verification from surveyor for each separate job followed by the surveyor's signature.

2.4.4.2.2.2 (IACS UR Z17) Section 16: Mechanisms

The *mechanisms* stipulated under Annex 16 of IACS UR Z17 are identified in the following:

Mechanisms involved in the Preliminaries:

S. 16.4: Training Plan for Personnel

Mechanisms Involved During Conduct of Task:

S. 16.2: Close-up Survey of ships' structure and mobile offshore units' structure by deploying RIT;

2.4.4.2.2.3 (IACS UR Z17) Section 16: Tools

The different *tools* recommended in Annex 16 of IACS UR Z17 are identified in the following:

Tools involved in the Preliminaries:

S. 16.4: A plan (developed by supplier) for training of personnel;

S. 16.8: The supplier shall ensure the following operational procedures and guidelines well document:

- Requirements for preparation of inspection plans when UAV are part of the equipment flight plans shall be included;
- Operation of the remotely operated platforms;
- Operation of lighting;
- Calibration of the data collection equipment;
- Operation of the data collection equipment;
- Two-way communication between the operator, platform, Surveyor, other personnel such as support staff and ships officers and crew;
- Guidance of the operator to provide complete coverage of the structure to be inspected;

- Guidance for the maintenance of the remotely operated platforms, data capture and storage devices and display screens, as applicable;

- Requirements for the collection and validation of data;

- If data is to be stored, then requirements for location attribution (geo-tagging);

- validation and storage of data; and

- Requirements for the reporting of inspections, including the recording of damages and defects found during inspection and repair work.

S. 16.9: The supplier is under an obligation to maintain the following:

- Records of training;

- Operator statutory and regulatory certificates and licenses;

- Equipment register for UAVs, Robots, data collection devices, data analysis devices and any associated equipment necessary to perform inspections;

- Equipment maintenance manuals and records / logbook;

- Records of calibration; and

- UAV / Robot operation logbook.

Tools Involved During Conduct of Task:

S. 16.7: High-definition display screen with live high-definition feed from inspection cameras as an integral part of the RIT**.**

Tools Involved after Completion of Task:

S. 16.10: Verification is an important tool that confirms approval by surveyor for each job completed.

2.4.5 Take-Aways from Detailed Examination of IACS Class Rules[4]

Extracted from s. 2.4.3 (Detailed Examination of IACS Class Rules through the Lens of Three-part Framework)

A System Governed by the Concept of "Human-in-the-loop"

IACS is the key international body that comes into play in all discussions related to RIT international rules and requirements. Serving in the capacity as an RO on behalf of maritime administrations, IACS is composed of eleven members that set international classification standards covering "90% of the world's cargo-carrying ship tonnage". Taken together, IACS rules and requirements apply to both *statutory* (subject to the flag States agreement) and *classification surveys* --- the successful completion of which results in the issuance of statutory and classification certificates, respectively. Suffice to note that, the same statutory survey and certification procedures that were attached to a plethora of IMO instruments are now harmonized through IMO's Harmonized System of Survey and Certification (HSSC) with the objective of

[4] This section has been used verbatim in the forthcoming publication: Johansson, T., Skinner, J., Dalaklis, D., Klenum, T. and Pastra, A. (2022) "Harmonizing the Maritime Service Robotics Techno-regulatory Regime: Six Blocks of Influence for Good Environmental Stewardship", European Union Law Forum Publication; and Pastra, A.; Schauffel, N.; Ellwart, T. and Johansson, T., (in press: September 2022: Autumn 14.2 volume) "Building a Trust Ecosystem for Remote Technologies in Ship Hull Inspections", *Journal of Law, Innovation and Technology*, Vol. 14 (2), (Taylor & Francis) ©Taylor & Francis.

standardizing survey procedures and timelines. Within the harmonized texts, HSSC provides direct reference to classification society standards to strengthen uniformity that would enhance MS compliance with good environmental status.

Significantly, IACS advocates for the integration of RIT platforms under specified conditions. Those conditions are detailed in Recommendation 42. At the outset, Recommendation 42 stipulates that unmanned robot arm, ROV climbers, drones and other acceptable means may be deployed to "facilitate the required external and internal examinations, including close-up surveys and gauging" subject to approval and consultation among RIT technician, the owner's representative and the attending surveyor. Restrictions on RIT platform usage are also in place in the likelihood where severe damages and deterioration are observed in structures, in which case manual close-up surveys and thickness measurements may be initiated.

IACS UR Z17 titled Procedural Requirements for Service Suppliers embodies a theoretical extension of Recommendation 42. Composed of RIT-led standards, UR Z17 is aimed at firms providing *statutory survey* (where flag States reserve the right to conduct their own assessment and approval of service suppliers for statutory surveys) and *classification survey*. It is in this document there are detailed procedural as well as special requirements to be followed for the use of; ROVs to carry out in-water survey on ships and mobile offshore units by ROVs (s. 3), as well as RITs as an alternative means for Close-up Survey of the structure of ships and mobile offshore units (s. 4) (see Table, below).

Noticeably, while Recommendation 42 notes ROV as a division of RIT, ROV has nevertheless received specific attention through the formulation of a separate section under UR Z17. If this placement is guided by the rationale that ROVs operate underwater or on water surfaces, which is different than navigating RITs on air or on steel hulls then perhaps the methodology as well as external disruption factors (strong water current, ice-infestation during winter etc.) should have been highlighted and further explained for safety reasons. Moreover, the deployment of ROVs by service providers in in-water cleaning operations invoke the question whether s. 3 of IACS UR Z17 should enshrine a caveat within the texts referring to precautionary measures when removing heavy metal and coating flakes from vessels' hull (for environmental benefits). Turning to s. 16 which covers requirements, specifically, only when RITs serve as an alternative means for close-up surveys, it is noteworthy that s. 16.1 has adopted two terms: Unmanned Aerial Vehicles (UAV); and Drones --- under two distinct bullet-points. But what are the differences between the two, if any? Several other questions also remain unanswered, leaving the task of building beyond minimum standards to individual classification society members.

Analyses from the three-part framework (Actors-Mechanisms-Tools) denote the current system as being governed by human-in-the-loop. Although refinements are progressing in an expeditious manner, moving to a strict human-out-of-the-loop system in a movable asset containing valuable shipments requires more than just an effective and efficient machine-learning based technical infrastructure. A constructive balance between "human agency" and "autonomous modes" is required as it could very well enhance the level of trust in autonomous vessels. This balance is a pre-requisite given that shipping is by and large a hierarchical permission-based mobile system comprised of interested parties, e.g., charterers, shippers, consignees and container suppliers, and central actors, i.e., ship owner and master.

The pursuit of vessel autonomy has also called attention to multifarious smart-systems that could potentially improve vessels' safety and environmental performance and reduce human-based errors. RITs, distinguished from vessels, comprise an integral part of the sector for reducing carbon emissions and fulfilling IMO's targets to reduce emissions by 50% by 2050 compared to 2008 emissions. As of recent, manufacturers are focused on deploying semi-autonomous RITs for hull cleaning and enclosed-space inspection. Such deployment is likely to enhance surveyor's and owner's employee's safety and reduce the carbon footprint associated with a reduction in fuel consumption.

RITs are based on what is perceived as a human–autonomy teaming where two parties (i.e., human and autonomous digital agents) work interdependently towards a common goal. During a remote inspection process, the expectation is that the operator (of the robotic technology) and the semi-autonomous system will actively cooperate to perform the survey of the vessel. As such, this interdependency invokes the need for a well-calibrated level of trust and avoidance of mistrust and over-trust in RITs. It is submitted that the above requirements serve as a foundation for effective and efficient interaction between humans and robots and a critical prognosticator of technology acceptance and use.

2.5 Cross-comparative Examination Among Selected IACS Member Societies' Procedural Requirements

A cross comparative examination has been conducted with a view to extracting unique provisions related to procedural requirements developed by selected member societies. A total of nine member societies, i.e., Lloyds Register (LR), Bureau Veritas (BV), Det Norske Veritas – Germanischer Lloyd (DNV as of 31 March 2021), Registro Italiano Navale (RINA), American Bureau of Shipping (ABS), Russian Maritime Register of Shipping, China Classification Society (CCS), Korean Register (KR), Nippon Kaiji Kyokai (NK) were targeted for the proposed cross comparative examination. This target is based on regional coverage in so far as Lloyd's register, Bureau Veritas, DNV and Registro Italiano Navale covers the European Union landscape; ABS represents the American developments and the Russian Maritime Register of Shipping covers development on the Russian front, and CCS, KR and NK covers the Asian part of the world. In order to flesh out the unique provisions, the following method has been observed:

Stage 1: Developing a pert diagram composed of three segments, namely, Preliminaries, During Inspection and Post-Inspection was developed with (click here to access Pert Diagram)

Stage 2A: Selection of documents for comparisons developed by selected member societies containing procedural requirements;

Stage 2B: Determining types of documents based on similarity with IACS UR Z17:

LR – (1) Procedures for Approval of Service Suppliers, 2020 [LR 2020]; and (2) Guidance Notes for Inspection Using Unmanned Aircraft Systems, 2016 [LR 2016];

BV – Approval of Service Suppliers, 2020 [BV 2020];

DNV – Approval of Service Supplier Scheme, 2021 [DNV 2021];

RINA – Rules for the Certification of Service Suppliers, 2020 [RINA 2020];

NK - Rules for Approval of Manufacturers and Service Suppliers, 2020 (Part 1 Chapter 1) [NK 2020];

CCS – (1) Guidelines for Ship Remote Surveys, 2019 [CCS 2019]; and (2) Guidelines for Use of Unmanned Aerial Vehicles, 2018 [CCS 2018];

ABS - Guidance Notes on the Use of Remote Inspection, 2019 [ABS 2019]; and

RS – Main Document: Annexes to the Guidelines on Technical Supervision of Ships in Service, 2019. **Selected Annexes (of Main Document): (**1) ROV Requirements: Annex I (Procedure for In-water Survey of Ships and Offshore Installations) of Guidelines on Technical Supervision of Ships in Service [RS 2019, Annex I]; and RIT Requirements: Annex 39 (Guidelines for the Use of Remote Inspection Techniques for a Survey of Ships and Marine Structures) [RS 2019, Annex 39]

Stage 3: Determining the title of all sections and sub-sections and creating an overarching title that resonates with the texts of the provision so examined;

Stage 4: Amalgamating the titles created under **Stage 3** and comparing the texts found under those titles with texts under similar titles of IACS UR Z17;

Stage 5: Observing the similarities between procedures developed by IACS UR Z17 and procedures developed by selected member societies. The similar traits between the above, in short, is summarized in the following:

A. Preliminaries:

1. **Verification and Approval:** Society shall verify and approve service beforehand. The process shall be defined within the society's quality management system;

2. **Documents** submitted by Service Provider: must include documented system complying with ISO 9000;

3. In addition, **General Requirements** to be followed to demonstrate competence to Society: includes how data will be controlled, personnel records, equipment, documented procedures and verification that services are carried out in accordance with procedures;

4. After **reviewing documents** and observing competence based on general requirements, the supplier is audited;

5. **Certification** after practical demonstration;

6. **Cancellation of Certificate** if service was improperly carried out or alterations made to the quality system, misrepresentation, deficiencies in the operating system; Supplier has the right to apply for re-approval (following 1-4);

B. Procedures:

7. Procedures for Firms carrying out an in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV);

8. Procedures for Firms Engaged in Survey using Remote Inspection Techniques (RIT) as an Alternative Means for Close-up Survey of the Structure of Ships and Mobile Offshore Units;

C. Reporting:

9. **Reporting:** shall be prepared in a form acceptable to the Society. Report should detail the results of inspections, measurements, tests, maintenance and or repairs carried out.

Stage 6: Examining member society (developed) provisions (texts) under titles that are non-existent in IACS UR Z17 (considered as unique additions by member societies); and

Stage 7: Findings from "stage 6" have been compiled into a table allowing tabular overview (see table 3).

2.5.1 Take-aways from Cross-comparative Examination

The following table provides a synoptic overview of unique provisions developed by selected IACS member societies that steps beyond the ambit of IACS UR Z17:

Table 3: Tabular overview of Unique/Additional Provisions Developed by Member Societies' After Comparison with IACS UR Z17 Provisions

Established Definitions (RIT, UAV, Crawlers and ROVs)				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 1 General (RIV and RIT) S. 1.1. UAVs S. 1.3 ROVs S. 1.5 Robotic Crawler	Imports new term not found in IACS UR Z17. Provides excellent clarity on the different terms.	Definitions provide a solid foundation for understanding the various RITs that could be deployed for survey.
Operational Limitations of UAVs, Crawlers and ROVs				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 4.3 Operational Limitations	Imports new requirements not found IACS UR Z17.	Imports much-needed understanding of operational limitations of RITs not found in IACS UR Z17.
Remote Inspection Vehicle Operational Conditions				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 4.7.1 Pre-operations S. 4.7.3 In-operations S. 4.7.5 Post-operation	Imports new requirements not found IACS UR Z17. It is important to note that while IACS UR Z17 contains requirements for every stage of remote survey; ABS, 2019 is observed as having carved out explicit	Sections 4.7.1, 4.7.2 and 4.7.3 includes: 1. Items to-be discussed during the short briefing session, such as reviewing weather forecast, confirmation of enclosed space free of sediments (for ROVs), reviewing RIV maintenance records, reviewing emergency escape/evacuation plan, reviewing identified risks and associated mitigation, verifying the responsibilities of all personnel, assessing field conditions and amending operation plans as deemed fit, and confirming the work-scope of intended RIV operation, and as a part of job safety analysis on the date of the field operations, but prior to the; commencement of the RIV operations; 2. Items to be included, e.g., checklist clearance, RIV Launch and Recovery Zones, Communication, Documentation, Visual

			requirements for each and individual steps.	Line of Sight for UAVs, Deconfliction for UAVs, in the Standard operation Procedure by the Service Provider; and 3. Post-operation considerations including logging and maintenance.
Survey/Inspection Planning				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 4.5 Survey/Inspection Planning	Imports new requirements not found IACS UR Z17.	Sections 4.5.1, 4.5.2 and 4.5.3 goes into greater details on planning the scope of survey, risk assessment and developing operations plan. Risk assessments include explosion risks in hazardous areas, dropped object risk, collision risk, and lost link risks.
Alterations to the Certified System Affection Quality System				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
LR	LR, 2020	S. 1.6.3 Alterations to the Certified Approved Service Supplier System	IACS UR Z17.	LR imposes those alterations must be informed to LR **in writing** (no communication means indicated in IACS UR Z17)
ABS	ABS, 2019	S. 9 Management of Change (MoC)	Imports new term not found in IACS UR Z17.	This section highlights the importance of implementing a MoC system to evaluate the potential impacts of a proposed change so as not to introduce hazards or increased risk of existing hazards.
Certification of Multi-site Organizations				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
LR	LR, 2020	S. 1.8.1 Introduction S. 1.8.2 Application S. 1.8.3 Site Sampling Procedure 1.8.4 Selection of sites 1.8.5 Multi-site Certification	Imports new requirements not found in IACS UR Z17.	Additional requirements concerning the certification of independent and large multi-site organizations.
Approval Database				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
LR	LR, 2020	S. 1.9 LR Approvals of Database	Imports new requirements not found in IACS UR Z17.	This section contains provision on approval and subsequent incorporation of the information of Service Supplier in the base that will be accessible by clients and LR colleagues.

Safety Management System				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 3 (7) Safety Management System S. 3 (7.1) Safety Policy S. 3 (7.3) Safety Risk Management S. 3 (7.5) Safety Assurance S. 3 (7.7) Safety Promotion	Imports new requirements not found in IACS UR Z17.	This section provides important provisions on safety management system, including safety policy, safety assurance, risk management system and promotion of safety.
Liability				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
LR	LR, 2020	S. 3 (13) Liability	Imports new requirement not found in IACS UR Z17.	This section stresses on the importance of maintaining third-party liability insurance in case of accidents or incidents.
Recognized External Specialist Program				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 15 ABS Recognized External Specialist Program	Imports new requirement not found in IACS UR Z17.	This section indicates that the ABS External Specialist Program already contains a list of Service Providers that perform on behalf of equipment, manufacturer, shipyard, asset owner or other clients in respect of classification/statutory surveys.
Reporting and Data Storage				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
DNV	DNV, 2021	**In-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV)** S. 3.1 Reporting (Appendix A) **Firms Engaged in Survey using RIT as an alternative means for close-up survey of the structure of ships and mobile offshore units**	Imports detailed requirement not found in IACS UR Z17.	Important to note that provisions on “data storage” stipulates that all files containing data should be named according to the structure so surveyed, and should be stored by the service supplier and readily available at request from DNV for 5 years.

		S. 16.1.4 Reporting and data storage (Appendix A)		
RIV Post-operation Data Review and Data Processing				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 4.9 Data Review S. 4.11 Data Post-Processing	Imports detailed requirement not found in IACS UR Z17.	S. 4.9 projects issues that may affect image quality including, poor image resolution, image focus, occluded camera lens, inadequate lighting, instable RIV, dark or shadowy areas, lost connectivity, glare from strong lights or sum etc. In addition to the recommendation that video footage, live streaming and recorded data should be uninterrupted, there are other stipulations found in s. 4.9, e.g., recorded data is to be made available to surveyor both on-site and off-site (within a specified period). In terms of data processing, ABS recommends advances image processing techniques for performing anomaly measurement; Artificial Intelligence for pattern recognition, cracks, fractures or corrosion; data analytics for anomaly trending and prediction; and 3D Model generation for data integration and recording.
Verification, Modification and Reissuance of Documents and Information Using Remote Survey				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
CCS	CCS, 2019	S. 2.1 General S. 2.2 Principal Requirements S. 2.3 Survey Process S. 2.4 Required Electronic Documentation	Imports detailed requirement not found in IACS UR Z17.	This section provides important provisions on documents and information using remote survey.
Survey Procedures				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
CCS	CCS, 2019	S. 1.6 Survey Procedures	Important and detailed specifics on remote survey not found in IACS UR Z17	Important concepts are introduced under the many sub-sections of 1.6 including Client Service System (CSM), livestreaming during remote survey and real-time collection of survey process information, solutions in case of problem with livestreaming, recording of process and conclusion in the ship log and conditions for certification.

Collection and Delivery of Survey Process Information				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
CCS	CCS, 2019	S. 1.5 Collection and Delivery of Survey Process Information	Important and detailed specifics on remote survey.	For remote surveys, CCS remains flexible in so far as tablet computers, intelligent remote glasses and digital cameras are permissible. When using those options, information and data could be livestreamed using livestreaming mobile application for which ships will need to be connected to the satellite. In this process, the applicant also needs to consider "restrictive requirements of the company SMS or the port of call to electronic equipment or internet, e.g., anti-explosion requirements for use of electronic equipment in the spaces where survey is intended to be carried out".
RIV Post-operation Reporting				
Classification Society	**Reference**	**Section and Title**	**Similar to**	**Observations/Remarks**
ABS	ABS, 2019	S. 4.13 Reporting	Imports post-operation requirements not found in IACS UR Z17.	Post-reporting, pursuant to s. 4.13 needs to be "factual and objective". The report should ideally include: general particulars of the asset, survey information "including survey type and cycle number, locations of the structure or space that was surveyed, and inspection results (satisfactory, further inspection required, or repair required"; detailed information on service provider; External Specialist Certificate number; RIV operation team members' name and the name of the RIV model used; details of operation including launch time, operation period and recovery time; digital data; and certified report endorsed by technician, owner and surveyor.

Legal Framework for Inspection Using Unmanned Aircraft		
Classification Society	**Reference**	**Section and Title**
LR	LR, 2016	S. 2 Definitions (Drone, Inspection Data End-user, UAS, UAV); S. 3 Considerations for Use of Unmanned Aircraft System (Cost, Inspection Data Requirements, Repeatability of Inspection Process, Safety with Working at Heights, Safety with Collisions and Drops, Safety with Hazardous Areas, Ship or Asset Environment Conditions, Skills Required for Flight Teams); S. 4 Organizational Recommendations for Unmanned Aircraft System (Regulations, Quality Standards (ISO 9001), Impartiality and independence, Safety Management System (SMS), Insurance, Policies and Procedures, Checklists) S. 5 Personnel (Operations Training, Minimum Training Requirements, Maintenance Training, Records)

		S. 6 Hardware and Software (Unmanned Aircraft System Selection, Unmanned Aircraft System Registry, Battery Handling, Alterations and Customizations, Original Equipment Manufacturer Technical and Safety Bulletins) S. 7 Operation of Unmanned Aircraft Systems (Site Permission and Flight Planning, Work Permits, Risk Assessment, Checklists, Pre-Flight Briefing, Commencement of Flight Operations, In-flight Operations (Flight Team Size, Take-off and Landing Zones, Communications, Visual Line of Sight), Post-Flight Operations (Flight Logbooks, Accident and Near-Miss Reporting) S. 8 *Inspection Data* (Photography and Videography Data Acceptability, Other Data Acceptability, Data Security)
Unmanned Aerial Vehicles for Survey		
Classification Society	**Reference**	**Section and Title**
CCS	CCS, 2018	S. 1.3 Definitions (UAV, Pilot, CCS, Applicant) S. 1.4 Application and Responsibilities (Application, Responsibilities, Responsibilities of the Applicant, Responsibilities of the Organization Performing UAV Inspection, Responsibilities of CCS) S. 2 Technical Standards for UAV's and Qualification of the Organization Performing IAV Inspection (General Requirements, Flight Control, Technical Standards for UAVs (Safety Performance, Operation Performance, Endurance Capacity, *Data Transmission and Communication*, *Data Storage,* Requirements for airborne Lighting, Requirements for Airborne Camera); Qualification Requirements for the Organization Performing UAV Inspection (Organizations Performing Inspection, Requirements for Pilots) S. 3 *Data and Information* (*Data Collection*, *Data Processing*, *Data Security*) S. 4 Application in Site Survey of Ships (General Requirements, Survey Conditions, Survey Plan, Risk Assessment, Survey Operations (Pilot, Pre-flight Preparation, Control of the Survey Process), *Survey Data*, Survey Report Annex I (3) Regulations on Air Space Restrictions

2.6 Certificates for Vessels and Service Suppliers

Upon successful completion of a statutory survey, a number of Certificates are issued by the flag State Administrations or their ROs nominated surveyors, subject to inspection by port State control officers. A list of the certificates that should be maintained onboard a bulk dry carrier can be found in table 4.

Table 4: Certificates for Dry Bulk Carriers

a/a	**Description**	**Intervals**
1.	Certificate of Registry	Permanent
2.	Classification Certificate	Annually/5-year
3.	Document of Compliance (Copy)	
4.	Safety Management Certificate	Inter/diate/5-year
5.	Vessels Compliance (ISO)	Inter/diate/5-year

6.	International Ship's Security Certificate	Inter/diate/5-year
7.	Safe Manning	Permanent
8.	International Tonnage Certificate	Permanent
9.	International Load Line Certificate	Annually/5-year
10.	Suez Canal Certificate	Permanent
11.	Panama Canal Certificate	Permanent
12.	Cargo Ship Safety Construction Certificate	Annually/5-year
13.	MARPOL	Annually/5-year
	i. International oil pollution prevention certificate	Annually/5-year
	- Record of construction and equipment for prevention of oil pollution (supplement to the Int'I oil pollution prevention certificate form A)	Permanent
	- Calibration Certificate for Oil Content Meter (Manufacturer)	5-year
	ii. International air pollution prevention certificate	Annually/5-year
	- Record of construction and equipment for prevention of air pollution (supplement to the Int'I air pollution prevention certificate)	Permanent
	iii. International sewage pollution prevention certificate	Annually/5-year
14.	Cargo Ship Safety Radio Certificate	Annually/5-year
	i. Record of equipment for the cargo ship safety Radio (Form R)	5-year
	ii. Ship radio station license	Flag
	iii. Record of approved GMDSS radio installation	Annually
	iv. Declaration of shore-based maintenance	Annually
	v. Annual EPIRB/AIS/SSAS/LRIT Test	Annually/5-year
15.	Cargo Ship Safety Equipment Certificate	Annually/5-year
	i. Record of equipment for the cargo ship safety equipment certificate (Form E)	5-year
	ii. Record of approved cargo ship safety equipment	Permanent
	iii. Exemption certificates (if applicable)	
	iv. Annual Performance Test VDR	Annually
	v. Life raft certificates	Annually
	vi. Portable fire extinguishers/ Breathing apparatus	Annually
	vii. Permanent fire-fighting (CO_2) system level check certificate	2-year
	viii. Portable fire extinguishers/ Oxygen bottles hydro test	10-year/5-year
	ix. Permanent fire-fighting (CO_2) system cylinders hydro test	10-year
	x. Immersion suits pressure test	3-year

	xi. Annual lifeboat davits test	Annually
	xii. Lifeboat & launching appliances overload test	5-year
	xiii. Accommodation ladders overload test	5-year
16.	Lifting Appliances	
	i. Certificate of test and thorough examination of lifting appliances	5-year
	ii. Certificate of annual thorough examination of lifting appliances	Annually
17.	Rapid Response Damage Assessment (RRDA)	Permanent
18.	Statement of compliance for carriage cargo in bulk	Annually/5-year
19.	Document of authorization for carriage of grain	Permanent
20.	Loading Instrumental approval	Permanent
21.	Statement of compliance for Antifouling System	Permanent
22.	Certificate of inspection ship's medical locker	Annually
23.	Derating certificate	Annually
24.	Hazardous materials certificate of registry	
25.	Gyro compass last inspection	
26.	Magnetic compass calibration	Annually

Source: Atlantic Bulk Carriers Management Ltd.

The most relevant Certificates under BUGWRIGHT2 are: Cargo Ship Safety Construction Certificate, Anti-fouling System Certificate, Classification Certificate, International Load Line Certificate and Diving System Safety Certificate (table 5). Provisions for the Cargo Ship Safety Construction Certificate exist in SOLAS, 1974 and 1988 SOLAS Protocol, regulation I/12 as well as in the *Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers* (IACS, 1994). The Certificate, which is valid for five years, ensures that the structure, machinery and equipment (e.g., structure, boilers, main and auxiliary machinery) are in accordance with chapters II-1 and II-2 of the Convention.

Based on AFS Convention of 2001, ships with a gross tonnage of 400 or above should obtain and retain an International Anti-fouling System Certificate after fulfilling the relevant survey requirements of the Convention. For the Classification Certificate, *UR Z7 Hull classification surveys* (IACS, 2019) ensure that a vessel is built and surveyed according to the standards laid down by the society issuing it. The International Load Line Certificate denotes that the ship complies with Article 14 of the Load Line Convention, ensuring that the freeboards are assigned and load lines are appropriately marked. The Diving System Safety Certificate is another document to be retained onboard a vessel upon proof of compliance with the requirements of the Diving-Code 1995 that sets standards for design, construction and survey of diving systems fitted onboard vessels.

Certificates related to service providers are the Certificate of Approval for Firms Engaged in Thickness Measurement and the Certificate of Approval of service supplier. The Certificate of Approval for Firms Engaged in Thickness Measurement, as per *UR Z10.2* for *Hull Surveys of Bulk Carriers* (IACS, UR Z10.2), is required for firms that are involved in decisions affecting statutory certification. Besides, IACS *UR Z17*

Procedural requirements for service suppliers (IACS, UR Z17) include specific minimum requirements for the certification of service suppliers in areas such as measurements, tests or maintenance of safety systems and equipment. The Unified Requirements provide specific requirements for firms carrying out an in-water survey on ships and mobile offshore units by diver or Remotely Operated Vehicle (ROV) and Firms engaged in survey using Remote Inspection Techniques (RIT).

Table 5: International Provisions Relevant to Certification for Vessels and Certification for Companies

Certification for Vessels			
	Instruments	**Provisions**	**Comments**
Cargo Ship Safety Construction (SC) Certificate	Recommendation No.76 (1994): IACS Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers (Rev.1 July 2001) (Rev.2 June 2004) (Corr.1 Sept 2007) and SOLAS, 1974, regulation I/12; 1988 SOLAS Protocol, regulation I/12	**SOLAS** (ii) A certificate called a Cargo Ship Safety Construction Certificate shall be issued after survey to a cargo ship which satisfies the requirements for cargo ships on survey set out in Regulation 10 of this Chapter and complies with the applicable requirements of Chapters II-1 and II-2 other than those relating to fire-extinguishing appliances and fire control plans **Recommendation No.76** 2.5.1 A Drydocking Survey is required in conjunction with the Special Survey to examine the external underwater part of the ship and related items. Two Bottom surveys are required to be carried out during the five-year period of validity of SOLAS, 1974 Cargo Ship Safety Construction (SC) Certificate, and the maximum interval between any two successive Bottom Survey is not to exceed three years.	Guidelines for surveys for the Cargo Ship Safety Construction Certificate exist in IMO Survey Guidelines under the *Harmonized System of Survey and Certification (HSSC), 2019* (Resolution A.1140(31), Annex I.
Anti-fouling System Certificate	AFS Convention, regulation 2(1) of annex 4	.1: The Administration shall require that a ship to which regulation 1 applies is issued with a Certificate after successful completion of a survey in accordance with regulation 1. A Certificate issued under the authority of a Party shall be accepted by the other Parties and regarded for all purposes covered by this Convention as having the same validity as a Certificate issued by them 2.2 Certificates shall be issued or endorsed either by the Administration or by any person or organization duly authorized by it. In every case, the Administration assumes full responsibility for the Certificate. 2.3 For ships bearing an anti-fouling system controlled under Annex 1 that was applied before the date of entry into force of a control for such a system, the Administration shall issue a Certificate in accordance with paragraphs (2) and (3) of this regulation not later than two years after entry into force of that control. This paragraph shall not affect any requirement for ships to comply with Annex 1.	Ships of 400 GT and above shall be issued after inspection and survey an international Anti-fouling System Certificate along with a Record of Anti-fouling Systems.

Classification Certificate	UR Z7 Hull classification surveys (*Rev.28 May 2019)*	2.1.1 Special Surveys are to be carried out at 5 years intervals to renew the Classification Certificate.	The scope and specified intervals of any statutory survey are further outlined in the IMO *Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), 2019* (Resolution A.1140(31)
International Load Lines Certificate	Load Lines Convention, article 6; 1988 and LL Protocol, article 16	16.1 An International Load Lines Certificate (1966) shall be issued to every ship which has been surveyed and marked in accordance with the present Convention. 16.2. An International Load Line Exemption Certificate shall be issued to any ship to which an exemption has been granted under and in accordance with paragraph (2) or (4) of Article 6. 16.3. Such certificates shall be issued by the Administration or by any person or organization duly authorized by it. In every case, the Administration assumes full responsibility for the certificate. 16.4. Notwithstanding any other provisions of the present Convention, any international load line certificate which is current when the present Convention comes into force in respect of the Government of the State whose flag the ship is flying shall remain valid for two years or until it expires, whichever is earlier. After that time an International Load Lines Certificate (1966) shall be required.	Guidelines for surveys for the International Load Line Certificate exist in the IMO *Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), 2019* (Resolution A.1140(31), Annex 2.
Diving System Safety Certificate	Resolution A.831(19): Diving-Code 1995 Code of Safety for Diving Systems, 1995	1.6.5 A Certificate should be issued either by the Administration or any person or organization duly authorized by it after survey or inspection to a diving system which complies with the requirements of the Code In every case the Administration should assume full responsibility for the Certificate.	The duration of the certificate should not exceed five years from the date of issue.
Certification for Vessels			
	Instruments	**Provisions**	**Comments**
Classification certificate and Certification of Firms Engaged in Thickness Measurement	Z10.2 Hull Surveys of Bulk Carriers *(Rev.36 May 2019)*	2.1.1 Special Surveys are to be carried out at 5-year intervals to renew the Classification certificate. 7.2.1 The thickness measurement is to be carried out by a qualified firm certified by the Classification Society according to principles stated in Table V.	Procedures for certification of Firms (Submission of Document and audits) Engaged in Thickness Measurement of Hull Structures to gain the Certificate of Approval, which should be

			renewed at intervals not exceeding 3 years.
Certification of Service Supplier	UR Z17 Procedural requirements for service suppliers (Rev.14 Mar 2019)	5.1.1 The following documents are to be submitted to the Society for review. General requirements concerning suppliers are given in 5.2, and specific requirements as relevant, in Annex 1. • Outline of company, e.g., organisation and management structure, including subsidiaries to be included in the approval/certification • List of nominated agents, subsidiaries and subcontractors • Experience of the company in the specific service area • For categories of Service Suppliers that require authorization from manufacturers, manufacturer's documentary evidence that the Service Supplier has been authorized or licensed to service the particular makes and models equipment for which approval is sought shall be provided. • List of operators/technicians/inspectors documenting training and experience within the relevant service area, and qualifications according to recognised national, international or industry standards, as relevant • Description of equipment used for the particular service for which approval is sought • A guide for operators of such equipment • Training programmes for operators/technicians/inspectors • Check lists and record formats for recording results of the services referred to in Annex 1 • Quality Manual and/or documented procedures covering requirements in 5.5 • Documented procedures for communication with the crew prior to commencing work, so that it is safe to decommission the equipment being maintained, and to provide a safe system of work in place • Evidence of approval/acceptance by other bodies, if any • Information on the other activities which may present a conflict of interest • Record of customer claims and of corrective actions requested by certification bodies	The objective of this procedure is to set minimum requirements for certification of service suppliers in areas such as measurements, tests or maintenance of safety systems and equipment.

		6.1 Upon satisfactory completion of both the audit of the supplier and the demonstration test, as applicable, the Society may issue a Certificate of Approval stating that the supplier's service operation system has been found to be satisfactory and that the results of services performed in accordance with that system may be accepted and utilized by the Society's Surveyors in making decisions affecting classification or statutory certification, as relevant. The Certificate shall clearly state the type and scope of services and any limitations or restrictions imposed including type of equipment and/or names of Manufacturers of equipment where this is a limiting restraint. The supplier may also be included in the Society's record of approved service suppliers. 6.2 Renewal or endorsement of the Certificate is to be made at intervals not exceeding five (5) years by verification through audits that approved conditions are maintained or, where applicable, on expiry of the supplier's approval received from an equipment Manufacturer, whichever comes first. In the latter case, the Society is to be informed in due course by the Service Supplier. Individual Societies may require renewal or endorsement of the Certificate at intervals shorter than five (5) years and may require intermediate audits. For firms engaged in thickness measurements, renewal/endorsement of the Certificate is to be made at intervals not exceeding 3 years by verification that original conditions are maintained.	

2.6.1 Take-aways from Segment on Certificates for Vessels and Service Suppliers

Researchers are of the view that the existing certification system is adequate. In addition, the following certification requirements (that is independent of the statutory certification of the vessel) of companies involved in the provision of RIT services are currently well defined in the texts of IACS rules and requirements:

• Firms Engaged in thickness measurement should be certified by the Classification Society

• Service Supplier should be certified by the Classification Society

• Service Suppliers that require authorization from manufacturers, manufacturer's documentary evidence that the Service Supplier has been authorized or licensed to service the particular makes and models equipment for which approval is sought shall be provided.

2.7 WIPO and WTO: Intellectual property and Transfer of Green Technology

WIPO and WTO are the two major UN specialised agencies for intellectual property issues and the dissemination of climate technology among developed and developing countries.

WIPO is the responsible body for the promotion of intellectual activities as well as the facilitation of technology transfer to developing countries. The organization brings stakeholders together to overcome challenges for trademarks, patents, copyrights, industrial designs, geographical indications and trademarks. Special emphasis is given to the intellectual property challenges of Artificial Intelligence since the existing IP system requires improvement to protect machine-generated works and inventions. WIPO GREEN is another initiative that enables providers and seekers of green technologies to connect through its online platform, network and acceleration projects. One of the strategic goals of WIPO GREEN is to facilitate, through greater transparency, the dissemination of climate-friendly technologies in developing countries. It is important to note that IP challenges can be tackled efficiently since WIPO provides the essential tools to the stakeholders to understand IP's role during the technology transfer process. WIPO GREEN is a valuable mechanism for implementing the objectives of United Nations Framework Convention on Climate Change (UNFCCC) for cooperation in the transfer of environmentally sound technologies (ESTs).

Relevantly, WTO provides the international framework for the protection and enforcement of intellectual property rights during the transfer and trade of systematic knowledge for an application or product with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS, 1994). The Agreement recognizes the interlinkages between intellectual property and trade and aims to narrow the gaps between the different jurisdictions by setting minimum standards for Member States. National legislation for intellectual property should conform with the provisions of the Agreement. TRIPS includes provisions of the two key treaties of WIPO, which is the Paris Convention for the Protection of Industrial Property and the Berne Convention on Copyright. The need for flexibilities concerning the national legal framework of the least developed countries (LDCs) is underlined in the Agreement. According to Article 7, entitled "Objectives," the protection of intellectual property rights should facilitate the promotion and transfer of technological innovation for mutual benefits between producers and users, contributing to social and economic welfare (TRIPS, 1994). Article 27 (Patentable Subject Matter) states that patents shall be available for any technological inventions, whereby Article 29 (Conditions on Patent Applicants) includes disclosure requirements for patents. In addition, Article 66.2 requires from developed countries to provide incentives to enterprises under their jurisdiction to promote technology transfer to least-developed country Members (TRIPS, 1994).

2.7.1 Take-Aways from the Work of WIPO and WTO

Various discussions have been raised on the IP challenges related to the transfer of climate-friendly technology as key stakeholders hold conflicting views on the IPRs of the relevant technologies. Gaps in the current international regime exist to transfer climate technologies to developing countries due to the differing national laws on protection and enforcement of intellectual property. It is suggested that TRIPS Agreement should be amended and introduce more provisions on the dissemination of green technologies. To this end, TRIPS should a) expand the existing TRIPS flexibilities for green technologies and offer clear incentives for the transfer of technologies to least developing states (LDCs) and b) facilitate compulsory licensing for the transfer of climate change technologies to reduce the research and development costs to LDCs (Zaman, 2013).

A collaborative mindset is essential between UNFCCC, WTO, and WIPO to clarify and improve technology transfer provisions (Zhou, 2019). UNFCCC, with its legal framework for technology transfer, should act as the facilitator of the corresponding adjustments required to the current international regime. All three organizations should attempt to strike the balance between private interest and national governments. The following issues could be taken into consideration for the improvement of the current regime for IP and technology transfer:

- Cooperation is crucial between UNFCCC, WTO, and WIPO to clarify and improve technology transfer provisions;
- TRIPS provisions relevant to climate technology transfer should be enhanced, clarified and amended. The provisions should focus more on climate technology transfer, considering the Paris Agreement's objectives;
- Establishment of the right balance between the way that developing countries can provide an appropriate environment for technology transfer and the way that developed nations can actively promote technology transfers;
- Expansion of the existing TRIPS flexibilities for green technologies and clear incentives to the developed countries for the transfer of technologies to least developing states (LDCs);
- Maintain a better balance between IPR and the socio-economic welfare objectives referred to in Articles 7 ((Objectives). The Article is too abstract to be practiced;
- Clarification on Article 29 (Conditions on Patent Applicants). Disclosure requirements for patents are not always feasible during the transfer of climate technologies.

2.8 Intellectual Property & Data Governance through the Prism of Artificial Intelligence and Standards

The following sections provides a comprehensive evaluation of intellectual property issues related to the use of service robotics. As a first step, the authors have evaluated the nexus between standards and intellectual property rights, centered on the role of patents for the development of standards that ensure the dissemination of breakthrough technologies. The challenges emanating from the intellectual property policy regime due to technology and service robots’ advent has also been analysed.

Today’s data proliferation raises challenges for service robotics; thus, a significant emphasis will be placed on data governance and data management challenges for RITs and ROVs. From the examination so conducted, it becomes evident that service suppliers, classification societies and shipping companies should adapt their modus operandi from controlling data to managing it properly in the various stages of data management process.

2.8.1 Interaction Between Standards and Intellectual Property Rights

Intellectual property (IP) is about “the creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce” (WIPO, 2020) and all the relevant IP regimes aim to protect the rights of inventors for a specific period of time. The main categories of (IP) are patents, trademarks, copyrights and trade secrets for which holders of IP have the right to exclude others from certain activities relevant to the knowledge-object under consideration. All regimes of IP protection call for a *quid pro quo* (“something for something”), denoting a “win-win” situation between society and the grantee for the creation and protection of the knowledge object (Brady, 2015). The most relevant IP regime that relates to the development of standards are patents.

For the development of standards that ensure the dissemination of technologies and interoperability between products, it is asserted that patented technologies should be protected. Patents that protect the technologies to operate the standard become SEPs. A patent is an exclusive right granted for inventions in any field of technology to an inventor for a specific timeframe (generally 20 years) in exchange of public disclosure of the invention (WIPO, 2020). Patents are a central element in the standardization process and plays a crucial role in the specific application of "standardization" including units of measurement, terminology and symbolic representation; products and processes, and safety of persons and goods (ISO, 1972, pp. 17-18). During the standard-setting process, multiple essential patents may cover any specific standard and upon expiration of a patent, the technical information contained in the patent is freely available to the public. The logic behind the patent system is that if intellectual creativity is rewarded, innovators will be encouraged to invent, excluding others from exploiting the innovation for a specific time period.

Standard-setting organizations (SSOs) such as CEN, CENELEC and ETSI have developed rules (IPR policies or patent policies) for the inclusion of patents in standards that safeguard the licensing of SEP. For example, the ETSI Intellectual Property Rights Policy of 2020, governed by the laws of France, aims to find a balance among the needs of standardization for public use in the field of telecommunications and the rights of the holders of IPRs. It includes provisions about disclosure of IPRs during the development of a Standard or Technical Specification, availability of licenses, use of the IPR Licensing Declaration Forms for IPR licensing declarations. Besides, the CEN-CENELEC Guide titled Standardization and Intellectual Property Rights is the guiding tool for the participants in their technical bodies and requests from patent holders for early disclosure on essential patents, utilizing the declaration form found in Clause 4 of the Guidelines. In the Declaration Form, the patent holder is not entitled to provide monetary compensation as a part of the licensing arrangement. For ISO, the Guidelines for Implementation of the Common Patent Policy (Annex I of the ISO/IEC Directives) ensure that recommendations and deliverables are accessible to everybody. According to the "Patent Statement and Licensing Declaration" Form that has to be filled in when a Recommendation or Deliverable is developed, three different situations may arise, out of which the first two declare the willingness of the submitting party to license:

> .1 The patent holder is willing to negotiate licenses free of charge with other parties on a non-discriminatory basis on reasonable terms and conditions. Such negotiations are left to the parties concerned and are performed outside ITU-T/ITU-R/ISO/IEC;
>
> .2 The patent holder is willing to negotiate licenses with other parties on a non-discriminatory basis on reasonable terms and conditions. Such negotiations are left to the parties concerned and are performed outside ITU-T/ITU-R/ISO/IEC; and
>
> .3 The patent holder is not willing to comply with the provisions of either paragraph 2.1 or paragraph 2.2; in such case, the Recommendation | Deliverable shall not include provisions depending on the patent. (ISO/IEC Directives, 2020).

In general, the holder of a patent should declare in writing, via respective declaration form of the SSO, to license essential patents for implementing a Standard. It is only through this process, the SSO can approve and publish the standard. For SEP, policymakers encounter the challenge of striking the right balance between a) the patent owner (licensor) to enjoy the full benefits of the patent; b) third parties (licensees) to develop standard-compliant products; and c) the users so as not to be confined into specific technology platforms (Lambert and Temple, 2015).

Patent policies of SSOs are generally classified into two principal categories, although there are cases where SSO's combined elements of both types: a) disclosure policies that relate to the disclosure of patents at an early stage for the implementation of a standard; and b) licensing policies for which participants' grant implementer's licenses under FRAND licensing principles (Contreras, 2019). However, FRAND operationalization has been elusive since there are diverging interpretations of the term "Reasonable" given that what is reasonable for the holder may not be concretely reasonable to other parties. According to the European Commission (2017), there is no one-size-fits-all solution to the conceptualization of the term and rational license fee expectations on both sides should be taken into consideration. Notably, the European Commission supports that FRAND value should: a) be based on the present value (value discounted to the time of the conclusion of the license agreement), b) be unrelated to the market success of the product; and c) safeguard continued incentives for SEP holders to contribute their best technology to standards.

When standards are developed and the participants' grant licenses are issued under FRAND terms, then the technology included in the standard is accessible to any potential user of the standard. A SEP friendly licensing environment should be provided by the SSO and the European Commission has underlined the need for a reasonable policy for SEPs to achieve the inclusion of breakthrough technologies in standards based on fair access conditions. Therefore, a framework has been developed for the inclusion of patent-protected technologies into standards (Setting out the EU approach to Standard Essential Patents, 2017) to contribute to the development of the "internet of things" and set out fundamental principles that foster a smooth framework for SEPs. The SSOs and SEP holders are encouraged by the Commission to cooperate and facilitate the licensing via transparent patent pools or other licensing platforms.

For the manufacturing of AUVs, Magnetic Crawlers and ROVs the development of standards is essential; consequently, the related patent applications should be safeguarded. The patent system for breakthrough technologies and service robots has a crucial role to play for the exploitation of technology complementarities and licensing arrangements.

2.8.2 Intellectual Property and Artificial Intelligence

In the previous section, the patent regime was analysed in tandem with standard-setting processes by relevant international organisation. In this section, the main focus is on the connection between IP and service robots. At the European Union level, the INBOTS project released a White Paper Interactive Robotics Legal, Ethics and Socioeconomic aspects (2019), identifying that Intellectual Property for Robots concerns Patents, Trade Secrets, Copyright, Trademarks and Designs.

At the international level, WIPO aims to set the basis for common understanding of the main challenges that need to be addressed for IP policy and AI. WIPO Conversation on Intellectual Property and Artificial Intelligence led to the development of the document titled *Revised Issues Paper on Intellectual Property Policy and Artificial Intelligence* (2020) that identifies all significant IP Challenges from the advent of AI that are relevant to: definitions, patents, copyright and related rights, data, designs, trademarks, trade secrets, technology gap & capacity building and accountability for IP administrative decisions.

- **Patents** are granted by the non-EU European Patent Office (EPO) and national patent offices. EU Robotic companies are eligible to gain a European Patent (EP) which consists of a number of national patents granted by the EPO.
- **Trade Secrets** namely information that is within the interests of the company to be kept confidential, is considered as an alternative option to patents. Trade secrets do not require disclosure. Unlike patents, trade secrets do not require a detailed description of the invention, enabling the protection to last indefinitely and competitors to be kept behind (McGurk and. Emsley, 2014). EU, Directive 2016/943 on the *protection* of Undisclosed Know-How and *Business Information* (trade secrets) against their Unlawful Acquisition, Use and Disclosure specifies which disclosure of a trade secret shall be considered illegal. As per Article 4, if there is no consent of the trade secret holder for access to relevant documents and materials, then the acquisition is unlawful. According to Article 6, each Member State shall have in place all the relevant procedures to ensure the availability of civil redress against this unlawful acquisition.
- Companies which develop software and software codes can be protected through **copyright**. In the EU, the harmonization of copyright law between the different member states has been slow and there is still room for action. Directive 2009/24/EC of the European Parliament and of the Council of 23 April 2009 on the legal protection of computer programs states in Article 1 that the EU States shall protect programs in any form by copyright, including those which are incorporated into hardware, as well as their preparatory design material. According to Directive 96/9/EC, the authors of databases shall be protected by copyright. Furthermore, EU Directive 2001/29 on Copyright in the Information Society provides legal protection “against the circumvention of any effective technological measures, which the person concerned carries out in the knowledge, or with reasonable grounds to know, that he or she is pursuing that objective.” This provision sets protection against third parties who want to access software code. However, it should be underlined that computer programs, databases and images can be protected by copyright if there is some degree of human authorship. Therefore, a distinction should be made between computer-aided works and computer-generated works since only the computer-aided works can be protected by copyright (Bonadio, McDonagh, Arvidsson, 2018).
- Reputed Robotics companies invest in registering trademarks in order to achieve commercial success for their products. **Trademarks** (symbols or characteristics of a product or service) are administered by the EU Intellectual Property Office (EUIPO).
- An industrial **design** is registrable if it is novel. EU Regulation 6/2002 specifies the relevant provisions for Community designs and Robot designs that can be registered with the European Union Intellectual Property Office (EUIPO). The legal instruments of WIPO along with national and regional laws comprise the international legal framework for industrial designs.

There are many issues arising from the intellectual property policy regime due to the advent of technology and service robots. It is noted that future legislation should be centered on two issues: copyright ownership and enforcement (Ihalainen, 2018). The current regime lacks provisions about computer-generated works given that AI is barred from being treated as an autonomous creator. AI has been mainly conceptualized as the end-product of the programmer. It is suggested that policymakers should incorporate clear copyright provisions about computer-created works and works created with the assistance of computers (Ihalainen, 2018). The report of the Committee on Legal Affairs of EU Parliament (2017) specifies that there is a need for a balanced approach to intellectual property rights for hardware and software standards, calling the

Commission to identify criteria for an 'own intellectual creation' for copyrightable works created by computers or machines.

For patents, policymakers have to clarify if future legislation will allow an AI application to be named as the inventor or joint inventorship with a human will be required. To protect the designs of products, an assessment should be made to examine if specific legal provisions need to be introduced to govern the ownership of AI-generated designs. As for trademarks, concerns raised by ownership of trademarks with respect to AI needs to be addressed. Lastly, for trade secrets, one of the questions that have been put forward is if the current law of trade secrets strikes the right balance between protecting innovations in the AI field and the legitimate interests of third parties in having access to certain data and algorithms.

The World Intellectual Property Organization (WIPO) aims to set the basis for common understanding of the main challenges that need to be addressed for IP policy and AI. The WIPO Conversation on Intellectual Property and Artificial Intelligence produced the document titled Revised Issues Paper on Intellectual Property Policy and Artificial Intelligence (2020) which identifies all the significant IP Challenges from the advent of AI that are relevant to: definitions, patents, copyright and related rights, data, designs, trademarks, trade secrets, technology gap & capacity building and accountability for IP administrative decisions.

2.8.3 Data Governance and Data Management for RITs and ROVs

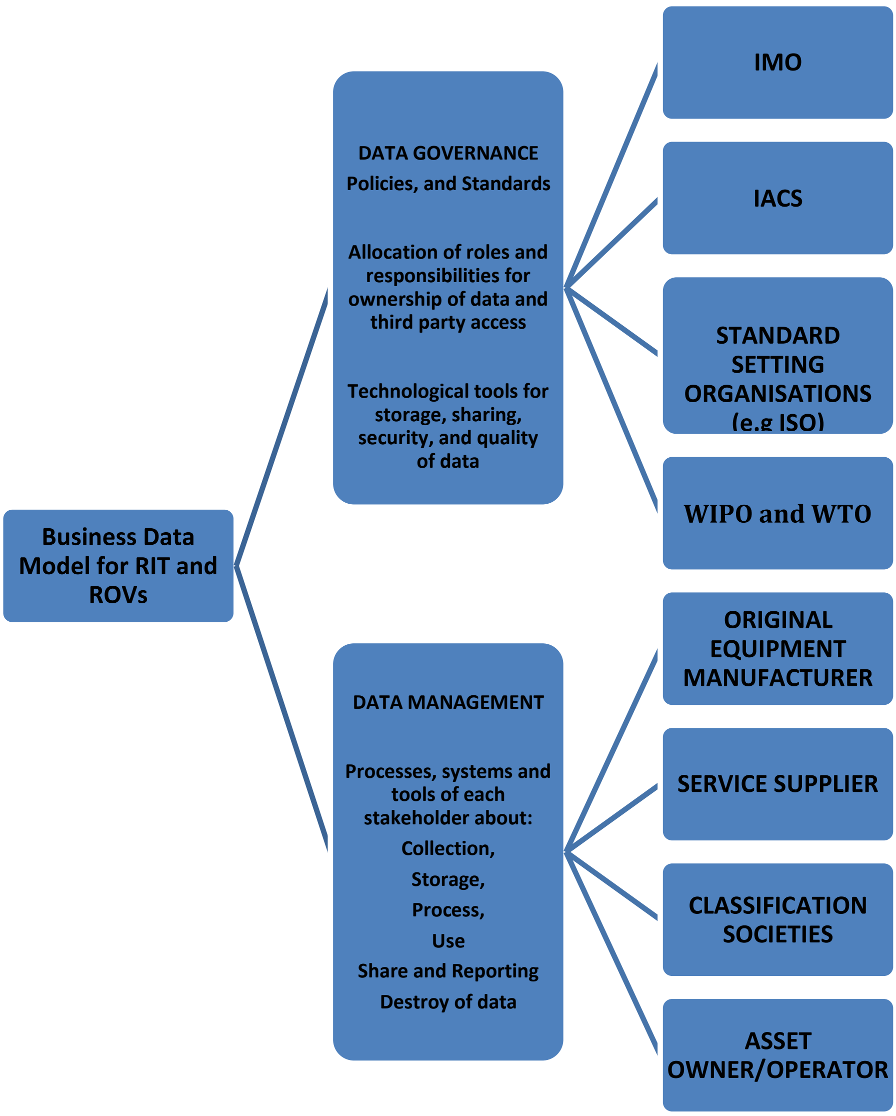
From all the IP elements examined above, "data" and "copyright" issues are the most relevant to the aims of to BUGWRIGHT2; therefore, attention should be given to the adequacy of current IP regimes for service robotics on data ownership, security, privacy, recognition of authorship, rights in data access and sharing between the different stakeholders. Data from remote inspection techniques include information from close-up surveys and gauging. During a survey programme, visual data, such as still images, live-stream and recorded video, is collected for the structural condition of the vessel, ship's holds and tanks, corrosion and thickness measurement.

At this point, it should be underlined that data for RITs and ROVs are not related to personal data but to data pertaining to the vessel's structure through the use of service robots (non-personal data). Personal data, according to the EU's General Data Protection Regulation (GDPR), is any piece of information that relates to an identifiable person. Non-personal data, according to *Regulation (EU) 2018/1807 on a framework for the free flow of non-personal data in the European Union*, includes aggregate and anonymized datasets used for big data analytics. It should also be noted that the distinction between the two terms is not clear-cut since any type of data can be combined with different datasets and transformed into personal data in cases where there is processing power and data availability (Chatzimichali and Chyrostomou, 2019; Mattoo and Meltzer, 2018). According to the Regulation, if such data is converted into personal data, then Regulation (EU) 2016/679 for General Data Protection Regulation is to apply.

Data management and data governance are the two critical concepts governing data flow for non-personal data. Data governance is related to the upper-level planning and the decisions about allocating responsibilities, access and control to data, whereas data management is associated with the implementation and monitoring of these decisions (Khatri and Brown, 2010). Therefore, data governance is an overarching term that encompasses policies, standards, allocation of responsibilities and technological tools. Data governance allows for distinct rules on data ownership from service robotics in the various stages of a data life cycle. The data management process falls under the umbrella of data governance and encompasses the sequence of the following activities: collection, storage, processing, using, sharing and destroying of data (Janssen et al., 2020).

Trustworthy cooperation among the key stakeholders in the data governance process is of utmost importance (Janssen et al., 2020). For marine service robotics, cooperation is essential between IMO, IACS, Standardization Organizations, Manufacturers of RITs/ROVs, Remote Inspection Service Providers, Classification Societies and Asset Owners/Operators. IMO, IACS and SSOs set the data governance framework and develop policies and standards for proper data practices. Manufacturers, service suppliers, classification societies and shipping companies ensure that they follow the relevant policies and set up appropriate organizational processes, systems and tools to safeguard data. Through cooperation, the allocation of authority and control during the data management stages (collection, storage, processing, using, sharing and destroying of data) should be specified. Figure 3 presents the business model for RITs and RVOs for building a trustworthy data foundation.

Figure 3: Business Model for RITs and ROVs for Trustworthy Data Foundation



Source: Developed by Authors

To identify current practices for data governance and management for RITs and ROVs, a careful examination of IACS and individual Classification Society documents have been conducted. In addition, interviews have been conducted with relevant stakeholders of the data management process, including executives of a service supplier company, a legal expert, an IT shipping consultant and a drone team of a maritime technical service company. The respondents noted the provisions for remote inspection techniques found in the following documents:

- IACS Recommendations No. 42, Guidelines for Use of Remote Inspection Techniques for Surveys;
- IACS UR Z7, Hull Classification Surveys 1.6 Remote Inspection Techniques;
- IACS UR Z17, Procedural Requirements for Service Suppliers;
- ABS Guidance Notes for UAVs, ROVs, and Robotic Crawlers (2019);
- Guidelines of China Classification Societies for the Use of Unmanned Aerial Vehicles, 2018 (CCS, 2018); and
- DNV Approval of service supplier scheme (2020) (For further details *see* s. 2.5.3).

IACS Unified Requirements on Hull Classification Surveys (Z7), s. 1.6 on Remote Inspection Techniques (RIT), specifies that the surveyor should "be satisfied with the method of data presentation including pictorial representation, and a good two-way communication between the Surveyor and RIT operator is to be provided (IACS, 2018) ".

For companies which are involved in surveys using RITs for Close-up Survey of the structure of ships, as per IACS UR Z17 regarding Procedural Requirements for Service Suppliers (s. 5.2.6), there are general software requirements for the approval and certification of suppliers:

> When computers are used for the acquisition, processing, recording, reporting, storage, measurement assessment and monitoring of data, the ability of computer software to satisfy the intended application shall be documented and confirmed by the service supplier. This shall be undertaken prior to initial use and reconfirmed as necessary (IACS, Z17)

In s. 16.7 of IACS UR Z17 there are provisions for the equipment that should be available for the inspection. The equipment includes remotely operated platforms with data capturing devices, data collection devices that include cameras capable of capturing videos and images in high definition and data recording devices. In section 16.8, it is stated that suppliers should have operational procedures for how to handle/operate the equipment and guidelines on the collection, validation and storage of data. In the same document it is specified that if data is to be stored, requirements for location attribution (geo-tagging), validation and storage of data should be documented.

Classification Societies follow the IACS data requirements for their service suppliers and have released similar guidelines to IACS UR Z17. However, it is important to note that some member societies have in place more detailed provisions than what is observed in IACS UR rules and requirements. For example, DNV has provided a more detailed analysis about the level of data management required from the supplier, requesting from the supplier to utilise ISO 80008 for quality assured information and a well-documented data security management system to encounter threats to the vessel network (DNV, Section 5.2.4, 2020).

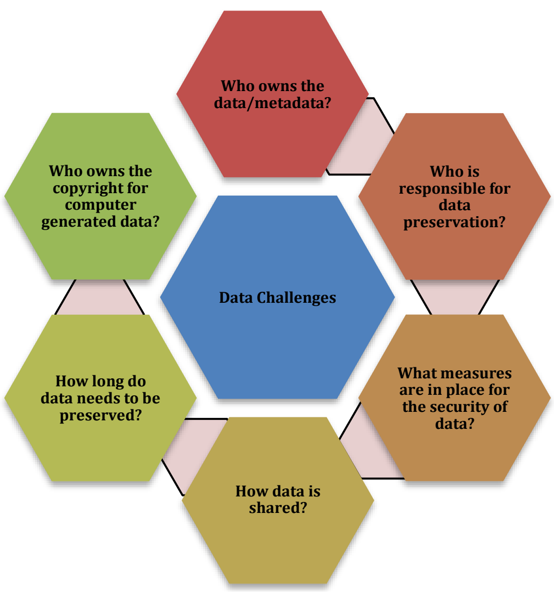
Notably, some Classification Societies have released specific guidelines for remote inspection surveys that include provisions about RIT system requirements, data collection review, storage, report and security. For example, ABS has released Guidance Notes on UAVs, ROVs, and Robotic Crawlers (ABS, 2019). In s. 3.11, relevant to the Recommendations for Remote Inspection Service Provider, there are specific requirements for the acquisition, review and security of remote inspection technology data. In Section 4 with regards to the Survey/Inspection Process, there are provisions about data review, data post-processing and reporting. In s. 3 of the Guidelines developed by CCS, there are provisions about data collection, processing and security (CCS, 2018). Section 16.1.1.4 of the Service Supplier Scheme developed by DNV for firms engaged in surveys using remote survey techniques- specifies that the storing of data by the service supplier should be up to five years (DNV, 2021).

2.8.4 Take-Aways: Data Governance and Data Management challenges for RITs and ROVs

There are various data governance and data management challenges that stem from the use of RITs and ROVs for manufacturers, service suppliers, classification societies and shipping companies. Based on the tasks related to data governance and data management, the following questions have been posed that arise from the use of remote inspection techniques (Figure 2):

1. **Data Ownership:** Who owns the data/metadata and the copyright to the recorded visual data (still images, live-stream video, and recorded video)? Is the service supplier or the service owner?
2. **Data Preservation Entity:** Who is responsible for data and image preservation?
3. **Security Measures of Data Preservation Entity:** What measures are in place for the security and confidentiality of Remote Inspection Technology data?
4. **Data Sharing:** How data is shared between the different stakeholders to ensure secure data transfer between data owners and users?
5. **Duration of Data Preservation:** How long do individual survey data and images need to be preserved?
6. **Copyright** for service robots autonomously capturing images or data without human interaction. If there is no human interaction, there is no copyright owner under the current regime. Therefore, the question is: who owns the copyright?

Figure 4: Data Challenges from the Use of RITs and ROVs



Source: Developed by Authors

2.9 Elements for Regulatory Blueprint Based on Legal Insights into International Arrangements

This section offers specific strands of action for consideration in the likelihood of international guidance being developed on RITs. The strategic action items proposed are founded on the principal objective of BUGWRIGHT2 (as found in p. 4 of the Grant Agreement): "[t]he objective of BUGWRIGHT2 will be to bridge the gap between the current and desired capabilities of ship inspection and service robots by developing and demonstrating an adaptable autonomous robotic solution for servicing ship outer hulls". According to the researchers of WMU, an "adaptable" solution pertaining to MAV, AUV and crawler will not only require technical adaptability, but will also require horizontal harmonization in the policies and practices that govern RITs altogether so that all member societies within and outside of the IACS-group could benefit from those while adhering to the IACS common rules and requirements. Although rules collectively developed by IACS member societies tend to class around 94% of commercial tonnage; it is noteworthy that there are no rules that bar other societies outside the "big 11" from developing their own class rules. Therefore, harmonization is of extreme importance for rules and requirements to keep pace with technological innovation. Dissimilar rules and requirements create the potential for fragmentation that must be avoided to unleash the full potentials of technology.

Another important aspect for developing harmonized guidance sources is the need to tackle ship-source pollution in a collective manner maintaining highest levels of safety-standards. Collective efforts should concentrate on resolving existing gaps when integrating technological innovation into what has been a human-centric task from the beginning. Findings from international arrangements that set the scene for further discussions could not be clearer. UNCLOS coupled with the UN Framework Convention on Climate change acknowledges technological developments and transfer of knowledge for reducing emissions that help conserve energy, which in turn, strengthens climate resilience. Collective adaptability through harmonization of existing service robotics rules and requirements will certainly complement and accelerate member States ongoing efforts under Article 10 of the Paris Agreement (as discussed earlier).

Can emerging technologies benefit from international guidance? The answer to the preceding question is with reference to the *IACS class rules* that govern the work of actors that comprise the business model in relation to MAV, AUV and crawlers – the three technological systems prioritized under BUGWRIGHT2. IACS class rules, especially IACS Recommendation 42 and IACS UR Z17 are, in fact, the international rules that ought to be adhered to by ship owners, member classification societies, service suppliers/companies, operators and supervisors. In other words, the above rules and requirements dictate the procedures that must be followed for effective and efficient completion of class surveys using MAV, AUV and crawlers. However, after examining the work of other international organizations, e.g., ISO, WIPO and WTO, it appears that there are integral elements that could be tabled for discussions at the appropriate public fora to assess the feasibility for considering further actions. Moreover, results from the cross-comparative analysis (among rules and requirements developed by selected member societies within IACS) further confirm the existence of additional provisions that go beyond the common minimum standards found in IACS UR Z17. Researchers of this report are cognizant that it may not be feasible to develop an exhaustive list of "dos and the don'ts" at this stage given that MAV, AUV and crawler technologies are not yet in mass deployment, but given that tests are being conducted by classification societies hint that mass deployment of those service robots are inevitable rendering it important to ensure that adequate rules and requirements are in place.

All examinations (conducted under this part of the report) lead to the proposition that there are specific action items that require attention from international actors, especially by IACS in consultation with IMO, individual class societies and relevant stakeholders. COVID-19 and the gradual shift towards remote survey have invoked the need to observe how other international governmental and non-governmental organizations with a standard mandate are addressing the core issues to help manufacturers pass the design bottleneck to enable the joint production of mutually valued outcomes and create a positive impact on innovation, safety and environment. While standard international guidance will help align the work helping to even out the international regulatory landscape, they will nonetheless, add positive value in the current process of service robotics integration at regional and national levels. The following table amalgamates the international elements that WMU researchers consider as integral to the regulatory progressive development of RITs currently explored under BUGWRIGHT2 for survey and maintenance of hull structural elements of bulks carriers.

Table 6: Elements for Regulatory Blueprint for Harmonization of International Arrangements

Element of Regulatory Blueprint	**Action Items**
International Consultation	**Action Item 1 (All Stakeholders):** Consultation among various relevant international organizations, i.e., ISO, IMO, IACS and WIPO, concerned with developing service robotics standards; **Action Item 2 (All Stakeholders):** Creation of a forum (taking into account Action Item 1) to conduct preliminary assessments on the benefits of developing international guidance taking into account safety, environment and end-users.
Reference for Further Information	IMO group concerned with MASS, ISO TC 8, IACS member States and WIPO. In this process, it is important to consider the insights provided by ship owners and ship owner representatives, service suppliers, RIT operator, surveyors using RIT and the specific department of IACS that deals with regulating the usage of RIT in ship survey, inspection and maintenance (with reference to hull structures).
Element of Regulatory Blueprint	**Action Items**
Categorization Based on Capacity	**Action Item 3 (Considering ISO 19649:2019 as the basis):** Classify pursuant to capacity and determine whether MAVs, AUVs and crawlers fall under the scope of “mobile robots” (see Table 6, s. 3.1.1 of ISO 19649:2019). Until the classification is finalized, refer to MAVs, AUVs and crawlers as Remote Inspection Technology or Remote Inspection Vehicles or Remote inspection Techniques as found in IACS rules and requirements. The terms “mobile robots” or Robotic and Autonomous Systems (RAS) do not currently apply to the types of MAVs, AUVs and crawlers given that they do not fully fall under the category of “autonomous” robotics since there is observed “human-in-the-loop” in all procedures noted by IACS.

Reference for Further Information	IACS Recommendation 76 (see s. 2.4.3.1.1 of this report); IACS UR Z3 (see s. 2.4.3.2.1 of this report); IACS UR Z7 (see s. 2.4.3.3.1 of this report); IACS UR Z10.2 (see s. 2.4.3.4.1 of this report); IACS Recommendation 42 (see s. 2.4.4.1.1 of this report); IACS UR Z17 (see sections 2.4.4.2.1.1, 2.4.4.2.2.1 and 2.4.4.2.3.1 of this report).
Element of Regulatory Blueprint	**Action Items**
Stand-alone Definitions	**Action Item 4 (Individual class society-developed definitions as the basis):** Consider stand-alone definitions (in the following manner) for MAVs, AUVs and crawlers rather than referring to all technologies under the overarching term "Remote Inspection Technologies": Crawler: A crawler is a tethered or wireless vehicle designed to "crawl" along a structure by means of wheels or tracks. Crawlers are often equipped with magnets which allow them to operate on a vertical surface or hull structures in air or underwater; MAV/AUV: An aircraft with no pilot on board that is controlled remotely or able to fly autonomously based on a predefined flight route and/or using dynamic automation systems. Unmanned Aerial Vehicles may be referred to by the industry as "drones" or Remotely Operated Aerial Vehicles or Multi Aerial Vehicles. UAVs are also referred to as Unmanned Aircraft Systems (UASs). A UAS is a system comprised of the unmanned aircraft (i.e., UAV) and its associated ground control station, data links, and other support equipment; and ROV: An unmanned unit designed for functions such as underwater observation, survey, inspection, construction, intervention or other underwater tasks.
Reference for Further Information	*Guidance Notes on the Use of Remote Inspection*, 2019, American Bureau of Shipping: Sections, 1.1, 1.3, 1.5 and 7 (see Table 8 of this report)
Element of Regulatory Blueprint	**Action Items**
Classification Pursuant to Degree of Autonomy	**Action Item 5 (Considering MASS as the basis):** In order for procedural rules and requirements to keep pace with technological innovation (towards full autonomy), service robots require a form of categorization along the lines of "degree of autonomy". A potential way forward is to follow closely the degrees rendered to vessels and how the different stages have been set by IMO's MASS (as the first step in scoping exercise): • First Degree: Ship (in this case service robotics) with automated processes and decision support; • Second Degree: Remotely controlled ship (in this case service robotics) with seafarers (in this case operators and surveyors in the loop) on board; • Third Degree: Remotely controlled ships (in this case service robotics) without seafarers on board; and • Fourth Degree: Fully autonomous ship (in this case fully-autonomous service robotics).

Reference for Further Information	IMO Doc. MSC 100/20/Add. 1, Annex 2, Framework for the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS), Dec. 7, 2018, ¶ 1 and IMO, MSC 99th Briefing (2018): http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx
Element of Regulatory Blueprint	**Action Items**
Operational Limitations & Conditions for Service Robotics	N.B. Action items 6 and 7 primarily depend on the scope and ambit of the international guidance and the feasibility of incorporating such items within the texts. **Action Item 6 (Individual class society-developed definitions as the basis):** Consider operational limitations for MAVs, AUVs and Crawlers that will help ensure effective completion of survey process; **Action Item 7 (Individual class society-developed definitions as the basis):** Consider pre-operation, in-operation and post-operation conditions for service robots.
Reference for Further Information	*Guidance Notes on the Use of Remote Inspection*, 2019, American Bureau of Shipping: Sections 4.3, 4.7.1, 4.7.3 and 4.7.5 (see Table 8 of this report)
Element of Regulatory Blueprint	**Action Items**
Expand Existing Provisions on “Alterations”	**Action Item 8 (Individual class society-developed provisions as the basis):** Revise existing IACS provisions in relation to survey and inspection planning, and consider all potential risk assessment options (see Table 8 of this report); **Action Item 9 (Individual class society-developed provisions as the basis):** Indicate in detail the procedures in cases where service supplier alters the certified system that affects the quality system (see Table 8 of this report); and **Action Item 10 (Individual class society-developed provisions as the basis):** Consider revision to include provisions on certification of multi-site organizations under the rules concerning “certification”; **Action item 11 (Individual class society-developed provisions as the basis):** Consider revision of existing provisions related to “survey procedures) to include Client Service System (CSM), livestreaming during remote survey and real-time collection of survey process information, solutions in case of problem with livestreaming, recording of process and conclusion in the ship log and conditions for certification (following provisions developed by China Classification Society); **Action item 12 (Individual class society-developed definitions as the basis):** Consider technological platforms for facilitation collection and delivery of survey-related information such as computers, intelligent remote glasses and digital cameras for livestreaming purposes (following provisions developed by China Classification Society);

	Action Item 13 (Individual class society-developed definitions as the basis): Consider more "factual and objective "post-reporting system (following provisions developed by American Bureau of Shipping)
Reference for Further Information	1. *Guidance Notes on the Use of Remote Inspection*, 2019, American Bureau of Shipping: Sections 4.5 and 9; 2. *Procedures for Approval of Service Suppliers*, 2020, Lloyds Register: Sections 1.6.3, 1.8.1, 1.8.2; and 3. *Guidelines for Use of Unmanned Aerial Vehicles*, 2018, China Classification Society: Section 1.5.
Element of Regulatory Blueprint	**Action Items**
Safety Management System	**Action Item 14 (Individual class society-developed definitions as the basis):** Consider incorporating valuable provisions related to "safety management system" with explicit reference to safety policy, safety risk management, safety assurance and safety promotion.
Reference for Further Information	*Guidance Notes on the Use of Remote Inspection*, 2019, American Bureau of Shipping: Sections 3 (7); 3(7.1), 3(7.3), 3(7.5) and 3 (7.7) (See Table 8 of this report).
Element of Regulatory Blueprint	**Action Items**
Liability Clause	**Action Item 15 (Individual class society-developed definitions as the basis):** Consider developing a standard "liability clause".
Reference for Further Information	*Procedures for Approval of Service Suppliers*, 2020, Lloyds Register: Section 3(13).
Element of Regulatory Blueprint	**Action Items**

Data Governance and Management	**Action Item 16 (On the basis of Intellectual Property Rights):** Hull inspection data should be kept confidential as this may constitute a trade secret for the shipowner. Legitimate practices should be in place for the collection, storage and use of unpublished data of economic significance. For overcoming barriers to data governance and data management, explicit provisions are needed in the form of a Contract that will specify the allocation of responsibilities and roles for the ownership, storage, security and sharing of information between service suppliers, classification societies and shipowners. Sound data governance principles are essential to help minimize risks and keep external cyber security threats out of their networks. The Contract should be signed during the planning stage of hull inspection; **Action Item 17 (On the basis of Intellectual Property Rights):** International guidance should elaborate on the provisions about data management from the use of remote techniques. Specifically, the guidance should specify data requirements for the Procedure for Approval and Certification of Suppliers. Guidance is required for manufacturers, service suppliers, classification societies and ship owners to ensure proper collection, storage, processing, using, sharing and destroying the digital data and metadata of hull inspection; **Action Item 18 (Defining Data Ownership):** Data ownership, which is one of the most critical parts of the data governance process, defines the rightful owner of the data elements, sharing policy and access rights to third parties granted by the data owner. During the planning stage of hull inspection, a clear understanding between service suppliers, classification societies, and ship owners/managers should be maintained about data ownership. If the service provider retains copyright ownership, this should be stated in the formal agreement that will be signed between the relevant parties to set out the terms under which the work may be produced, reproduced, distributed, edited, copied and used; **Action Item 19 (Scoping Data Preservation):** Digital data preservation gives reliable protection to information and systems needed to ensure the long-term usability of data and metadata. Clear allocation of responsibility should be given to the party which is responsible for data and image preservation. If the service provider is accountable for data preservation, this should be stated in the formal agreement signed between the relevant parties; **Action Item 20 (Scoping Data Security):** Distributed data between the different stakeholders intensifies data security efforts between participants in the data process. Cloud environments encounter increased security threats due to inadequate access management and system vulnerabilities. Measures should be in place for the security and confidentiality of remote inspection technology data by all the relevant stakeholders to ensure a sound data governance process. Each stakeholder should have an organizational "Information Systems Security Policy" and a "Backup Strategy" documentation. In the "Information Systems Security Policy" of each stakeholder, tools and techniques should be implemented to prohibit unauthorized access to programs and information resources. Users should have a unique user identifier (through passwords or other authentication mechanisms) to distinguish each user and establish accountability. In the "Backup Strategy" document, provisions should exist about backup tools, the backup scope, schedule, and infrastructure. Stakeholders could adhere to appropriate data security principles following ISO/IEC 15408 Information Technology - Security Techniques - valuation Criteria for IT Security and ISO/ IEC 27001: 2013 Information Technology - Security Techniques - Information Security Management Systems; **Action Item 21 (Considerations during the planning stage):** During the planning stage of hull inspection, it should be specified how the data is shared between the different stakeholders to ensure secure data transfer between data owners and users. Provisions should be clear about the sharing of data in the formal agreement. A secure industry platform could be utilized for secure data transfer between data owners and users, when saving and sharing the video stream from the remote survey. The concerned party should implement and administer access restrictions to ensure that only authorized individuals have the ability to access or use information resources. The use of Universal Serial Bus (USB) for data sharing is not recommended;

Action Item 22 (Explicit criteria through a formal agreement): In cases where a service robot autonomously captures images or data (without human intervention), provisions in the form of a formal agreement should be included to specify the copyright owner. A distinction between computer-aided data and computer-generated data is considered essential to identify the right-holder of data. The current copyright regime does not protect computer-generated data; thus, explicit provisions in the contract should be made to safeguard computer-generated works.

Besides, companies that develop software and software codes for service robots should be protected through copyright;

Action Item 23 (Determining liability): Potential liability issues that stem from the use of data should be underlined in the Contract. Input material supplied by the asset owner to the service supplier before the hull inspection (i.e., images, drawings and designs) should not infringe the copyright or other rights of a third party. In case of infringement, the service supplier shall be held unaccountable against any loss, damage, or other claims arising from such violation. On the other hand, hull survey data shall not be used for marketing reasons by the service supplier without the prior approval of the asset owner.

Table 7: Data Management Provisions for Inclusion in the Formal Agreement

Data governance stages for RITs and ROVs	**Provisions for inclusion in the Formal Agreement**
Collection of Data	- In the formal agreement, provisions should be included to indicate the copyright ownership of data and the terms under which the data may be produced, reproduced, distributed, edited, copied and used by its customer; - Digital data collected (picture and video quality) by the service supplier is to be reviewed in real-time and/or submitted to the attending Surveyor as agreed in the survey planning stage; - Visual data collected should be continuous and uninterrupted, with stable quality. If there are any gaps in the data, the Surveyor and owner/operator should be notified; - Data cannot be used for marketing reasons by the service supplier, without prior approval from the asset owner.
Storage	- The Service Provider should have data security policies to ensure that data and metadata is stored in a secure way that has minimum vulnerability to unauthorized manipulation and distribution; and - Each party in the agreement should have data storage and infrastructure policies for effective organizational data management.
Processing	The raw data and related metadata should be stored separately from any post processed data.

<table>
<tr><td></td><td><table>
<tr><td>Using</td><td>Data protocols governing data use and third user access should be put in place by each party.</td></tr>
<tr><td>Sharing</td><td>- Utilization of a secure industry platform to ensure secure data transfer between data owners and users, when saving and sharing the video stream from the remote survey;

- If the Remote Inspection Service Provider provides the data management system for remote access to the data, the security of the remotely accessed data is to be ensured (data encryption to protect digital data confidentiality may be applied);

- Third-party sharing provisions should be included in the agreement; and

The use of Universal Serial Bus (USB) for data sharing is not recommended.</td></tr>
<tr><td>Destroying</td><td>Specify when data is authorized for deletion</td></tr>
</table></td></tr>
<tr><td>Reference for Further Information</td><td>1. Approval of Service Supplier Scheme, 2016, Det Norske Veritas-Germanischer Lloyd: Sections 3.1 and 16.1.4 (see Table 8 of this report);

2. Guidance Notes on the Use of Remote Inspection, 2019, American Bureau of Shipping: Sections 4.9 and 4.11 (see Table 8 of this report); and

3. Guidelines for Use of Unmanned Aerial Vehicles, 2018, China Classification Society: Sections 1.3, 1.4, 3 and 4 (see Table 8 of this report).</td></tr>
<tr><td>Element of Regulatory Blueprint</td><td>Action Items</td></tr>
<tr><td>Harmonization between Statutory and Class Rules with Reference to Close-up Survey</td><td>Action Item 24 (IMO): Consider aligning the definition of close-up survey found in IMO’s Enhanced Survey Programme given that the current definition of close-up survey is inadequate given that IACS has created the possibility to use RITs for remote inspection allowing the surveyor to conduct close-up surveys through sensors.</td></tr>
<tr><td>Reference for Further Information</td><td>Amendments to the 2011 ESP Code: Use of Remote Inspection Techniques (RITs), 2019; SDC 7/10, Submitted by IACS</td></tr>
<tr><td>Element of Regulatory Blueprint</td><td>Action Items</td></tr>
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Controlling Variety for Optimum Quality Performance by Regulating Technical and Operational Standards	**Action Item 25 (Product categorization):** Develop a methodology to establish standards based on product categorization with the aim of reducing variety to identify the best product from all categories of RIT's endorsed by IACS. This approach requires stakeholder consultation and should serve as a foundation to guide future technology without inhibiting innovation. Additionally, further discussion among IACS members is warranted with due consideration given to other types of standard "equipment" found in IACS Recommendation 42.
Reference for Further Information	Johansson, T., *Advances in Robotics and Autonomous Systems for Hull Inspection and Maintenance* (2021) in "Emerging Technology and the Law of the Sea" (James Kraska and Young-Kil Park, eds.), Cambridge University Press;
Element of Regulatory Blueprint	**Action Items**
Creating a Remote Inspection Technique "Trustworthy Ecosystem" for End-users Conducting Remote Surveys	**Action Item 26 (Triple Helix assessments for increasing effectiveness of remote surveys and efficient end-user integration):** While, according to the current international rules and requirements, confirmatory surveys are conducted by surveyors to follow-up on the work completed using Remote Inspection Techniques, the nature of this task will likely require a governance scheme considering techniques that function under different degrees of autonomy in the near future, and in cases where surveys are done remotely, especially during pandemic-situations. Separate assessments should be conducted jointly by the Triple Helix (industry, government and academia) to develop, in detail, considerations that will enable end-users to conduct surveys on board and remotely using semi-autonomous/supervised-autonomous and fully autonomous systems. Researchers rely on the three stipulations of the EU High-Level Expert Group on Artificial Intelligence: lawful, ethical and robust, that will enable the creation of a "trustworthy ecosystem" that will, in turn, help determine the degree of reliance on confirmatory surveys and end-users' trust in the products deployed for survey and maintenance tasks.
Reference for Further Information	Pastra, A.; Schauffel, N.; Ellwart, T. and Johansson, T., (in press: September 2022: Autumn 14.2 volume) "Building a Trust Ecosystem for Remote Technologies in Ship Hull Inspections", *Journal of Law, Innovation and Technology*, Vol. 14 (2), (Taylor & Francis) High-Level Expert Groups on Artificial Intelligence, *Ethics Guidelines for Trustworthy AI*, European Commission, 1-36 (2019): https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

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3. Review of National Arrangements

ABBREVIATIONS

ESP Code	International Code on the enhanced programme of inspections during surveys of Bulk carriers and Oil tankers
2011 Guidelines	The 2011 Guidelines for the Control and Management of Ships' Biofouling to minimize the Transfer of Invasive Aquatic Species
ABS	American Bureau of Shipping
USCG	United States Coast Guard
CIP	Inter-American Committee on Ports
NOAA	National Oceanic and Atmospheric Administration
EPA	Environmental Protection Agency
NISA	National Invasive Species Act
ANS	Aquatic Nuisance Species
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act
CFR	Code of Federal Regulations
BWMP	Ballast Water Management Plans
BTCOE	Blue Technology Centre of Expertise

EPA	Environmental Protection Agency
VGP	Vessel General Permit
COTP	Captain of the Port
BMPs	Best Management Practices
EEZ	Exclusive Economic Zone
SLC	State Lands Commission
VGP	Vessel General Permit
META	Maritime Environmental and Technical Assistance
NSTC	National Science and Technology Council
NIST	National Institute of Standards and Technology
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
RINGS	Resilient and Intelligent Next-Generation Systems
EPIC	Electronic Privacy Information Centre
FTC	Federal Trade Commission
UMV	Unmanned Maritime Vehicle
OCMI	Officer in Charge, Marine Inspection
CG-CVC	Office of Commercial Vessel Compliance
OCS	Out Continental Shelf
COI	Certificate of Inspection
ROs	Recognized Organizations
TVNCOE	Towing Vessel National Centre of Expertise
SP	Service Provider
RFI	Request for Information
USVs	Unmanned Surfaces Vehicles
DHS	Department of Homeland Security
NAVSAC	Navigation Safety Advisory Council
COLREGs	International Regulations for Preventing Collisions at Sea
UMS	Unmanned Maritime Systems
SOCP	Ship Operations Cooperative Program
UAV	Unmanned Aerial Vehicle
AUVSI	Association for Unmanned Vehicle Systems International
MAC	Maritime Advocacy Committee
DoD	Department of Defense (US)
NOAA	The National Oceanic and Atmospheric Administration
MARAD	U.S. Maritime Administration
FAA	Federal Aviation Administration

NAS	National Airspace System
UAS	Unmanned Aircraft Systems
sUAS	Small Unmanned Aircraft Systems
UAG	Unmanned Aircraft General
NASA	National Aeronautics and Space Administration
AAM	Advanced Air Mobility
UAM	Urban Air Mobility
UTM	Unmanned Aircraft System Traffic Management
eVTOL	Electric Vertical Takeoff and Landing
USDOT	United States Department of Transportation
ADS	Automated Driving Systems
TNO Netherlands	Netherlands Organisation for Applied Scientific Research
ZBO	Autonomous Administrative Authority
WRR	Netherlands Scientific Council for Government Policy
AWTI	Advisory Council for Science, Technology and Innovation
ECHR	European Convention on Human Rights
AWGB	Algemene Wet Gelijke Behandeling (the Dutch General Equal Treatment Act)
GDPR	General Data Protection Regulation
UAVG	Uitvoeringswet Algemene verordening gegevensbescherming (GDPR Execution Act)
AVG	Algemene verordening gegevensberscherminga (New General Data Protection Regulation)
CCNR	Central Commission for the Navigation on the Rhine
NSI	Netherlands Shipping Inspectorate
ILT	Human Environment and Transport Inspectorate
AUVs	Autonomous Underwater Vehicles
RWS	Rijkswaterstaat
PoRA	Port of Rotterdam Authority
NMT	Netherlands Maritime Technology
SMASH!	The Netherlands Forum Smart Shipping
KVNR	Royal Association of Netherlands Ship-owners
PPPs	Public-private Partnerships
NEN	Dutch Committee for Standardization
CEN	European Committee for Standardization
VSNU	Association of Universities in the Netherlands
RDW	Netherlands Vehicle Authority
DGCA	Directorate General of Civil Aviation

ILT	Human Environment and Transport Inspectorate
RDW	Netherlands Vehicle Authority
LUC	Light UAS Operator Certificate
STS	Standard Scenario
EASA	European Aviation Safety Agency
ITS	Intelligent Transport Systems
SWOV	Dutch Institute for Road Safety Research
VSSF	Vehicle Safety & Security Framework
FSP	Functionality-Security-Privacy
DNB	De Nederlandsche Bank
SAFEST	Soundness-Accountability-Fairness- Ethics- Skills- Transparency
SWOT	Strengths-Weaknesses-Opportunities-Threats)
TC	Transport Canada
CEO	Chief Executive Officer
RPAS	Remotely Piloted Aircraft Services
CV	Connected Vehicles
AMII	Alberta Machine Intelligence Institute
Mila	Montreal Institute for Learning Algorithms
CNRS	Centre national de la recherche scientifique
UKRI	UK Research and Innovation
OECD	The Organisation for Economic Co-operation and Development
UNESCO	The United Nations Educational, Scientific and Cultural Organization
VSCR	Vessel Safety Certificate Regulations
GPS	Global Positioning System
USBL	Ultra Short Baseline
RD&D	Research, Development, and Deployment
R&D	Research and Development
ACATS	Advance Connectivity and Automation in the Transportation System
SEATAC	Sensing, Engineering, and Analytics Technology Access Centre
NSCC	Nova Scotia Community College
MEOPAR	Marine Environmental Observation, Prediction, and Response Network
NRC	National Research Council
RPAS	Remotely piloted aircraft systems
CPAs	Canadian Port Authorities
OCR	Optical Character Recognition
FY	Fiscal Year
OPP	Oceans Protection Plan

DFO	Fisheries and Oceans *Canada*
CCG	Canadian Coast Guard
NRCan	Natural Resources Canada
ECCC	Environment and Climate Change Canada
ROCs	Regional Operations Centres
GDP	Gross Domestic Product
OEMs	Original Equipment Manufacturers
CARs	Canadian Aviation Regulations
RPAS	Remotely Piloted Aircraft Systems
CCMTA	Canadian Council of Motor Transport Administrators
NOK	Norwegian krone
NTNU	Norwegian University of Science and Technology
EEA	European Economic Area
NMA	Norwegian Maritime Authority
NOR	Norwegian Ordinary Ship Register
NIS	Norwegian International Ship Register
ABS	American Bureau of Shipping
BV	Bureau Veritas
HSS	Hull Skating Solutions
LED	light-emitting diode
NFAS	Norwegian Forum for Autonomous Ships
ConOps	Concept of operations
VLOS	Visual Line of Sight
BLOS	Beyond Line of Sight
RPAS	Remotely Piloted Aircraft System
ICAO	International Civil Aviation Organization
CONOPS	Concept of Operations
SORA	Specific Operations Risk Assessment
RPAS	Remotely Piloted Aircraft Systems
ITU	International Telecommunication Union
NAPLab	NTNU Autonomous Perception Laboratory
FDI	Foreign Direct Investment
MPA	Maritime and Port Authority
MINT	Maritime Innovation and Technology
MTP	Maritime Transformation Programme
MPs	Members of Parliament
MOT	Ministry of Transport

IMDA	Infocomm Media Development Authority
PEP	Pro-Enterprise Panel
eBL	electronic Bills of Lading
AISG	Artificial Intelligence Singapore
NRF	National Research Foundation
SRS	Singapore Registry of Ships
IACS	International Association of Classification Societies
RIT	Remote Inspection Techniques
UAS	Unmanned Aircraft System
NDT	Non-Destructive Test
JIP	Joint Industry Project
MoU	Memorandum of Understanding
LNG	Liquefied Natural Gas
MSP	Marina South Pier
ESDN	Electronic Supply Delivery Note
SMEs	Small and Medium-sized Enterprises
RSI	Remote Ship Survey and Inspection
EDB	Economic Development Board
TEUs	Twenty-foot Equivalent Units
AGVs	Automated Guided Vehicles
TR	Technical Reference
UAPL	Unmanned Aircraft Pilot Licence
CAAS	Civil Aviation Authority of Singapore
LTA	Land Transport Authority
EVs	Electric Vehicles
AI	Artificial Intelligence
AIOIPs	National New Generation Artificial Intelligence Open Innovation Platforms
APU	Accelerated Processing Unit
BAAI	Beijing Academy of Artificial Intelligence
BCH	Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, as amended
BSO	British Standardization Organization
BWM	International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, as amended
CAAC	Civil Aviation Administration of China
CCP	Chinese Communist Party
CCS	China Classification Society

CEN	The European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CMSA	China Maritime Safety Administration
COP	Conference of the Parties
CSDC	China Ship Design & Research Center
CTCN	Climate Technology Centre and Network
DNV	Det Norske Veritas
DoA	Description of Actions
ESTs	Environmentally Sound Technologies
ETSI	European Telecommunications Standards Institute
EU	European Union
FRAND	Fair, Reasonable and Non-discriminatory
GBS	Global Based Standards
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GL	Germanischer Lloyd
GPU	Graphics Processing Unit
HSSC	The Survey Guidelines under the Harmonized System of Survey and Certification, 2019
IBC	International Code for the Construction and Equipment of Ships Carrying
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended
IoT	Information of Things
IP	Intellectual Property
IPRs	Intellectual Property Rights
IT	Information Technology
ITU	International Telecommunication Union
KPI	Key Performance Indicators
LDCs	Least Developed Countries
LLC 66/88	International Convention on Load Lines, 1966 as modified by the Protocol of 1988 relating thereto, as amended
LR	Lloyds Register
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, and as further amended by the Protocol of 1997, as amended
MASS	Maritime Autonomous Surface Ships

MAV	Micro Aerial Vehicles
MC	Magnetic-wheeled Crawlers
MOST	Ministry of Science and Technology
NDCs	Nationally Determined Contributions
NK	Nippon Kaiji Kyokai
NPC	National People's Congress
P&I Clubs	Protection and Indemnity Clubs
Polar Code	International Code for Ships Operating in Polar Waters
PRC	People's Republic of China
RAS	Robotic and Autonomous Systems
RINA	Registro Italiano Navale
RO	Recognized Organizations
RS	Russian Maritime Register of Shipping
SAC	Standards Administration of China
SEEMP	Ship Energy Efficiency Management Plan
SEP	Standard Essential Patent
SOLAS 1974	International Convention for the Safety of Life at Sea, 1974
SSO	Standard Setting Organization
TC	Technical Committees
TEC	Technology Executive Committee
TNAs	Technology Needs Assessments
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
UCAEZs	Unmanned Civil Aviation Experimental Zones
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
UR	Unified Requirements
US	United States
WIPO	World Intellectual Property Organization
NSDS	National Sustainable Development Strategies
SDGs	Sustainable Development Goals
SET Plan	Strategic Energy Technology Plan
CO2	Carbon Dioxide
NOX	Nitrogen Oxides
SOX	Sulphur Oxides
PM	Particulate Matter
EEDI	Energy Efficiency Design Index

GT	Gross Ton

3.1 Setting the Scene

Digitization and the emergence of Artificial Intelligence-based technologies are increasingly pervading all areas of our lives, posing multiple challenges for nations. AI has turned into a strategic priority for governments leading to global competition for the development of AI applications and policies (Smuha 2021). In 2017 Canada became the first country to establish a national plan for AI, the "Pan-Canadian Artificial Intelligence Strategy," to foster a collaborative AI ecosystem by establishing interconnected nodes of scientific excellence in three major centres for AI: Edmonton, Montreal, and Toronto. The European AI strategy (2018) specifies the EU's goal to "lead the way in developing and using AI for good and for all, building on its values and its strengths." In 2019, the United States, through Executive Order 13859, promised to sustain and enhance the scientific, technological, and economic leadership position in AI research and deployment through a coordinated Federal Government strategy (Centre for Homeland Defense and Security, 2019). The same year, Singapore launched the "National AI Strategy" that spells out plans to deepen the use of AI technologies and rethink business models by 2030. With its ambitious "Next Generation Artificial Intelligence Development Plan," China has set out a top-level design blueprint charting its approach to developing AI technology by 2030.

From the above mentioned, we note that the governments have realised the necessity to adopt policies that can stimulate beneficial innovation while safeguarding their citizens from AI's risks. Safety, responsibility, and product liability aspects of AI, including negligence, design defects, and manufacturing defects, usually fall into a legal and regulatory vacuum. At the same time, participants in regulatory debates hold diverging views of autonomy. Promoting uniformity in approaches that relate to safety and liability is vital to mitigate possible AI harms and ensure that AI is 'trustworthy,' namely legal, ethical and robust.

The different AI national plans set specific targets for the ocean and maritime sectors, including research and development of autonomous vessels and autonomous onboard systems. In this context, autonomous and semi-autonomous remote inspection techniques for vessel inspection have triggered the attention of the relevant stakeholders. IMO, the global standard-setting authority for the maritime sector, is the body that could facilitate with appropriate requirements and guidelines the safe and practical application of autonomous and semi-autonomous RITs. The IMO can develop a regulatory framework that will be universally adopted and implemented, enabling Flag Registries, Classification Societies and ship-owners to adhere to relevant norms and regulations. Regulations and policies for ship inspection and hull cleaning to prevent the spread of invasive species should be handled through international conventions, uniform norms and standards.

The current national comparative study aims to contribute to the reform and the progressive development of uniform norms for autonomous robotics regulation and standards. To ensure a satisfactory outcome, the national comparative study has the following objectives:

- Review status of national norms, regulations, standards, and initiatives related to autonomous robotics, artificial intelligence, autonomous ships, and remote inspections;
- Advance understanding of the regulatory and self-regulation national approaches for robot-technologies and remote inspections;

• Exemplify the existing usage of different regulatory tools in the aviation and automotive sectors;

• Identify the national strengths and weaknesses of the country and the opportunities and threats to which it is exposed; and

• Identify best practices that could be utilized to produce a distinctive and state-of-the-art regulatory and policy blueprint.

Data was collected through primary and secondary sources of information. Secondary sources included scholarly materials written by legal experts, governmental publicly available documents, legal directories and policy documents provided by maritime administrations. Primary data was collected through in-depth semi-structured interviews with maritime administrations, policy advisors, classification societies, service providers and subject matter experts. The discussions took place between March and July 2021 and the organizations and agencies interviewed are presented in Table 1. The interviewees offered their view on how leading countries are paving the way to autonomous operations, more specifically hull inspections and cleaning, through technological advancements. The information gathered helped flesh out a distinctive regulatory and policy blueprint considering the state-of-the-art as well as gaps and drawbacks, which can be used by the concerned regulatory bodies when developing new regulations or reforming existing laws and policies.

3.2 The United States of America (US)

The United States of America (US) is a maritime nation comprising 25,000 miles of coastal and inland waters and rivers serving 361 ports (USCG, 2018). It is apparent that the US marine transportation system is expansive. It includes waterways, ports and land-side connections, moving people and goods to and from the water. US's extensive network of ocean, coastal, and inland waterways, harbours, and seaports supports $4.6 trillion of economic activities each year and accounts for the employment of more than 23 million Americans (AAPA, 2019). At a glance, the marine transportation system includes (approximately):

- 25,000 miles of navigable channels;
- 250 locks;
- 3,500 marine terminals;
- thousands of recreational marinas; and
- and the Great Lakes and St. Lawrence Seaway (U.S. Department of Transportation, n.d.)

This review of the US case study is based on primary and secondary sources of law, as well as explanations and rational interpretations provided by respondents interviewed between May and July 2021. Interviews were conducted with senior advisors from the US Coast Guard (USCG) and the Flag State Control Division of the USCG, Association for Unmanned Vehicle Systems International, Marine Consulting, University of Florida Levin College of Law, DNV US and TMA BlueTech. Significant input and feedback were provided by Mr. Sean T. Pribyl, Esq., Senior Counsel of Holland & Knight LLP and member of the WMU-GOI BUGWRIGHT2 Senior Advisory Group on the regulatory framework for Artificial Intelligence (AI) technologies and autonomous operations. In addition, critical insight was provided by two members of the WMU-GOI BUGWRIGHT2 Senior Advisory Group: Mr. Andrew Baskin, Vice President, Global Policy and

Trade of HudsonAnalytix, Inc.; and Ms. Mona Swoboda, Program Manager of the Inter-American Committee on Ports.

3.2.1 Brief Overview: National Law & Policy with a Focus on BUGWRIGHT2 Technologies

3.2.1.1 Overview of the National System

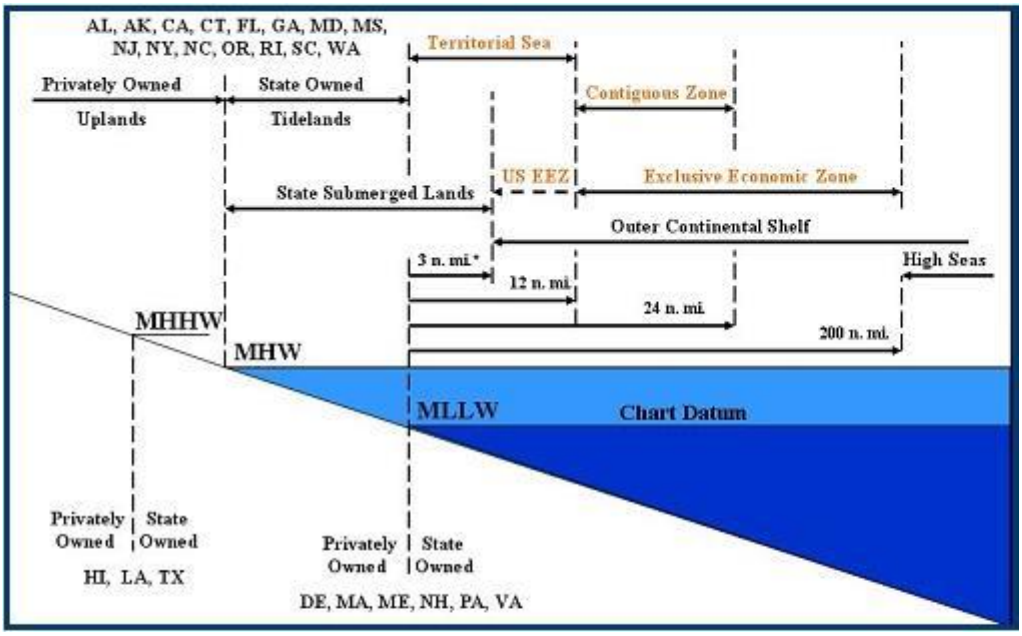
The US federal government comprises 50 States, a Federal District, five major self-governing territories, and several island possessions. Each State has its own legislation. The Federal Government typically allows the States to implement their environmental legislation with some oversight to ensure that the State legislation is at least equivalent to the Federal legislation. Congress is the legislative branch of the federal government and is responsible for the creation of national laws. There are two distinct legislative bodies of Congress: the US Senate and the US House of Representatives. A new legislation may be proposed by anyone elected to either the House of Representatives or the Senate (USA.gov, n.d.). The legislative proposals that are presented before the US Congress are called Congressional bills (govinfo, n.d.). First, a bill is sponsored by a representative. A committee is then appointed to study the bill. If the committee releases the bill, it is placed on the agenda for vote, debate, and amendment. If the bill is approved by a simple majority (218 of 435), it will be sent to the Senate, where it is assigned to another committee of the Senate and, if released, discussed and voted on. Here again, the bill passes with a simple majority (51 of 100). Ultimately, a conference committee comprised of delegates from both the House and Senate resolves any differences in the House and Senate iterations of the bill. It is then returned to the House and Senate for final approval via a process called enrolling. After approval, the Government Printing Office prints the revised bill. Finally, the US President must sign or veto the bill within 10 days (US House of Representatives, n.d.). Public bills address issues affecting the general public, whereas private bills address issues affecting individuals or organizations, such as lawsuits against the government (govinfo, n.d.).

Jurisdiction:

The US maritime domain involves a complex regulatory framework in a variety of locations, from inland ports and waterways to the high seas, often with overlapping legal authorities and agency-responsibilities. Several jurisdictional zones exist in the maritime domain that may implicate international and domestic law. Within these zones, governments assert varying degrees of authority over specific activities. The location and use of the autonomous systems' operations may call into play multiple overlapping jurisdictional concerns, including domestic and international legal obligations (Pribyl, 2018).

Maritime commerce in the US generally falls under recognized maritime zones that include internal waters, the territorial sea, the contiguous zone, the exclusive economic zone (EEZ), the continental shelf, the high seas and the Area (NOAA, 2021). Maritime limits and boundaries for the US are measured from the official US baseline, recognized as the low-water line along the coast as marked on the NOAA nautical charts in accordance with relevant articles of the Law of the Sea: the territorial sea (12 nautical miles), contiguous zone (24nm), and exclusive economic zone (200nm, plus maritime boundaries with adjacent/opposite countries) (NOAA, n.d.).

Figure 5: Maritime Zones in the US



Source: NOAA, n.d.

The US does not have regulations that directly address automated hull cleaning systems. Within the US federal government framework, there is no clearly defined lead agency for the entire marine transportation system. Rather, responsibility for areas such as vessel traffic management, marine safety, waterway maintenance, environmental protection, customs and border protection, and national security stretches across a variety of agencies. Agencies involved in enforcing laws related to these issues include the Department of Homeland Security, US Coast Guard (USCG), Immigration and Customs Enforcement, Customs and Border Protection, Department of Transportation, US Army Corps of Engineers, National Oceanic and Atmospheric Administration (NOAA), and Environmental Protection Agency (EPA).

To support the ongoing objective of further reducing the potential risk of the spread of invasive aquatic species by shipping, the USCG, EPA, and the State of California have incorporated regulations specifying operational measures to prevent the spread of invasive aquatic species via biofouling.

USCG:

The USCG has 11 statutory missions and maintains broad authority over navigation safety in the navigable waters of the United States, including the ability to order vessels to operate as directed (33 U.S.C. § 1223). The Coast Guard prescribes regulations for the inspection and certification of vessels (46 U.S.C. § 3306). Also, the Coast Guard safeguards marine protected resources by enforcing living natural resource authorities like the Magnuson-Stevens Fisheries Conservation and Management Act 16 U.S.C. § 1801, the Lacey Act 16 U.S.C. §§ 3371-3378, the Endangered Species Act 16 U.S.C. §§ 1531-1544, and the National Marine Sanctuaries Act 16 U.S.C. §§ 1431-1445. The Coast Guard may also respond to discharges or threats of discharges of oil and hazardous substances into the navigable waters of the US and promulgate certain pollution prevention regulations (33 U.S.C. § 1321).

Environmental Stewardship is one of the key missions of the USCG. The most relevant USCG authorities dealing with hull fouling are those that are working to promote marine environmental protection. Over the past four decades, the environmental effects of the MTS have become a topic of increasing importance around the world. In recent years, the US and international regulations and standards addressing airborne and waterborne discharges from ships and pollution handling at waterfront facilities have sought to prevent environmental pollution. Coast Guard marine and facility inspectors monitor and enforce compliance (with laws and regulations) concerning pollution from recreational and commercial vessels, emanating from a variety of sources, including anti-fouling paints.

The current state of biofouling regulation remains fragmented from international levels to local jurisdictions, including the US. Entities have taken one of two general approaches to biofouling management, i.e., developing policies that either: a) recommend and/or require hull management regimes, or b) require that vessels arrive with “clean” hulls (usually in addition to requiring specific maintenance practices). The IMO, the USCG, Australia, and California are examples of the first approach, requiring a set of anti-fouling practices and ships documentation, and in some cases (California, Australia), also specifically requiring removal of fouling “on a regular basis”. The underlying assumption behind this approach is that these specified (or sometimes unspecified) anti-fouling practices are sufficient to reduce biofouling risks to an acceptable level. It is unclear whether this assumption is correct, but these types of regulations are more likely to be accepted by the shipping industry and compliance can be more readily documented (USCG, 2015).

The USCG has the authority to prevent the introduction and spread of aquatic nuisance species (ANS) through hull fouling, *inter alia*. This authority is granted by the National Invasive Species Act of 1996 (NISA), which amended the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA). The USCG has exercised this authority by requiring the regular cleaning of vessel hulls, via regulations in 33 Code of Federal Regulations (CFR) 151.2035. Regulations for in-water cleaning are also in place or under development in a handful of foreign countries and some states, most notably California. The USCG pursuant to the NISA, is tasked with controlling the introduction of invasive species. As per the NISA, the USCG operates a ballast water program to minimize the risk of introduction of invasive species.

Federal and State regulations prohibit the discharge of debris resulting from hull cleaning in state waters. The USCG currently addresses hull fouling and hull husbandry related to non-indigenous species through regulations included in 33 CFR §151.2035 that require rinsing of anchors and anchor chains to remove organisms and sediment, and removal of fouling organisms from the hull, piping and tanks on a regular basis. Additionally, although crude oil tankers engaged in coastwise trade are exempt from the requirements of 33 CFR §151.2035 by statute, many ship companies trading via tankers conduct voluntary hull maintenance operations, generally in conjunction with regular dry dock inspections mandated by Merchant Class Societies such as the International Association of Classification Societies, Ltd (IACS), and the US Coast Guard.

In accordance with 33 CFR 151.2050 (e): every vessel equipped with ballast tanks operating in US Waters is required to rinse anchors and anchor chains when the anchor is retrieved to remove organisms and sediments at their places of origin. In addition, these vessels are required by 33 CFR 151.2050(f) to remove fouling organisms from the vessel’s hull, piping, and tanks on a regular basis and dispose of any removed substance in accordance with local, State and Federal regulations.

To assist the owners/operators and ship’s crew, as well as Coast Guard Inspecting Officers/Teams, in the management of biofouling, the USCG regulations (33 CFR 151.2050(g)) specify that the required Ballast

Water Management Plan shall include detailed fouling maintenance procedures. While the regulations do not detail the items to be included within the fouling maintenance procedures, the USCG has advised that IMO Resolution MEPC.207(62) and the California State Lands Commission (specifically Sections 2298.3 entitled “Biofouling Management Plan” and 2298.4 titled “Biofouling Record Book”) provide a basis for developing and implementing a vessel-specific biofouling management plan. The USCG has also advised that inclusion of such a biofouling management plan in the required Ballast Water Management Plan or a reference in the Ballast Water Management Plan to an independent vessel-specific Biofouling Management Plan would satisfy this regulation. The prevention of biofouling, as such, is observed as being a critical aspect of the Plan.

The USCG does not require the approval of Ballast Water Management Plans (BWMP), except that a ship-specific BWMP is to be maintained on board the vessel following the requirements in 33 CFR 151.2050(g). However, approval of the Ballast Water Management Plan is required by the IMO Ballast Water Management Convention since its entry into force on 8 September 2017.

In addition to the aforementioned, the Blue Technology Centre of Expertise (BTCOE) of the Coast Guard is a department relevant to the aims of this project and dedicated to innovative ocean-focused technologies to enhance the service’s missions. BTCOE aims to create public awareness for the Coast Guard missions and technology requirements and to facilitate the integration of state-of-the-market tools and capabilities.

Environmental Protection Agency (EPA)

The EPA administers the Vessel General Permit (VGP) which is issued to commercial ships in US waters. As a part of VGP 2.2.23, vessel owners are required to remove fouling organisms from the vessel’s hull, piping, and tanks regularly and properly dispose of any detrimental substances in accordance with local, State and Federal regulations. In addition, all ships equipped with a ballast water tank must clean tanks, anchors and anchor chains, removing organisms and sediments at their places of origin.

Furthermore, the EPA requires vessel owners/operators to minimise the release of copper-based antifouling paint into the water during vessel cleaning. Vessels that use copper-based antifouling paint are required to refrain from cleaning the hull in copper-impaired water within the first 365 days after the initial paint application short of a significant visible indication of hull fouling. Generally, vessel owners/operators must minimize the transport of attached living organisms when they travel into the US waters from outside the US economic zone or when traveling between COTP zones (EPA, 2013). It remains unclear how “minimize” is interpreted, evaluated, and enforced.

The EPA’s “Underwater Ship Husbandry Discharges” contains information on best management practices (BMPs) for reducing pollutant discharges during underwater ship husbandry (EPA, 2011). Underwater ship husbandry is the maintenance of the underwater portions of a vessel, usually initiated in response to marine biofouling of the underwater hull and hull appendages of boats and ships including propellers, rudders, through-hull fittings, and corrosion control equipment.

The EPA prohibits hull cleaning that produces a visible plume when within the EEZ of the US. Whenever possible, rigorous hull-cleaning activities should take place in dry dock, or at other land-based facilities where the removal of fouling organisms or antifouling paint coatings can be contained. If water-pressure based systems are used to clean the hull and remove old paint, facilities which treat the wash water prior to discharge to remove the antifouling compound(s) and fouling growth from the wash water should be used. If mechanical means (scraping, etc.) are used to clean the hull and remove old paint, the materials removed from the hull during that process should be collected and disposed of properly (e.g., onshore). The materials removed should not be allowed to contaminate nearby waters. Vessel owners/operators who remove fouling organisms from hulls while the vessel is waterborne must employ methods that minimise the discharge of fouling organisms and antifouling hull coatings. These shall include:

- Use of appropriate cleaning brush or sponge rigidity to minimise removal of antifouling coatings and biocide release into the water column;
- Limiting use of hard brushes and surfaces to the removal of hard growth; and
- When available and feasible, use of vacuum control technologies to minimize the release or dispersion of antifouling hull coatings and fouling organisms into the water column.

Both the USCG and EPA refer to the International Marine Organization's (IMO) Marine Environmental Protection Committee (MEPC) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species adopted at MEPC 62 in July 2011 (IMO, 2011). Table 1 provides a summary of the US Management Strategies for Underwater Ship Husbandry (EPA, 2011).

Table 8: Summary of U.S. Management Strategies for Underwater Ship Husbandry

Country or State	Management Strategy	Details
United States	Vessel General Permit (VGP)	Underwater ship husbandry must be conducted in a manner that minimizes the discharge of fouling organisms and antifouling hull coatings, and the cleaning of copper-based AFCs must not produce a visible plume of paint. Rinse anchor chains and anchors at place of origin. Remove fouling from hull, piping and tanks on a regular basis. Dispose wastes in accordance with local, State, and federal law.
California	State VGP 401 certification requirements	Propeller cleaning is allowed until January 1, 2012. All other underwater hull cleaning is prohibited without special permission from the State Lands Commission (SLC) and State Water Board. Submit annual Hull Husbandry Reporting Form. Rinse anchor chains and anchors at place of origin Remove fouling from hull, piping and tanks on a regular basis. Dispose wastes in accordance with local, State, and federal law.
Hawaii	Information Framework Targeting High Risk Vessels (Proposed)	Pro-active measures: Education/outreach, vessel arrival monitoring, evaluation for high-risk arrivals Re-active measures: Rapid response/investigation of high-risk event post-event measures: long term regulations for high-risk events Limit time in port Vessel quarantine Out of water cleaning
Maine	State VGP 401 certification requirements	No vessel may conduct underwater hull cleaning except as part of emergency repairs
Merchant Classification Societies	Requirements (Applies to majority of merchant fleet)	Dry dock requirements vary somewhat depending on classification society. Cleaning and painting is usually conducted, but is at the discretion of the company. Interim underwater cleanings are done periodicity at the discretion of the company, typically dependent on results of fuel consumption tests

Source: EPA, 2011

MARAD:

The US Maritime Administration's (MARAD) Maritime Environmental and Technical Assistance (META) Program supports the research and development of emerging technologies, practices, and processes that improve maritime industrial environmental sustainability (U.S. Department of Transportation, 2021c). Since the early 2000s, MARAD has cooperated with the maritime sector to tackle issues related to the introduction of non-indigenous aquatic species through ballast water and hull biofouling. The Agency established its Ballast Water Initiative to assist industry and government agencies in moving treatment technologies from the laboratory to shipboard application. With support and guidance from MARAD, the Alliance of Coastal Technologies and Maritime Environmental Resource Centre have taken the lead on international efforts to facilitate the development and approval of ship biofouling in-water cleaning innovations.

California:

California's Marine Invasive Species Program is a program that reduces the risk of introduction of aquatic non-indigenous species into California's waters and works to prevent new species introductions by implementing vessel ballast water and biofouling management requirements that are authorized by the Marine Invasive Species Act. The governing agency is the California Land Acts Commission.

The State of California has regulations that govern biofouling and "anti-fouling systems". The "Biofouling Management Regulations to Minimize the Transfer of Nonindigenous Species from Vessels Arriving at California Ports" (California Code of Regulations, title 2, section 2298.1 et seq.) are aligned with the International Maritime Organization's 2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Resolution MEPC.207(62)). The Regulations focus on efforts to prevent biofouling accumulation on a vessel's wetted surfaces, move the State expeditiously toward elimination of the discharge of non-indigenous species into the waters of the State, or into the waters that may impact the waters of the State, based on the best available technology economically achievable (California State Lands Commission, 2017). The master, owner, operator, or person in charge of a vessel carrying ballast water that arrives at California port shall maintain a Biofouling Management Plan.

Jones Act Fleet:

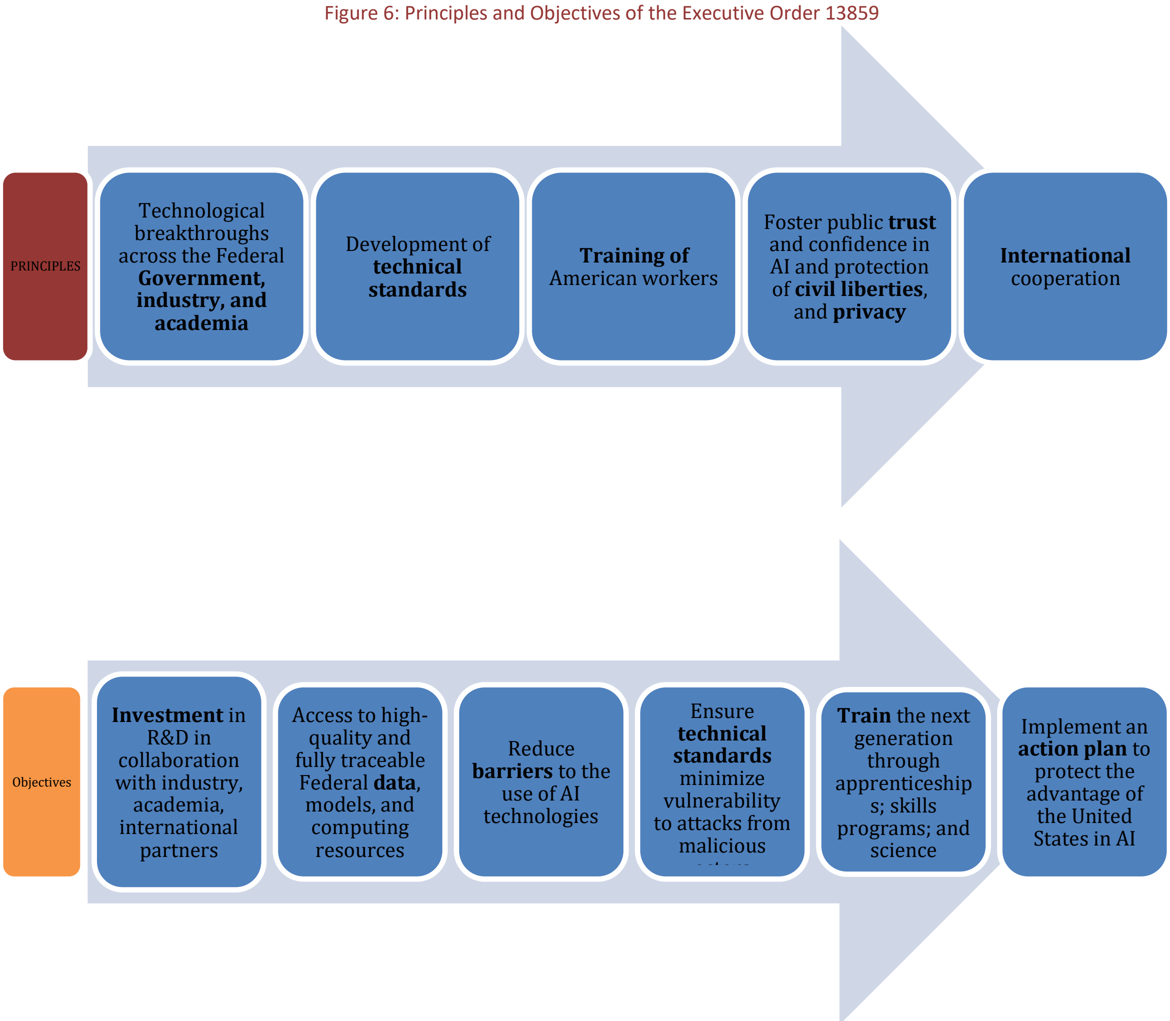
Maritime commerce in US waters is regulated by the Jones Act, which refers to Section 27 of the Merchant Marine Act of 1920, promoting American vessels from foreign competition. This primary federal law specifies that cargo shipped between US ports should be transported by US-built, owned, and crewed vessels. The 40,000 vessels that comprise the Jones Act fleet transfer millions of tons of cargo annually along US internal waterways, across the Great Lakes, and over the oceans to Hawaii, Alaska, Puerto Rico, and the US territories. Regarding the US merchant marine, the flag privately-owned Fleet of 1,000 gross tons or greater entails 180 vessels from which 96 are Jones Act Eligible and 84 Non-Jones Act Eligible (U.S. Department of Transportation, 2021a).

3.2.1.2 National Framework for AI Technologies and Autonomous Operations

The US, through its robust innovation ecosystem, can strengthen even further its role as one of the global leaders in technology. There is no comprehensive Federal legislation on AI. The current framework is largely dependent on existing rules covering issues such as product liability, data privacy, intellectual property, unfair treatment and discrimination.

On 11 February, 2019, the US President launched the American Artificial Intelligence Initiative, the Nation's strategy for promoting American leadership in AI, by signing Executive Order 13859: "Maintaining American Leadership in Artificial Intelligence" (Center for Homeland Defense and Security, 2019. The aim of the Executive Order is to enhance the scientific, technological, and economic leadership position of the US through a coordinated Federal Government strategy. The American AI Initiative (coordinated Federal Government strategy) is based on five principles: AI research funding, unleashing Federal AI computing and data resources, setting AI technical standards, nurturing America's AI workforce, and fostering international partnerships (Figure 2). The Initiative is coordinated by the National Science and Technology Council (NSTC) Select Committee on Artificial Intelligence (Select Committee).

Figure 6: Principles and Objectives of the Executive Order 13859



Source: Adapted from Executive Order 13859

In addition, concerns over malicious uses and abuses of AI have spurred attempts to explore and set standards, such as the US National Institute of Standards and Technology (NIST) initiative, which involves discussions and workshops to develop federal standards that serve as the foundation for robust, reliable, and trustworthy AI systems. (NIST, 2019). State legislators are also exploring the advantages and challenges of AI, as an increasing number of new measures have been proposed to evaluate the effect of AI and policymakers' potential roles. (NCSL, 2021).

Further, in February 2020, one year after the AI Initiative was released, the First Annual Report of the American Artificial Intelligence Initiative was published to assess the progress toward achieving the national strategy's objectives (Executive Office of the President of the United States, 2020). Among others, the country was urged to eliminate impediments to the safe development and testing of AI technologies. This should be accomplished primarily by appropriate guidance that is compatible with the Nation's values and technical standards for AI.

Consistent with Executive Order 13859, the Office of Management and Budget (OMB) in cooperation with the Office of Science and Technology Policy (OSTP) issued a draft memorandum in early 2020 with guidelines governing how federal agencies should develop and use AI technologies (Office of Management and Budget, 2021). The memorandum establishes ten Principles for good Stewardship in relation to AI Applications that agencies should take into account before enforcing regulation:

1. Public Trust through the promotion of reliable, robust, and trustworthy AI applications;
2. Public Participation in all the phases of the policymaking process;
3. Scientific Integrity and Information Quality throughout the rulemaking process:
4. Risk Assessment and risk management for regulatory and non-regulatory approaches to AI across various agencies and various technologies;
5. Benefits and Costs assessment before considering regulations related to the development and deployment of AI applications;
6. Flexible approaches that can be adapted easily to technological changes;
7. Fairness and Non-Discrimination with respect to outcomes produced by the AI application;
8. Disclosure and Transparency for addressing questions about how the application impacts human end-users;
9. Safety and Security methods and approaches for the development of AI systems that guarantee systemic resilience and prevent malicious actions and exploitations of AI system weaknesses; and
10. Interagency Coordination for consistency and predictability of AI-related policies.

Following the Presidential Executive Order 13859 and the establishment of the AI Initiative, the White House Office of Science and Technology Policy released the new "AI.gov" website (The White House, 2021a). This will provide American citizens with information on federal government activities advancing the design, development and responsible use of trustworthy AI (The White House, 2021a).

The Resilient and Intelligent Next-Generation Systems program (RINGS), with a funding of 40 billion US dollars– is the largest public-private partnership effort for advanced communications' technologies that visions to boost US leadership in next-generation wireless networks and satellite systems (The White House, 2021b). Private partners include companies such as Apple, Ericsson, Google, IBM, Intel and Microsoft.

Finally, to establish federal regulations for commercial AI use, the Electronic Privacy Information Center (EPIC) petitioned the Federal Trade Commission (FTC) to conduct rulemaking concerning the use of AI in commerce (EPIC, 2020). The goal is to define and avoid consumer harms resulting from AI products. EPIC called on the FTC to enforce the AI standards established in the Recommendation of the OECD Council on Artificial Intelligence (OECD, 2019), the OMB AI Guidance (Office of Management and Budget, 2021) mentioned above, and the Universal Guidelines on Artificial Intelligence (The public voice, 2018).

3.2.1.3 National Maritime Framework for Remote Inspections

The Coast Guard is responsible for inspecting vessels registered in the US or sailing in US waters. In terms of autonomous vehicles, the USCG is the lead agency for marine vehicles and exercises its oversight in this regard under its port state control, vessel inspection, environmental compliance, and navigational safety authorities.

The USCG generally uses the term "hull cleaners" as autonomous or semi-autonomous underwater robots used to scrub ship hulls clean while still in the water. Hull cleaning robots in the US are used in one of the three operation modes: manual, semi-autonomous and autonomous. In manual mode, the robot is completely under the control of a human operator – in autonomous, the robot operates with no interaction from humans. Semi-autonomous robots automate some of their functions but not all.

One of the most prevalent operational considerations is whether a "marine vehicle" or "robot" will be deemed a "vessel" since US maritime law generally refers to and applies to "vessels" and thus, such determination involves questions of fact, law, and policy. An important threshold-relevant matter is determining a respective unmanned system's "legal status" because there are numerous types of unmanned system platforms that vary in size and capabilities with different designation, and whether a given UMV is deemed a "vessel" also depends on a review of the context of the purpose, classification, design, and operational characteristics of a respective UMV.

Based on the information provided via email communication with the Flag State Control Division, the number of US Flag Inspected Vessels is presented in Table 15. The majority of the fleet is comprised of barges, passenger and towing vessels.

Table 9: Buber of US-flagged Vessels

Barge	5086
Cargo	570
Outer Cont. Shelf Vessels	522
Passenger	6556
Research or School	56
Towing	6608

Source: US Flag State Control Division

According to 33 CFR 1.01-20, the Coast Guard delegates this responsibility to Officer in Charge of Marine Inspection (OCMI) that has the primary responsibility for inspecting vessels to ensure compliance with applicable relevant laws and regulations related to safe construction, operation and manning (govinfo, 2001). The Office of Commercial Vessel Compliance (CG-CVC) is the designated body for the development and maintenance of marine safety and security policies and standards.

According to the Chief of Commercial Vessel Compliance of the United States Coast Guard, there are currently no regulations that govern the use of remote technologies. As a response to the COVID-19 crisis and considering the lessons learned --- guidelines and tick-boxes will be developed in the near term to specify under what circumstances remote technologies could be utilized. Most of the statutory surveys are performed by Recognized Organizations (ROs) that are acting on behalf of the Coast Guard. ABS is the largest RO in the US. For remote inspections, the Coast Guard approves it based on a case-by-case assessment.

In March 2020, the Marine Safety Information Bulletin 09-20 of the Coast Guard Assistant Commandant for Prevention Policy included information about “Vessel Inspections, Exams, and Documentation”. During the COVID-19 outbreak, the Coast Guard encouraged its inspectors to use remote methods to verify vessel compliance, stating that the relevant units should “liberally use remote inspection techniques to verify vessel compliance, and if needed, defer inspections”. Under this guidance, US-flagged vessels and US Out Continental Shelf (OCS) units due for required Certificate of Inspection (COI) renewal, annual inspection, dry dock exams or internal structural examinations could pursue remote evaluation based on documentary evidence. Eligibility is assessed on a case-by-case basis by the local Coast Guard Officer in Charge, OCMI and vessel operators. ROs/TPOs that will use remote survey in lieu of attendance on vessels that are both classed and certificated are required to contact the Flag State Control Division (CG-CVC-4) or the Towing Vessel National Center of Expertise (TVNCOE) to propose the methods and administrative procedures that will be used.

The Coast Guard has been utilizing remote techniques for operational inspections, including photos for deficiencies and inspections prior to the COVID-19 outbreak, and, since the pandemic, the capabilities for routine inspections expanded. However, given the current stage of technological development, remote techniques have not yet achieved an optimum level since they cannot substitute the human element, given that they do not possess senses of hearing, vibrations, and smell. More studies are needed to compare the existing regime of inspections with remote technologies to provide evidence as to which option is better suited and feasible.

The US Coast Guard provided a summary with the relevant links of the Acts and policies for the current regime of statutory inspections. The information has been synthesized in the following table:

Table 10: Summary of the links of the Acts and policies for the regime of statutory inspections

Links for the Acts and policies for the regime of statutory inspections: Office of Commercial Vessel Compliance (CG-CVC)	
Links	**Description**
Marine Safety Manual Vol. II Materiel Inspection	This Manual establishes marine safety policies and guidance for use by industry, mariners, the General Public, and the Coast Guard, as well as other federal and State regulators, in applying statutory and regulatory requirements.
Navigation and Vessel Inspection Circulars (NVIC)	Provides detailed guidance about the enforcement or compliance with a certain Federal marine safety regulations and Coast Guard marine safety programs.
CG-CVC Policy Letters (uscg.mil)	Policy Letters of the USCG.
CG-CVC Mission Management System	MMS serves as the Coast Guard's quality management system to oversee the effective implementation of IMO requirements for the safety of life at sea and protection of the marine environment.
Marine Safety Information Bulletins (MSIB)	Coast Guard MSIB Publications.
Domestic & Offshore Annual Report	Annual Reports.
Classification Society Authorizations:	The Coast Guard authorizes classification societies to conduct work in the United States and delegates authority related to certain statutory certification and services.
Alternative Inspection Programs	Information on Alternate Compliance Program (ACP), Maritime Security Program (MSP), and Streamlined Inspection Program (SIP).

Source: USCG

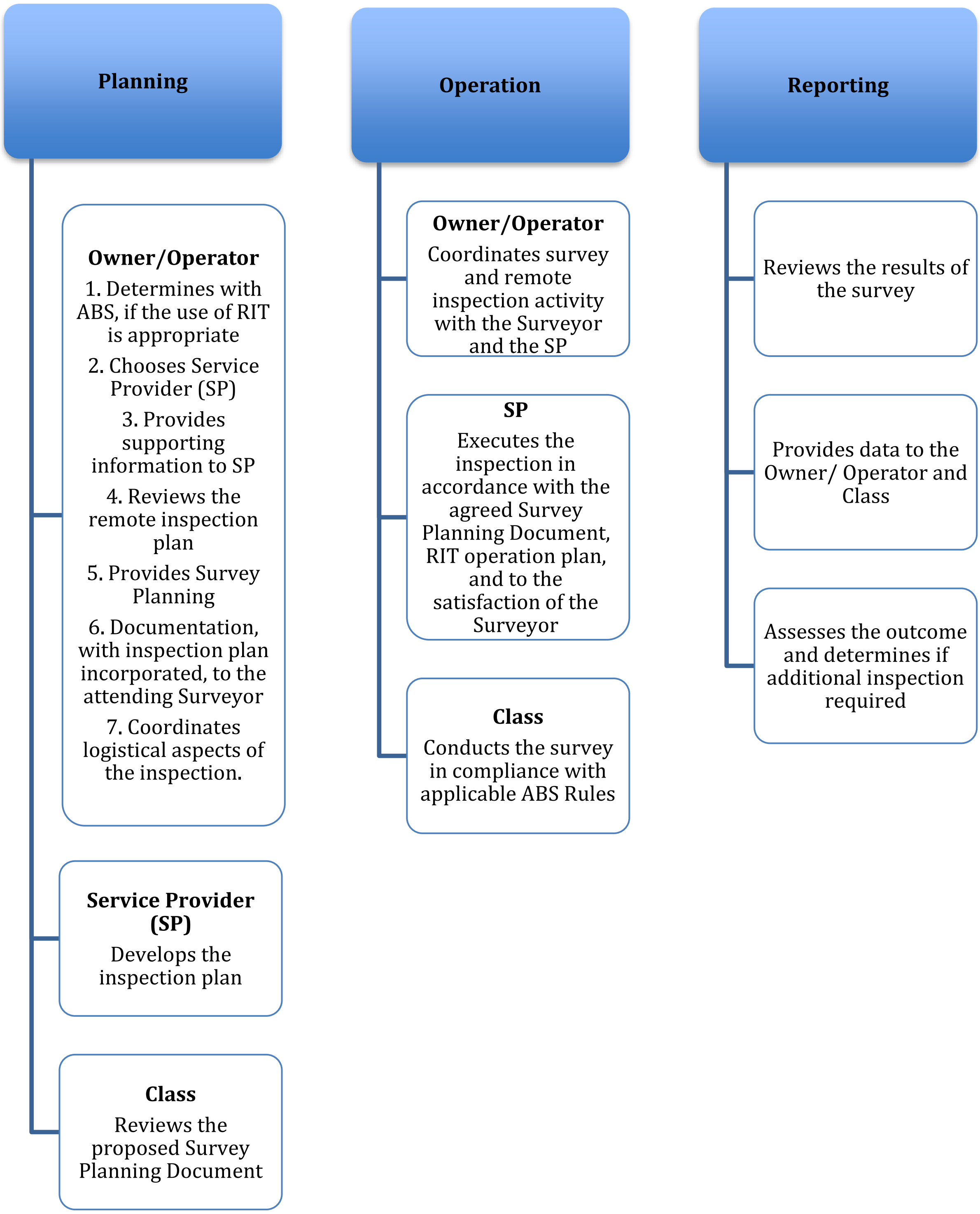
The Coast Guard authorises classification societies, such as ABS, to conduct work in the US and delegates authority related to certain statutory certification and services. The ABS Guidance Notes on the Use of Remote Inspection Technologies (ABS, 2019) offer best practices for class surveys and non-class inspections carried out using UAVs, ROVs, and Robotic Crawlers. The document offers a holistic approach to governing RITs and adequate emphasis is given on "data security policies and procedures" in Section 4.11.1. Nonetheless, according to the document, it should be noted that those policies and procedures should be developed by the concerned end-users, including service providers. The Guidance Note includes reference to the following relevant international documents:

- IACS Recommendations No. 42, Guidelines for Use of Remote Inspection Techniques for Surveys
- IACS UR Z7, Hull Classification Surveys 1.6 Remote Inspection Techniques
- IACS UR Z17, Procedural Requirements for Service Suppliers

According to the ABS Guidelines, during the planning stage, the ship owner/operator should liaise with ABS and decide jointly on whether to proceed with survey using RITs. The owner is responsible for selecting an ABS Recognized service provider. Approved service providers should possess all applicable certificates of authorization from recognized national/local authorities and have an internal Quality Management

System, Safety Management System, Safety Risk Management, Safety Assurance and competent personnel to oversee all above aspects. The owner should provide all documents and drawings related to the work scope to the selected provider, approve the remote inspection plan, and set the Survey Planning. The provider, during this stage, develops the inspection plan that includes the different types of RITS to be used and a risk assessment. The Class reviews the Survey Planning Document to verify whether the survey plan satisfies the applicable ABS Rules. During the operation, which is the second stage of the inspection process, the owner coordinates the survey with the surveyor and the provider. The provider conducts the inspection according to the Survey Planning Document, RIT operation plan, and ABS requirements. The attending class surveyor ensures that the RIV operations team conducts the survey according to the relevant requirements. During the reporting phase of the survey, the provider sends the report and data to the asset owner and Class. The Class surveyor will assess if an additional inspection is required.

Figure 7: Roles and Responsibilities of the key stakeholders during the three phases of the inspection process



Source: Adapted from ABS (2019)

3.2.1.4 National Framework for Autonomous Shipping & Robotic Onboard Systems

In 2019, the USCG, consistent with the policies and strategies articulated in E.O. 13859, requested public input regarding the introduction and development of automated and autonomous commercial vessels and vessel technologies subject to US jurisdiction, on US-flagged commercial vessels, and in US port facilities.

The Coast Guard examined the barriers to the introduction of autonomous vessels through its Coast Guard Request for Information (RFI) on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (USCG, 2020). The development of the results of that project remains ongoing as the USCG received close to 400 comments from the public on a wide range of topics related to autonomy in the maritime sector. Results are yet to be released by RFI. It is important to note that responses from the two leading classification societies, DNV America and ABS can be found at the official site of Regulations.gov (2020).

The USCG has also utilized unmanned and autonomous technology at sea for naval and scientific purposes, including marine scientific research and search and rescue operations. Information from the 30-day testing of Autonomous Unmanned Surface Vehicles (USVs) sponsored by the Department of Homeland Security (DHS) was also shared with the public. The testing showed how a USV would be valuable to daily search and rescue operations of the Coast Guard as it 'self-operates' on a search pattern, enabling the operators to keep a lookout for distressed persons (US Department of Homeland Security, 2020).

The Coast Guard Navigation Safety Advisory Council (NAVSAC) has published the only US-based best practices for unmanned vehicles in its "Unmanned Vehicles/Vessels" (2011) (Resolution 11-02) and "Unmanned Maritime Systems Best Practices" (Resolution 16-01):

- NAVSAC (Resolution 11-02) made recommendations that the U.S. Coast Guard sponsor amendments to both the Inland Rules and COLREGs that, among other measures, amends Rule 5 to exclude unmanned surface vessels from the look-out requirement by adding "manned" before "vessel," and to "promulgate an interpretive rule under 33 C.F.R. Parts 82 and 90 to provide that a vessel being operated remotely is considered to be manned and must comply with the applicable Navigation Rules and annexes"; and

- NAVSAC (Resolution 16-01) provides guidance and information on "Unmanned Maritime Systems Best Practices" to UMS owners and operators on matters concerning UMS development and operations in the maritime environment.

Neither of these Resolutions resulted in wide range implementation nor did they lead to more formal guidance documents from the USCG. Currently, projects related to the use of advanced autonomy for marine vehicles must seek *ad hoc* approval for operations from a respective USCG Captain of the Port.

Most recently, the USCG is developing a strategy for unmanned systems and to inform the potential establishment of a permanent unmanned systems office, and help apply a holistic approach towards unmanned systems across the range of Coast Guard multi-mission operations (Seapower, 2021).

National initiatives for autonomous shipping and robotic onboard systems include, among others, the Smart Ships Coalition which is a broad stakeholder community. The Coalition is developing an application process for interested parties in testing autonomous surface or sub-surface vessels within the proposed testbed in Keweenaw Peninsula Waterway (Smart Ships Coalition, n.d.). Besides, the Ship Operations Cooperative Program (SOCP) is a non-profit and non-partisan member-driven organization of industry leaders to promote and improve the maritime industry through collaboration, facilitation, recommendation, and innovation. Their members are the primary maritime stakeholders that include owning and operating companies, labour, training and educational professionals, mariners, regulatory, government and non-government organizations. SOCP projects include emerging Technologies, Unmanned Aerial Vehicle (UAV) and Autonomous Vessels and (SOCP, nd).

In addition, TMA BlueTech™ is another US ocean initiative and one of the largest, oldest and best-known ocean and freshwater tech clusters in the world that brings education, policy and technological resources together to promote innovation and economic development in this era of Blue Economy. Furthermore, the Association for Unmanned Vehicle Systems International (AUVSI) is the world's largest non-profit organization dedicated to the advancement of unmanned systems and robotics. They represent corporations and professionals from more than 60 countries spread across industry, government, and academia. The AUVSI Maritime Advocacy Committee (MAC) sets the federal legislative and regulatory priorities for the association based on input and feedback from its membership. The committee develops advocacy goals and policy positions to enable all AUVSI members to speak with a unified voice on behalf of the UMS industry. The MAC and its members focus on both defense and commercial applications of autonomous maritime technologies and serve as a resource for Congress and government partners at DoD, NOAA, Coast Guard, and MARAD.

3.2.1.5 National Action Plan: Standards & Guidelines

With the concern that existing AI technologies may be misused or have unforeseen consequences, efforts were made to explore new standards. Within this context, NIST contributes to the research and data required to realize the full promise of artificial intelligence (AI) and establish federal standards that would serve as the foundation for secure, effective, and reliable AI systems.

A Plan for Federal Engagement in Developing Technical Standards and Related Tools prepared in 2019 in response to Executive Order 1385 (NIST, 2019) advises those participating in AI standard development to act consistently with US government policies and principles, including those that address societal and ethical issues, governance, and privacy. As stated in the Plan, the US approach in standard development is dependent on the voluntary standards developed by the private sector, with Federal agencies contributing to and using these standards. US government agencies should prioritize AI standards that are Consensus-based, transparent and include input reflecting diverse and communities of users.

Standardization of AI safety, risk management, and some aspects of trustworthiness seems to be in their formative stages whereby more research is needed to further solidify the robust technical basis for future developments. The following table presents a comprehensive list of AI standard development activities that have Federal involvement.

Table 11: AI Standards Development Activities with Federal Involvement

AI Standards Development Activities	
Links	**Scope**
ISO	
ISO/IEC JTC 1/SC 42 Artificial Intelligence	Serves as the focus and proponent for JTC 1's standardization program on Artificial Intelligence
ISO/IEC JTC 1 SC 7: Software and systems engineering	Standardization of processes, supporting tools and supporting technologies for the engineering of software products and systems.

ISO/IEC JTC 1 SC 17: Cards and security devices for personal identification	It covers Identification and related documents, cards, security devices and interface associated with their use in inter-industry applications and international interchange
ISO/IEC JTC 1 SC 22: Programming languages, their environments and system software interfaces	JTC1/SC 22 is the international standardization subcommittee for programming languages, their environments and system software interfaces
ISO/IEC JTC 1 SC 24: Computer graphics, image processing and environmental data representation	Standardization of interfaces for information technology-based applications relating to: computer graphics and virtual reality, image processing, environmental data representation.
ISO/IEC JTC 1 SC 27: Information Security, cybersecurity and privacy protection	It covers generic methods, techniques and guidelines to address both security and privacy aspects.
ISO/IEC JTC 1 SC 28: Office equipment	Standardization of basic characteristics, test methods and other related items of products such as 2D and 3D Printers/Scanners, Copiers.
ISO/IEC JTC 1 SC 29: Coding of audio, picture, multimedia and hypermedia information	Standardization in the field of efficient coding of digital representations of images, audio and moving pictures.
ISO/IEC JTC 1 SC 32: Data management and interchange	Standards for data management within and among local and distributed information systems environments.
ISO/IEC JTC 1 SC 36: Information technology for learning, education and training	Standardization in the field of information technologies for learning, education, and training to support individuals, groups, or organizations, and to enable interoperability and reusability of resources and tools.
ISO/IEC JTC 1 SC 37: Biometrics	Standardization of generic biometric technologies pertaining to human beings to support interoperability and data interchange among applications and systems.
ISO/IEC JTC 1 SC 40: IT Service Management and IT Governance	Developing standards, tools, frameworks, best practices and related documents for IT Service Management and IT Governance, including areas of IT activity such as audit, digital forensics, governance, risk management, outsourcing, service operations and service maintenance
ISO/IEC JTC 1 SC 41: Internet of Things and related technologies	Standardization in the area of Internet of Things, Digital Twins and related technologies.
ISO TC 184: Automation systems and integration	Standardization in the field of automation systems and their integration for design, sourcing, manufacturing, production and delivery, support, maintenance and disposal of products and their associated services.
ISO TC 199: Safety of machinery	Standardization of basic concepts and general principles for safety of machinery incorporating terminology, methodology, guards and safety devices.
ISO TC 299: Robotics	ISO/TC 299 has the goal to develop high quality standards for the safety of industrial robots and service robots to enable innovative robotic products to be brought onto the market.

IEEE	
IEEE P7000 - Engineering Methodologies for Ethical Life-Cycle Concerns Working Group	Establishes a process model by which engineers and technologists can address ethical consideration throughout the various stages of system initiation, analysis and design.
ASTM	
ASTM Committee F15 on Consumer Products	Committee on Consumer Products.
ASTM Committee F45 on Driverless Automatic Guided Industrial Vehicles	Committee on Driverless Automatic Guided Industrial Vehicles.
ASTM Committee F38 on Unmanned Aircraft Systems	Committee on Unmanned Aircraft Systems.
ASTM Committee F42 on Additive Manufacturing (AM) Technologies	Committee on Additive Manufacturing Technologies.
ASTM Administrative Committee 377, Autonomy Design and Operations in Aviation (AC377)	Administrative Committee, Autonomy Design and Operations in Aviation.

Source: NIST, Standards.Gov

3.1.2 Techno-policy Developments in National Aviation and Automotive Sectors

3.1.2.1 Aviation

The Federal Aviation Administration (FAA) is the federal agency responsible for maintaining the safety and efficacy of the US aviation system. Pursuant to 49 U.S.C. § 40103, the FAA has exclusive sovereignty over domestic airspace from "the ground up," and thus regulates UAS/UAV/remotely piloted aircraft as "aircraft." Domestic airspace is the airspace above US territory and extends 12 nautical miles from shore. A UAS is considered an "aircraft" as defined in the Federal Aviation Administration's (FAA's) authorizing statutes, and therefore UAS operations in the National Airspace System (NAS) are subject to FAA regulations. The FAA imposes stringent legal requirements that restrict government operations of UASs to personnel that have UAS pilot licenses, and there are numerous rules concerning where UASs can be flown.

In the US, while the US Coast Guard regulates navigation under several federal statutes, the FAA has exclusive sovereignty over the airspace of the US and regulates commercial UAS as aircraft. Generally, aircraft flight authorization is necessary unless an operator is within controlled airspace, such as the US National Airspace System (NAS). As with territorial seas, domestic airspace generally extends to 12 NM off the coast of the 48 contiguous United States and Alaska and beyond 12 NM under certain circumstances (14 CFR § 71.33). Oversight of the use of Small Unmanned Aircraft Systems (sUAS), or "drones", generally falls under federal FAA authority, and thus not governed by state law, although some ports have attempted to exercise some oversight of drone operations in ports and thus should be considered as part of any proposed operation.

The rules for drones in the US are regulated by the FAA. Drones' operations under 55 pounds (25 kg) are governed by the Small Unmanned Aircraft Systems Rule, which is Title 14 of the Code of Federal Regulations part 107. According to the Rules, unmanned aircraft must remain within VLOS of the remote pilot with a maximum groundspeed of 100 mph and a maximum altitude of 400 feet above ground level (FAA, 2016). A remote pilot certificate is required, and operators should pass the initial aeronautical knowledge exam: "Unmanned Aircraft General – Small (UAG)". For Certificate renewal, a biennial online training is required. For specific drone operations not covered under part 107, the interested party can request an operational waiver, demonstrating that the drone can fly safely using alternative methods.

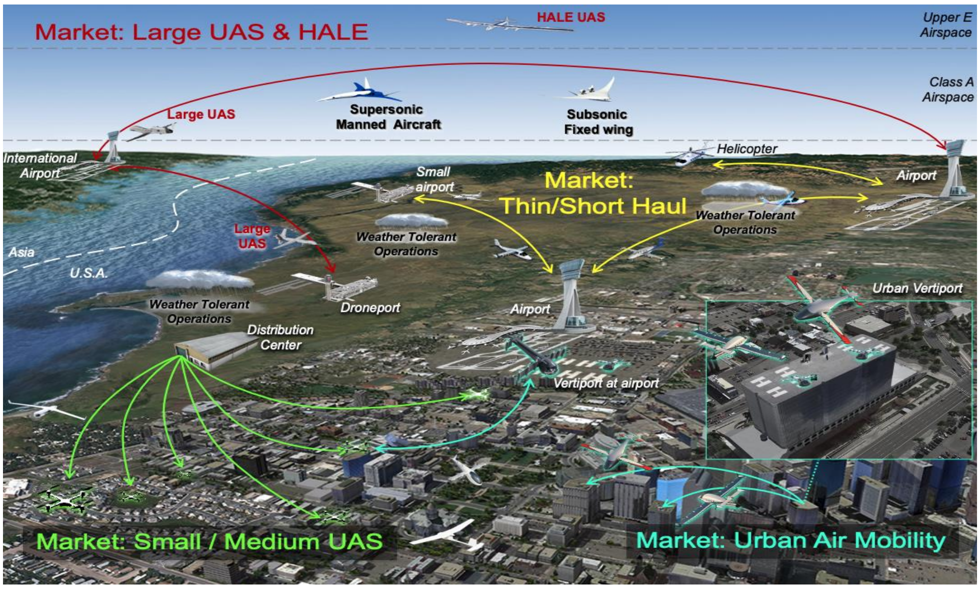
The Operation of Unmanned Aircraft Systems Over People rule published in 2021 enables certain routine operations over people and routine operations at night (FAA, 2021). This rulemaking is one of the FAA initiatives to allow the growth of small UAS operations and increase their operational flexibility. The Rule specifies four categories of operations over people. The first three are based on the risk of injury they present to people on the ground, whereas the fourth focuses on the airworthiness certificate of the aircraft. Operations of small UAS at night are allowed if: a) the remote pilot completes an online recurrent knowledge test to ensure familiarity with night-time operations; and, b) the aircraft has lighted anti-collision flashing lighting visible for at least 3 statute miles.

FAA and National Aeronautics and Space Administration (NASA) have signed a number of cooperative agreements that appoint NASA as lead in conducting research that will aid the FAA in meeting its regulatory obligations to manage a safe transportation system.

The NASA Advanced Air Mobility (AAM) Mission aims to facilitate the emerging aviation markets to develop an air transportation system that transfers safely people and cargo between places previously not served by aviation (NASA, 2021). This Mission includes NASA's work on Urban Air Mobility (UAM) that allows for safe air manned and unmanned aircraft traffic system operations in a metropolitan area. Within this framework, Uber Technologies Inc. cooperates with NASA in the field of flying taxis and their safe air traffic management to make large-scale operations possible. It is noted that Uber envisions to commercialize its products in 2023.

Furthermore, NASA's Ames Research Center is in the process of developing an UAS Traffic Management (UTM) platform for drones into urban area that will help, via digital data sharing, the operation of large number of drones flying at low altitude along with helicopters and airplanes.

Figure 8: Future airspace management domains to leverage UTM System and concepts.



Source: NASA

The autonomous flying vehicle industry is expected to grow dramatically by 2040, impacting passenger travel, military operations, and freight transportation. According to the BluePaper from Morgan Stanley Research, the sector will utilize best practices from various sectors, including autonomous systems, drones, propulsion systems and ultra-efficient batteries (Morgan Stanley, 2019). Companies such as Airbus, Boeing and Toyota are investing in electric vertical take-off and landing (eVTOL) air taxis. Boeing's NeXt program is working on autonomous flight technologies and through its mobility ecosystem, autonomous and piloted air vehicles for urban and global mobility will coexist safely.

3.2.2.2 Automotive Sector

The former President of the US, President Donald Trump, signed the Consolidated Appropriations Act of 2018 (2018 Omnibus Bill) into law on March 23, 2018. Among other aspects, this legislation orders the US Department of Transportation (USDOT) to carry out studies and provide funding for the advancement of Automated Vehicles (AV) (govinfo, 2018). To maintain the US's place as a leader in automation, the USDOT is fully committed to innovation in the transportation industry. Coalitions and stakeholder management are used to ensure the secure development, evaluation, and deployment of automated vehicle technology with industry, academia, states, and local governments. The number of states introducing legislation to regulate autonomous vehicles continues to grow year after year (NCSL, 2020).

The document titled "Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0" (AV 4.0) was established by the USDOT and the White House Office of Science and Technology Policy. The document serves as a guide for Federal agencies, innovators, and other stakeholders representing the US government's position on automated vehicles. AV 4.0 focuses on ensuring a consistent approach to AV with regards to AV technologies, as well as detailing the authorities, research, and investments being made around the USG in order for the US to maintain its status quo leadership in AV. (U.S. Department of Transportation, 2020). The AV Federal Principles consist of three core interests, which are: a) Protect Users and Communities; b) Promote Efficient Markets; and, c) Facilitate Coordinated Efforts), each of which is comprised of several sub-areas (Table 18).

Table 12: Government Automated Vehicle Technology Principles

US Government Automated Vehicle Technology Principles		
Protect Users and Communities	Promote Efficient Markets	Facilitate Coordinated Efforts
1. Prioritize Safety; 2. Emphasize Security and Cybersecurity; 3. Ensure Privacy and Data Security; and 4. Enhance Mobility and Accessibility	5. Remain Technology Neutral; 6. Protect American Innovation and Creativity; and 7. Modernize Regulation	8. Promote Consistent Standards and Policies; 9. Ensure a Consistent Federal Approach; and 10. Improve Transportation System-Level Effects

Source: US Department of Transportation, 2020

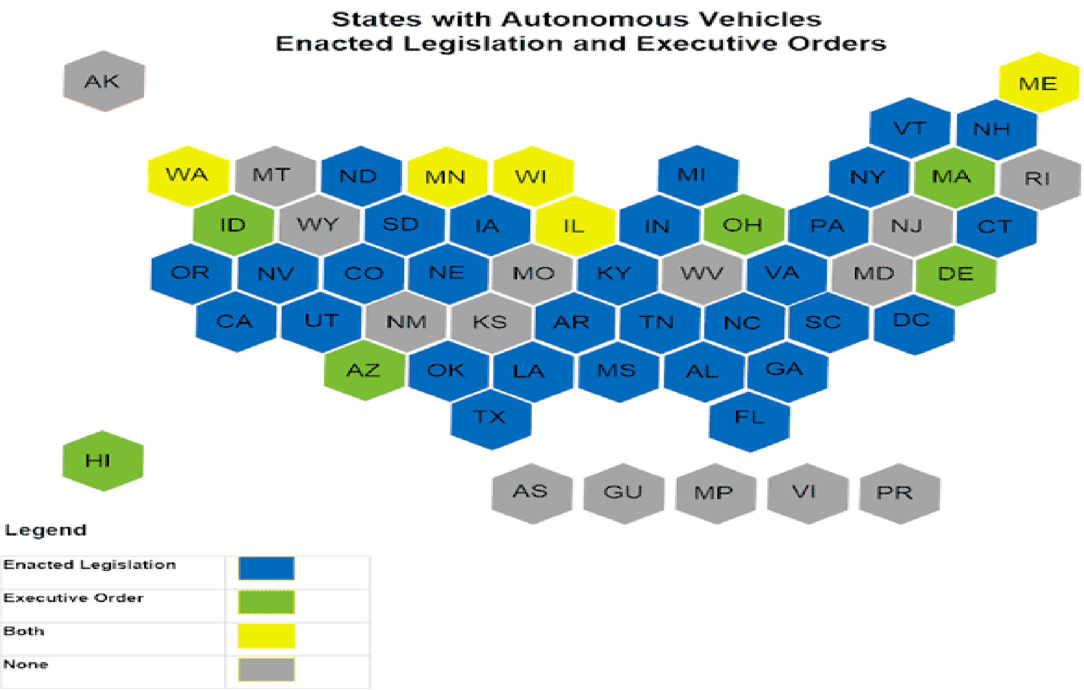
The Automated Vehicles Comprehensive Plan of USDOT promotes the incorporation of Automated Driving Systems (ADS) into the Nation's surface transportation infrastructure. The Plan is based on the principles outlined in AV 4.0 and identifies three objectives (U.S. Department of Transportation, 2021b):

- Encourage collaborative efforts with stakeholders, including the general public, as well as Transparency of information concerning the potential advantages and limitations of ADS;
- Modernize the regulatory environment, remove impediments to innovative automotive design, and advance safety frameworks; and
- Prepare the Transportation System in order to conduct a safety evaluation and integration of ADS (U.S. Department of Transportation, 2021b).

To ensure leadership and advancement in AV technology, the US government provides enticing tax incentives to AV innovators and entrepreneurs who perform AV research and development in the US.

Many States, such as Arizona, Delaware, Hawaii, Idaho, Illinois, Maine, Massachusetts, Minnesota, Ohio, Washington, and Wisconsin all have governors that have issued executive orders regarding autonomous vehicles (NCSL, 2020).

Figure 9: States with Autonomous Vehicles Enacted Legislation and Executive Orders



Source: NCSL, 2020

3.2.3 SWOT Analysis

The SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis is based on primary information collected through interviews with industry representatives, academia and public authorities.

Table 13: US SWOT Analysis

Strengths	The US is one of the global leaders in this new era of AI. The American Artificial Intelligence Initiative aims to enhance the scientific, technological, and economic leadership position of the United States through a coordinated Federal Government strategy. Robust innovation ecosystem.
	Existing guidelines governing how federal agencies should develop and use artificial intelligence.
	The Coast Guard has utilized unmanned and autonomous technology at sea for naval and scientific purposes, including marine scientific research and search and rescue and rescue operations.
	The Coast Guard encouraged its inspectors to use remote methods to verify vessel compliance during COVID-19 outbreak.
	"Guidance Notes on the Use of Remote Inspection Technologies" developed by the ABS in 2019 offer a holistic approach to governing UAVs, ROVs and robotic crawlers, taking into account rules and requirements as found in IACS Recommendations 42 and 76 and IACS UR Z17.
	Ongoing efforts to explore and develop new Federal standards to serve as the foundation for secure, effective, and reliable AI systems.
	The Advanced Air Mobility (AAM) Mission of NASA aims to facilitate the emerging aviation markets to develop an air transportation system that could transfer safely people and cargo between places previously not served by aviation. The autonomous

	flying vehicle industry is expected to grow dramatically by 2040, impacting passenger travel, military operations, and freight transportation.
	The US Department of Transportation (USDOT) is fully committed to innovation in the automotive sector. Many states have passed autonomous vehicle (AV) legislation to help address liabilities associated with self-driving cars.
	There are various government initiatives that enable the public to offer views on regulatory topics. For example, before an MEPC or MSC IMO meeting, the Coast Guard releases the IMO agenda and invites interested public members to participate in a teleconference and offer views.
Weaknesses	There are no regulations that enable the use of remote technologies. For remote inspections, the Coast Guard should approve it based on a case-by-case assessment.
	One of the most expensive countries in the world to manufacture products.
	The U.S. Merchant Marine has dropped dramatically since the last decade.
	Maritime industry is historically conservative and fragmented, with little reward for experimenting and failing as an early innovator – there is often a “race to second” with innovation.
Opportunities	Promote consistent standards and policies and comprehensive federal legislation on Artificial Intelligence. The current framework is mainly dependent on existing rules covering product liability, data privacy, intellectual property, unfair treatment and discrimination.
	More studies are needed to compare the existing inspection regime with remote technologies to provide evidence on which option is more efficient, economically beneficial and/or environmentally sustainable.
	Development of new technological products and services to garner more global market share.
Threats	Global warming and extreme weather conditions could threaten US infrastructure, agriculture, economy and population.
	Cybersecurity of the data ecosystem is a concern to the country.
	Tensions of the world's two largest economies (US and China) for green energy, global data control and AI. China will continue to push for "data sovereignty" so as to reduce its dependence on American technology and cloud computing.

3.3 Review of National Arrangements: Netherlands

The Kingdom of the Netherlands has a longstanding maritime tradition dating back over five centuries and holds a strategically significant geographical position with connections to rivers and seas. According to the Maritieme Monitor (2020), the maritime cluster incorporates eleven sectors: shipping, shipbuilding, offshore (energy), inland shipping, dredging, ports, navy, fishing, maritime services, yacht building/watersport industry and marine equipment supply. The cluster generates 3.1% of the total GDP of the country and employs approximately 284,917 individuals, which equates to 3.0% of the national workforce (Maritieme Monitor, 2020).

The Dutch framework study is based on primary and secondary sources of law, as well as explanations and rational interpretations provided by respondents interviewed in March 2021. Interviews were conducted with key experts from the Ministry of Infrastructure and Water Management, Global Drone Inspection, TNO Netherlands, RINA Netherlands, Lloyds Register Nederlands, Lloyds Register Deutschland, Airborne Composites Automation, Tilburg Law School and Captain AI.

3.3.1 Brief Overview: National Law & Policy with a Focus on BUGWRIGHT2 Technologies

3.3.1.1 Overview of the National System

The Netherlands is a parliamentary democracy with a decentralized unitary constitutional system in which legislation is established collaboratively by the parliament (parlement) and the government (egering) (European Union Agency for Fundamental Rights-FRA, 2020). The government is involved in developing and executing statutory acts, government decrees, ministerial decrees, and policy strategies such as AI and open data. The parliament has, in principle, a monitoring role in scrutinizing the government and the quality of legislative framework and policy proposals (Government of the Netherlands, 2021). In cooperation with other ministries and provincial/municipal authorities, the Ministry of Infrastructure and Water Management coordinates the national policy for environment, road network, aviation and maritime affairs, ensuring EU legislation implementation into national regulations. The decentralized system of the Netherlands is based on 12 Provinces (provincies), 355 Municipalities (gemeenten) and 21 Water authorities (waterschappen), which are responsible for the execution and enforcement of laws and policies (European Union Agency for Fundamental Rights-FRA, 2020). All these decentralized bodies have substantially explored big data analyses and algorithms' opportunities in their policy activities and decision-making (European Union Agency for Fundamental Rights-FRA, 2020). Furthermore, many independent administrative bodies (ZBOs), such as the Chamber of Commerce, exercise public authority and have regulatory power in functional policy fields.

Many advisory bodies have been formed to provide scientific knowledge and expertise to the government. For example, the Netherlands Scientific Council for Government Policy (WRR) is an advisory body for government policy on a number of political and societal topics, including digital disruption and digitalization. Besides, the Advisory Council for Science, Technology and Innovation (AWTI) offers expertise to the Dutch government and parliament on technological development policy issues.

In addition to the legal instruments, the government enters into agreements with private companies, technological institutions, universities and private organizations through public-private partnerships (PPPs). For example, the 'Green Deals' approach is one of the most effective ways to overcome obstacles to green developments. Companies, local, regional governments and stakeholders cooperate with the government on green growth and social issues. The Netherlands' AI Coalition (NL AIC, 2021) is another crucial public-private partnership with over 300 parties in which governmental agencies, private companies and knowledge institutions collaborate to accelerate AI developments based on five building blocks: a) human capital parameters for structural changes in the labour market; b) data policies for removing obstacles for efficient data sharing; c) human-centric aspects to safeguard fundamental rights and democratic freedom; d) research and innovation across the value chain; and, e) support of AI start-ups and scale-ups. (NL AIC, 2021).

The Smart Shipping program is a significant public-private cooperation initiative between the Ministry of Infrastructure and Water Management and private parties, commercial organizations and research institutions. The objective is to facilitate the development of automated sailing on seas and inland waterways and develop; a) vessels that are sustainable; b) unmanned vessels for dangerous work in ports; and, c) automated cargo transhipment. The Ministry is currently exploring the specific legislation that requires revised with a view to making autonomous shipping possible without adverse safety consequences.

Overall, the country's private sector is heavily involved in AI-policy making and self-regulation (European Union Agency for Fundamental Rights – 000FRA-2020).

3.3.1.2 National Framework for AI Technologies and Autonomous Operations

The protection of fundamental human rights and ethical aspects of AI form the cornerstone of the Dutch policy. The government intends to promote the development of AI, acknowledging a human-centric approach. The 2019 Policy Brief on AI, public values, and human rights provides an overview of AI's opportunities and risks for safeguarding public values and human rights (Tweede Kamer der Staten-Generaal, 2019). The Policy Brief underlines the need for cohesion in the different policies (international, European and national levels) and coordination that will enable the government to reap the benefits generated from AI. The government continues to examine the way that human rights and human-centered AI values can be operationalized into system principles.

The main tools for AI technologies in the Netherlands are based on the broad framework of the EU legislation on fundamental rights, data protection, product safety and liability. The main EU tools of the Dutch framework include:

- The European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL) that includes general principles concerning the development of robotics and artificial intelligence for civil use (European Parliament, 2017);
- The Ethics Guidelines from the European High-Level Expert Group on Artificial Intelligence, which was appointed by the Commission in June 2018 (European Commission, 2018). The Dutch government is an active participant in the High-Level Expert Groups on AI;
- The European Commission's published its digital strategy for 2020-2025 which is outlined in three documents: a) The White Paper on Artificial Intelligence (European Commission, 2020a), b) A European strategy for data: Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons concerning the processing of personal data and on the free movement of such data and c) Shaping Europe's digital future. document (European Commission 2020b); and
- The EU Charter of Fundamental Rights (European Union 2012/C 326/02), which is the overarching framework for human rights in the EU, as well as the European Convention on Human Rights (ECHR) (Council of Europe, 2010), that covers civil and political rights. The instruments have direct effect and priority over national acts of parliament and the Dutch Constitution.

The EU White Paper on AI (2020) specifies the European vision and the key policy measures and investments in the field of AI. The Dutch Government Assessment of White Paper on Artificial Intelligence (2020) (Kingdom of Netherlands, 2020) reveals the Dutch position on EU's proposals. The Dutch position is similar to the EU but more emphasis is given on the 'learning approach' that is needed when developing policy in the field of artificial intelligence:

> When developing policy and possible legislation in the field of artificial intelligence, the Netherlands advocates a 'learning approach' in which we use research, experiments and pilot projects to assess whether and where there are problems with regard to AI applications, training data and its quality, and processes surrounding these applications. If it becomes apparent from this learning approach that new legislation is needed, the question is whether this should be 'generic' – i.e., applicable to the entire AI domain – or specific to a single AI application. In this context, it is important for the results of the learning approach to be made available quickly, allowing for prompt investment in generic legal safeguards where necessary and possible, partly from a legal certainty perspective'' (Government Assessment of White Paper on Artificial Intelligence, 2020).

The supreme law in the Netherlands is the Dutch Constitution, and its current version entered into force in 1983. The Constitution specifies all the rules of the national system of governance and civil and political fundamental rights such as the right to privacy and the right to equal treatment. In contrast with other European countries, the courts are not entitled to review primary legislation to assess compatibility with the Constitution and declare it unlawful in case of incompatibility (Government of the Netherlands, 2021).

AI Dutch policies and documents mention that algorithms should not cause direct or indirect discrimination on protected grounds. Particular reference in these documents is made to the Dutch General Equal Treatment Act (Algemene Wet Gelijke Behandeling – AWGB), the European Convention on Human Rights (ECHR) and the Dutch Constitution. AWGB covers equal treatment of persons without distinction based upon religion, race, political opinion, sex, nationality, sexual orientation, or marital status. The Law implements relevant EU directives with a focus on equality, in particular:

- Directive 2000/78 / EC on establishing a general framework for equal treatment in employment and occupation;
- Directive 2000/43 / EC on the application of equal treatment between persons irrespective of racial or ethnic origin; and
- Directive 2006/54 / EC on the implementation of the principle of equal opportunities and equal treatment of men and women in matters of employment and occupation.

In terms of Data protection, the government, businesses and associations should ideally comply with Regulation (EU) 2016/679 of the European Parliament and the Council on the protection of natural persons. This compliance concerns the processing of personal data and the "free movement" of such data (Algemene verordening gegevensbescherminga-AVG). The GDPR also leaves room for nationally tailored options, which have been specified in the GDPR Implementation Act (UAVG: Uitvoeringswet Algemene verordening gegevensbescherming) (Staatsblad van het Koninkrijk der Nederlanden, 2018a). Today GDPR and UAVG regulate the tasks and powers of the Dutch Data Protection Authority (AP).

Another instrument that directly applies to the Dutch Framework is Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union. The Dutch Act on the Security of Network and Information System (Wet beveiliging netwerk- en informatiesyst emen – Wbni) implements EU Directive 2016/1148 (Staatsblad van het Koninkrijk der Nederlanden, 2018b).

3.3.1.3 National Maritime Framework for Remote Inspections

According to the Ministry of Infrastructure and Water Management, there is no single law for all transport modalities to facilitate autonomous drones and service robots. Maritime autonomous robotic systems are not permitted to operate on the Dutch inland waterways but experiments are ongoing with (semi-) autonomous inspection vessels. Parties that wish to experiment with any type of smart shipping, including maritime drones and robotic systems, are invited to contact RWS to evaluate the possibilities and learn-by-doing.

The maritime sector is subject to national, as well as international and European regulations. The Schepenwet (Ships Act) is the central instrument that applies to all seagoing vessels flying the Dutch flag (Staatsblad van het Koninkrijk der Nederlanden, 1909). The Act aims at preventing shipping disasters at sea and addresses issues such as ship safety and shipping disaster investigations. There are no provisions in the Act about remote technologies.

In the inland maritime sector, service robots are not defined as a separate category. The national legal framework on inland waters, excluding waterways governed by the standards and regulations of the Central Commission for the Navigation on the Rhine (CCNR), can be found in the Inland Navigation Act-Binnenvaartwet (Staatsblad van het Koninkrijk der Nederlanden, 2007). The Act includes provisions for inland navigation vessels regarding a vessel's condition, design and equipment, on board working conditions and competency of the captain. The Act has in place an inspection certificate or inland navigation certificate system for ensuring a sound technical condition of the vessel. Floating equipment and constructions, though not autonomous, are defined in the Act and are subject to the same regulations as inland shipping vessels.

The Dutch Flag Registry is known as the Netherlands Shipping Inspectorate/NSI (Inspectie Leefomgeving en Transport), which is a part of the Human Environment and Transport Inspectorate (ILT) of the Ministry of Infrastructure and Water Management. The Registry has delegated all statutory certification services to seven pre-assigned EU Recognised Organisations (ROs): Bureau Veritas (BV), DNV, Indian Register of Shipping, Lloyd's Register, Nippon Kaiji Kyokai (Class NK), RINA Services S.p.A. and Register Holland. In this context, Register Holland is a Classification Society only non-Convention and/or non-European legislation-based surveys. Discussions with respondents revealed that it is the intention of the Human Environment and Transport Inspectorate to avoid remote surveys and audits. There may be some exceptions, in cases where the ship-owner/manager, in agreement with the captain and personnel on board, has provided written justifications in support of intentions to conduct a remote survey. Strict criteria set by the RO should assess this request. If this request is accepted, then IACS 42 Rev.2 should be followed. Remote inspections are evaluated on a case-by-case basis and as such no uniform guidelines apply. The request for remote inspection imposes an additional burden on the ship-owner/manager and RO, and that is why it is important to justify why a remote survey is more appropriate than a physical inspection.

The Covid-19 pandemic could have been the catalyst and the paradigm for remote inspections, but the Flag registry did not explore this option further. Instead of remote inspections, extensions were mainly granted for the statutory ship certificates by the Human Environment and Transport Inspectorate. Moreover, the Dutch fleet is in decline, and vessels are usually too small to obtain financial benefits from the usage of UAVs and ROVs. There are also ship owners that are yet to be convinced about the advantages of deploying remote technologies for survey and inspection. Moreover, discussions with Dutch key experts revealed the following challenges in relation to the use of remote technologies:

a) Visibility in the Dutch water imposes a burden for underwater inspections with autonomous Underwater Vehicles (AUVs);

b) Problems have been noted with the live streaming technology. The sector needs companies that can provide effective live-streaming video-audio tools for a thorough examination of the structural defects.

c) Drones, during the livestream operation, should always show their exact location during the inspection. This facilitates the work of the surveyors;

d) Permission for hull cleaning from the Port Authority remains a challenging task. It should be kept in mind that hull cleaning is not a part of the Statutory certification and remains at the ship-owner's discretion;

e) Flag Registries like Liberia are keener than the European ones to promote the use of remote technologies; and

f) Specific Regulations are needed for trials and inspections. The findings of these trials should be crosschecked with findings from physical inspection to address gaps and overcome barriers.

It should be noted that the discussions confirmed that the Ministry of Infrastructure and Water Management is currently working to facilitate new initiatives and innovations in the inland maritime sector. A national policy initiative is underway that has the potential to allow the usage of maritime (inspection) drones on a case-by-case basis in the future.

3.3.1.4 National Framework for Autonomous Shipping & Robotic Onboard Systems

In general, maritime autonomous robotic systems are not permitted to operate on the Dutch inland waterways. There are, however, experiments ongoing with semi-autonomous inspection vessels. For vessels and maritime devices governed by autonomy or semi-autonomy, efforts are ongoing to establish a legal framework to guide usage on a case-by-case basis. On the basis of lessons learned, Netherlands aims to allow certain types of autonomous vessels within national waterways. Parties that wish to experiment with smart shipping, including maritime drones and robotic systems, should contact RWS to evaluate the possibilities.

There are two policy rules that allow experiments with autonomous vessels and automated on-board smart shipping technologies within inland and territorial waters. The former is the policy rule stipulated by the Ministry of Infrastructure and Water Management that allows for experiments with far-reaching automated navigation within national waterways (Beleidsregel experimenten vergaand geautomatiseerd varen rijksvaarwegen, No. IENW / BSK-2018/183049). This policy rule proceeds to set the relevant provisions for testing in the above areas (Staatsblad van het Koninkrijk der Nederlanden, 2018c). Testing of Smart Shipping technologies is permitted on Dutch inland waterways, and managed by the government on the basis of a pre-set condition that an application form shall submitted to the national Smart Shipping HelpDesk monitored by Rijkswaterstaat (RWS). Details regarding the ship, the level of automation, and the type of experiment should be included in the form. During the assessment process, special consideration is given vessel safety and smooth traffic systems --- aspects that ought to be taken into account during the experiment. Provinces, municipalities and ports remain responsible for policies and regulations related to experiments within inland waterways that are subject to their jurisdiction.

The latter is the policy rule laid down by the Minister of Infrastructure and Water Management for experiments in the context of highly automated shipping in the territorial waters (Beleidsregel experimenten vergaand geautomatiseerd varen territoriale zee, nr. IENW/BSK-2019/122815). In other words, this specifies the rules for experiments in the context of highly automated sailing in the territorial waters (Staatsblad van het Koninkrijk der Nederlanden, 2019a). Applications and experimental plans for testing in territorial waters are forwarded to the Smart Shipping Desk managed by the Director of the Coast Guard. Information that needs to be communicated includes the training and knowledge of those involved in the automated applications, the level of automation of the ship, surroundings of the location and expected risks during the experiment.

Both the aforementioned policy rules clarify that if the experiments necessitate a deviation from existing maritime laws and regulations (i.e., crew composition and technical requirements), relevant exceptions should be granted by the relevant competent authorities. For example, in case of safety concerns, the Smart Shipping Desk may forward the application to the Human Environment and Transport Inspectorate. If the experiment takes place beyond the territorial waters, the neighbouring countries or international organizations, such as the IMO, should offer their views.

The experiments/tests will set the foundation for the development of future legislation and policy-making in the field of Smart Shipping. To this end, the Dutch Ministry of Infrastructure and Water Management cooperates with cross-border experiments with the Flemish government.

The Port of Rotterdam has positioned itself as an EU frontrunner in autonomous shipping technology and services through partnerships with tech-start-ups, leading institutions and national authorities. All stakeholders' have joined forces to implement smart shipping in the Netherlands, designating autonomous ship-testing areas in the port adapting to the ship's surroundings accordingly. Reliable data is of paramount importance for the transition to autonomous shipping. The Port of Rotterdam Authority (2021) has converted a patrol vessel into a Floating Lab that collects different types of data using cameras, sensors, and measurement equipment. The data gathered is said to offer information about weather, water conditions, vessel's operation, power, and engine. The Floating Lab is also utilized for new technologies and systems, such as automatic inspection of quay walls or detection of objects in the water (PoRA, 2021). A Memorandum of Understanding (MoU) has been signed between PoRA and tech start-up *Captain AI* to use artificial intelligence to the existing data, enabling computers to be trained as artificial captains with the use of simulation, sensors, latest AI models for object detection and state-of-the-art deep learning techniques (Captain AI, 2021).

The Netherlands' Maritime Technology (NMT) trade association has created a strong network of shipyards, marine equipment suppliers and service providers to boost innovative partnerships throughout the maritime ecosystem. One example of collaborative innovation of NMT is the Dutch Joint Industry Project Autonomous Shipping (2017-2019) that achieved the world's first full-scale autonomous shipping trials in the North Sea. The trials showed that an autonomous system linked to an on-board autopilot and machinery control system has the potential to perform and manoeuvre safely, eliminating the risk of collision with other vessels.

The Netherlands' Forum Smart Shipping SMASH! is another exemplary partnership between the government and the private parties, which brings the Dutch maritime sector together to implement smart and autonomous shipping. Some of the members of the SMASH! include the Port of Rotterdam, Port of Amsterdam Netherlands Maritime Technology, Ministry of Infrastructure and Water Management, the Royal Association of Netherlands Shipowners (KVNR), the municipality of Rotterdam and the Delft

University of Technology. Their experiences with autonomous shipping is communicated to international organizations, such as the IMO, in a befitting manner.

3.3.1.5 National Action Plan: Standards & Guidelines

The Strategic Action Plan bearing the title "Strategisch Actieplan AI – SAPAI" (Government of the Netherlands, 2019a and 2019b) outlines the policy initiatives to strengthen Netherlands' competitiveness in AI, focusing on the following three tracks:

1. Capitalization of societal and economic opportunities through intensive public-private partnerships (PPPs). The Dutch AI Coalition, while calling on companies and organizations to join in these efforts;

2. Track 2 aims to develop the essential economical and societal foundations for a favourable AI climate: developments of skills in data science in higher education, research programmes for state-of-the-art research, increasing access to innovation funding for start-ups high-quality data and intelligent connectivity; and

3. Track 3 covers the development of ethical and legal frameworks and the protection of citizens' fundamental rights.

The government has released several guidelines relevant to AI and service robots. For example, the Policy Brief on offering guarantees against the risks of data analyses by public bodies (Waarborgen tegen risico's van data-analyses door de overhead) sets out guidelines for the application of the different types of algorithms aimed at public bodies (Tweede Kamer, vergaderjaar 2019–2020). The policy aims to create awareness regarding the risks of using algorithms for achieving transparency around Big Data analytics.

The Roadmap Digitally Safe Hard- and Software (Roadmap Digitaal Veilige Hard- en Software) promulgated by the Ministry of Economic Affairs and Climate Policy Ministry of Justice and Security provides a coordinated approach with measures intended to eliminate gaps in the field of digital hard-and software security (Government of the Netherlands, 2018). The roadmap proposes the application of standards accompanied by mandatory certification systems.

The Dutch government collaborates with industry and key stakeholders to develop a monitoring mechanism that will provide information on the digital security of products that are part of the Internet of Things. The country will boost its research on cybersecurity as the focus is on the development of minimum-security requirements for devices under the EU's Radio Equipment Directive. Besides, the Supervision Framework of the Data Protection Authority (Toezichtkader Autoriteit Persoonsgegevens Uitgangspunten voor toezicht) provides guidelines for the use of personal data in AI-driven technologies (Autoriteit Persoonsgegevens, 2018).

In terms of "standard" development work, NEN serves as the national standardization body that applies standards at both national and international levels. NEN is a leading member of CEN and ISO which, in cooperation with a broad range of stakeholders, facilitates technological development, innovation, sustainability, safety and international trade. The NEN Committee on Artificial Intelligence and Big Data is involved in developing standards that deal responsibly and efficiently with AI and big data.

Another noteworthy initiative is the ECP (ECP Platform voor de InformatieSamenleving), an independent platform for the information society where government, businesses, knowledge institutions and civil society organizations work together to support technological innovation. The AI Impact Assessment (ECP, 2018) includes a number of steps that are essential for the identification of the legal and ethical elements that should be taken into consideration by organizations when making decisions regarding the usage of AI applications. The Assessment contains an Annex titled "Artificial Intelligence Code of Conduct" which focuses on the criteria that renders an AI application ethical and legally justifiable. In short, three conditions should be fulfilled: reliability, safety and transparency. For AI to be reliable, the system must function effectively and the outcomes should be technically and statistically correct. For safety, it should ensure that the application does not pose a hazard to the physical work and take into account user-rights, such as those of data protection of end-users. Transparent AI enables the users to understand how decisions are made and what the implications are for social actors. It should also be underlined that in the context of furthering developments, 14 Dutch universities have formed the Association of Universities in the Netherlands (VSNU) towards shared values and goals, education and research.

3.3.2 Techno-policy Developments in National Aviation and Automotive Sectors

3.3.2.1 Aviation

In the Netherlands, all drone operators must be registered with the Netherlands Vehicle Authority (RDW), with the exception of toy drones with a CE marking and drones without a camera that weigh less than 250 grams (Business.gov.nl, 2021). The Netherlands Directorate General of Civil Aviation (DGCA) is the responsible authority for drones. Dutch rules for drones fall under the common European regulatory framework and include:

- Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems;
- Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft; and
- Commission Implementing Regulation (EU) 2020/639 of 12 May 2020 amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight.

Drone operators flying drones of more than 250 grams must complete relevant training for the drone certificate. Drones are not allowed to operate in the dark and are not permitted to fly more than 120 meters above the ground or the water. Based on the EU framework, three different risk-level categories have been specified:

- Category Open: Includes flights with low-risk commercial activity where no permission from the Human Environment and Transport Inspectorate (ILT) is required. Pilots of drones heavier than 250 grams should apply for a flight license for subcategory A1A3 and subcategory A2 at the RDW. Operators of a drone lighter than 250 grams with an installed camera must also register at the RDW and gain an operator number;

- Specific category: This category includes medium-risk flights not covered under the 'open' category where permission from the Human Environment and Transport Inspectorate (ILT) is required. Pilots can apply for an operating license or a Light UAS Operator Certificate (LUC). Operators can also utilize a Standard Scenario (STS) from the European Aviation Safety Agency (EASA) as specified in an appendix to EU regulation 2019/947. In this case, drone operators should send a declaration to the respective authority instead of applying and waiting for authorization; and

- The Certified Category is related to high-risk flights where drones either fly over crowds or transport people and dangerous goods. The rules for this category are not yet fully established.

Drone certificates are valid for 5 years. Renewals require retaking the training course, knowledge test and refresher seminar. It should be underlined that internal flights of drones within the inner parts of a vessel are not governed by current regulations.

Table 14: Categories of Drones

Category	Sub-categories	Authorization and certificates
Open	A1 (up to 250 grams): fly over people but not over assemblies of people; A2 (up to 2 kilograms): fly close to people A3 (up to 25 kilograms): fly far from people.	Certificate of Completion for the A1 / A3 subcategory from RDW. Proficiency Certificate for the A2 subcategory.
Specific	-	Operational permit from the Human Environment and Transport Inspectorate (ILT) unless the operation is covered by a Standard Scenario. Alternatively, application from ILT for a Light UAS Operator Certificate (LUC). Certificate of Completion and a Proficiency Certificate are needed from the RDW.
Certified Category	-	The rules not fully established. Until then you will have to apply for a licence to the national aviation authority for drones weighing less than 150 kilograms. The licensing procedures will be comparable with those for manned aircraft.

3.3.2.2 Automotive Sector

In the automotive sector, there are critical techno-policy developments. The government is making efforts to pave the way for the Netherlands to become a lead country in automated car testing and Intelligent Transport Systems (ITS) (Government of the Netherlands, 2021). Priority is given to data transmission, data quality and wireless vehicle-to-vehicle communication between on-road vehicles and roadside installations. The Netherlands is at the forefront of the EU and is in the process of developing legislation to facilitate self-driving vehicles through the previously mentioned pragmatic 'learning-by-doing' approach.

The Netherlands ranks second in the Autonomous Vehicles Readiness Index (KPMG, 2020), which evaluates the preparedness of 30 countries in the race towards mass deployment of autonomous vehicles. The country excels in terms of a well-founded infrastructure pillar, ranking first on EV charging stations per capita, and second only to Singapore in terms of road quality. The Index illustrates that the Netherlands shows one of the most compelling performances on AV regulations and has one of the highest ratings on government-funded AV pilots. Current challenges revolve around two notable situations: truck platooning revealed problems in maintaining that vehicles are connected at all times, and unsuccessful governmental efforts to test and award AV driving licenses.

Since 2015, the testing of self-driving vehicles on public roads is permitted as long as an exemption from the Netherlands Vehicle Authority (RDW) has been granted and a driver is present during the experiment. Law governing the experimental use of self-driving vehicles (Experimenteerwet zelfrijdende auto) entered into force in 2019 to remove legal obstacles and allow large-scale testing of self-driving cars and lorries on public roads (Staatsblad van het Koninkrijk der Nederlanden, 2019b). The Law enables manufacturers and companies to apply for a permit to conduct tests with driverless vehicles on public roads. The experimentation law amends the 1994 Road Traffic Act (Wegenverkeerswet -Wvw) (Staatsblad van het Koninkrijk der Nederlanden, 1994) that includes safety provisions on public roads.

The Ministry of Infrastructure and Water Management, the Road Authority (Rijkswaterstaat), the Netherlands Vehicle Authority (RDW), the Dutch police and the Dutch Institute for Road Safety Research (SWOV) have been jointly exploring safe ways to evaluate requests from stakeholders to conduct experiments based on the Exceptional Transport Exemptions Decree (Over15, 2015). The Road Transport Agency is the authority that grants permits for the admission of self-driving passenger cars and self-driving lorries to the public road, focusing on the vehicles' technical safety requirements. Driverless vehicles are allowed on public roads if the RDW has granted an exemption. Companies must provide evidence that the tests will be conducted safely, and an application for admission should be submitted. There are no specific standards and criteria regarding the exemption process, and these are granted on a case-by-case basis. The Agency follows internal procedures and makes a thorough analysis of the vehicle's functional descriptions, conducts risk analysis and assesses if the applicant owns insurance. When the administrative work is completed, tests are conducted in a private testing facility to test the system's technical robustness. If the system passes these tests, then the exception is granted. The exemption also applies to the obligation of standard liability whereby RDW may set other alternative requirements if no standard insurance is available. In case of collision, the manufacturer or owner of the vehicle, as per Section 185 of the Road Traffic Act 1994, is liable for the damage to persons or objects caused by this vehicle.

Truck platooning is also an area of great interest for the government and the market is rising due to the adoption of the Internet of Things (IoTs). Truck platooning refers to a group of lorries traveling automatically in convoy, like 'a short train', at less than 1 second apart from each other. Only the first truck of the platoon is required to be steered by a driver. It aims to achieve cleaner and safer transport, which leads to a 5 to 15% decrease in fuel consumption from aerodynamic drag reduction. The Rotterdam Port Authority is part of a group that is preparing to test autonomous lorries. The liability and insurance regime for track platooning raises global legal challenges and questions such as: who is liable: the driver, the manufacturer of the truck or the manufacturer of the software?

The Netherlands supports the harmonisation of EU regulations for the smooth introduction of self-driving trucks on European markets. The lack of regional legislation and the absence of standards for the manufacturers makes it almost impossible for independent oversight bodies, such as RDW, to sufficiently monitor all software updates that impact vehicle behaviour (Doll and Feddes, 2020).

RDW, in cooperation with car manufacturers, developed the Vehicle Safety & Security Framework (VSSF) to support the smooth co-creation of legislation for autonomous vehicles (Figure 2). For the development of the framework, a set of principles categorized to design a method that evaluates the in-vehicle software of self-driving cars. The framework can be utilized for the development of software for remote technologies utilised in hull inspection. For the achievement of functional and security software there should be a categorization of the different strategies that focus on four different areas: process engineering, product evaluation, dynamic operations and future autonomy.

Table 15: Vehicle Safety & Security Framework. [Klik op de afbeelding voor een grotere afbeelding]

Goals		**Functionality-Security-Privacy (FSP)**			
Strategy		Process Engineering	Product Evaluation	Dynamic Operations	
Lifecycle		**Development and In-use Compliance**			
Learning Areas		Functional Safety Cybersecurity Privacy Engineering	Software Verification	Data	Ethics
		Software Requirements Design & Development	System Validation	Software Updates and Patch Management	Machine and Deep Learning
		Software Configuration Management	Product Statistics	Human Machine Interaction	Advanced Perception Planning and Control
Quality		Software Quality Assurance			

Source: Doll and Feddes, 2020

3.3.2.3 Financial Sector

De Nederlandsche Bank (DNB) published the general principles for the use of AI in the financial sector (De Nederlandsche Bank, 2019), noting that the regulatory requirements for responsible use of AI in financial services should focus on the SAFEST principles. The principles can be utilized for the development of remote technologies for hull inspection:

- Soundness: AI applications should be reliable, accurate and fully compatible with applicable rules and regulations. Data quality aspects should be emphasized;
- Accountability: institutions should demonstrate they have a deep understanding of their responsibility for their AI applications and Integrate accountability in the organization’s risk management framework;
- Fairness: institutions should operationalize the concept of fairness for the use of AI;

• Ethics: AI applications should be in line with ethical standards specified in an ethical code so the stakeholders are not mistreated;

• Skills: The leadership team and employees should possess the required skills and expertise to understand AI and identify AI-enabled systems' strengths and weaknesses;

• Transparency: Institutions should develop transparent policies on the use of AI in their business processes.

3.2.3 SWOT Analysis

The SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis is based on primary information collected through interviews with industry representatives, academia and public authorities.

Table 16: The Netherlands SWOT Analysis

Strengths	The Netherlands is one of the most active players in promoting responsible and trustworthy AI at the international and European level through a *learning-by-doing* approach. The government invests in innovation and the development of human-centric AI.
	Continuous work by the Ministry to facilitate new initiatives and innovations in the inland maritime sector. A national policy initiative is underway to: 1) be able to permit the use of maritime (inspection) drones on a case-by-case basis; and, 2) to be able to permit the usage of different kinds of robotic, (semi) autonomous vessels, including inspection vessels.
	Parties that wish to experiment with any kind of smart shipping, including maritime drones and robotic systems, are invited to contact RWS to evaluate the possibilities, and thus, learn by doing.
	Robust Public-Private Partnerships (PPPs). Strong cooperation between the government, private parties, universities and technological institutions in the field of developing human-centric, trustworthy and responsible AI. Experiments and pilot testing are well underway for developing new technologies that could have a public function. The Dutch AI Coalition (Nederlandse AI Coalitie – NL AIC) is a critical PPP.
	An extensive number of advisory councils and bodies have been established by the Dutch Constitution. The bodies may consult the government in areas such as the fair use of technology.
	Various public bodies and agencies (zelfstandige bestuursorganen) have the liberty to experiment with AI, and are able to participate in policy-making.
	Up-to-date national legislative policies that enable the testing of autonomous vessels and cars.
	The government stimulates the private sector to be involved in AI-policy making and self-regulation (e.g., Dutch ICT sector developed an ethical code for Artificial Intelligence).
	Most universities and public institutes conduct research on new technologies, fundamental rights and AI. Fourteen universities have established the Association of Universities in the Netherlands and cooperate in achieving common AI-goals.
	Robust Stakeholder Management approach in which civil society engages in public consultations on new policies and regulation.

	Strategic Action Plan AI (SAPAI) that includes policy plans and initiatives to ensure that AI is optimally used to respond to: societal challenges, human rights, entrepreneurship, the safety and security of citizens.
	Extraordinary infrastructure of inland waterways that will facilitate the use of autonomous vessels.
	Top rated global performance on Automated Vehicles (AV) regulations and government-funded AV pilots.
Weaknesses	The Dutch Flag State has not considered remote technologies for hull inspection (let alone the area covered under BUGWRIGHT2).
	The national maritime framework does not include provisions for remote surveys.
	Shipyards do not utilize remote technologies for hull inspections.
	Important stakeholders (including respondents) raised concerns about the limited visibility of RIT in Dutch waters emanating from ineffective live streaming technology.
Opportunities	The Dutch Flag State should amend its policies to allow the use of remote technologies for hull inspection.
	The Schepenwet (Ships Act) should be amended to incorporate provisions for remote technologies and hull inspection.
	The Dutch Government has the potential to become the global leader with regards to testing of automated vessels and remote technologies. The testing of autonomous vessels and robotic technologies will enable the Netherlands to develop new regulations, standards and frameworks, covering the whole independent ship chain including shipyards, suppliers, authorities, the ship and the seafarers.
	Clear definitions for different smart ships should be formed for: smart conventional vessels, inspection vessels, floating equipment, maritime drones and remote technologies.
	Work is well underway in relation to definitions on different levels of autonomy, a framework for maritime drones and smart innovations on board of conventional inland ships.
Threats	The absence of a common EU framework covering standards and policies creates obstacles for furthering the usage of remote technologies for vessel survey and inspection.
	Limited underwater visibility in the Dutch sea and ineffective live streaming may delay the wide use of remote technologies for in-water surveys.
	Some Ship-owners consider that the cost of remote technologies would be relatively high compared to manual survey and inspection.
	The Dutch Registry avoids remote inspections for which the RIT market-growth is likely to be hindered.
	Flag Registries, such as Liberia, are more optimistic than the European ones when it comes to promoting and using remote technologies.

3.4 Review of National Arrangements: Canada

With the world's longest coastline and connection to three oceans, the maritime sector in Canada contributes around CAN$31.7 billion annually in gross domestic product and accounts for close to 300,000 jobs (Government of Canada, 2021a). Similar to other major maritime nations, Canada aims to be a global leader in the blue economy by integrating growth with ocean conservation and climate action.

Activities dependent on the ocean, such as fish processing, shipbuilding, and marine transportation, create stable jobs and prosperity for coastal regions. Canada envisions a safe, secure, green, innovative, and integrated transportation system that supports a cleaner environment along with economic growth. The vehicle to support this vision is Canada's Transportation 2030 --- the strategic plan of the country that aims to build a strong future by protecting the marine environment and securing jobs for the Canadian citizens.

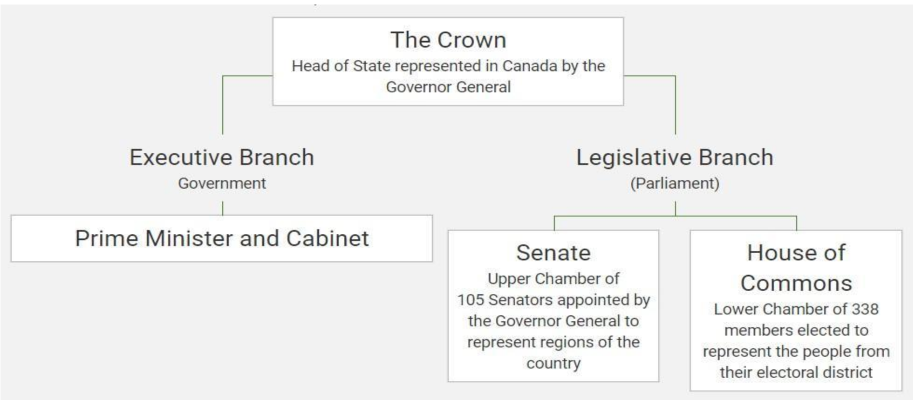
The Canadian case study is based on primary and secondary sources of law, as well as explanations and rational interpretations provided by respondents interviewed in June and July 2021. Interviews were conducted with key experts from Transport Canada (TC), Deep Trekker Inc and Avestec. The author acknowledges the assistance provided by Executive Director/ Domestic Vessels Regulatory Oversight (AMSD) officer of Transport Canada (government of Canada), Mr Luc Tremblay, and President & CEO Logistro Consulting International Inc., Mr. Yoss Leclerc for the insightful information on the Canadian regulatory framework pertaining to maritime remote technologies as well as invaluable feedback and comments on the final report.

3.4.1 Brief Overview: National Law & Policy with a Focus on BUGWRIGHT2 Technologies

3.4.1.1 Overview of the National System

Canada is a federal state comprised of provincial and territorial unions governed by a central government. Canada has a federal parliament in Ottawa that makes laws for the whole country and legislatures in each of the ten provinces and three territories that deal with legislation in their respective jurisdictions (Government of Canada, 2017). Canada is both a constitutional monarchy and a parliamentary democracy, established on the rule of law and the respect of individual rights and freedoms. Under the Crown, the Head of State is represented by the Governor General. The national system of Canada is composed of two main branches: the Executive and Legislative (Figure 10) (House of Commons, n.d.).

Figure 10: Overview of the Canadian Legal System



Source: House of Commons, n.d.

3.4.1.2 National Framework for AI Technologies and Autonomous Operations

The executive power in Canada is vested in the Crown and exercised via the Governor in Council—the Prime Minister and cabinet. The Prime Minister appoints a group of confidential advisors, typically elected parliamentarians from the ruling party, who are sworn in as ministers and members of the Privy Council. They form the ministry or cabinet and are individually accountable for departments or portfolios. Cabinet is the government of Canada's principal decision-making body. It is in charge of leading and directing the executive branch of government. Cabinet serves as an executive council, formulating policies for the country's governance and introducing legislation to enact these policies (House of Commons, n.d.).

In terms of the legislative branch, Parliament is Canada's legislature; it is the federal institution charged with the responsibility of enacting legislation, raising taxes, and authorizing government expenditures. Canada's Parliament is "bicameral," consisting of two chambers: the Senate and the House of Commons. The Senate is made up of 105 Senators chosen by the Governor General on the recommendation of the Prime Minister. The House of Commons is Canada's elected legislature and presently has 338 seats. A minister introduces government proposed legislation in one of the two chambers, often the House of Commons. Once presented, a bill undergoes a lengthy review, discussion, examination, and amending procedure from both Houses before receiving ultimate approval. All legislation must be approved in identical form by both Houses and obtain royal approval to become law.

Canada's legal system is built on the foundations of the English and French legal systems. These systems were brought into Canada in the 17th and 18th centuries by explorers and colonists. Except for Quebec, which follows civil law, the nation came under English common law after the Battle of Quebec in 1759. Canada is one of the few nations in the world where civil and common law coexist and cooperate inside the same legislative framework, revealing the country's history and constitutional and legal system. Statutes, legislation, or acts are the terms used to refer to laws enacted at any level. Legislation passed by Parliament, or a provincial or territorial legislature replaces common law or existing precedents on the subject matter. Developing legislation in this manner may pose as challenging. The following example assumes that the federal government wanted to enact legislation to aid with pollution management.

1. Government ministers or senior public officials thoroughly analyse the issue and propose methods for legislation dealing with pollution within federal jurisdiction.

2. They would be responsible for drafting the proposed legislation.

3. The legislation must be approved by the cabinet, which is usually composed of members of Parliament appointed by the prime minister.

4. This version is then introduced into Parliament as a bill for members to study and debate.

5. If both the House of Commons and the Senate approve the bill, it becomes law. Additionally, it must be assented by the Governor General in the name of the Queen. Royal assent is required for every law. (House of Commons, n.d.)

Recognizing the critical need for maintaining effective and relevant regulatory frameworks, in 2017, the Minister of Transportation unveiled a Transformation Strategy aimed at modernising the department's programs and service delivery, acknowledging regulatory modernisation as a critical component. According to the Strategy, Transport Canada is dedicated to modernising its regulatory system to make it more outcome-driven, risk-informed, nimble, and transparent while also fostering innovation and enhancing the transportation sector's safety and security (Government of Canada, 2019a). Stakeholder involvement is a critical component of all the regulatory reviews and Canadians, academics, and other stakeholders are encouraged to become involved. This involves consultations in the Canada Gazette, in which stakeholders were sought for input on how to improve the agility, transparency, and responsiveness of regulations. There are many initiatives and timeframes suggested in the Transportation Sector Regulatory Review Roadmap that will help modernize transportation regulations focusing on areas such as Transportation Issues Addressed by Transport Canada, Remotely Piloted Aircraft Services (RPAS) and Automated Vehicles and Connected Vehicles (AV/CV) (Government of Canada, 2019b). Due to the fact that the COVID-19 pandemic has impacted a major part of these efforts, the timeframes for many of the regulatory plan initiatives have been, nevertheless, altered. Transport Canada is committed to completing all initiatives by 2023 (Government of Canada, 2019c).

3.4.1.3 National Maritime Framework for Remote Inspections

Canada was the first country in the world to establish a national plan for artificial intelligence (AI) in March 2017, the Pan-Canadian Artificial Intelligence Strategy, with the federal government investing CAN$125 million over the next five years. The strategy is divided into four objectives. The first objective is to expand the number of AI researchers and graduates. The second is to set up three groups of scientific excellence. The third is to assist national research communities on AI by helping the country understand its ethical, legal, economic, and policy implications and the fourth is about supporting the national AI research community.

The Canadian Institute for Advanced Research leads the strategy in close collaboration with the Canadian government and the three new AI institutes in Edmonton, Montreal, and Toronto: the Alberta Machine Intelligence Institute (AMII), the Montreal Institute for Learning Algorithms (Mila), and the Vector Institute for Artificial Intelligence (Invest in Canada, n.d.).

Simultaneously, the Canadian government has launched a number of programs aimed at involving the private sector and advancing the country's innovation agenda. The Innovation Superclusters Initiative is one such example, with a CAN$950 million investment in regional industrial superclusters. In 2018, a total of five superclusters were identified. While only one of them is specifically focused on AI (scale.ai), all five intend to incorporate AI into their strategy. These projects significantly complement the Pan-Canadian AI Strategy since they promote close cooperation between industry and academics on AI (UNESCO, 2018).

As Canada's AI ecosystem matures, the Vector Institute applauds the government budget pledge in 2021 to extend the CIFAR Pan-Canadian Artificial Intelligence Strategy with a $443.8 million investment over ten years beginning in 2021-22. These pledges expand on the initial Pan-Canadian AI Strategy, allowing Canada's national AI institutes – Vector, Amii, and Mila – to recruit and retain outstanding research talent while maintaining their momentum in using AI to promote economic growth development that will, in turn, enhance Canadians' lives (Vector Institute, 2021).

A focused research program on AI's social, ethical, and economical consequences is included in the Pan-Canadian Artificial Intelligence Strategy. CIFAR is collaborating with academics and partners in Canada, France (CNRS), and the United Kingdom (UKRI) to investigate these problems and synthesize current thinking on the concerns and possibilities presented by this transformative new technology. Yet, policies included in other plans, such as investments in key areas, data and privacy, and talent development, are not included in the overall strategy. That is not an indication that the Canadian government does not have these rules in place; they exist, but they are not a part of the Pan-Canadian Artificial Intelligence Strategy (UNESCO, 2018).

Regardless, there is currently no AI-specific regulatory framework in place in Canada. Instead, basic privacy, technology, and human rights laws govern AI systems in Canada. Although Canada has yet to establish a complete AI regulatory system, there are efforts at the federal and provincial levels to build more responsive AI regulatory frameworks. In 2019, the Canadian government established an Advisory Council on Artificial Intelligence. The Council advises the Canadian government on how to capitalize on Canada's capabilities in AI. It seeks to foster entrepreneurship, stimulate economic development, and generate jobs. Researchers, academics, and business executives comprise its members.

The Commercialization Working Group of Canada established in August 2019 as a part of the Government of Canada's Advisory Council on Artificial Intelligence to examine ways to translate Canadian-owned AI into economic growth. The group investigates ways to utilize AI to foster inclusive economic development and forward progressive suggestions on how to translate AI research more effectively into goods and services, boost corporate acceptance and foster the growth of Canadian companies. Group's suggestions range from increasing access to AI skills and experience to creating an innovation-friendly legislative environment and making AI computer infrastructure more affordable.

Transparency in the use of digital and data-driven technologies is critical for public trust. The Public Awareness Working Group was formed to provide recommendations to the Government of Canada Advisory Council on Artificial Intelligence and investigate methods to raise public awareness on AI. The group will facilitate an open dialogue with Canadians on artificial intelligence to better understand their perspectives and concerns. Its objective is to generate a report with suggestions for sustaining AI public awareness.

Subsequently, the government submitted Bill C-11 to Enact the Consumer Privacy Protection Act and the Personal Information and Data Protection Tribunal Act to the Parliament in November 2020 to formalize its commitment to public trust in AI and digital technologies. If enacted, the Act would strengthen privacy safeguards for Canadians by giving individuals more choice and transparency over how their personal information is used. Additionally, it would enable increased data exchange and access under certain situations, resulting in societal advantages in infrastructure, public health, and environmental protection.

Canada has sought to guarantee that AI and digital technologies adhere to the ten principles outlined in the country's Digital Charter. "Universal access, safety and security, control and consent, transparency, portability, and interoperability" are only a few of these concepts. Canada is an active player in international forums for governing AI systems, including "the Ad hoc Committee on AI, Digital Nations, the Freedom Online Coalition, the G7, the G20, the OECD, the Open Government Partnership, the UN Roadmap for Digital Cooperation, and UNESCO". The government continues to advocate for governance based on existing international law frameworks, including human rights and humanitarian law (OECD AI Policy Observatory, 2021).

3.4.1.4 National Maritime Framework for Remote Inspections

Respondents informed that there are currently no regulations/provisions for remote inspection techniques. However, the current four-level regime that entered into force in June 2021 will facilitate the eventual adoption of new inspection techniques in the future. The four levels of documents in the hierarchy systems of vessel inspection are:

1. Canada Shipping Act, 2001

Overarching legislation for marine safety and pollution prevention. The Act set the legal framework, and inspection authority, details of inspection are found either in regulations or supporting instruments (Government of Canada, 2001).

2. Regulations, such as the Vessel Safety Certificate Regulations (VSCR) as of 10 of June, 2021

The regulations specify which vessel needs a safety certification, and therefore need to be inspected. The regulations do not specify the inspection details; these are included in the TP15456 document (Canada Gazette, 2021).

3. Standards, such as the new Canadian Plan Approval and Inspection Standard, TP 15456

The objective of this standard entered into force on 23 June 2021 is to provide instructions and guidance for inspections of vessels subject to the Vessel Safety Certificates Regulations under the authority of the Canada Shipping Act, 2001 (CSA 2001). This document contains crucial details, for example, when a vessel needs to be inspected and what elements need to be inspected. If modern remote inspection techniques will be included in the Canadian regime, it will be done at this level or at the next one (fourth level). This would be an administrative exercise (done by Transport Canada Marine Safety and Security), rather than a legal one (e.g., Act or regulatory amendment, with Canadian Justice Department and others) (Government of Canada, 2021b).

4. Supporting material such Guidelines and works instructions

These may be developed on a needed basis to address certain specific elements.

When comparing the above four levels to the IMO instruments, it is observed that the VSCR could be linked to SOLAS, 1974 Chapter I, and the TP 15456 with the Harmonized System of Survey and Certification (HSSC) guidelines. It is important to note that level 4 is comparable to IMO circulars.

In the context of the COVID pandemic, like many other administrations, Transport Canada adapted its inspection process on a case-by-case basis and accepted remote inspection to a certain level. To do this, Transport Canada developed an interim process to define the procedures that marine safety inspectors should undertake when planning and/or conducting periodic or intermediate inspections of domestic vessels to reduce the risk of inspectors contracting coronavirus (Government of Canada, 2021c). The first objective of these procedures was to protect health and open the door for acceptance of remote inspections with “low tech” using available means, such as pictures and videos.

Transport Canada is looking forward to developing a framework that would support the use of new emerging technology. To this effect, there is a multimodal (air, surface, rail, marine) departmental oversight modernization initiative, and the use of remote inspection techniques is one of the objectives of this initiative. In this context, Transport Canada program group that owns interprovincial ferries in the Canadian Atlantic region has a pilot project in place to test small Remotely Operated Vehicles (ROV) for underwater inspection, which will commence during the end of 2021. For inspections, such as the cargo inspection program, respondents confirmed that the use of drones is an element that may be utilized in the future.

The discussions with Deep Trekker, one of the largest providers in the country for remotely operated vehicles & robots, confirmed the limited use of remote techniques on Canadian vessels. According to the company, for the three different types of underwater surveys (Classification Survey, General Visual Inspection and Spot Survey), the inspection methods that can be applied are dry dock, divers and ROVs (Table 22). Each method has its advantages and disadvantages (Table 17).

Table 17: Different methods of underwater surveys

Application / Method	Dry dock	Divers	ROVs
Classification Survey			
General Visual Inspection			
Spot			

Source: Deep Trekker (interview)

Note: Green = Best suited as of current technology and industry preferences; Yellow = Second best suited as of current technology and industry preferences; Red = Third best suited as of current technology and industry preferences.

Table 18: Pros and Cons for underwater inspection methods

Inspection Method	**Certainty**	**Pros**	**Cons**
Dry dock	High certainty	Clear visibility above water	Extremely high cost and time-consuming.
Divers	Moderate certainty	1. Proven to perform adequately well, regulated and guided worldwide. 2. Moderately high cost.	1. Difficult to clarify if divers have inspected the entire vessel and difficult to know their exact position when finding defects. 2. It can be time-consuming to wait and schedule a dive team. 3. It is dangerous to send divers underwater.
Remotely Operated Vehicles (ROVs)	Lower certainty but technology is evolving rapidly	Quick to deploy, most cost-effective and safest alternative.	Inability to know its position. The ROV can run in transects along the hull in straight lines to maintain an understanding of position

Source: Deep Trekker

Respondent from Deep Trekker underlined those three main obstacles are present when it comes to using ROVs:

1. Understanding what you have inspected (vs. not inspected);

2. Visualising the data in a meaningful way; and

3. Sending the data to stakeholders in a meaningful way.

The first obstacle is related to the location of the inspection. GPS positioning systems do not work underwater as they can travel only a couple of inches through the water. One potential solution is the utilization of technology such as the Underwater Positioning System (USBL), which provides a position of the ROV using acoustic positioning. USBL consists of a transceiver mounted on the vessel and a transponder mounted on the ROV which jointly cooperates to communicate the ROV's position relative to the vessel. However, there are cases that USBL on its own does not work well because the vessel is an obstacle for acoustics to communicate from the dunking transducer to the ROV's transponder. USBL is also inherently inaccurate by 20 cm, making autonomous motions difficult and unreliable using just USBL. Deep Trekker is currently working on other methods for getting positioning and allowing for autopilot functionality.

The second obstacle is the visualisation of the data in a meaningful way. Like a diver's eyes, video has a limited field of view to give positional context to the images the surveyor is seeing. A 3D rendering or model allows the surveyor to analyse the aggregate of the data points collected during an inspection. Currently, underwater 3D models are too time-consuming, require expert-level expertise, and their technology remains prohibitively expensive. Table 18 shows the advantages and disadvantages of the three main technologies that can be used to create 3D models: sonar, laser and photogrammetry.

The third obstacle is the proper interpretation of the data. The surveyors usually rely on divers' expertise to confirm the vessel's condition. In contrast, an ROV allows video streaming or video recording where stakeholders can monitor the inspection process. However, there are many hours of footage to comb through to get the answers needed for the surveyor. The operator of the ROV should still be certified and experienced in hull inspections to identify issues. If the surveyor can monitor the inspection process next to the pilot, the quality of the report could be increased. A hull survey report engine must enter the inspected data and then produce a PDF report with photos of points of interest and easy access to key milestones during the video with text added for additional details.

Table 19: Main technologies for 3D models

Technology	Pros	Cons
Sonar	• Can work at longer distances, up to 30m from targets for 3D models, better when working closer range. • Can work in murky water. • Low bandwidth (lower data requirements and easier to integrate on smaller machines).	• Limited precision and accuracy. • Can be time consuming depending on the model.
Laser	• Extremely precise. • Can be fastest of three to develop a model.	• Struggles in murky water. • Short range (1m from target). • High bandwidth (harder to integrate, a lot of data to manage).

Photogrammetry	• Can be precise. • Has highest likelihood to have costs driven down. • Has highest likelihood to be developed into something easy to use.	• Struggles in murky water • Short Range • Can be high bandwidth

Source: Deep Trekker (interviews)

3.4.1.4 National Framework for Autonomous Shipping & Robotic Onboard Systems

Regarding maritime autonomous surface ships, the activities have been very modest compared to countries such as Norway or Finland. The small number of fleets and the low shipbuilding activity have led to limited direct expertise in autonomous ship technology (CISMaRT, 2020). In the future, the country could contribute to autonomous vessels research by transferring knowledge from other sectors, such as underwater autonomous and land-based autonomous vehicles, that could be applied to the design and construction of these vessels (CISMaRT, 2020). In general, Canada's ocean technology sector is a cross-cutting advanced industry focused on products and services in marine transportation, offshore oil/ gas, defense and security. These capabilities should be transferred to other high-value marine manufacturing and service firms.

Nonetheless, TC is working with both the Ocean and the AI superclusters to ensure that MASS is integrated into future Smart Supply Chain logistics developments. In 2019 the Canadian Forum for Maritime Autonomous Surface Ships was established to support the MASS development and continues to collaborate with national/international stakeholders (Transport Canada, 2020a).

The country has given more emphasis on environmentally sound and recyclable vessels. In April 2021, Transport Canada announced a CAN$ 200,000 funding to Innovation Maritime, a Green Marine partner, that develops recyclable boats. The aim of the project is to replace as many hull and deck components as possible with more environmentally friendly ones and create a method to help in easier vessel dismantling. A prototype will be built and tested in real-world navigation conditions.

Numerous initiatives have been launched throughout the country to promote innovation in the transport and ocean sectors. For example, the Innovation Centre is a transportation innovation research, development, and deployment (RD&D) institution dedicated to advancing new transportation technologies in order to guarantee that Canadians benefit from a safe, secure, clean, and interconnected transportation system (Government of Canada, 2019d). They are preparing for these technologies by implementing the following measures:

- Transforming the cutting-edge Motor Vehicle Test Centre in Blainville, Quebec;
- Developing novel collaborations with government, industry, and academics;
- Contributing to the advancement of new transportation technologies via R&D; and
- Building on existing federal innovation financing initiatives, such as the Innovative Solutions Canada, The Build in Canada Innovation Program, the Program to Advance Connectivity and Automation in the Transportation System (ACATS).

In addition, more than 300 businesses in Nova Scotia are involved in the oceans industry, including approximately 80 innovators of novel, high-tech services and products such as ocean technology, renewable energy and boatbuilding (Nova Scotia Business Inc, n.d.). Nova Scotia has become a leader in the ocean industry as a result of the development of numerous research laboratories and institutes, such as:

- The Bedford Institute of Oceanography is Canada's biggest oceanographic research facility.
- Dalhousie University is the first and only institution in Canada to provide an interdisciplinary bachelor's degree in ocean sciences.
- The Sensing, Engineering, and Analytics Technology Access Centre (SEATAC) is one of many applied programs and degrees offered by Nova Scotia Community College (NSCC).
- The Ocean Frontier Institute is a worldwide ocean scientific center that connects researchers and institutions from across the world to better understand the changing ocean and offer safe, sustainable development solutions.
- The Marine Environmental Observation, Prediction, and Response Network (MEOPAR) is a national network of Centers of Excellence that fosters strategic collaborations between leading marine researchers and highly skilled employees, organizations and communities, funds cutting-edge research, and assists in the training of the next generation of marine specialists.
- The National Research Council (NRC) is the primary research organization of the Government of Canada, advancing industrial innovation, knowledge progress, and technological development. It is home to a large number of research facilities dedicated to marine research, algal carbon conversion, and aquaculture in Nova Scotia (Nova Scotia Business Inc., n.d.).

3.4.1.5 National Action Plan: Standards & Guidelines

Transportation 2030: A Strategic Plan for the Future of Transportation in Canada

Transportation 2030 is the official plan of the country that will achieve the vision of establishing a national transportation system that is smarter, cleaner, and safer. Transport Canada aims for modern policies, acts, and regulations that support transportation efficiency, safety, and environmental responsibility. These policies should be up to date with current developments and align with global standards and complex changes in transportation, such as connected and automated cars. The plan divides work into five themes with distinct objectives. These themes span modes of transport -air, marine, trucking and rail- as well as activities, such as setting and enforcing regulations (Government of Canada, 2019e) (figure 11).

Figure 11: Transportation 2030 Actions

Source: Government of Canada, 2019f

"Green and Innovative Transportation" is one of the themes included in Transportation 2030, the Government of Canada's "strategic plan for a safe, secure, environmentally responsible, innovative, and interconnected transportation system" (Government of Canada, 2019g). The theme's objective is to minimize air pollution and embrace new technologies to enhance Canadians' lives. To realise the above objectives of green and innovative transportation, they are focused on:

• Collaborating with provinces and territories to advance a low-carbon transportation system via a Pan-Canadian Framework on Clean Growth and Climate Change;

• Promoting methods for transportation to adapt to climate change, particularly in Canada's north, where melting permafrost impacts the efficiency, safety, and upkeep of infrastructure,

• Pursuing the appropriate balance in regulating unmanned aircraft system technology in order to ensure that:

o Remotely piloted aircraft systems (RPAS) continue to contribute to the advancement of scientific study, exploration, and search and rescue missions; and

o Regulations governing RPAS contribute to public safety and economic development.

• Promoting the use of connected and autonomous cars on public highways in order to:

o Bolster road safety;

o Alleviate congestion;

o Enhance mobility;

o Safeguard the environment; and

o Foster economic growth for Canadian companies.

• Ensuring that their activities advance government objectives, such as:

o Phase 2 of Canada’s infrastructure plan;

o A Pan-Canadian Framework on Climate Change and Clean Growth; and

o A national agenda for innovation (Government of Canada, 2019g).

As a part of the implementation of Transportation 2030, Transport Canada has embarked on a comprehensive review of Canada’s strategic ports (CPAs). The Ports Modernization Review is exploring how best to optimize their capacity to support economic prosperity, position them to respond to future challenges and opportunities, and maximize sustainability and good governance.

Canadian Port Authorities (CPAs) employ a number of steps to optimise and digitalise the supply chain. For example, the Port of Vancouver uses GPS-tracked trucks and data from train track readers to forecast bottlenecks and upgrade operations — which also reduces vehicle idle time. The Port of Montreal uses optical character recognition (OCR) to automate truck and container data processing and validation, while also reducing idle time and increasing vehicle crossings per hour. Other ports are linked to a worldwide digital platform developed by Maersk and IBM to improve efficiency, decrease paperwork, cut prices, and expedite shipping. Furthermore, analytics are being used to optimise the trip to and from port facilities by predicting truck turn and dwell times and optimizing rail connections.

Oceans Protection Plan:

In fiscal year (FY) 2017 - 2018, the Government of Canada launched a five-year Oceans Protection Plan (OPP) with an investment of CAN$1.5 billion investment (Government of Canada, 2020). The OPP aims to create a world-class marine safety system that will safeguard Canada’s marine ecosystems. It is comprised of 58 sub-initiatives organised around four pillars, each of which is focused on a distinct anticipated result. The OPP is being implemented by Transport Canada in cooperation with Fisheries and Oceans Canada (DFO), the Canadian Coast Guard (CCG), Natural Resources Canada (NRCan), and Environment and Climate Change Canada (ECCC). The ECCC’s efforts in the OPP are classified as a part of the State-of-the-Art Marine

Safety System Pillar. This pillar's activities seek to strengthen Canada's marine safety system's potential to inhibit and react to marine safety and pollution incidents (Government of Canada, 2021d).

In June 2021, the Minister of Transport released the "4th Report to Canadians" --- an overview of the work completed so far under Canada's OPP. The Report details the outcomes of more than 50 programs and hundreds of projects across the country. Since the launch of the OPP in 2016, over 1,200 engagement sessions with Indigenous communities throughout Canada have been conducted to develop, co-produce, or inform maritime safety and/or environmental activities (Government of Canada, 2021e). The report's key points are summarized in the following:

1. Increasing maritime safety by establishing a Marine Training Program on all three coastlines. Hundreds of underrepresented groups, including indigenous peoples, Northerners, and women, have begun new careers in the maritime sector due to this program's inception;

2. Canada can better prevent and react to marine incidents by ensuring that the Regional Operations Centres (ROCs) are operating around the clock and having new maritime weather forecasts and radar coverage installed;

3. Through the Coastal Restoration Fund, they are preserving and restoring 64 marine ecosystems along the three coastlines; and

4. Working with indigenous communities to create the Enhanced Maritime Situational Awareness system, which offers near real-time data on marine traffic and the environment, as well as environmental monitoring and protection, and waterway management throughout Canada;

5. Funding of approximately 300 initiatives to remove and dispose of abandoned or wrecked boats in order to minimize navigational risks in the country's waterways; and

6. Over 30 studies were funded under the Multi-Partner Research Initiative to enhance oil spill response procedures and decisions that reduce the environmental impact of oil spills. (Government of Canada, 2021e)

3.4.2 Techno-policy Developments in National Aviation and Automotive Sectors

3.4.2.1 Aviation

The aerospace industry of Canada contributed $13.1 billion to Canadian Gross Domestic Product (GDP) in 2018 (Government of Canada, 2019h). The industry's leading-edge technology and cost competitiveness has positioned aerospace companies as strong Original Equipment Manufacturers (OEMs). First-class world capabilities include the design and production of regional and business aircraft, flight simulator systems as well as space robotics, earth observation systems and communications satellites.

The Canadian Aviation Regulations (CARs). Part IX – Remotely Piloted Aircraft Systems contain most of the rules that apply to drones up to 25 kilograms operated within a drone pilot's visual line-of-sight (Canadian Aviation Regulations, 1996). Drone pilots should hold a valid drone pilot certificate, fly drones that are marked and registered at a height below 122 meters in the air.

Besides, due to the absence of a regulatory framework for remotely piloted aircraft systems (RPAS), TC is in the process of Amending the Canadian Aviation Regulations to provide more flexibility for these systems (Government of Canada, 2019i). For the amendment of these regulations, Transport Canada is partnering with the Canadian industry to conduct trials of RPAS within visual line-of-sight and beyond visual line-of-sight flight tests. These test sites are located in the Unmanned Aerial System Centre of Excellence test range in Alma (Quebec), and the Foremost Centre for Unmanned Systems test range in Foremost (Alberta). The aim of these tests is to inform the development of regulations for remotely piloted aircraft systems operating within visual line-of-sight and in the long term, they will enable regulatory planning for higher-risk beyond-visual-line-of-sight operations.

3.4.2.2 Automotive Sector

The Council of Ministers responsible for Transportation and Highway Safety approved the report "The Future of Automated Vehicles in Canada" on January 29, 2018. The vision is for a consistent national strategy to testing and deployment of AV/CVs on Canadian roadways, resulting in a more secure, efficient, and innovative transportation system. To do this, the Policy Framework:

1. Promotes and guarantees the safe operation of these vehicles by offering guidance to trial organizations and Canadian jurisdictions on how to conduct safe testing and deployment of AV/CVs;

2. Brings Canadian jurisdictions into alignment on critical policy and legal concerns; and

3. Strengthens government-industry-academia partnerships to assist in promoting, testing, and investing in AV/CV technologies (Government of Canada, 2021f).

Canada is dedicated to developing a coordinated national strategy for AV/CV introduction on public roadways. Due to the different roles of the federal, provincial/territorial, and municipal governments, all jurisdictions must adhere to a unified approach to testing and using AV/CVs.

The Federal Government of Canada:

• Takes the lead in harmonizing regulations among jurisdictions, particularly those regulating pilot testing systems;

• Promotes cooperation between government and industry at all levels; and

• Holds vehicle manufacturers accountable for compliance with safety and technology standards worldwide, especially in the United States and Mexico.

Provincial and territorial governments:

• Establish a legislative regime for the testing and deployment of AV/CV in their respective jurisdictions;

• Enact legislation incorporating federal vehicle safety standards; and

• Regulate

• Driving licenses

• Registration and insurance for vehicles

• Road regulations; and

• Highway infrastructure changes that may be required to enable AV/CV deployment.

Municipalities:

• Implement the provincial and territorial legislative and regulatory frameworks, particularly those enforcing AV/CV safety;

• Decide on land use planning; and

• Manage the transit system (Government of Canada, 2021f).

Government and industry both value public education and outreach. Federal, provincial, territorial, and municipal governments may also contribute to the effective deployment and broad public acceptance of AV/CVs during the early stages of adoption by proactively addressing public concerns. Besides, Transport Canada and the Canadian Council of Motor Transport Administrators (CCMTA) created the Guidelines for Testing Automated Driving Systems in Canada Version 2.0. (Government of Canada, 2021g) to ensure that trials are conducted safely, according to a baseline of nationally consistent safety practices. The Guidelines apply to companies conducting research and development trials of automated vehicles. The information in the Guidelines is based on safety practices and lessons learned from domestic and international testing activities.

Transport Canada also released the “Canada’s Vehicle Cyber Security Guidance (Guidance)” which offers a risk-based strategy for firms operating in the automotive sector to help detect, manage, and identify cybersecurity threats throughout the life cycle of a vehicle (Transport Canada, 2020b). The Guidance is a significant, though cautious, step forward in establishing a robust cybersecurity regulatory framework for CAVs. While the Guidance focuses on cybersecurity instead of privacy, the overlapping concerns contribute to the ongoing discussion about reforming Canada’s privacy laws, which was sparked by the federal government’s 2019 Digital Charter. The Guidance provides four technology-neutral, non-prescriptive principles for enhancing the cybersecurity of CAVs via risk identification, monitoring, and response (Jarvie & Nagy, 2020). Those principles are:

1. Identify and manage cybersecurity risks;
2. Protect the vehicle ecosystem by implementing adequate safeguards;
3. Detect, monitor, and respond to cybersecurity events; and
4. Recover from cybersecurity events safely and quickly (Jarvie & Nagy, 2020).

3.4.3 SWOT Analysis

The SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis is based on primary information collected through interviews with industry representatives, academia and public authorities.

Table 20: Canada SWOT Analysis

Strengths	Transport Canada is dedicated to modernizing its regulatory system to foster innovation and enhancing the transportation sector's safety and security. To this effect, there is a multimodal (air, surface, rail, marine) departmental oversight modernization initiative, and the use of remote inspection techniques is one of the objectives of this initiative. Transportation 2030 is the official plan of the country to achieve the vision of establishing a national transportation system that is smarter, cleaner and safer.
	The current four-level regulatory regime for vessel safety and pollution prevention that entered into force in June 2021 will facilitate the eventual adoption of new inspection techniques in the near future.
	Canada's Ocean Technology (OT) sector is a cross-cutting advanced technology industry and technologies, among others, include complex onboard navigation systems, hybrid electrical power systems on a tugboat; or high-tech acoustics and sonar systems.
	The Oceans Protection Plan aims to create a world-class marine safety system that will safeguard Canada's marine ecosystems.
	Canada's aerospace companies possess strong world-class capabilities in: design and production of regional and business aircraft, flight simulator systems, sp robotics, earth observation systems and communications satellites.
	Sustained commitment to research and development (R&D) keeps Canada at the forefront of aircraft and ocean technology development and applications.
	Stakeholder involvement is a critical component of all the regulatory reviews and Canadians, academics, and other stakeholders are encouraged to become involved.
	Canada was the first country in the world to establish a national plan for AI in March 2017. Simultaneously, the Canadian government has launched a number of programs aimed at involving the private sector and advancing the country's innovation agenda.
Weaknesses	There are currently no regulations/provisions for remote inspection techniques. Limited use of remote technologies from the Flag Registry and Classification Societies.
	For autonomous surface ships, the activities have been very modest compared to countries such as Norway or Finland.
Opportunities	The country could contribute to autonomous vessels research by transferring knowledge from other sectors, such as land-based autonomous vehicles, that could be applied to the design and construction of these vessels.
	There is a potential of remote technology deployment for statutory inspections. Comparative studies of traditional surveys with remote inspection techniques to assess the similarity of the two options.
	Training and encouragement of the surveyors for the utilization of RITs.
	Prevention of hull fouling using RITs.
Threats	The effects of widespread warming are evident in Northern Canada and oceans surrounding Canada. Oceans have become more acidic, and less oxygenated. Warming will continue to change patterns of Arctic Sea ice, increase the severity of heatwaves and wildfire risks. This threat increases the need for technological solutions in all the ocean-related fields.

3.5 Review of National Arrangements: Norway

Norway is a leading ocean economy with well-developed business clusters and local communities living along the coastline. The Norwegian shipping industry is at the forefront of exploiting new technologies like autonomous ships and onboard systems. Of recent, Norway has developed the world's first commercially operated autonomous container ship.

The Norwegian Government's Ocean Strategy (Norwegian Government, 2019a), which focuses on the oil and gas industry, the maritime industry and aquaculture, aims to establish a stable regulatory framework for future growth and sustainability. Maritime research, development, and innovation are the cornerstones of Norwegian national Strategy.

3.5.1 Brief Overview: National Law & Policy with a Focus on BUGWRIGHT2 Technologies

Norway has set ambitious national plans to exploit and develop new technologies and reduce climate footprint. The country is turning to waterways for public transportation and national infrastructure development via the most extensive National Transport Plan ever presented (Norwegian Ministry of Transport and Communications, 2017). The Plan aimed to organize the transport sector and provide the appropriate infrastructure, which was a progressive move for the period 2018-2029. Rapid technological developments and the testing of innovative ideas also gained significant attention during the same period. Moving forward, the government plans to develop an efficient transport network, investing more than 400 billion NOK in roads, railways, coastal infrastructure and aviation. As it was evident from the discussions with respondents, a priority of the National Plan is the transport of goods via sea routes. To strengthen the maritime industry, the plan provides grants and benefits to: a) ship-owners who shift freight transport from road to sea; b) ports that improve their efficiency and environmental performance; and, c) cooperative initiatives between ports.

The Norwegian framework study is based on primary and secondary sources of law, as well as explanations and rational interpretations provided by respondents interviewed in April and May 2021. Interviews were conducted with key experts, CEOs, scholars, and policy advisers from the Norwegian Maritime Authority, DNV, Norwegian university of science and technology (NTNU), West Underwater inspection Ltd. (VUVI AS), University of Stavanger, University of South-Eastern Norway, Kongsberg Maritime, Blueye robotics, Jotun A/S, Nordic Unmanned and Zeabuz.

3.5.1.1 Overview of the National System

Based on the Norwegian Constitution of 1814, Norway is a constitutional monarchy with the King as the Head of the State. According to the Norwegian Government (2017) the power is divided between three branches:

- Legislative branch: 169-seat parliament (Storting);
- Executive branch: the government formed by the prime minister and the Statsråd (Council of State); and,
- Judicial branch: the courts.

The Norwegian government's European policy is based on the Agreement on the European Economic Area (the EEA Agreement) that links countries through a common internal market, ensuring economic security and predictability. Norway benefits from the development of common rules for the European market. In cases where legislation is not well-suited to Norwegian interests, the government uses alternative options provided by the Agreement to protect Norway's interests (Norwegian Ministry of Foreign Affairs, 2012). Norway cooperates with the EU in energy, climate change, seafood, labour mobility, digital economy, international politics, free trade and multilateralism (Norwegian Ministry of Foreign Affairs, 2018). Norway's AI national strategy was founded upon the Declaration of Cooperation on Artificial Intelligence (AI) signed in 2018 between 25 European countries (European Commission, 2018).

3.5.1.2 National Framework for AI Technologies and Autonomous Operations

Norway is at the forefront of developing and exploiting new technologies. There is a flat structure in society with short communication lines rather than a vertical chain of command. This horizontal organizational structure enables more interaction and exchanges of ideas, inside and outside the organization, and multidisciplinary work for autonomous operations.

The National Strategy for Artificial Intelligence (Norwegian Ministry of Local Government and Modernisation, 2020) specifies that the government will facilitate the establishment of AI infrastructure through user-friendly regulations, robust communication networks and data sharing across industries. The government will assess whether regulations hinder AI in the public and private sectors, and it will eliminate all impediments that will help the country move towards digitalization and innovation. Policy instruments that promote responsible innovation are an integral part of the National Strategy. The government welcomes the development of new regulatory sandboxes, such as those developed in autonomous transport, to test new technologies or business models. The responsibility for developing these regulatory sandboxes lies with local and regional authorities best qualified to test new systems. Under the remit of the Norwegian Data Protection Authority, an important sandbox under consideration is one that relates to the area of data protection.

The National Strategy for Artificial Intelligence goes hand in hand with the Digital Strategy for the Public Sector 2019–2025 (Norwegian Ministry of Local Government and Modernisation, 2019) and the new Public Administration Act (Lov om saksbehandlingen i offentlig forvaltning,) that amends the Public Administration Act (LOV-1967-02-10) of 1967 (Regjeringen, 2019). The Public Administration Act specifies how public authorities shall handle cases to safeguard individuals' rights to responsible and correct treatment. It incorporates provisions about confidentiality and how cases are to be prepared when the public administration makes individual decisions or adopts regulations. Although Norway has an effective public sector, the Digital Strategy will enhance the digital transformation throughout the entire public sector and enable more tasks to be performed digitally through seamless services. Local and central government agencies, as well as the private sector are said to join forces to create a digital ecosystem that will facilitate innovation.

The main strength of the Norwegian framework is its flexibility to amend its legal framework to meet new technological developments. For example, the Amendment Act on electronic communications (LOV-2001-12-21-117) aims to remove obstacles to electronic communication and make laws technology-neutral, ensuring their continued effectiveness even when new technologies change (Lovdata, 2001). Norway intends to pursue regulations that facilitate automated administrative proceedings and are machine-readable so that AI systems could utilize them.

The Norwegian AI foundation is an important part of the global AI community and brings together public and private stakeholders for the promotion of ethical use of AI and disruption technologies.

3.5.1.3 National Maritime Framework for Remote Inspections

The Norwegian Maritime Authority (NMA) is an agency of the Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment. NMA is the administrative and supervisory authority for environmental, safety and legal issues of vessels flying the Norwegian flag and foreign ships in Norwegian waters. The headquarter lies in Haugesund with the Department of Ship Registration operating in Bergen.

The Register of NMA consists of the Norwegian Ordinary Ship Register (hereinafter referred to as NOR), the Norwegian International Ship Register (hereinafter referred to as NIS) and the Shipbuilding Register (a sub-unit to NOR). For the Norwegian Ordinary Ship Register (NOR), there is a mandatory registration for all Norwegian ships of 15 meters and above and voluntary registration of Norwegian fishing and commercial vessels less than 15 meters. The regulatory framework for registration to NOR is based on the Norwegian Maritime Code of 24 June 1994 no. 39 (NMA, 1994). The NOR is open to EU or Norwegian owners and is the responsible body for surveys and statutory certificates of vessels registered in NOR. International ship certificates for cargo ships above 500 GT usually are usually delegated to RO, upon request from the owner in accordance with the Class Agreement Annex I (NMA, 2013).

NIS was formed as a competitive alternative for Norwegian shipping companies operating in international waters and is mainly competing with flags of convenience registers such as Panama and Liberia. NIS, which aims to maintain Norwegian vessels under the Norwegian flag, is open to owners of all nationalities. Ships are registered according to the law of 12 June 1987 No. 48 related to the Norwegian International Ship Register (NMA, 1987). Passenger and Cargo ships above 500 GT classed by a RO are delegated to class according to the Class Agreement. The NMA inspects ships less than 500 GT as well as NIS ships of 500 GT and more which are not classed by one of the ROs.

The number of vessels by the end of 2020 for NOR and NIS are presented in table 21.

Table 21: Norwegian Registered Vessels 2020

Norwegian Registered Vessels 2020	Registry	Norwegian Owned 2020	Foreign Owned
Ships in the Merchant fleet	NOR	892	24
	NIS	485	170
Ships not in the Merchant fleet	NOR	20,417	73
	NIS	29	11

Source: Statistics Norway

The NMAs inspection regime is divided between inspections on Norwegian flagged vessels and foreign-flagged vessels in Norwegian waters. The inspection-regime is based on the following instruments:

- Ship Safety and Security Act (skipssikkerhetsloven LOV-2007-02-16-9.) that implements SOLAS, 1974; MARPOL 73/78; and STCW 1995 as amended by Act of 19 June 2015 No. 65 (Lovedata, 2007);
- Regulations of 22 December 2014 No. 1893 on supervision and certificates for Norwegian ships and mobile offshore units as amended in 2020 (NMA, 2015);
- Annex I of the Agreement of 1 June 2002 between the Ministry of Trade, Industry and Fisheries and ROs concerning surveys of ships registered in a Norwegian ship register (NMA, 2019); and,
- Regulations of 20 March 2001 No. 373 on the control of ro-ro ferries and passenger high-speed craft in regular service, regardless of flag (NMA, 2001).

Six classification societies are authorized to carry out surveys on behalf of the Norwegian administration namely, American Bureau of Shipping (ABS), Bureau Veritas (BV), DNV, Lloyds Register of Shipping, RINA and Nippon Kaiji Kyokai (ClassNK). Classification societies are used for the inspection of NIS vessels. For surveys of the NOR, the inspectors of NMA are usually appointed. The 130 in-house surveyors of the Norwegian Maritime Authority perform all vessel-related surveys. Thickness measurements are performed by RO approved suppliers on the "IACS List of Thickness measurement Firms", and according to IACS UR-Z7.

Currently, there are no specific regulations and policies for remote surveys, especially when it comes to surveys conducted for the Norwegian Ordinary Ship Register. Norwegian respondents noted that remote surveys are not the preferred option and are currently performed only on an experimental basis. The NMA may utilize remote technologies when achieving equivalency with a traditional survey. The NMA also favors the notion that remote surveys might be more time-consuming than traditional ones conducted through physical presence of the surveyor.

As a consequence of COVID-19, Instructions to Class (IC) 6-2020 rev.1 released by NMA allows ROs to extend the validity of statutory certificates for three months (NMA, 2020a). Section 7.2, as seen from the text below, refers to the possibility of conducting a remote survey:

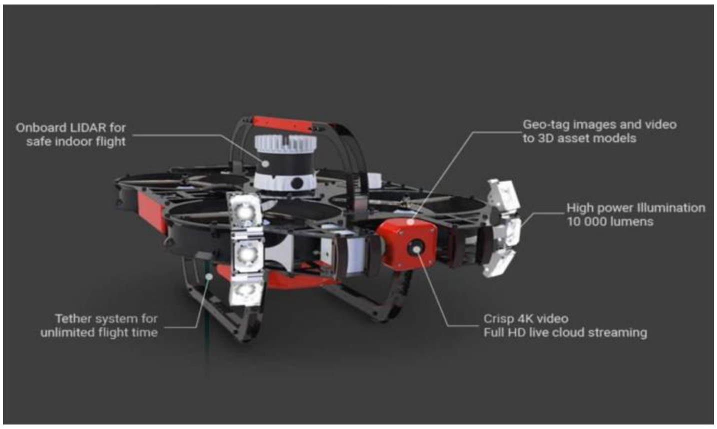
> Before approving a dispensation, alternative methods for inspection and survey shall be considered with the objective of achieving equivalency with a traditional survey. For instance, it shall be considered whether a bottom survey carried out whilst the ship is afloat is a realistic alternative to a bottom survey in dry-dock or if a survey assisted by means of remote technologies may be carried out to compensate for lack of competent personnel due to travel restrictions. (NMA, 2020a).

DNV works in close cooperation with the NMA and completed the world's first in-water remote ship surveys using ROVs in 2020. When a classification society decides to perform a remote survey, especially for NIS registered vessels, no further approval is required from the NMA. Many of the remote surveys using ROVs are conducted in collaboration with VUVI, a Norwegian inspection company certified with the Class Programme of DNV-CP0484 for approval of service supplier scheme for in-water inspections. VUVI, through its high-quality live streaming and powerful router, enables surveyors and ship-owners to attend the survey remotely from their personal device with seamless connectivity from any place in the world. The live stream is said to have only a 2 second delay. VUVI uses a van equipped with the appropriate equipment to perform and monitor the survey. Discussions with the CEO of VUVI informed that survey planning and review of hull drawings are usually performed one day before the survey, optimizing the level of survey assurance. After completing the survey, the company submits a detailed report of approximately 20 pages to the ship-owner and Classification Society. The technical challenges with underwater visibility and location of the hull equipment are addressed with VUVI's sonar technology which includes echo sounder sensors, speed log sensors and sea chests. Veracity is the platform utilized by DNV and service providers of hull inspection to transmit and save the video stream from the survey.

Scout Drones Inspection, another spin-off developed by the Norwegian University of Science and Technology (NTNU), has been utilized by DNV for drone inspections. According to the information provided by the organization, the complete drone system for inspecting confined spaces and indoor industrial assets eliminates the need for scaffolding or climbing and is based on:

- **Onboard 3D LiDAR:** enables safe and easy operation in GPS-denied environments and continuously creates a 3D map of the environment. Images and video are accurately location-tagged. Scout Ground Control application: controls the drone via a tablet and displays the live video stream;
- **Scout Cloud portal:** follows inspections live, provides remote support, re-plays inspections in a split screen view, collects data over time to develop trends, shares data and automatically generates reports; and
- **Tether system:** provides the drone with unlimited flight time and high bandwidth data link. Contact with the drone cannot be lost, even if it is deployed from the outside of a tank or a confined space (Scout Drones Inspection, 2021).

Figure 12: Scout 137 is a complete drone system for inspection of confined spaces



Source: ScoutDI

Interview with a key expert from the Norwegian headquartered firm Jotun, the world leader in marine coatings, emphasized that their innovative solution keeps ships' hulls free of biofouling through a cleaning process that ranges between two and eight hours, depending on the ship's size and type. With Semcon as a technology partner, Jotun contributes to reduced emissions and healthier oceans through its revolutionary Hull Skating Solutions (HSS). HullSkater has not been exploited yet by ROs for hull inspection but is used proactively by ship-owners. Its most innovative aspect is that it stays with the vessel at all times and is lodged in a custom housing on deck when not in use, roaming the ship on magnetic wheels when operated through Jotun's control centres via 4G connection.

Another technological trend in Norway is the Blueye Pioneer, an underwater drone, which is designed for optimal performance in all conditions, from the Arctic oceans to tropical waters, and all the way down to 150 meters below the surface. Its camera captures video footage in full HD quality even in the deep dark sea thanks to powerful LED lights. The 2021 next-generation mini ROV of the Blueye company integrates external software and hardware such as grippers, positioning systems, extra cameras, and other innovative appliances. The drones of Blueye are able to multi-task and can be utilized for underwater inspections, emergency hull and propeller inspections or identification of underwater security threats. Blueye is currently in talks with DNV about the deployment of Blueye technology in remote inspections. Currently the underwater drone is used extensively in the aquaculture and port sector.

Respondents observe that the NMA is willing to embrace remote technologies for inspection. Respondents also displayed a high level of trust in remote technologies, especially in drones given that mitigating technical challenges through drone testing has been successful in other sectors (i.e., aerospace and oil industries).

Discussions with respondents also revealed that the current regime for remote inspection is at a satisfactory level. In the near future, more emphasis should be given to the development of guidelines for data-relevant issues, such as minimal requirements for data quality, data ownership and data flow. Guidelines will be required to govern the work of service robots once they reach the stage of full autonomy. Drone swarms are expected to be the next generation of robotics in the maritime sector. Aerial drone swarms deployed from an unmanned marine robotic station will autonomously inspect the vessel removing the need for manual human inspection system.

3.5.1.4 National Framework for Autonomous Shipping & Robotic Onboard Systems

Norway is undoubtedly leading important developments on autonomous vessels. The Norwegian Forum for Autonomous Ships (NFAS), initiated by the Norwegian Maritime Authority and the Norwegian Coastal Administration and SINTEF Ocean, contributes to the development of the Norwegian strategy for the development and deployment of autonomous ships. A series of projects related to autonomous ships are being developed to evaluate new technology and operate small and battery-powered unmanned vessels as well as fully electric and autonomous container ships.

There are no specific regulations for autonomous or remotely operated ships. Their construction and operation are based on the existing legislation applicable to relevant ship type (cargo ships, passenger ships, fishing vessels etc.). In the process of participating in relevant projects, NMA aims to develop regulations on autonomous ships.

NMA follows the IMO MSC.1/Circ.1455.that provides guidelines for the approval of alternatives and equivalents with regard to ship and system design (IMO, 2013). NMA must be contacted for being able to review operating systems or ships that perform unmanned or partially unmanned operations. According to their degree of autonomy and existing legislation, the assessment of the autonomous vessels is assessed by NMA on a case-by-case basis. During the process, DNV remains closely tied to the work of NMA. No prescriptive rules currently exist. The whole process emphasizes on a risk-based approach when introducing a new technology into marine operations. The entire process must ensure that new technology makes the vessel's operation safe or safer when compared to safety aspects concerning traditional coastal shipping.

NMA issued Circular No. RSV 12-2020-Guidance in connection with the construction or installation of automated functionality aimed at performing unmanned or partially unmanned operations that describes the documentation requirements applied in the processing of ships that are to be autonomous, and fully or partially remotely operated (NMA, 2020b). These ships have a level of autonomy equal to levels three to five, and are engaged in Norwegian domestic voyages and maintain the same level of safety as conventional ships. From a pragmatic prism, three to five autonomy levels refer to the degree of autonomy where onboard functions usually attended by persons are replaced entirely, partially, or periodically by remote operation or automation (NMA, 2021).

Autonomous or remotely operated ships accepted by NMA in accordance with the Circular No. RSV 12-2020 may be provided with a certificate or approval to operate on domestic voyages. Other existing regulations that are relevant to autonomous ships include:

- Ship Safety and Security Act (LOV-2007-02-16-9): Chapter 2, Section 3 states that a ship shall be navigated without posing a risk to life, health, property and the environment. Chapter 3 includes provisions about the technical and operational safety as well as about the maintenance and manning/watchkeeping of Norwegian ships; and

- Construction Regulations FOR-2014-07-01-1072 (Lovdata, 2014) cover the construction of Norwegian ships. Section 75 states that NMA may exempt a ship from one or more of the requirements in the regulations if the shipping company applies in writing for an exemption and one of the following conditions is to be met: a) it is proven that the requirement is not significant and that the exemption is considered safe b) it is proven that compensatory measures will maintain the same level of safety as the requirement in the regulations.

RSV 12-2020 explicitly refers to the ConOps (Concept of operations) as a document that is to be used to communicate the design of autonomous ship systems and operations. ConOps should be submitted to the NMA as part of the autonomous ship system design study to initiate the preliminary design approval process. It is relevant to note that ConOps should be updated when changes are made to the design or operation of the ship.

The discussion with Kongsberg Maritime focused on two large-scale autonomous ship projects. The first one is Yara, the world's first electric and zero-emissions commercially operated autonomous container ship. The vessel will enter into operation at the end of 2021 and will be used for the transport of fertilizer from Yara's factory on Herøya to the ports of Brevik and Larvik. Kongsberg Maritime also cooperates with the grocery distributor ASKO, which is currently transporting their cargo via more than 800 trucks daily. ASKO will replace its supply chain with a zero-emission transport alternative and equip two new vessels with autonomous technology.

Besides, Norway is a global leader in electric ferries and the world's first battery-powered passenger ferry "milliAmpere" launched in Sognefjord in 2015 by Zeabuz. Zeabuz was founded by researchers of the Norwegian University of Science and Technology (NTNU), and is in the process of developing autonomous boats that provide an alternative to land transport and connecting communities across and along their waterways. The Zeabuz mobility system includes autonomous ferries, docking stations with wireless charging, passenger handling, ticketing systems and a remote support centre (Official Homepage of zeabuz).

Kongsberg Seatex, Marintek, Maritime Robotic, NTNU, Rolls-Royce Marine, Trondheim Harbour, NMA and the Norwegian Coastal Administration joined forces and created the world's first test site for unmanned vessels, drones and ROVs (Official Homepage of testsitetrd.no). The testing site will boost Trondheim's cutting-edge autonomy environment and effectively commercialise new technologies.

3.5.1.5 National Action Plan: Standards & Guidelines

Through its compelling Climate Action Plan, the government will transform Norway and promote green growth in every sector of the society by 2030 (Norwegian Ministry of Climate and Environment, 2021). Emphasis is given on emissions not included in the Emissions Trading System (non-ETS emissions), especially emissions from transport, oil, and gas industries. Provisions also exist about the EU Emissions Trading System and land-use emissions. Norway aims to exceed the assigned target from the EU for non-ETS emissions, which is 40 %, and targets a decrease of 45 %. The main tools to achieve the target are taxation of greenhouse gas emissions, regulatory measures, funding for environmental technologies and research on innovative products/services/processes. The taxes on greenhouse gas emissions will be gradually increased from 590 NOK per tonne CO2 - equivalent to about 2000 NOK per tonne CO2 by 2030. Within this framework, there will be specific requirements for zero-emission solutions for passenger cars in 2022 and local buses from 2025. For the shipping sector, biofuel quota obligations for off-road diesel and fuel for shipping will be introduced in 2022.

In the same line, the National Transport Plan for 2018–2029 underlines the intention of the government to set criteria concerning zero- and low-emission solutions for high-speed passenger vessel services.

Innovation and research for digitalization and autonomous solutions for ocean systems, port logistics chain and vessels are main priorities within the Norwegian Government's Ocean Strategy (Norwegian Government, 2019). This is likely to enable Norway to maintain its leading global position in sustainable ocean management.

Norway has committed itself to reducing greenhouse gas emissions by at least 50 percent and towards 55 percent by 2030. Within this framework, the Green Shipping Programme is a significant public-private partnership between DNV, the Norwegian Ministry of Climate and Environment, the Norwegian Ministry of Trade, Industry and Fisheries, and other approximately 60 interested parties. The partnership will establish the world's most environmentally friendly domestic shipping through a series of projects such as the development of green ports, battery-powered ferries, autonomous, zero-emission vessels, LNG/VOC/battery-powered shuttle tankers and hydrogen-powered speed boats.

Enova SF, a state-owned enterprise owned by the Ministry of Climate and Environment is a substantial funder of energy and climate technology projects for Norway's transition to a low-emission society that will meet the 2030 climate targets.

3.5.2 Techno-policy Developments in National Aviation and Automotive Sectors

3.5.2.1 Aviation

Norway aspires to be a global leader in electric aviation and has set up Norwegian companies operating as subcontractors to produce components and parts for electric aircraft. Norway has developed a framework that promotes electrification in road traffic, ferries and the airline sector to achieve the targets set out in the Paris Agreement. Avinor, which operates in 44 national airports, and the Civil Aviation Authority of Norway (CAA Norway) were requested by the Norwegian Ministry of Transport to introduce a program for the introduction of electric aircraft. Avinor, Widerøe, SAS, the Norwegian Association of Air Sports, and Zero Emission Resource Organisation cooperate in electrifying short-haul flights that will in turn help in the overall reduction of greenhouse gas emissions by 80% in 2040.

The Green Flyway is a joint EU-funded project between Norway and Sweden that provides an international test arena for airline companies, drone manufacturers and maritime autonomous test arena.

Regulation for Civilian aircraft A 7-1 (CAA Norway) for unmanned aircrafts applies to drones or RPAS (Remotely piloted aircraft system) and classifies their use into three categories (RO1, RO2, and RO3), distinguishing between drones that are operated in visual line of sight (Visual Line of Sight – VLOS), and beyond the line of sight (Beyond Line of Sight – BLOS).

- **RO1:** Drones weighing up to 2.5 kg, with a maximum speed of 60 knots, operated exclusively within VLOS during daylight hours. The only prerequisite is the notification of the Civil Aviation Authority before the initiation of the operation. No permit is required and the operator confirms that he is aware of the regulations to operate as a category 1 RPAS operator;

- **RO2:** Drones up to 25 kg with a maximum speed of 80 knots, used for VLOS or EVLOS operations during daylight hours. A license from the CAA Norway is required. The application to CAA must be accompanied with a risk analysis and an operation manual. Operators have to pass an electronic examination (e-exam); and

- **RO3:** Aircrafts above 25 kg -or with a maximum speed of 80 knots, or operated by a turbine engine- used for BLOS operations at altitudes of more than 120 meters, or will operate in controlled airspace at altitudes of more than 120 meters or will operate over or in the vicinity of crowds of people. A license from the CAA Norway is required. The application to CAA must be accompanied by a risk analysis and an operation manual. Operators have to pass an electronic examination (e-exam).

If goods are to be transported with RPAS a plan has to be developed and adequately described in the operations manual. Transportation of goods requires special permits. It is important to note that the operator has a strict liability for any damage or losses but the provision does not apply to damage to another aircraft or injury to persons or damage to objects in such an aircraft.

One of the largest Nordic drone companies in the fields of energy and maritime is Nordic Unmanned. Discussions with the CEO underlined that the company provides a range of different services including UAVs with sniffer sensors of SO_2, CO_2, NO_2, measuring maritime emissions from ships and ensuring compliance with MARPOL Annex VI. The company is committed to implementing the International Civil Aviation Organization (ICAO) rules and monitoring any legislative amendments for RPAS.

Nordic Unmanned also provides consultation services related to drone regulations, Concept of Operations (CONOPS) and Specific Operations Risk Assessment (SORA). CONOPS has the potential to act as an important tool for reliable BVLOS operations once it provides detailed information of the aircraft, systems, procedures and risk assessment parameters. For the CONOPS and risk assessment documents, Nordic Unmanned addresses important elements relevant to a number of varying authorities:

1. RPAS (UAV, ground station, radio links) performance, limitations, reliability, behavior in normal and abnormal situations including a Detect and Avoid approach;
2. Radio links frequency coordination according to the applicable ITU rules;
3. Pilots and staff qualification/certification;
4. Airspace coordination with the relevant authority for safe fly; and
5. Safety: conduct regular risk and hazard review exercises which are also shared by the CAA where we operate to keep an open and transparent communication culture (Official Homepage of Nordic Unmanned).

The CEO of Nordic Unmanned underlined that most of the country's focus is on the research side of drones instead of the commercial aspect. The respondents supported that relevant stakeholders should take full advantage and value of all the benefits that the technology is ready to offer.

3.5.2.2 Automotive Sector

In Norway, preparing and enacting legislation permitting experiments with self-driving vehicles on public roads is marked as a "swift process". The entire process was initiated in 2016 when Norway signed the Amsterdam Declaration on Cooperation in the field of connected and automated driving and the new legislation was promptly passed in 2017 (Hansson, 2020). The "Testing of Automated Vehicles Act' Self-driving vehicle testing law (Lov om utprøving av selvkjørende kjøretøy) aims to promote the development of new technology in the transport sector and to facilitate the testing of self-driving vehicles. (Lovdata, 2017). The Act allows the responsible authority to make exceptions to the Road Traffic Act (Lov om vegtrafikk) and the Commercial Transport Act (Lov om yrkestransport med motorvogn og fartøy (Lovdata, 1965 and 2002).

Testings should be made within a framework that safeguards traffic safety and privacy. Permission may be granted to a natural or legal person that shall be obliged to take all necessary measures to prevent and deter the vehicle from causing damage to life, health, the environment or property. Liability departs from the car driver to the applicant for AV testing, paving the way for fully autonomous vehicle testing putting into traffic. The testing of self-driving cars is carried out by the Norwegian Public Roads Administration, which operates under the direction of the Ministry of Transport and Communications and the Urban Environment Agency in Oslo.

A number of technical institutions and universities conduct research on automated vehicles. For example, the SPACE (Shared Personalised Automated Vehicles) project envisions the use of AVs in public transport. The project develops business models for the best use of shuttle buses, enabling a substantial reduction in car ownership. Furthermore, Ruter has been experimenting with self-driving vehicles as an integrated part of the Oslo region's public transport services. This way, they introduce self-driving technology to end-users and prepare the national authorities, policymakers and the Norwegian Public Roads Administration for the emergence of autonomous transport solutions. The NTNU Autonomous Perception Laboratory (NAPLab) of the Norwegian University of Science and Technology carries out state-of-the-art models for autonomous vehicles and transfers knowledge from simulated environments to real-world scenarios. It is noteworthy that Norway is the global leader in electric vehicles per capita in the world (Government of Netherlands, 2019b).

3.5.3 SWOT Analysis

The SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis is based on primary information collected through interviews with industry representatives, academia and public authorities.

Table 22: Norway SWOT Analysis

Strengths	Fast process of preparing for and passing legislation permitting experiments and testing of autonomous operations. The main strength of the Norwegian framework is its flexibility to amend its legal framework to meet new technological developments.
	The government welcomes the development of new regulatory sandboxes in different fields. Regulatory sandboxes, like the ones in the automotive sector, enable entrepreneurs to test new technologies. Through legislative amendments that incorporate trial provisions within a limited geographical area or time, the relevant competent authorities play a monitoring role to ensure the safe testing of products.
	There is a flat horizontal structure in the Norwegian society with short communication lines inside and between the organizations that enable multidisciplinary work for autonomous operations, Strong collaboration between government, private and public agencies.
	Service provider companies for remote technologies, approved mainly by DNV, provide a state-of-the-art remote inspection. High-quality live streaming and a powerful router enables surveyors and ship-owners to attend the survey remotely from their personal device with seamless connectivity from any place in the world.
	A high level of trust between organizations and individuals sets the basis for multidisciplinary research, human-friendly and trustworthy artificial intelligence. The high level of trust between NMA and DNV enables remote inspections for NIS to be performed despite the absence of specific regulations.
	Substantial in-house resource capacity for vessel inspections in the NOR. The number of surveyors is approximately 130 surveyors.
	Tremendous Innovations in the oil and gas sectors. Norway leads the autonomous operations in these two sectors.
	Many spin-off autonomy-related initiatives established during the last years.
	Industry and public sectors are technologically advanced and digitalized compared to other countries, especially in green shipping, aquaculture, and petroleum activities.
	Strong cooperation between the Nordic Countries, through the Nordic Council of Ministers on matters related to Artificial Intelligence.
	Local and central government agencies work on developing their services based on a shared digital ecosystem for collaboration. Most of the services will be digital and seamless by 2025.

	Trondheim Fjord is the world's first test site for autonomous vessels, ROVs and drones and will boost technological development and commercialization of automated products.
	The Norwegian government aims to reduce greenhouse gas emissions by at least 50 percent and towards 55 percent by 2030 through integration of autonomous systems.
	Norway built the world's first commercially operated autonomous ship: Yara Birkeland.
	Norwegian society is characterized by trust and respect for fundamental values such as human rights and privacy.
Weaknesses	Need for better mechanisms for funding and coordination among the different Ministries. There is a need for a public funding coordinator and dedicated funding streams for innovation.
	Dependence on oil and gas industries and fewer companies compared to other Nordic countries that contribute to innovation. Norway is a thriving economy but could achieve the highest ranking in global innovation scoreboxes. Norway holds the 20th position in Global Innovation Index (GII) that ranks 131 world economies according to their innovation capabilities. Norway has relatively high values when it comes to human resources and research systems, public R&D investment and degree of innovation in small and medium-sized enterprises (SME) but lower values for patents, design and exports of high-tech products.
Opportunities	The country has one of the most digitalized public sectors and should continue to build on these advantages to fully exploit the potentials introduced by AI.
	More robust governance, coordination and clarification of roles and responsibilities between governmental sectors and administrative levels is required.
	AI represents vast opportunities for achieving the Sustainable Development Goals and the targets of the Paris Agreement.
	Emphasis on the development of AI for fully autonomous service robots. Drone swarms are expected to be the next generation of robotics that will autonomously inspect hulls and tanks, preventing risks to humans caused by survey and inspection conducted via physical presence.
Threats	The global shift occurring away from 'hydrocarbon molecules' to renewable sources of energy could reduce the demand for fossil fuels and the economy's welfare. Ambitious national climate change mitigation targets may lead to lower prices for fossil fuels in the future. According to the Paris Agreement, oil consumption in 2050 should be reduced by at least 50 percent and gas demand by one-third.
	Like many European countries, Norway will be affected by the age wave. Norway should continue to work on innovation and fully capitalize on key trends created by a rapidly aging population.
	Climate change and increasing globalization may challenge the competitive position of the country, and the level of social and economic welfare.

3.6 Review of National Arrangements: China

China, the largest developing country in the world and one of the most competitive global economies, has achieved science and technology breakthroughs, China has a specific roadmap for developing a fully integrated and innovative smart transport system by 2035. The low carbon development of the transport sector is a policy objective in the context of the country's 2030 carbon dioxide emission and 2060 carbon neutrality goals. The target of carbon neutrality (to be achieved by 2060) serves as a catalyst for Chinese businesses to drive technical innovation and industrial upgrading in the direction of green and sustainable economic growth. To this end, China's government has taken a very active role in promoting a national AI development agenda.

The Chinse report mainly draws upon public sources including Chinese laws and official press documents, academic journals, and news articles. Primary information collected through Interviews with key experts from China Classification Society and Bureau Veritas.

3.6.1 Brief Overview: National Law & Policy with a Focus on BUGWRIGHT2 Technologies

3.6.1.1 Overview of the National System

The Chinese Communist Party (CCP) established the People's Republic of China (PRC) in 1949. For nearly thirty years after the formation of the PRC, there was a widespread belief that a formalized legal system was superfluous in many sectors of national life as the economy was centrally controlled, and conflicts could therefore be handled via mediation or administrative methods without referring to legal rights and obligations (Clarke, 2005). However, the late 1970s "Reform and Open Door" policy, which sparked China's present fast economic growth and triggered the country's continuing transition to a market economy, had profound consequences for the country's legal evolution. In the 1980s and 1990s, a plethora of legislation was enacted, including numerous environmental laws, rules, and regulations.

Over the last several decades, the reconstruction of China's legal system has largely abandoned ideological constraints in favour of a major effort of law transplantation from western legal systems and globally recognized norms. Thus, modern Chinese law, in its form, structure, and methods, shows several western features, despite its legislative procedures being mainly based on the European Continental civil law tradition (Chen, 2008).

China's central government is similar to European parliamentary systems in that the governing head, the prime minister, is elected from and forms a cabinet with other members of the legislature. As a result, the head of government (the prime minister) is a separate entity and institution from the head of state (the president of the nation). Power in the People's Republic of China is vested in the National People's Congress (NPC) and people's congresses at lower levels of government (State Council of the People's Republic of China, 2004). The Structure of the government is comprised of three branches: executive, legislative and judiciary branches, briefly explained below:

A. Executive Branch

Articles 79–84 of the 1982 Constitution of the People's Republic of China outlines the roles and powers of the President and Vice President. Individuals are elected to these posts by the NPC for a five-year term with a maximum of two consecutive terms. The President is vested with many responsibilities, including the authority to promulgate laws and to appoint and remove members of the State Council (The National People's Congress of the People's Republic of China, 2004). The State Council is the PRC's government, as defined under Articles 85–98. It is the supreme organ of state authority and administration (Art. 85). Premiers, Vice-Premiers, State Councillors, Ministers in charge of ministries, Ministers in charge of commissions, the Auditor-General, and the Secretary-General comprise the State Council. The State Council has a five-year tenure of office (Art. 86). The State Council is vested with a variety of duties and authorities, including but not limited to the approval of administrative measures, regulations, and directives, as well as the submission of recommendations to the National People's Congress (The National People's Congress of the People's Republic of China, 2004).

B. Legislative Branch

The National People's Congress is charged with the responsibility of establishing and overseeing all administrative, judicial, and prosecutorial entities at all levels of government. The NPC is accountable to and supervises all administrative, judicial, prosecutorial, and military agencies, as well as other state-level organizations. The NPC's legislative functions include electing the President of China, overseeing the Constitution's implementation, revising the Constitution, passing fundamental legislation, selecting the Premier of the State Council upon the President's nomination, and electing the President of the Supreme People's Court. The NPC meets annually for about two weeks. Between these sessions, its authority is exercised by its Standing Committee, which is chosen by NPC members and is accountable to the NPC for its activities (lawinfochina, n.d.).

C. Judicial Branch

Articles 123–135 create the PRC's judicial system, which is composed of people's courts, the Supreme People's Court, people's procuratorates, the Supreme People's Procuratorate, military procuratorates, and other special people's procuratorates. The Supreme People's Procuratorate, which reports to the National People's Congress and its Standing Committee, is China's top prosecutorial body, exercising and overseeing prosecutorial power at all state and local levels (The National People's Congress of the People's Republic of China, 2019). There is a hierarchy within the court structure taking the top-down approach: the Supreme People's Courts, the Higher People's Courts, the Intermediate People's Courts, and the Basic People's Courts. Additionally, there are a number of specialty courts, including those that deal with railway sector, forest matters, the People's Liberation Army (PLA), and maritime matters (lawinfochina, n.d.).

3.6.1.2 National Framework for AI Technologies and Autonomous Operations

China has one of the most ambitious AI plans in the world, leading the way for AI in terms of technological development and market applications. On July 20 2017 China's State Council issued a seminal document, "The Next Generation Artificial Intelligence Development Plan", which includes strategic goals, R&D, talent development through education and skills acquisition as well as ethical norms, aims to make the country the leading AI power by 2030 in production segments, social governance, national security and defense (State Council, 2017). The Plan asks for fostering "local industry and innovation chains focused on AI" and the establishment of "AI industrial clusters." Local governments across the nation have launched similar initiatives and the Beijing region, which is already home to many major businesses and research institutes, supports best examples in the context of China.

In addition to the "Next Generation Artificial Intelligence Development Plan", the government has passed other policies, such as "Made in China 2025" and "Action Outline for Promoting the Development of Big Data" for the development of AI (Chinese Government, 2015). These policies aim to motivate different stakeholders on the ground that AI is a field that is being backed by the government and is worth investing in (Li, Tong and Xiao, 2021). Moreover, the term "National New Generation Artificial Intelligence Open Innovation Platforms" (AIOIPs) surfaced in November 2017, when China's Ministry of Science and Technology (MOST) approved the establishment of four private sector companies to construct platforms for particular objectives. The companies were Baidu (for autonomous driving), Alibaba (for smart cities), Tencent (for medical imaging), and iFlyTek (smart audio, i.e., natural language processing). In 2018, a fifth AIOIP, SenseTime (smart vision), was introduced. The project was extended to include 15 AIOIPs in August 2019 and is still available for more applicants (Stanford-New America, 2019).

The Ministry of Science and Technology of China and the Beijing Municipal Government jointly launched the Beijing Zhiyuan Action Plan (the "Zhiyuan Plan") in November 2018 and created the Beijing Academy of Artificial Intelligence (BAAI). BAAI was founded by a coalition of academic and private sector leaders with the support of some of Beijing's most influential institutions and corporations in the field of artificial intelligence, including Peking University, Tsinghua University, the Chinese Academy of Sciences, Baidu, ByteDance, Megvii, Meituan-Dianping, and Xiaomi (Stanford-New America, 2019). The Zhiyuan Plan is the result of a complex network of central and local science and technology development policies and efforts. The Zhiyuan Plan, according to Beijing Municipal Science and Technology Commissioner Xu Qiang, is intended to fulfil the following four responsibilities:

1. Establish an innovative artificial intelligence ecosystem, develop Beijing's open-source platform, and promote open-source algorithms via the utilization of open data, intelligent computer programming frameworks, and computing infrastructure;

2. Establish a high-level collaborative lab to address fundamental ethical issues, initiate integrated and collaborative research, and foster indigenous innovation;

3. Identify, convene, and nurture top AI talent; and,

4. Establish Beijing as a worldwide centre for artificial intelligence by enhancing corporate, academic, and institutional collaboration and hosting global AI conferences (Stanford-New America, 2019).

In 2019 the "Beijing AI Principles" were also released by the Beijing Academy of Artificial Intelligence (BAAI), an organization backed by the Chinese Ministry of Science and Technology and the Beijing municipal government. (Zhang et al, 2021). The principles have been endorsed by leading universities and research institutions and are proposed as an initiative for the deployment and use of AI.

Three elements have substantially strengthened China's position in this "AI global race": a) fostering local talent; b) society's trust in AI; and, c) the architecture of China's AI ecosystem (Candelon, et al. 2021). The first element refers to the increasing number of AI research departments in universities that have been formed in the last decade nurturing data, computer science and engineering talents. In 2020 China has surpassed the US in the share of AI journal citations (Zhang et al, 2021). High innovation skills and expertise that have been gained by local residents led China to fill more AI patents in 2020 than any other country, accounting for 74.7 percent of the world's total of 520,000 (World Scientific, 2020). Most of these patents are filed by universities and research institutes, the majority of which are government-owned or funded.

Regarding the second element, that of trust, Chinese users show a high level of trust in AI-based decisions given the fact that cultural and political attitudes to data and privacy in China differ from those in the West (Candelon, et al. 2021). As for the architecture of China's AI ecosystem, governments, institutions, and companies interact differently from that in the EU and US. Chinese technological companies develop AI platforms, and frameworks to solve business problems and keep it accessible to interested parties. Therefore, industry incumbents and medium enterprises are able to access AI at a lower cost. Chinese companies excel over their overseas counterparts in AI fields such as speech, image and video recognition as they are fast in bringing their products and services to the market. In this AI context, China's government has taken an active role in promoting a national AI development agenda. Thus, it is developing new methods for directing development in close collaboration with top private sector firms that create key AI technology and applications. Following in the footsteps of past development plans, a few businesses have been chosen as members of the "National AI Team," an endorsement that entails assistance from both the national and local governments and access to regional initiatives and associated public data resources. In exchange, the government anticipates that essential standards for the growth of the AI ecosystem will be more efficiently coordinated among stakeholders, while small businesses will be able to keep pace with leading AI advances via open innovation platforms.

Apart from the three elements mentioned above, other aspects contribute to the booming AI sector in China. One is its huge market size that gives the chance to firms to assemble big databases (Li, Tong and Xiao, 2021) and explore different AI applications in different market segments at a fast pace. Furthermore, clear data privacy policies and regulations boosts AI application fields in China (Li, Tong and Xiao, 2021).

Despite the success stories of the AI sector, there are some challenges that has the potential to impede future developments:

1. Truly original ideas are lacking, even though scientific publications and patents are rising; and

2. Companies favour applied AI research that can bring quick profit instead of more research and development with long-lasting impacts (Li, Tong and Xiao, 2021).

Policy uncertainty and weak regulations, especially on data protection creates various concerns for companies. However, the new Personal Information Protection Law that will enter into force 1st November 2021 (The National People's Congress of the People's Republic of China, 2021) enhances the Chinese legal framework for data security which bears similar markings to the European Union's General Data Protection Regulations (GDPR) that limits the use of personal data by businesses and protect user's rights. The Law addresses many of the data misuses that have plagued Chinese consumers for years. This new Law along with the Data Security Law (The National People's Congress of the People's Republic of China, 2021) and Cybersecurity Law (Standing Committee of the National People's Congress, 2016) influence all enterprises that employ networks or information systems in their operations and impose technical alterations on IT infrastructure and system application and design.

It should also be noted that the level of AI and the implementation of the national strategy varies from region to region. There are regions such as Shanghai and Shenzhen that have built robust infrastructure for new AI companies, whereas other regions are still in the process of exploring AI systems. Shenzhen policymakers have drafted local regulations for AI in June 2021 on the Promotion of Artificial Intelligence Industry of Shenzhen Special Economic Zone to the local People's Congress for review. The Regulations aim to establish a framework to govern the approval of AI products and services, AI usage ethics and residents' data privacy rights. This initiative may pave the way for the development of similar standards at the national level.

3.6.1.3 National Maritime Framework for Remote Inspections

The Maritime Safety Administration of the People's Republic of China (CMSA) is the governmental agency for maritime safety, vessel inspection, and pollution from ships. The Agency is responsible for regulations, technical codes, and standards in safety supervision, marine pollution prevention, and navigational aid. The Agency supervises the statutory survey and certification for ships. For international trading ships, the statutory survey processes have been delegated to the China Classification Society (CCS). According to respondents, no specific regulations or guidelines have been released by the Agency that enable the use of remote inspections.

CCS provides classification services to ships including statutory surveys, verification, certification and accreditation and other services in accordance with the IMO rules and requirements and relevant regulations of the authorising flag states or regions. Class services are provided to more than 32,000 international and domestic shipping ships and 2,600 ocean fishing vessels. Surveys utilising RITs are mainly operational and not statutory, and are assessed on a case-by-case basis and dependent on approval from the Flag Service. These techniques are applied on oil tankers, but not for hull survey, inspection and cleaning. In 2018 the CCS released the "Guidelines for Use of Unmanned Aerial Vehicles for Surveys" (CCS, 2018) for ships and offshore installations following the relevant requirements of IACS Recommendation 42 titled "Guidelines for Use of Remote Inspection Techniques for surveys". Remote inspections by way of UAVs are to be carried out by professional organizations. The specified technical standards are relevant to safety, operational performance, endurance capacity, data transmission and communication, storage, airborne lighting, and airborne cameras. Provisions also exist for the collection, processing of visual data and data security.

Steel ships are built and surveyed in accordance with the Rules for Construction and Classification of Steel Ships published by CSS (CCS, 2020a). The updated version of the rules includes provisions for RITs utilized in: a) thickness measurements and close-up surveys - hull structures; and b) In-Water Survey (Table 1). For surveys conducted using RIT, one or more of the following means for access, acceptable to the Surveyor, is to be provided: (1) unmanned robot arm; (2) Remotely Operated Vehicles (ROV) (3) Unmanned Aerial Vehicles/Drones; and (4) Other means acceptable to the Society.

Table 23: RITS provisions in the Rules for Construction and Classification of Steel Ships, 2020

2.1.4 Procedures for class related service (a) Thickness measurements and close-up surveys - hull structures	(x) 1. The RIT is to provide the information normally obtained from a close-up survey. RIT surveys are to be carried out in accordance with the requirements given here-in and the requirements of IACS Recommendation 42 "Guidelines for use of Remote Inspection Techniques for surveys". These considerations are to be included in the proposals for use of a RIT which are to be submitted in advance of the survey so that satisfactory arrangements can be agreed with the Society; (2) The equipment and procedure for observing and reporting the survey using a RIT are to be discussed and agreed with the parties involved prior to the RIT survey, and suitable time is to be allowed to set-up, calibrate and test all equipment beforehand; (3) When using a RIT as an alternative to close-up survey, if it is not carried out by the Society itself, it is to be conducted by a firm approved as a service supplier according to UR Z17 and is to be witnessed by an attending Surveyor of the Society;

	(4) (4) The structure to be examined using a RIT is to be sufficiently clean to permit meaningful examination. Visibility is to be sufficient to allow for a meaningful examination. The Society is to be satisfied with the methods of orientation on the structure. (5) The Surveyor is to be satisfied with the method of data presentation including pictorial representation, and a good two-way communication between the Surveyor and RIT operator is to be provided. (6) If the RIT reveals damage or deterioration that requires attention, the Surveyor may require a traditional survey to be undertaken without use of a RIT.
2.1.4 Procedures for class related service (b) In-Water Survey	(i) The In-Water Survey is to be carried out under the surveillance of the Surveyor by an In-Water Survey firm approved by the Society according to CR "Guidelines for Approval of Service Suppliers", by diver or Remotely Operated Vehicle (ROV). (ii) The Society's approval is to be granted to the firms whose organization and management structure are satisfactorily established, which employ the divers using closed-circuit television with two-way communication or operators using Remotely Operated Vehicle (ROV) for the In-Water Survey work and which have sufficient equipment proved suitable for the work undertaken. (iii) The continued approval of the firm is to depend on its original standards and ability being maintained. Any changes in the information originally supplied are to be reported to the Society; however, the approval is to be renewed after a period not exceeding 5 years.

Source: CCS, 2020a

3.6.1.4 National Framework for Autonomous Shipping & Robotic Onboard Systems

The discussions with the BV team revealed that Class is constantly searching for new ways to survey new builds and in-service vessels. BV's Digital Classification program aims to transform its classification operating model through 3D classification, remote surveys and optimized survey schemes. The main objective is the development of an end-to-end solution that will support ship owners and ship managers in anticipating repairs and better maintaining the ship's hull condition. RITs were reflected in BV's rules in 2019. The Class since that time has conducted tests and established 'proof of concept' for the most advanced inspection techniques to confirm that the technologies provide safer and even better-quality evidence than traditional surveys of bulk carriers and tankers. BV supports that RITs significantly reduce time and cost in needing staging, raft surveys or rope access specialists combined with the required thickness measurement capabilities. Although China has ambitious national AI plans, the level of automation in the maritime sector is still low. The main problem in China is the lack of reliable service providers to provide remote inspection techniques.

China has taken great strides in testing and developing autonomous vessel technology as well as patenting those innovative developments. A significant number of R&D activities are launched in collaboration with academic institutions and private companies registering thousands of patents to build the next generation of MASS technology, which is increasing the chances for China to be the leader in the sector by 2025. Thetius research identified almost 3,000 patents relating to autonomous shipping technology worldwide, of which 96% were registered in China (Thetius, n.d). Chinese companies also have taken the lead in marketing Autonomous Underwater Vehicle for marine surveying and reconnaissance, mine warfare and cable inspection.

In 2019, the Zhuhai-based technology group Yunzhou Tech completed the trial of the 12.9 meters autonomous cargo ship *Jin Dou Yun 0 Hao*. This was the first autonomous sailing cargo ship to be evaluated and tested in accordance with the IMO "MASS Trial Guidelines". The project was developed in collaboration with the Wuhan University of Technology, China Classification Society and Zhuhai municipal government with the objective to reduce 20% of vessel construction costs, 20% of the total operation costs and 15% fuel consumption. In December of the same year, Navigation Brilliance contracted Yangfan Shipbuilding's Qingdao Shipyard to construct a small 300 TEU autonomous container ship in cooperation with the China Waterborne Transport Research Institute and Dalian Maritime University. In 2021 the research institute of Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai) announced its new project that aims to develop the world's first research vessel with remote control and autonomous navigation that will be able to travel at a speed of 18 knots. China Ship Design &Research Center (CSDC) started designing the world's first research vessel with remote control and autonomous navigation in 2021, and is currently built by Huangpu Wenchong Shipyard. CSDC is a platform for R&D design and technology innovation of civil vessels and marine engineering equipment established by China Shipbuilding Industry Corporation with the joint investment of 68 million Yuan from 8 well-known shipbuilding enterprises and research institutes. Huangpu Wenchong is a subsidiary of the China State Shipbuilding Corporation and one of the largest shipyards building military and commercial cargo ships.

In 2015, CCS has commenced with the development of technical standards and compilation of smart ship specifications. The ''Smart Ship Specifications'' of the Chinese Classification Society, revised in 2020, includes smart navigation, smart engine room, intelligent energy efficiency management, intelligent cargo management, remote control and autonomous operation functions (CCS, 2020b). The regulations will provide sufficient support and basis for the classification of smart ships in the future. CCS has formed a series of guidelines for smart ships based on the requirements of the smart ship specifications. In addition, CSS released the "Guidelines for the Inspection of Unmanned Surface Vessel" in (2018) based on the concept of the IMO Goal Based Ship Construction Standards (GBS). The Guidelines contain rules on the conception, construction, inspection, maintenance and use of unmanned vessels (CCS, 2018).

3.6.1.5 National Action Plan: Standards & Guidelines

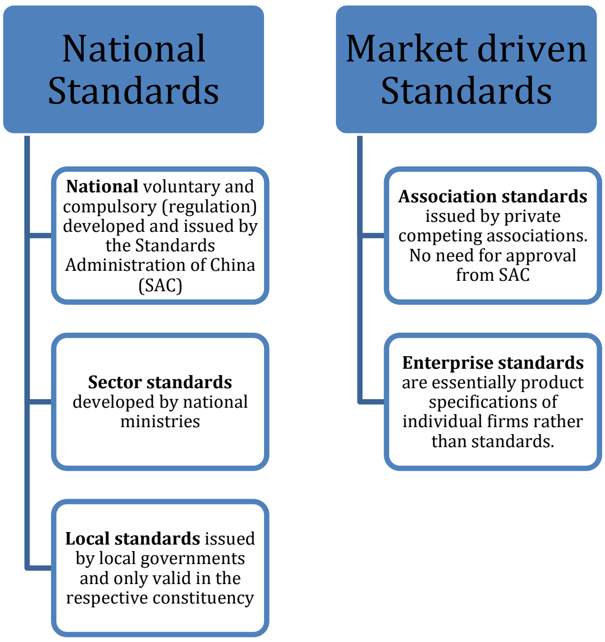
The ''14th Five-Year Plan of the People's Republic of China—Fostering High-Quality Development for 2021-2025'' sets out China's blueprint for economic and social policy development, providing guidance for long-term macroeconomic plans for the period 2021 - 2035. The Plan highlights high-quality green and low carbon development and emphasizes innovation as the core of growth, relying on a dual circulation strategy as the growth paradigm (Asian Development bank, 2021). The dual circulation strategy, which may reduce the country's dependence on overseas markets in the long term, will be developed relying on domestic manufacturing, consumption and distribution networks (internal circulation). Nonetheless, the country has no plans to turn away from the global markets (external circulation).

The Plan, in short, tables strategies for reducing carbon dioxide emissions before 2030 and reach carbon neutrality before 2060. Twenty quantitative targets are set under five categories: economic development, innovation, people's well-being, green development, food and energy security. For innovation, the plan aims for a 7% annual growth in R&D spending whereby the key focus areas include artificial intelligence, integrated circuits, brain science and Deep space, deep sea and polar exploration. Digitalization and key digital technologies are the focus area in the Plan which will potentially increase the percentage of the digital economy core industry added value to GDP by 10%.

The ''Made in China 2025'' is a part of China's overarching plan to become a global technological leader by 2049 (State Council of the People's Republic of China, 2015). The blueprint is divided into three periods of action: 2015-2025; 2026-2035 and 2036-2049 that will gradually help achieve its global technological dominance and manufacturing power, reducing its dependence on global technologies. The Made in China's objectives are improving manufacturing innovation, fostering Chinese brands, green manufacturing, and promoting breakthroughs in ocean engineering equipment, robots, railway equipment, aerospace equipment, and energy-saving cars. All regions and government departments are encouraged to implement the Made in China 2025 strategy at respective levels.

Chinese technical standards are found in the important fields, namely information technology and railway equipment. Although technical standardization in Europe and the US is predominantly driven by private self-regulation, China follows a state-driven approach transforming standardization into strategic state policies and power politics (Rühlig, 2020). As per Diagram 1, the Chinese system entails three types of state-driven standards and two market-driven standards (Rühlig, 2020). State-driven standards include: a) national standards developed and issued by the Standards Administration of China (SAC); b) sector standards developed by national ministries; and c) local standards issued by local governments and only valid in the respective constituency (Rühlig, 2020).

Figure 13: Chinese Standardisation system



Source: (Rühlig, 2020)

China launched the "China Standards 2035", which entails a blueprint for China's government and leading technology companies to take the initiative in developing technical standards for emerging technologies (Horizon Advisory, 2020). Therefore, through the "Made in China 2025" - the country will be self-dependent in terms of designing and producing high-tech products and, through "China Standards 2035", will be able to set global standards for these products. China's standards strategy will amplify the power of the Chinese state but could also potentially distort global trade.

Moreover, China's State Council published the "Outline of the National Comprehensive Three-Dimensional Transportation Network Planning" in January 2021 (changing-transport.org, 2021). The Outline is a strategic top-level policy for China's development of a comprehensive and fully integrated transport system by 2035. The Outline emphasizes that the country will accelerate green and low-carbon development by lowering carbon dioxide emission intensity by 2035. This policy builds upon the "Outline for Building China's Strength in Transport'' (gov.cn, 2019) that envisions China as the global transport superpower by 2050. In short, it is fully aligned with the goals of the 14th Five-Year Plan and other relevant roadmaps.

3.6.2 Techno-policy Developments in National Aviation and Automotive Sectors

3.6.2.1 Aviation

The civil aerospace and aviation services sector of China ranks second in the world with the highest growth rate. According to statistics from the Civil Aviation Administration of China (CAAC), China's aviation industry generated $53.3 billion in value in 2019. Commercial possibilities exist in almost every subsector of China's civil aerospace and aviation services markets. Given the industry's difficulties as a result of COVID-19, airports and ground support equipment are currently the most attractive sub-sectors for the Chinese market. (International Trade Administration, 2021).

The Civil Aviation Administration of China (CAAC) has increased its support for the industry's development and prioritized "safe, green, smart, and human-centered airports" (xinhuanet.com, 2019). The CAAC has implemented several measures in order to meet the requirements of green airport development, ground power unit (GPU) to replace auxiliary power unit (APU), establishing specifications for GPU and APU use, and standardizing the charge of GPU. (Sun, Pan and Hu, 2021). By 2025, Zhejiang Province plans to double the size of its aviation and aerospace industries. By 2035, the East China province hopes to be one of the country's leading aerospace industrial clusters.

As a part of the 14th Five-Year Plan (2021-25), the Zhejiang province shall add two listed aerospace firms, launch five landmark aerospace manufacturing projects, and nurture more than ten private businesses in the supplier system of Chinese aircraft maker Comac. Observing innovation, the province is expected to cooperate in the construction of around 20 research institutes, as well as new R&D facilities. Additionally, it intends to establish ten aerospace application service companies that will focus on general aviation and drone development (Global Times, 2021).

Shenzhen is China's drone capital, with over 360 drone firms competing in a market worth more than 40 million RMB per year. The need for drone pilots and experts is yet to be met, creating one of the most significant challenges for the drone industry's growth. In 2015, the Shenzhen UAV Industry Association established the city's first drone training facility, which provides AOPA (Aircraft Owners and Pilots Association of China) certification to drone pilots. DJI also established its UTC (Unmanned Aerial Systems Training Center) in 2016 to make Shenzhen the export hub for drone expertise. In 2018, the Shenzhen Municipal Market and Quality Supervision and Management Committee published a roadmap for the commercial drone sector outlining the steps necessary to become a top drone talent hub (Jiang, 2020).

Chinese firms manufacture more than 80% of commercial drones worldwide. DJI has its headquarters in Shenzhen, and has been a longstanding market leader in civilian unmanned aerial vehicles, accounting for 70% of the global consumer drone market (Intelligent Aerospace, 2021). China is also a significant player in the world market for military drones. China's state-owned Aviation Industry Corp. (AVIC) aims to take lead in the global military UAV industry in the long run. Bloomberg reports that AVIC sold more than $22 billion worth of military equipment in 2019 (Einhorn, 2021). According to the research organization Sipri, China has supplied 220 armed drones to 16 nations over the last decade, including Nigeria, Saudi Arabia, Egypt, and the United Arab Emirates. China ranks fifth in weapons exports, but it has emerged as the world's go-to drone supplier (Che, 2021).

In contrast with consumer drones, which are entirely privately financed, Chinese military drones are manufactured by state-owned firms. However, the government is becoming more involved in the commercial drone industry. To this end, the government has opened up airspace known as Unmanned Civil Aviation Experimental Zones (UCAEZs) to commercial drone manufacturers such as EHang (Nasdaq: EH) — China's sole publicly traded drone firm — to explore aerial tourism, aerial firefighting, search and rescue, and other operations. The government intends to expand the drone sector to a total value of $27 billion by 2025 (Che, 2021).

Drones are permitted under the following circumstances:

• Maximum altitude: 120m (400ft); anything beyond this requires a commercial license from the CAAC. The majority of drones, automatically set the maximum altitude limit to 120m and alert users if they attempt to manually change the maximum altitude limit.

• Maximum Distance: China, mandates a VLOS, or "Visual Line of Sight," for any drone.

• Maximum Weight: China requires drones weighing more than 250 grams (.55lbs) to be registered using their official names. A CAAC license is required for any drone that weighs more than 7kg (15lbs) (drone-laws.com, n.d.).

Permits for Drones:

1. Registration is required for any drones and Remotely Piloted Aircraft Systems (RPAS) weighing more than 250 grams (g). This is necessary for recreational drone usage;

2. Any operator or company wishing to operate a drone for commercial reasons in China must get a commercial drone license;

3. To apply for a commercial drone flying authorization in China, the following criteria must be met:

- A legal business entity in China with a Chinese citizen as its legal representative;
- This legal entity must already own at least one Aviation Authority-registered drone;
- Liability insurance is required to cover the usage of the drone;
- The drone operator must be qualified via a training program authorized by the Chinese government;
- Registration;
- Any drone weighing more than 250 grams (0.55 lb.) must be registered with the CAAC;

- Individuals must register with their personal information in addition to information about the drone and its intended usage. They will be required to supply the following information:

- The name of the proprietor;

- A valid personal identification number;

- Contact information, including a telephone number and an e-mail address;

- The product's model number;

- Serial Number;

- What purpose will the drone serve (objective);

- After registering the drone, users must print and attach the registration sticker with the QR code on their drone; and

- Knowledge of the Chinese language and ownership of a Chinese mobile phone number may be required for registration (drone-laws.com, n.d.).

Occasions that necessitate CAAC license include the following:

• A CAAC license is required for any drone weighing between 7 kilograms (15 pounds) and 116 kilograms (256 pounds);

• All drones used for commercial reasons must be licensed by the CAAC; and

• To fly any drone weighing more than 116 kilograms (256 pounds), a pilot's license and UAV certification are needed.

All drones are prohibited in China's NFZs ("No Fly Zones"). These zones include the areas immediately surrounding airports, military bases, certain cities such as Beijing, and sensitive areas such as Tibet and Xinjiang. Lastly, China's drone laws require operators to insure themselves against third-party liability (drone-laws.com, n.d.).

Organizations providing UAV inspection services for CCS-classed ships or offshore installations should satisfy the requirements on UAV operation stipulated by the local competent authorities where the survey is conducted, such as the Regulations on the Operation of Light and Small Unmanned Aerial Vehicles (for trial implementation) issued by Civil Aviation Administration of China (CAAC).

3.6.2.2 Automotive Sector

China is vying to become the world's top testbed for AV technologies. According to BNEF statistics, since approving AV testing on selected public roads in 2018, a total of 70 firms and 600 AVs have been permitted to operate in 27 cities. Over 2.5 million kilometres of AV testing have been conducted in Beijing and Shanghai alone, which is approximately 10% more testing than what US firms have achieved during the same time period after the authorization of public road testing in California (Albanese, 2021).

As a result of Baidu's partnership with state-owned BAIC Group, 1,000 driverless vehicles will be built over the next three years, and a robotaxi service will be introduced throughout China. While Baidu will supply the autonomous driving technology and software, the Apollo Moon vehicles will be produced under BAIC's ARCFOX electric vehicle brand. Thanks to technological maturity and mass manufacturing capabilities, each vehicle can be made for 480,000-yuan ($74,729) each, as opposed to the typical 1-million-yuan ($144,262) price for an autonomous car.

The operational cycle of Apollo Moon is expected to last more than five years. It is unclear as to when manufacturing will begin and when robotaxis will be deployed, and if Baidu, which will manage the fleet, would charge passengers for services (Kharpal, 2021). Over the last year, the Chinese tech giant has deployed robotaxis in several major Chinese cities, including Shanghai. Baidu has started charging passengers in Beijing for trips in its autonomous vehicles in Shougang Park, one of the venues for the 2022 Winter Olympics. Baidu hopes to advance robotaxis beyond the testing phase and towards a mass-market deployment of a service via the BAIC collaboration.

Since December 2020, another Chinese firm, AutoX, has been testing completely autonomous cars in Shenzhen. Since January 2021, the service has been available to select members of the public, but AutoX has not yet begun charging for rides (Lee, 2021). In May 2021, the Chinese self-driving vehicle company Pony.ai's smart logistics subsidiary received a license to undertake commercial autonomous freight operations in Guangzhou (Limin and Yi, 2021). A number of Chinese firms are developing self-driving technologies (Lee, 2021).

The favourable policies of the government have propelled China's remarkable progress. In June 2019, regulators authorized AV developers to begin offering passenger-rides. The Ministry of Industry and Information Technology issued a draft regulation in January of 2021 allowing for autonomous vehicle testing on highways. The short-term objective is for robotaxis, autonomous shuttles, and self-driving heavy trucks to be commercialized by 2025 (Albanese, 2021).

China has changed its regulations on autonomous vehicle testing in an effort to expedite the commercialization of self-driving technology. The revised regulation, which was jointly issued on 30 July 2021 by the Ministries of Industry and Information Technology, Public Security, and Transport, permits qualified companies to undertake trials of autonomous vehicles for passenger and goods transportation on specified sections of highways, urban roads, and regional areas designated for the passage of social vehicles. The "test area" (specified section) refers to a location with defined physical boundaries, roads, networks, and other facilities and environmental conditions necessary for the testing of autonomous driving functions of intelligent networked cars (Ministry of Industry and Information Technology of the People's Republic of China, 2021).

In order to be eligible for a road test, an intelligent networked vehicle, namely a vehicle that integrates network technology, so that the "brain" inside the vehicle and external nodes can realize data sharing and coordinated control to improve safety. This vehicle must meet the following criteria:

(1) An autonomous legal entity registered in the People's Republic of China's territory;

(2) Have business capabilities relating to intelligent networked vehicles, such as automobile and component manufacturing, technological research and development, or testing and inspection;

(3) Have adequate civil compensation capabilities for personal and property damages caused by intelligent networked vehicle road testing;

(4) It includes methods for testing and evaluating the automated driving function of intelligent networked vehicles;

(5) Be able to do real-time remote monitoring of road test vehicles;

(6) Be able to record, evaluate, and recreate incidents involving road test vehicles;

(7) Be able to guarantee the network security of road test vehicles and remote monitoring platforms; and

(8) Other requirements imposed by laws, administrative regulations, and rules (Ministry of Industry and Information Technology of the People's Republic of China, 2021).

Driverless vehicles equipped with real-time remote monitoring and the ability to collect and retain driving data for at least 90 seconds prior to an accident or system failure are qualified to participate in the experiment. Human drivers must be present in the self-driving vehicles utilised in the testing and will be held liable for any traffic infractions that occur in line with the country's existing traffic laws. The regulation's publication coincides with a redoubling of attempts by Chinese self-driving vehicle companies to commercialize their technology at a time when the general public still has concerns about the safety of autonomous trips (Limin and Yi, 2021).

3.6.3 SWOT Analysis

The SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis is based on secondary sources of information as well as primary information collected through interviews with industry representatives and academia.

Table 24 China SWOT Analysis

Strengths	China has one of the most ambitious and systemic AI strategic plans in terms of technological development and market applications and by 2030 aims to become a global AI innovation center.
	The Zhiyuan Plan is the result of a complex network of central and local science and technology development policies and efforts.
	High Innovation skills and expertise have been gained by local residents, guiding China to fill more AI patents than any other country, accounting for 74.7 percent of the world's total patents.
	With the government's support, Chinese universities have set up AI R&D departments with the number of relevant bachelor's and master's degree programs to increase significantly. Society shows an astonishingly high level of trust in AI with consumers being fast in adopting new products and services.
	The provision of legal frameworks coupled with local freedom to adapt is creating a rapidly growing AI industry.
	Well-developed national roadmap for a fully integrated and innovative smart transport system by 2035.
	Low carbon development of the transport sector is a policy objective in the context of the country's 2030 carbon dioxide emission peaking and 2060 carbon neutrality goals.

	China's strong 'ecosystem' is comprised of a national and regional administrative state that works closely with universities, research institutions, investors and industry to build a thriving AI ecosystem. The ecosystem excels at speech, image and video recognition fields.
	The new Personal Information Protection Law addresses the concerns that existed for data issues of corporations and privacy aspects for consumers.
	Local and central government agencies work on developing their services based on a shared digital ecosystem for collaboration. Most of the services will be digital and seamless by 2025.
	CCS released coherent guidelines for the use of unmanned aerial vehicles for survey of vessels.
	China has taken great strides in testing and developing autonomous vessel technology.
	"China Standards 2035" is the official work plan for standardization that seeks for leading technology companies to take the initiative in developing technical standards for emerging technologies. This official plan differs from other global practices, such as that of the US, which relies on businesses to identify the commercial value of standards and follow them accordingly.
Weaknesses	Surveys with the utilization of RITs are mainly operational and not statutory. Surveys are assessed on a case-by-case analysis and after approval granted from the Flag Service.
	Truly original ideas are lacking, despite the fact that scientific publications and patents are rising.
	Companies favour applied AI research that can bring quick profit instead of more research and development with long-lasting impacts.
	Significant differences from region to region regarding the level of learning and development process and the implementation of the national AI strategy.
	China's setting of standards strategy will amplify the power of the Chinese state and may distort potential trade.
	China is the world's second-largest civil aerospace and aviation services sector, with the highest growth rate. Chinese firms manufacture more than 80% of commercial drones worldwide.
	More focus is needed on the principles of safety, usability and interoperability of products.
Opportunities	Artificial intelligence and innovation can bring new opportunities for social development and building a relatively well-off society. By 2030 AI theory, technology and application could turn China into an AI superpower.
	Companies should continue to register thousands of patents to build the next generation of MASS technology, making China the leader in the MAAS sector by 2025.
	China could become the next years the world's top testbed for AV technologies.
	The Flag State should speed up the adoption of RITs and improve surveyors' skills to utilize these technologies. Use of databases to compare traditional and remote ways of inspection.
	Development of laws and regulations as well as ethical norms related to promoting AI development.

	Focus on principles of safety, usability, interoperability and traceability in the field of innovation and AI applications and encourage businesses to participate in or formulate international standards. Identify AI legal entity and related rights, obligations and responsibilities.
	Massive data resources obtained in the last decade and the gigantic market size have created a unique advantage for China to develop AI and assemble big databases.
	Enhance early prevention and guidance to address the risks of cybersecurity and ensure the safe, reliable and manageable development of AI.
	Use of international organizations and regional relationships to export China's standards and influence international standards organizations, including the International Standards Organization (ISO).
	China continues to discuss "concrete actions in the 2020s to reduce emissions aimed at keeping the Paris Agreement-aligned temperature limit within reach".
Threats	US - China trade war, tariff disputes and geopolitical competition will heighten conflicts over intellectual property rights, increasing protectionism. Europe will increasingly attempt to regulate and control AI in an attempt of integration in its jurisdiction.
	AI is a widely influential technology that raises serious concerns about economic security, social stability, changing employment structure, law and social ethics and personal privacy.
	Catch-up cycles and changes in industrial leadership from an incumbent country to a latecomer have been noted many times in various sectors, such as the automobile industry. Due to policy environments and market conditions, incumbent countries may not maintain their technology superiority. AI is open science AI research doesn't provide a durable advantage.
	Enormous population, intense urbanization and heavy dependence on coal may continue to contribute to climate change, making the country to remain the world's biggest polluter, responsible for more emissions than the US and EU combined.

3.7 Review of National Arrangements: Singapore

Singapore, after its independence in 1965, has experienced one of the world's highest GDP growths. Through foreign direct investment (FDI), businesses can benefit from a politically stable environment, advantageous tax regime, access to the Asian market, growth opportunities and government incentives. The country has positioned itself as a global leader in the freight transport sector, attracting global logistic companies to open distribution centres to manage their regional and global supply chains. The country is one of the most efficient international trading hubs due to its efficient port infrastructure. In 2018, Singapore ranked 7 out of 160 countries in the latest Logistics Performance Index (OECD, 2021).

3.7.1 Brief Overview: National Law & Policy with a Focus on BUGWRIGHT2 Technologies

Singapore's maritime network is an amalgam of entrepreneurs, research and development institutions, classification societies, technology companies and international partners. Over the last two decades, the MPA has funded the Maritime Innovation and Technology (MINT) to expand its maritime innovation ecosystem. The maritime sector is undertaking vast innovative developments and the Maritime Transformation Programme (MTP) expands the maritime research capabilities and the transformation of the sector through five Strategic Research Thrusts: a) Intelligent World-Class Next Generation Port; b)

Maritime Traffic Management; c) Smart Fleet Operations and Autonomous Vessels; d) Maritime Safety & Security; and, e) Sustainable Maritime Environment & Energy (MPA, n.d.a).

The Singapore framework study is based on primary and secondary sources of law, as well as explanations and rational interpretations provided by respondents interviewed in May and June 2021. Interviews were conducted with key experts from Bureau Veritas Singapore, DNV Singapore, Performance Rotor, Madfly and Red Dot Analytics. A team of Senior Advisers from the Maritime and Port Authority of Singapore (MPA) has provided researchers with specific information and materials to complete the report at hand. The researchers are sincerely thankful to Mr. Shu Yong Koh, Head of Commercial and Innovation Bureau Veritas Marine (Singapore) Pte Ltd., for providing insightful information in relation to the regulatory framework for remote technologies in the Singapore domain.

3.7.1.1 Overview of the National System

Following its peaceful secession from the Federation of Malaysia on 9 August 1965, Singapore has maintained a legal system largely based on the British legal system, with noteworthy differences such as a written constitution (Kevin & Thio, 1997; Thio, 1999). In essence, the government is structured around the trichotomy of powers with the following three branches:

- The Executive, which is led by the Prime Minister and entails the Cabinet Ministers and office-holders;
- The Legislature that entails the President and Members of Parliament (MPs); and
- The Judiciary, which comprises the Supreme Court and Subordinate Courts of Singapore (Parliament of Singapore, n.d.).

The President of Singapore appoints the Prime Minister. In Singapore, statutes and subsidiary legislation are the main legislative instruments. Statutes are written laws that have been passed by the Singapore Parliament and other entities that previously held the authority to establish regulations for Singapore. Statutes that originated from other authorities remain in effect if they have not been repealed. Subsidiary legislation is, on the other hand, written law enacted by ministers or other administrative authorities (Chan, 1995).

Public-policy objectives, such as safety and consumer protection are achieved with the relevant laws and regulations. In cases where restricted market forces impose unnecessary costs on productivity and efficient functioning of markets --- a comprehensive competition review is made to develop alternative and less restrictive policies (OECD, 2021). The country has an effective regulatory framework with a free public access legal database (Singapore Statutes Online) that supports the business environment and increases foreign direct investment in logistics and innovation sectors (OECD, 2021).

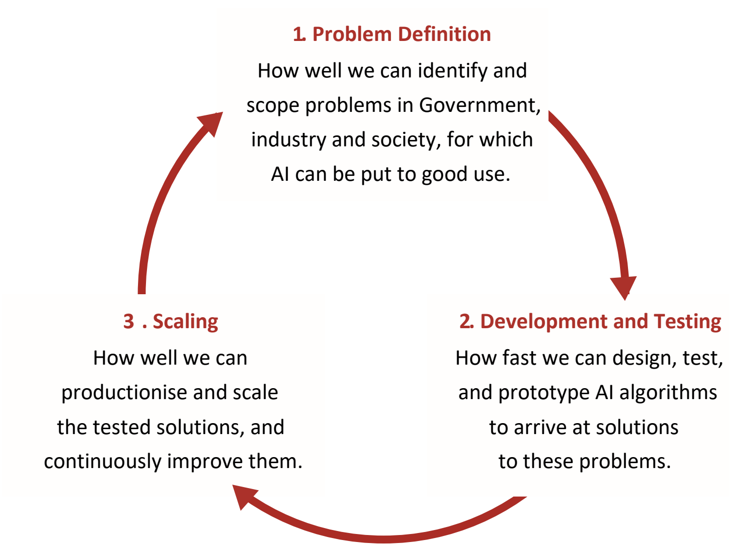
The national maritime legislation is transposed from IMO maritime conventions and instruments and fully complacent with the global maritime standards. The Ministry of Transport (MOT) is the regulatory body for air, land, maritime transport and ports. The Maritime and Port Authority of Singapore (MPA) is the port authority and regulator for safety, security and environmental protection aspects, and aims to uplift Singapore as a premier global hub port and international maritime centre. The Infocomm Media Development Authority (IMDA) is another governmental agency that cooperates with MPA and guides companies in their digital transformation efforts to address logistics issues as well as upskilling their workers.

The Pro-Enterprise Panel (PEP) of the Ministry of Trade and Industry is a best practice in the country as it serves as an internal advocate for businesses to streamline rules and processes to ensure that legislation does not hold back entrepreneurship. This is a joint private-public panel of public officers and business executives that cooperate with public authorities to address all the regulatory challenges and obstacles faced by businesses. The Panel encourages start-ups to be more innovative through the First Mover Framework, giving entrepreneurs the chance to identify an agency to lead the assessment and utilize public assets to implement their ideas. PEP allows start-ups for an extended regulatory sandbox to test the effects of their products.

3.7.1.2 National Framework for AI Technologies and Autonomous Operations

Singapore is essentially rethinking business models, implementing fundamental changes to generate new growth areas and adopt a human-centric approach to AI. In 2019, Singapore launched a National AI Strategy, i.e., a milestone in the Smart Nation journey that will drive Singapore by 2030 towards the leading position of deployment of impactful AI solutions in critical sectors. The country has identified five National AI Projects in: a) transport and logistics; b) smart cities and estates; c) healthcare; d) education; and, e) safety and security (Smart Nation and Digital Government Office, n.d.). Three aspects have been taken into account for the effective deployment in the aforementioned sectors: problem definition, development/testing, and scaling (Figure 14).

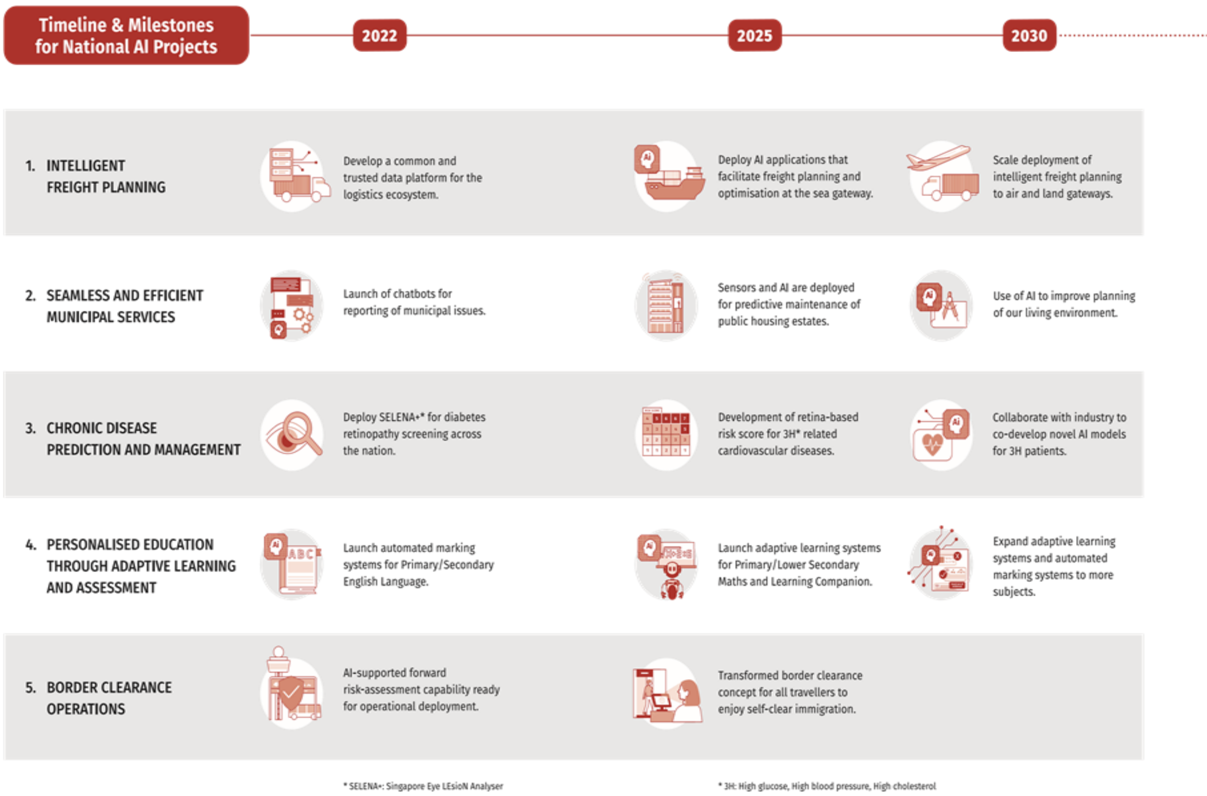
Figure 14: Effective deployment of AI



Source: Smart Nation and Digital Government Office, n.d.

In the transport sector, Singapore will optimise freight movement through intelligent routing and scheduling of tracks and urban AI planning. The key milestones of the Strategy are presented in Figure 14. It is also noted that the MPA takes various initiatives for wider industry adoption of digitalization initiatives, such as electronic bills of lading (eBL) and funds start-ups that develop cutting edge technologies. The sector's digital transformation enables the relevant maritime stakeholders to share data and deepen service integration among the different data platforms. AI Singapore (AISG) is a government-wide partnership AI programme launched by the National Research Foundation (NRF) that will facilitate the development of the AI ecosystem and the effective deployment of AI.

Figure 15: Milestones for AI projects



Source: Smart Nation and Digital Government Office, n.d.

3.7.1.3 National Maritime Framework for Remote Inspections

The Singapore Registry of Ships (SRS), with more than 4,400 vessels, aggregating over 96 million gross tons (GT), ranks fifth among in the list of global fleets (MPA, n.d.b). The Merchant Shipping (Safety Convention) Regulations is the instrument for traditional surveys and certificates (Singapore Statutes Online, 2021). MPA has delegated the survey and certification of ships under the Singapore Registry of Ships (SRS) to eight (8) Recognized Organizations that are full members of the International Association of Classification Societies (IACS): ABS, BV, CCS, DNV, KR, LR, NK and Rina.

Singapore advocates the use of emerging technologies to innovate and improve the safety and efficiency of the maritime industry. Since 2018, Singapore has accepted the conduct of surveys on board Singapore Registered Ships via the use of RIT. Where permitted, RIT may be used to facilitate the required external and internal examinations. Before any inspection, the Flag State should proceed towards approval on a case-by-case basis. Shipping Circular No.13 of 2018 dated 23 Oct 2018 was promulgated to inform all stakeholders regarding approval aspects concerning RIT (Table 26). The RIT, to that end, may comprise of the following:

- Unmanned Robotic Arm;
- Remote Operated Vehicles (ROV);

- Unmanned Aircraft System (UAS); and

- Other means acceptable to the Administration.

Table 25: Circular No. 13 of 2018: Acceptance for the use of remote inspection techniques for surveys

UAS	For periodical surveys using UAS, if the UAS is not operated by the RO itself, the company engaged to operate the UAS for the inspection is to be approved by the RO for carrying out such services in accordance to the RO’s criteria for approving service providers. Inspections should be carried out in the presence of the Surveyor.
Inspection Plan	An inspection plan for the use of remote inspection technique(s), including any confirmatory survey/close-up survey/thickness measurements, is to be submitted to the RO for review and acceptance in advance of the survey. The proposal for usage of UAS in periodical surveys is to be submitted by the RO to the Administration for acceptance.
Acceptance	The results of the surveys by remote inspection techniques when being used towards the crediting of surveys are to be acceptable to the attending Surveyor. Confirmatory surveys/close-up surveys may be carried out by the Surveyor at selected locations to verify the results of the remote inspection technique, if required.
Thickness Gauging	The acceptance of remote inspection techniques does not waive the requirement for thickness gauging where applicable. Thickness gauging by remote inspection techniques can be accepted subject to the same criteria of approval as applied to other Non-Destructive Test (NDT) techniques by the RO. Confirmatory thickness measurements on-site may be requested by the attending Surveyor, if required.
Close-up Survey	Reference is made to the ESP Code Annex A (Bulk Carrier) and Annex B (Oil Tankers); “Close-up survey is a survey where the details of structural components are within the close visual inspection range of the surveyor, i.e., normally within reach of hand.” In addition to requirements in paragraph 1 to 7 above, the usage of remote inspection techniques such as UAS can be accepted for close-up survey on ships subjected to the ESP Code, if the attending surveyor is satisfied that the information provided by the remote inspection technique, such as video footage from the UAS, is equivalent to a survey where the details of structural components are within the close visual inspection range of the surveyor.
Annex 1	Unless agreed by the Administration, the usage of remote inspection technique is not accepted or not to be continued for the specific location on the ship, at the following conditions: • Where there is existing record or indication of abnormal deterioration or damage to structure or to items to be inspected; • Where there are existing recommendations for repairs or conditions affecting the class of the vessel; • Where during the course of the inspection survey, defects were found such as damage or deterioration that requires attention. In such cases, the normal close-up survey/thickness measurement without the use of remote inspection technique is to be carried out to determine the scope of repairs required; and • Where the coating condition of the tank/hold is rated as less than “Good” by the Surveyor. This does not apply to sections of cargo oil tanks that are not coated and stainless-steel cargo tanks.

Source: MPA, 2018

Remote surveys have been embraced by the sector for quite some time, albeit still lacking a standardised approach. Singapore is seeking to address the lack of industry standardisation and for this reason a Joint Industry Project (JIP) has been launched. Through the Maritime Innovation and Technology (MINT) Fund, MPA has awarded DNV to establish a Joint Industry Project for the development of a Singapore standard in remote surveys, inspections, and audits. Data gathered by interviews and surveys with various stakeholders of the maritime ecosystem with the goal to develop a remote inspection procedure that could be utilized by the owners, operators, service providers and class societies. The standard development currently is in the scoping exercise phase, paving the way for a focused discussion to ensure that regulation will keep pace with autonomous operations. The ultimate aim of the project is to lay the foundation for a global standard. It is important to note that the content of the scoping exercise is strictly confidential.

DNV and MPA have signed a Memorandum of Understanding (MoU) to promote the decarbonisation, innovation and digital transformation of the maritime sector. Besides, MPA cooperates closely with Bureau Veritas Singapore which has developed tools for remote operations. In 2020 BV cooperated with PSA Marine to conduct the first remote survey for a harbour tug registered under the Singapore Registry of Ships. The tug underwent a fully accredited annual survey of the hull, machinery, load lines, safety and telecommunications equipment using smart mobile devices and optimized live-streaming without the physical presence of a surveyor. The vessel was a dual fuel LNG-powered harbour tug and this imposed additional steps into the remote survey, including an overview of the LNG bunkering station and demonstrating the switch of fuel usage from diesel to LNG on the system onboard. During the COVID-19 outbreak, another remote inspection took place in cooperation between Bureau Veritas (BV) Nokia and Sembcorp Marine. The inspection set the basis for establishing a new class procedure for the remote survey of vessels under construction, assessing the integrity of the hull components efficiently. The inspectors of Sembcorp Marine were equipped with rugged head-mounted cameras with high-definition video streaming and voice communication that enabled the BV surveyor stationed at the remote monitoring centre to assure the production quality and spot defects. All the projects relevant to the maritime sector that currently take place in Singapore are presented in the following table:

Table 26: Joint Industry Projects (JIP) to Build Post-COVID-19 Competitiveness and Resilience

No.	JIP	Project Scope	Expected Benefits	Beneficiary	JIP Leader
1	Contactless launch services at Marina South Pier (MSP)	Pilot a project to automate and digitalize processes of launch services such as: -Open platform development to enable any solutions/ systems from the launch operators to interoperate on mobile devices or kiosks. -Universal display panel(s) at the pier for information on arrival/departure time and other information about the launch services -Smart Locker system for fully traceable bunker sample deposits, with audit trail notification provided via a Mobile App.	-More efficient launch services at across 10 MSP and WCP counters which will translate to better port services in Singapore including crew change, ship supplies, bunkering, surveyors, agents and labs. -Reduces human queues and COVID risk. -Enhanced customer experience through data transparency. -Enhanced security and fraud mitigation compared to the current system.	Harbourcraft operators	Shipsfocus Services Pte Ltd and 26 other industry partners
2	Contactless launch services at West Coast Pier (WCP)			Harbourcraft operators	Innovez One and 5 other industry collaborators including ship agents and carriers

3	Electronic Supply Delivery Note (ESDN)	Digitalise the Delivery Note process by linking the various suppliers, chandlers, stockists, freight forwarder to a remote and digital approval process, including using 3 factor authentication architecture to authenticate the vessel stamp and Master's signature.	• Improved productivity, e.g., billing turn-around time, reduced human errors, reduced costs of transactions through the value chain, from a pilot trial of 60 ESDNs; • Enhanced transparency and security of maritime documentation; and • Enables Jurong Port lighter terminal to forecast and plan Resources.	Ship supplies/ Harbourcraft operators	SG Smart Tech Pte Ltd (leader), Jurong Port, 5 ship chandlers and ship management companies.
4	Development of a set of Singapore standards in remote ship survey, inspection & audit	Develop a baseline document to map out standards required for various technology providers, service companies and vessels, owners and managers to adopt for remote ship survey, inspection and audit processes. These standards could also be evaluated for Port State Control adoption. The project will also examine the trade-offs of remote survey compared to physical attendance, such as efficiencies and time zone challenges, time spent by crew, interruptions, crew fatigue and safety, information manipulation, etc.	• Standards that will guide the industry's approach to remote inspection; • Improves operational resilience by supporting the ships' safety assurance system; and • Prepares our maritime SMEs to scale overseas		
5	Development and Pilot of Universal Tool for Remote Ship Survey and Inspection (RSI)	Develop a universal remote ship inspection/survey ('RSI') tool that can facilitate a standard, secure and safe remote inspection/survey, in place of physical inspection, in part or full. The tool comprises a software system that can be interfaced with various ERP, databases, IoT systems and provides the surveyor/inspector with access to secured information (text, image, audio and video) on conditions onboard ship and at shore. The surveying/inspecting process	• Productivity gains and cost savings to cargo, insurance and regulatory inspections, through pilot trial of 20 inspections/surveys; • Reduces risk of being exposed to COVID-19 for crew; and • Improves operational	Ship owners/ Ship managers	Alpha Ori Technologies Pte Ltd, and collaborators from the ship owners/ operators, P&I clubs and classification society sub-sectors to capture and cater to their requirements.

		will be supported by hardware such as wearable cameras and voice recording devices to capture activities on board.	resilience by supporting the ships' safety assurance system		

Source: MPA

The service providers that conduct hull inspection and survey using RIT are authorised service providers under the respective Recognized Organizations. The Recognized Organizations follow UR Z17 Rev14 CLN issued by IACS for the procedural requirements for approval and certification of service providers. Recognized Organizations authorized by MPA in carrying out statutory survey and certification are required to ensure that the service providers meet the service standards. Respondents from MPA informed that, disputes concerning liability between service provider and client should be settled through appropriate legal clauses in the service contract governing unsatisfactory quality of service rendered on board.

Interviews were conducted with two leading service providers of remote technologies. Performance Rotor is a leading provider of revolutionary drone solutions for confined-space inspections that has been certified by BV and LR. The drones have been field-tested and used commercially since 2020. The company aims to serve as the de facto model of confined space inspection within the aerial industry with the drones that they have manufactured and deployed in 2021. The company secured investment from EDB New Ventures, the Singapore Economic Development Board (EDB) corporate venture building arm that supports companies in building innovative businesses in Singapore. The funding will help the company to expand the adoption of robotics and software and shorten inspection times. Madfly is the second leading provider of Unmanned Vehicle Systems (UVS) certified by BV, RINA, ABS, LR, DNV and ClassNK. The company offers drone solutions and Underwater inspection and utilises HD & thermal videos and pictures on a 3D model, allowing easy follow-up for maintenance to meet the access constraints reducing asset immobilization. The discussion underlined some of the drone-related limitations and the strict drone regulations of Singapore for which approval is needed for closed cargo tanks. Respondents noted that partnership between the key stakeholders for the adoption of technology is required to overcome challenges in order to make RIT trustworthy. For example, regarding 'thickness measurement' of the hull structures, ninety percent of the inspection could be performed by the drone and as for the remainder, access should be given to the surveyor.

Respondents from the MPA informed that they would like to see further development of detailed guidelines from IACS on RIT, in particular, with reference to IACS Recommendation - REC 42 REV 2 CLN. Currently, they have noted a plethora of guidance and notes prepared by different classification societies, such as ABS, DNV, LR and RINA. A comprehensive guidance from IACS, detailing the principles of usage, limitations and procedures would be helpful for the flag administration and its stakeholders, such as ship owners/managers to assess the suitability of RIT deployment subject to specific conditions experienced by the ship. With the development of a comprehensive guidance from IACS and experiences gained by ship owners/managers on RIT, a global framework to adopt the use of RIT promulgated under the auspices of IMO, would be much welcomed to achieve uniform application of RIT by IMO member States and the maritime industry.

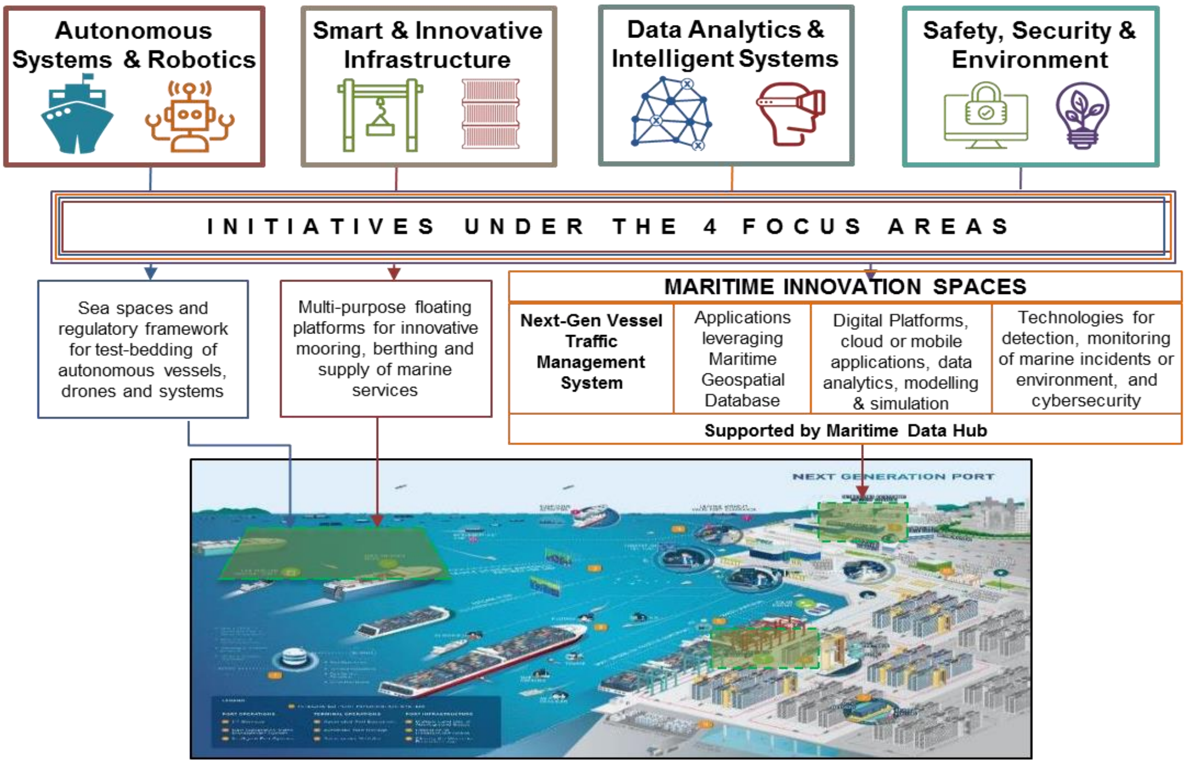
3.7.1.4 National Framework for Autonomous Shipping & Robotic Onboard Systems

Singapore, following Shanghai, is the world's second business port based on the overall number of twenty-foot equivalent units (TEUs) transported through the port (Lloyd's list, 2020). Singapore is home to one of the world's busiest hub ports and waterways, which provides an environment conducive to the development of innovative initiatives. Nevertheless, one obstacle that technology developers in various countries encounter is a dearth of real-world operational environments and marine data to verify and test solutions/technologies.

Singapore aims to push forward for pilot trials for autonomous vessels, set standards and build interoperable systems through regional and international collaborations with a view to becoming a future-ready port. Singapore is a member of MASSPorts that aims to develop detailed guidelines for MASS trials in ports, common terminology and data exchange to enhance interoperability of systems across different ports. MASSPorts members are flag, coastal and port authorities from Singapore, China, Denmark, Finland, Japan, the Netherlands, Norway and the Republic of Korea.

MPA Living Lab, in collaboration with PSA Living Lab and Jurong Port Living Lab, intends to connect process owners, technology suppliers, and researchers in order to co-innovate, testbed novel systems, and accelerate the commercialization of technology and engineering solutions. The MPA Living Lab comprises both physical and digital areas, including a physical presence at PSA Vista (the "Maritime Innovation Lab"). This co-creation facility provides a platform for developing innovations including "remote pilotage, next-generation vessel traffic management, and maritime data hubs". (MPA, n.d.c). Additionally, the MPA Living Lab includes physical test beds at sea, such as designated anchorages, to conduct trials of autonomous vessels, wireless communication technologies, and marine drones in a port environment. (MPA, n.d.c). The MPA Living Lab offers a collaborative support mechanism for future Next Generation Port (NGP) 2030 initiative, which has as its central theme building technology and capability development, with a particular emphasis on the following areas (Diagram 3): Data analytics and intelligent systems, autonomous systems and robotics, smart and innovative infrastructure, safety/ security/environment" (MPA, n.d.c).

Figure 16: Next Generation Port (NGP) 2030 Initiative



Source: MPA, n.d.c.

The next generation Tuas Terminal is a critical component of the NGP 2030. The Tuas terminal will be equipped with cutting-edge port technologies as well as various automated systems. Automated Guided Vehicles (AGVs), automated yard and quay cranes, and an Automated Storage and Retrieval System for containers are all being developed to expand yard storage capacity and build a giant intelligent container terminal (CSC, n.d.).

3.7.1.5 National Action Plan: Standards & Guidelines

National plans and norms related to service robots comes with reference to various Industry Transformation Maps developed by the Singapore government for different sectors, such as:

- Sea Transport Industry Transformation Map:

  Driving digitalization of port community in developing intelligent cargo terminals, digital platforms, smart harbour craft, autonomous systems and robotics;

- Marine and Offshore Engineering Industry Transformation Map:

  Spurring the adoption of robotics and automation to improve productivity and reduce labour dependency.

Open standards and interoperability are preferred options for the supply chain network of Singapore. The MPA developed the digitalOCEANS™ platform in 2018 to facilitate cross-border data exchange and automated services across supply chain players and national authorities, clearance authorities and other national single windows. The goal of digitalOCEANS™ is to develop and harmonise global data standards for maritime digitalisation. For the achievement of this initiative, an MOU was signed between MPA, Port of Rotterdam and other technological service providers. Digitals OCEANS falls within the scope of the IMO FAL Convention that makes the electronic exchange of information for clearance processes in ports mandatory.

The Manufacturing Standards Committee of Singapore has developed a Technical Reference (TR) entitled "TR 78: 2020 - Building facade inspection using unmanned aircraft systems (UAS)" to ensure that the use of UAS for inspection of building facades is conducted safely and ethically. The specifications cover all stages of the inspection process and focus on personal data protection, the liability regime and risk assessment. DNV has previously utilised TR for risk assessment and mitigation of unmanned systems.

3.7.2 Techno-policy Developments in National Aviation and Automotive Sectors

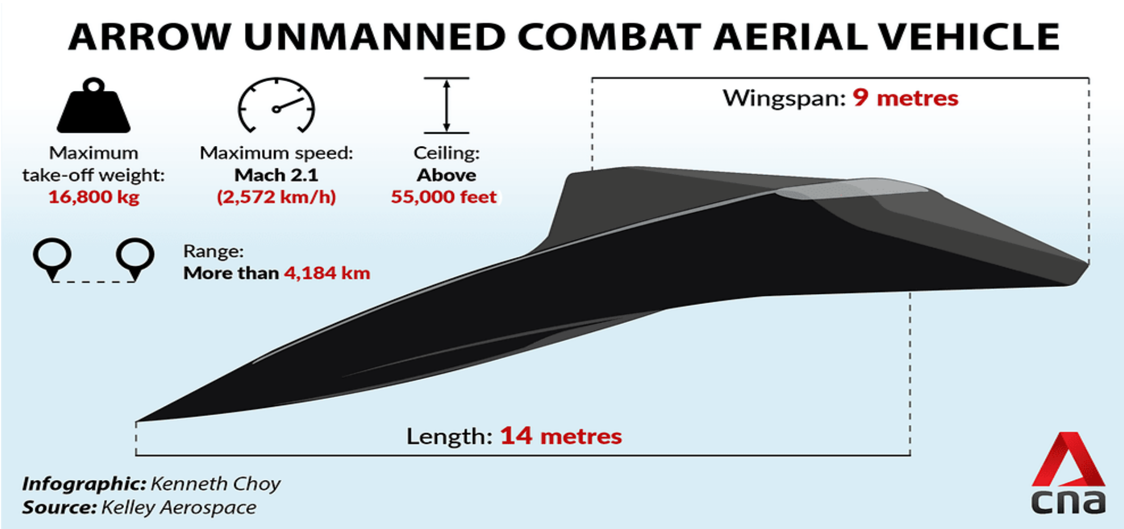
3.7.2.1 Aviation

CAAS takes a firm stance against errant unmanned aircraft (UA) activities that jeopardise aviation or ones that put the personal safety of others at risk. As of February 2021, adults who fly drones with a weight of more than 1.5 kg will have to complete training and pass an exam in order to get a license, otherwise, they may risk serious fines. Individuals who fly drones without the necessary licenses face a fine of up to $50,000 or imprisonment for up to two years, or both, for the first offense. A second or subsequent offense carries a fine of up to $100,000 or up to five years of imprisonment or both. Anyone who fails to provide a UABTC, UAPL, activity, or operator permit upon a CAAS enforcement officer's verification check is subject to a fine of up to $20,000 for the first offense, and a fine of up to $40,000 or imprisonment for up to 15 months, or both, for the second or subsequent offense (CAAS, 2020a).

The Civil Aviation Authority of Singapore (CAAS) announced on October 13 2020, that there would be two certificates: an unmanned aircraft basic training certificate (UABTC) and an unmanned aircraft pilot license (UAPL). (CAAS, 2020a). To be eligible for the relevant license, applicants must be at least 16 years old. Applicants that are under the age of 16 should be under the supervision of a license holder. Currently, drones weighing more than 250g must be registered with the CAAS before they are flown in Singapore. Additionally, a permit is required for flying drones weighing more than 7kg and for flying any drone above 60m. (CAAS, 2020b). Training and testing for drone licenses will concern safe drone operating. The UABTC applies to operators of drones weighing between 1.5 kg and 7 kg, and those that are flown for recreational or educational purposes. Applicants must complete a one- to two-hour online training session and pass an exam administered by any CAAS-approved unmanned aircraft training organization. Individuals flying drones weighing more than 7kg or for non-recreational or educational purposes, on the other hand, should apply for the unmanned aircraft pilot license (UAPL). This will necessitate a theoretical test, which may be self-studied but must be taken at the Singapore Aviation Academy. A CAAS examiner or an approved flight examiner will also perform a practical assessment. Users that acquire the unmanned aircraft pilot license will still be required to undergo a proficiency check at least once every four years. (CAAS, 2020b).

The Singapore-based Kelley Aerospace has manufactured the Arrow, the world's first supersonic av flies at speeds of up to 2,572km/h. The unmanned aircraft can be launched autonomously and be remotely controlled by two personnel on the ground. It can be utilized in air enemy war fights, surveillance or search-and-rescue missions. Instead of steel or aluminium, the company uses carbon fibre components to create products that are robust, durable, and lighter.

Figure 17: Arrow Unmanned Combat Aerial Vehicle



Source: Kellye Aerospace

3.7.2.2 Automotive Sector

Autonomous vehicles are expected to be crucial in laying the groundwork for a sustainable transportation system, and while the technology is anticipated to be 10-15 years away from maturity, the Singaporean government has already started to include them in its mobility development plans since 2013. (World Economy Forum and Israel Innovation Authority, 2020).

According to plans developed by the Land Transport Authority (LTA) on 24 October 2019, the whole western section of Singapore will become a trial site for autonomous vehicles (AVs). More than 1,000 kilometres of public highways are opened for self-driving car testing as a part of the expanded testbed. In contrast, the present biggest testing location is in the Buona Vista region that has around 70 kilometres of roads suitable for testing autonomous vehicles. Existing testbeds in Buona Vista, Sentosa, and Jurong Island, as well as Nanyang Technological University and the neighboring CleanTech Park, have been included in the extended testing site (Abdullah, 2019).

Vehicles will be subjected to a comprehensive safety inspection before they can be driven on public roads. In the event of an emergency, they must have a safety driver on board who can take control. They must also have third-party liability insurance and noticeable decals and other marks to identify themselves as autonomous cars to other road users. In these trials, public safety is of primary importance (Abdullah, 2019).

In the third edition of the 2020 KPMG AVRI index, 30 nations and jurisdictions have been evaluated in relation to progress in adopting and advancing AVs. The indicators are classified into four categories: legislation and policy, innovation and technology, infrastructure, and consumer acceptability. Singapore was ranked first in the Index as the country with the highest preparedness for AV adoption and acceptance. For the first time, Singapore has taken the lead in the AVRI, and its ranking represents the country's leadership in consumer acceptability, policy, and legislative pillars.

Singapore's position reflects the significant initiatives it has made since the beginning of 2019 to further the advancement of AVs. The legislative and governance framework for AVs is ideal, with Singapore having established national guidelines for AVs and opening up a tenth of all public roadways to AV testing. Additionally, the government has made extra expenditures to ensure that the necessary resources and human capital are in place for the deployment of AV, which includes the re-training of public transportation drivers expressly for driverless vehicles. Singapore is also a leader in promoting electric cars (EVs). Over the next nine years, the country plans to substantially expand the number of electric vehicle charging stations from the current 1,600 to more than 28,000. As evidence of the state's prospect and responsiveness to embracing AVs, it has drawn investments from multiple private sector firms, which have established several innovation and research centres to advance AV capabilities.

The Road Traffic (Autonomous Motor Vehicles) Rules 2017 came into effect on 24 August 2017. According to these Rules, autonomous motor vehicle trials on any road are permitted only with the proper authorization from the Land Transport Authority of Singapore. Among other requirements, the authorization may specify a geographic region in which the trial may be conducted, require an autonomous motor vehicle to have a certified safety driver sitting in the vehicle to monitor its operation and, if required, take over its control; prohibit any self-driving vehicle from transporting passengers and prohibit the use of any self-driving vehicle for hiring or reward. For applications to be approved for the LTA's authorization to undertake trials of AVs in Singapore, the applicants must expressly provide the objectives of the trial, type of vehicles, the autonomous system to be employed, etc. when submitting an application.

Trial or usage of automated vehicle technology or an autonomous motor vehicle is prohibited where an individual does not have the required authorization under regulation 7(1)(a)(i)(i). They must also refrain from using an autonomous vehicle on a road if the vehicle's autonomous system is not activated. (Singapore Statutes Online, 2021b). It is important to note that the following responsibilities apply to those authorized by the LTA under the 2017 Rules to conduct trials or use AVs in Singapore:

- The authorised person is responsible for maintaining the AV in good functioning condition and always operating correctly, ensuring that no injury or damage is caused to any individual in the vehicle or to any other individual, or to any property; and

- The authorised person is responsible for notifying the LTA of any event involving the AV's autonomous system malfunctioning, as well as any accident involving death, bodily harm, or property damage caused by or arising out of the AV's usage. (Singapore Statutes Online, 2021b).

3.7.3 SWOT Analysis

The SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis is based on primary information collected through interviews with industry representatives, academia and public authorities.

Table 27: Singapore SWOT Analysis

Strengths	Market oriented and innovation driven economy, with political stability and very low unemployment, propelled by high value-added manufacturing and services sectors. Foreign Direct Investment (FDI) flows thanks to the stable and efficient institutional framework, advantageous tax regime, and excellent business environment. Investments in digital technologies, artificial intelligence, aviation, healthcare, and energy are growing. No investment constraints in most logistics sub-sectors for member states of The Association of Southeast Asian Nations (ASEAN).
	Global leader in the freight transport sector and efficient global trading hub due to the quality of its trade and port infrastructure.

	Effective regulatory framework to achieve public-policy objectives. When regulatory instruments affect competition and restrict market forces less, then restrictive policies are developed to fulfil national goals.
	MPA and national authorities support the development of innovation in the transport/ logistics sector through a number of policy initiatives, such as the digitization of supply chains. Digital transformation by adopting AI-based technologies, internet of things, block chain and robotics.
	The Pro-Enterprise Panel (PEP) is a best practice. This is a joint private-public panel of public officers and business executives that cooperates with public authorities to timely address all the regulatory challenges and obstacles that businesses face.
	Observed heavy investment in education and highly educated and skilled workforce. The National University of Singapore (NUS) and Nanyang Technological University (NTU) maintain a leading position in the global academic landscape for nanotechnology, engineering & technology, energy science, automation & control. Spin-off companies set up by universities are supported by university's research innovation programmes to commercialize their products and create societal impact through interdisciplinary research.
	Diversity into the workplace that fosters success and innovation.
Weaknesses	High costs of operating business. Measures are implemented to encourage businesses to employ local workers. Singapore's Ministry of Manpower has increased the minimum qualifying salaries for foreign workers in order to receive the Employment Pass (pass for expatriates employed as executives or skilled professionals) and S Pass permits (pass for mid-level skilled employees.
	Scarcity of land.
Opportunities	Develop expertise that may create new industries based on a solar and wind energy value chain.
	Given the scarcity of land, Singapore should continue to look into alternative ways of developing domestic infrastructure, such as underground goods movement systems.
	Singaporeans need to understand the region to increase the success of entering the South-east Asian market.
	Given the restrictions and quotas for hiring foreign workers, annual studies should be made to define the supply and demand of workers in the logistic sector. Liaise with the industry and governmental agencies about possible corrective regulatory measures.
Threats	A small open economy that is Highly sensitive to the world economic cycle and especially vulnerable to the US-China geopolitical tensions and US-China trade war. Imports and exports representing 150% and 160% of GDP respectively.
	Skilled labor and housing shortages, aging population.
	Cybersecurity of the data ecosystem is a concern to the country.

3.8 Elements for Regulatory Blueprint Based on National Best practices

The following table amalgamates the national elements that WMU researchers consider as integral to the regulatory progressive development of RITs currently explored under BUGWRIGHT2 for survey and maintenance of hull structural elements of bulks carriers.

Table 28: Elements for Regulatory Blueprint Elements for Regulatory Blueprint Based on Insights from National comparative study

Element of Regulatory Blueprint	**Action Items**
Robust Stakeholder Management	**Action Item 1: Action Item I:** Cooperation between IMO, IACS, Maritime Administrations, Class Societies, Service Suppliers and Ship-owners. In this process, it is essential to ensure robust stakeholder cooperation to enable the effective deployment of remote-based solutions and exchange best practices.
Reference for Further Information	Action Items 1 (All Stakeholders) and 2 (All Stakeholders) of the International Study: Table 12- Elements for Regulatory Blueprint for Harmonization of International Arrangements.
Element of Regulatory Blueprint	**Action Items**
Uniform definitions for the different types of RITs and levels of autonomy	**Action Item 2:** Consistent definitions for the various types of RITs and level of autonomy. In this process, consider uniform definitions to set a solid foundation for understanding the various types of RITs (MAVs, AUVs and crawlers). The different degrees of autonomy of these systems should also be considered.
Reference for Further Information	• Action Items 4 (Re: IACS UR Z17): and 5 (Re: IACS UR Z17) of the International Study: Table 12- Elements for Regulatory Blueprint for Harmonization of International Arrangements. • Guidance Notes on the Use of Remote Inspection, 2019, American Bureau of Shipping: Sections, 1.1, 1.3, 1.5 and 7) • IMO Doc. MSC 100/20/Add. 1, Annex 2, Framework for the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS), Dec. 7, 2018, ¶ 1 and IMO, MSC 99th Briefing (2018): http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx
Element of Regulatory Blueprint	**Action Items**
Proof of Concept	**Action Item 3:** Proof of Concept should be achieved through repeated tests in controlled environments. Classification societies should get involved in extensive testing and establish ‘proof of concept’ for the remote inspection techniques to ensure that these technologies provide safer and even higher-quality evidence in the survey process.

Reference for Further Information	Bureau Veritas proof of concept: BV deploys artificial intelligence solutions in actual survey conditions for corrosion detection and ship inspection. The aim is to develop an end-to-end solution that will support ship owners in anticipating repairs and better maintaining the hull condition of the ship (see also proof of concept for Bugwright2: https://marine-offshore.bureauveritas.com/newsroom/bureau-veritas-proves-value-inspection-technologies-oceanbulk-ship).
Element of Regulatory Blueprint	**Action Items**
Risk assessment framework for determining the feasibility of remote inspections	**Action Item 4:** Risk assessment framework for the feasibility of remote inspections Classification societies should utilize a risk assessment framework that will assist in determining whether a physical inspection is necessary. A common risk assessment framework should be developed based on the age of the vessel, hull condition, severity of corrosion on hull structure, type of survey, areas to be inspected, ship location and environmental conditions in the area.
Reference for Further Information	*Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*, 2020, American Bureau of Shipping.
Element of Regulatory Blueprint	**Action Items**
Risk assessment framework for determining the risks in the planned remote inspection	**Action Item 5:** Risk assessment framework for the risks in remote inspections. The organization involved in remote inspection should conduct a risk assessment to identify any hazards to the planned inspection and provide mitigation measures. The risks are relevant: hazardous areas, payload of the machine, battery storage, operational accidents, dropped object risks, collision, unexpected interruption of the pilot operation and blind area of flight and communication control link. The risk report should agree upon before the ship inspection by the ship-owner/operator class society and service supplier.
Reference for Further Information	• *Guidance Notes on the Use of Remote Inspection*, 2019, American Bureau of Shipping, Section 5.3 • *Guidelines for Use of Unmanned Aerial Vehicles*, 2018, China Classification Society: Section 4.4. • *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*, 2020, American Bureau of Shipping.
Element of Regulatory Blueprint	**Action Items**

Human Element	**Action Item 6:** Human Element Oversight and Skills Development. According to International legislation employers should supply the right equipment and have the correct procedures in place to ensure safe working practices of their employees. The choice of equipment and implemented procedures are based on risk-assessments. These Risk assessments must be reviewed by the human-element in case experience, changes in working methods or circumstances or level of technology give rise. For visual inspections of enclosed spaces and areas on heights the equipment has become mature, pilots trained and companies well certified, so level of technology has changed. This should trigger the choice to use remote inspection, not putting peoples live at risk anymore. Due to the fact that all stakeholders are used to and accept the traditional risk assessments, there is no clear enforcement to make the usage of remote inspection mandatory during certain type of inspections. Or even worse, not even accepted (ie during CAP-surveys). An interesting "torsion" in the industry, which can only be straightened when all stakeholders do what the regulations require them to do: review the existing risk assessments and chose the best available technology for the job, which in many cases is Remote Inspection Technology: ● **Information flow** Data from inspections carried out by RIT have a few purposes: O Surveys (Safety/Compliance/Record keeping) O Asset Management (preventive maintenance, trend analysing/forecasting) ● Format of RIT-Inspection data for surveys, whether it is done by operators or (semi) autonomous can be standardized. As Classification Societies must have unique selling points harmonizing this might be a challenge ● Data required for trend analysing and forecasting require different processing/technology ● Human oversight should be considered as a safeguard throughout the lifecycle of RITs; ● If the inspector is not satisfied with the outcome, alternative or traditional survey techniques may be required; ● RITs surveyors should have specific training on remote inspections; and ● UAVs and ROVs should be piloted by qualified and trained operators with a deep understanding of their technology.
Reference for Further Information	• Pastra, A., Schauffel, N., Ellwart, T. and Johansson, T., (in press: available September 2022) “Building a Trust Ecosystem for Remote Technologies in Ship Hull Inspections”, Journal of Law, Innovation and Technology, Vol. 14 (2), (Taylor & Francis) • IACS UR Z17: Procedural Requirements for Service Suppliers: 14 Revisions since 1999
Element of Regulatory Blueprint	**Action Items**

Allocation of Responsibilities	**Action Item 7:** Allocation of Responsibilities in the Planning, Operation and Execution Process. During RITs-aided inspections, there should be clear allocation of roles and responsibilities of the classification society, service provider and ship-owner/ship operator during the planning, operation and reporting stages.
Reference for Further Information	*Guidance Notes on the Use of Remote Inspection*, 2019, American Bureau of Shipping, Section: 2.
Element of Regulatory Blueprint	**Action Items**
Data management	**Action Item 8:** Data management terms between ship owner/operator, classification society and service provider. The key parties in the remote inspection's planning, operation, and reporting stages should consider trusted data platform to safeguard the data generated by the remote system and its sharing. Data terms should be included in the contract signed by the relevant parties about data ownership and copyright, collection, preservation entity, storage, security measures of data preservation entity, data post-processing and report.
Reference for Further Information	• Johansson, T, Dalaklis, D., Pastra, A. Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers. Journal of Marine Science and Engineering. 2021; 9(6):594. https://doi.org/10.3390/jmse9060594 • See also Data Governance and Management Action Items 16,17,18,19,20,21,22, 23 of the International Study: Table 12- Elements for Regulatory Blueprint for Harmonization of International Arrangements.
Element of Regulatory Blueprint	**Action Items**
Robustness of Systems	**Action Item 9:** Technical Robustness of the Systems Classification societies, manufacturers and service providers should consider the integrity of the system since the remote application should be reliable and work properly every time it is needed. Reproducibility of the results is also crucial, and the system should produce consistent results if the operation is repeated. Besides, the system's usability is a factor that should be considered since it must prove itself that is easier and cheaper than a traditional mode of survey. **Action Item 10:** Data Robustness Recorded data submitted to the surveyor should be of high quality and uninterrupted.

Reference for Further Information	• Pastra, A., Schauffel, N., Ellwart, T. and Johansson, T. (in press: available September 2022) "Building a Trust Ecosystem for Remote Technologies in Ship Hull Inspections", *Journal of Law, Innovation and Technology*, Vol. 14 (2), (Taylor & Francis). • Johansson T., Dalaklis, D., Pastra A., "Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers", *Journal of Marine Science and Engineering*, 2021; 9(6):594. https://doi.org/10.3390/jmse9060594 • *Guidelines for Use of Unmanned Aerial Vehicles*, 2018, China Classification Society: Section 4.4.
Element of Regulatory Blueprint	**Action Items**
Safety and Liability	**Action Item 11:** Product safety. **Action Item 12:** Product liability. • Safety and liability are two complementary mechanisms to ensure high levels of safety and minimal risk of harm to users; • The Original Equipment Manufacturers (OEMs) should follow internationally agreed and accepted requirements for safe commercial operations; • Certified products according to international standards should be provided by manufacturers and utilized by service providers; and • Clear provisions in the form of a contract should specify the liable party (manufactures, developer of the AI system or pilot of the drone) in different scenarios when a remote system operated by a pilot crashes and cause damage
Reference for Further Information	Alexandropoulou, V.; Johansson, T.; Kontaxaki, K.; Pastra; A., Dalaklis, D., (in press: available 2022) Maritime Remote Inspection in Hull Survey & Inspection: A Synopsis of Liability Issues from a European Union Context", *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, ISSN: 2572-5084

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4. Inspecting Ships Autonomously under Port State Jurisdiction: Towards Sustainability and Biodiversity in the EU

4.1 Introduction

Robotic systems capable of visually inspecting, measuring for corrosion and thickness, and cleaning the hulls and structures of large ships are currently the object of growing technological development and investment.[5] These systems can be composed of multiple individual robots of different kinds – for example micro aerial vehicles (drones); underwater vehicles; and crawlers that magnetically attach to a metal surface – potentially operating to varying extents autonomously and making decisions based on artificial intelligence capabilities. While these technologies are still under development, it seems likely that they will become more widely used in situations where the structures, and especially the outer hulls, of large ships are inspected and/or cleaned. By potentially facilitating more frequent and detailed inspections of the outer hulls and structures of ships by states asserting port State jurisdiction these technologies could contribute to the reduction of substandard shipping and to the protection of the marine environment. By inspecting for, and subsequently removing accumulated organic matter (biofouling) on ship hulls these robotic systems could support significant fuel savings through the greater fuel efficiency created by smooth hulls, leading to lower Greenhouse Gas (GHG) emissions. More rigorous monitoring and removal of biofouling could also protect marine biodiversity from threats posed by alien invasive species introduced to a new ecosystem having been carried there on a ship's hull. This research addresses the question of how we can build these technologies into legal regimes that contribute to the enforcement of standards relating to the safety and maintenance standards of ships; the protection of the marine environment; and climate change mitigation. This perspective views these new technologies not as posing new problems for European Union (EU) or International Maritime Organization (IMO) regulators, but as offering new possibilities.

This research outlines the legal framework applicable to the use of such autonomous robotic inspection systems by EU Member States asserting port State jurisdiction over ships entering their ports. Thus, by examining the EU's harmonization of the way its Member States fulfil their responsibilities as port states, the research focuses on a point of intersection between EU law and the law of the sea.[6] The research analyses the extent to which the aims pursued by EU legislation on port State jurisdiction – the improvement of "maritime safety, security, [and] pollution prevention" – could be supported by the employment of autonomous inspection robots that are currently under development. This focus on EU port State jurisdiction as it relates to autonomous inspection technologies is useful for three main reasons.

[5] The research that resulted in this publication was conducted under the European Union Horizon 2020 funded project 'Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks' (BugWright2), grant agreement No. 871260.
[6] For a conceptualisation of the concept of "responsible port state" see: E J Molenaar, 'Port State Jurisdiction: Toward Comprehensive, Mandatory and Global Coverage' (2007) 38 *Ocean Development and International Law* 225-257.

First, the European Commission is currently engaged in a process of revising the primary piece of EU legislation governing port State jurisdiction, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (the PSC Directive).[7] Through close analysis of the current version of the Directive alongside the Commission's assessment of its operation to date, this research examines how wider adoption of autonomous ship inspection robots could support the aims pursued by this significant legislative initiative.

Second, the EU has been particularly active in policy areas related to these technologies, especially on reducing substandard shipping, and on combatting climate change. On the topic of reducing substandard shipping, an interest can be perceived, especially among Members of the European Parliament (MEPs), to use EU legislation to prompt Member States to exercise their jurisdiction as flag, coastal or port States with more force and frequency with the aim of making shipping safer, cleaner, and less polluting. It could be argued that this interest connects with a wider current impetus to expand regulatory powers of the state over maritime spaces in ways not limited to the flag and zonal architecture of the United Nations Convention on the Law of the Sea (LOSC). This impetus was well-captured by the observation made by Malcolm Evans' when giving evidence before the International Relations and Defence Committee of the UK House of Lords in October 2021, that much room existed to "ratchet up" assertions of state regulatory power within the existing LOSC framework.[8] With regard to climate change policies, the EU's increasingly strenuous efforts to reduce the contribution made by shipping to GHG emissions have taken the form of an argument with the IMO, conducted in a legal idiom but which is in substance a clash over the politics of climate change.

Third, this focus on the EU is merited because the EU's activity in these areas is of global systemic relevance. The EU has expressed a willingness to threaten to squeeze the IMO's position as prime regulator in the area of maritime policy. The EU's economic power and importance as a market for shipping makes this threat credible, with the consequence that EU law and policies are of interest internationally as they have the potential to both set standards and have effects beyond the EU.[9]

The research proceeds as follows. The first section explains what autonomous inspection robots are, and what kinds of inspection and cleaning tasks they can perform, or are likely to be able to perform in the near future. The second section outlines the EU legal framework concerning port State jurisdiction, its interaction with the prerogatives and obligations of States under the law of the sea, and with the Paris Memorandum of Understanding on Port State Control. The third section offers a truncated history of attempts to regulate and adequately enforce construction, safety and maintenance standards of merchant ships since the 1980s, focusing on EU acts and the specific problems associated with bulk carriers and oil

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[7] Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57.

[8] M Evans, 'Formal meeting (oral evidence session) of the International Relations and Defence Committee of the House of Lords: UNCLOS: Fit for purpose in the 21st century?' available at https://committees.parliament.uk/event/6011/formal-meeting-oral-evidence-session/; accessed 10 March 2022.

[9] S Kopela, 'Port-State Jurisdiction, Extraterritoriality, and the Protection of Global Commons' (2016) 47(2) *Ocean Development and International Law* 89-130, at p. 90; On the EU's use of extraterritorial jurisdiction see: Joanne Scott, 'Extraterritoriality and Territorial Extension in EU Law' (2013) 62(1) *American Journal of Comparative Law* 87-126 (cited in Kopela); See also: J Leeuwen, 'The Regionalization of Maritime Governance: Towards a Polycentric Governance System for Sustainable Shipping in the European Union' (2017) 117 *Ocean & Coastal Management* 23-31.

tankers. The fourth section closely analyses provisions of EU legislation on port State jurisdiction that require the inner and outer structures of ships to be inspected, linking these requirements to capabilities of autonomous inspection robots. The fifth section examines the Commission's ongoing work on a review of the PSC Directive, examining how autonomous inspection robots could support the aims pursued by this initiative. The possibility of new EU legislation mandating that ships entering Member State ports comply with standards prescribing maximum acceptable levels of biofouling is examined, drawing a comparison with such initiatives in other jurisdictions. The fifth section briefly concludes.

4.2 What are autonomous inspection robots?

The autonomous inspection robots referred to in this research comprise a system of multiple different kinds of robots operating cooperatively to inspect and potentially clean a large structure composed of metal plates, such as the hull of a medium or large ship. There are three primary categories of such robot. Micro aerial vehicles are small multi-propeller drones that can systematically move around a large vessel, providing visual feedback to an operator. Autonomous underwater vehicles are small submersibles that can systematically visually map the portion of a ship's hull that is underwater. Finally, magnetic wheeled crawlers can attach to a steel plate surface and conduct acoustic based inspection of the surface above and below the waterline. By transmitting sound waves at the surface as they move slowly across it, these crawlers can measure the thickness of the steel, thus identifying points thinned by corrosion with significant accuracy. It is possible for all three categories of robot to work together, with several individual units of each kind transmitting data into a single augmented reality representation of a vessel, monitored by a human inspector. This vision, which is the object of the BugWright2 research project on which this research draws, is sketched in figure 18.

Figure 18: Drones, magnetic wheeled crawlers and submersibles working autonomously to visually and acoustically scan a ship while transmitting data a human operator[10]

Drones, submersibles and crawlers of these kinds are currently most commonly operated remotely by a dedicated human operator, without making autonomous decisions about their own navigation or about the surfaces they inspect. However, significant research effort is currently being dedicated to developing inspection systems composed of robots that can navigate autonomously, while decisions about defects identified are taken by a human operator. It is not unrealistic to imagine that in the near future a greater level of autonomous operation may be attained, with teams of robots making independent decisions in

[10] Cédric Pradalier, 'Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks' (BugWright2), Description of the Action, EU Horizon 2020, grant agreement No. 871260.

order to synchronise their movements around a vessel, while using large stores of data from past inspections to make further decisions about defects identified on the vessel being inspected.

In the near future, the most holistic use of all three categories of inspection robot, represented in figure 1 above, could permit ship surveys and inspections that would ordinarily take place in dry dock to be undertaken at quay, potentially even while a vessel is unloading and loading cargo. Depending on the type of vessel and the level of inspection being undertaken, drones, crawlers or submersibles might also be used independently of each other. For example, submersibles could conduct a visual inspection of the underwater portion of the hull of a fishing vessel, while drones could be well suited to conducting a visual inspection of the massive sides of a cruise vessel, or the outer hull and inner cargo areas of a bulk carrier. Where hull cleaning is the aim, a team of crawlers fitted with brushes can be deployed to systematically sweep the hull clean of organic matter. The advantage offered by these technologies is that they can make it easier to quickly and effectively examine and clean difficult to access parts of a ship's outer and inner structure.

4.3 A Point of Intersection between EU law and the Law of the Sea

This research focuses on ways such autonomous inspection robots could be used in the future by national authorities asserting port State jurisdiction in EU ports. Hence, the immediately applicable and overarching legal framework is provided by the PSC Directive, with its three implementing regulations.[11] With this Directive, the EU has sought to harmonise how its Member States exercise prerogatives they enjoy as port States under the law of the sea.

The ability of port States to prescribe and enforce legal standards with respect to ships choosing to enter their ports follows from a concurrent reading of several provisions of the LOSC[12]. Article 11 provides that outer parts of harbour work form part of the coast, making them part of the baseline and placing ports within internal waters; Article 8(1) specifies that waters landward of the baseline are internal waters; and, in stating that that the sovereignty of a State extends "beyond its land territory and internal waters…" to other specified zones, Article 2(1) makes clear that States enjoy territorial sovereignty over internal waters.[13] It follows from this pattern of provisions that States exercise prescriptive and enforcement jurisdiction that is territorial in nature over all ships, whether flying that State's flag or not, while they are in port, subject to any agreements with other states that may limit such jurisdiction. As noted by Robin Churchill, this is also the position under customary international law, binding states with maritime ports, but which have not ratified the LOSC[14].

[11] Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State (n 7). The Directive's three implementing regulations are: Commission Regulation (EU) No 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships, OJ L 125; Commission Regulation (EU) No 801/2010 of 13 September 2010 implementing Article 10(3) of Directive 2009/16/EC of the European Parliament and of the Council as regards the flag State criteria, OJ L 241; and Commission Regulation (EU) No 802/2010 of 13 September 2010 implementing Article 10(3) and Article 27 of Directive 2009/16/EC of the European Parliament and of the Council as regards company performance, OJ L 241.
[12] R Churchill, 'Port State Jurisdiction Relating to the Safety of Shipping and Pollution from Ships - What Degree of Extra-Territorialty?' (2016) 31(3) *International Journal of Marine and Coastal Law (IJMCL)* 442-469.
[13] United Nations Convention on the Law of the Sea (Montego Bay, 10 December 1982, in force 16 November 1994) 1833 UNTS 3; Churchill (n 8), at p. 444.
[14] Churchill (n 12), at p. 444. Noting recognition of a State's wide discretion in exercising sovereignty over ports within its territory under customary international law, see: Molenaar (n 2), at p. 227. This view was stated by the ICJ in: *Case concerning*

This research addresses the broader concept of port State jurisdiction, as opposed to port State control. Erik Jaap Molenaar usefully clarifies the distinction between these concepts by noting that port State control is best understood by reference to the terms of regional memoranda of understanding (examined below) defining voluntary commitments among States Parties to undertake control inspections of foreign ships calling at their ports with the aim of verifying compliance with internationally agreed standards, and to take enforcement action with respect to those standards that is largely corrective in nature.[15] Port State jurisdiction can be understood to encompass such control inspections, but to also include prescriptive and enforcement jurisdiction of port States over foreign flagged ships in their ports with respect to national or supranational legislation that may be more onerous than internationally agreed standards. A wider focus on port State jurisdiction is appropriate here because applications of autonomous inspection robots are envisaged that would support enforcement of international conventions, as well as applications that could support EU Member States exercising prescriptive jurisdiction over foreign flagged ships in their ports, e.g., with regard to standards intended to safeguard marine biodiversity by prescribing minimum acceptable levels of biofouling.

Today, a consensus can be said to exist, in scholarship and as evidenced in state practice, that views port State jurisdiction as an increasingly important supplement to (though not a replacement of) flag state jurisdiction. It is a jurisdictional basis that is widely seen as supporting the assertion of relatively broad regulatory powers by port States over foreign flagged ships, and as an important tool with which to pursue the realization of community interests such as the protection of the marine environment; the rigorous enforcement of construction, design, equipment and manning (CDEM) standards pertaining to ships; and relating to climate change mitigation.[16] With respect to port State control, the sixth recital to the PSC Directive evokes a widespread current emphasis of the role of port States in enforcing international standards neglected by flag States:

> … there has been a serious failure on the part of a number of flag States to implement and enforce international standards. Henceforth, as a second line of defence against substandard shipping, the monitoring of compliance with the international standards for safety, pollution prevention and on-board living and working conditions should also be ensured by the port State, while recognising

Military and Paramilitary Activities In and Against Nicaragua (Nicaragua/United States of America) (Merits) [1986] ICJ Reports 14, at 111.

[15] Molenaar (n 6), at p. 227.

[16] On jurisdiction to prescribe and enforce CDEM standards see: Churchill (n 12), at p. 445-458; For an overview of international law debate concerning port State jurisdiction see the 2016 special issue of the International Journal of Marine and Coastal Law: C Ryngaert and H Ringbom, 'Introduction: Port State Jurisdiction: Challenges and Potential' (2016) 31(3) *International Journal of Marine and Coastal Law (IJMCL)* 379-394. The more contentious aspects of this debate tend to concern States asserting jurisdiction over ships in their ports on jurisdictional bases that are extra-territorial in nature (such as with regard to discharges alleged to have occurred outside maritime zones of the State in question), or in ways that have, or can be argued to have, extra-territorial effects. See: Kopela (n 9). On discharges outside the port State's maritime zones, see: Z Sun, 'The Role of East Asian Port States in Addressing Ship-Source Pollution in Arctic Shipping' (2022) *World Maritime University [forthcoming publication]*; Y Tanaka, 'Protection of Community Interests in International Law: The Case of the Law of the Sea' (2011) 15 *Max Planck Yearbook of United Nations Law* 329-375, at p. 350-356. The territorial basis for assertions of port State jurisdiction addressed in this research can be considered sufficient, although some of these acts may be argued to have extra-territorial effects. Adopting a similar position see: Molenaar (n 6), at p. 228. On this point, and considering the position of the European.

that port State control inspection is not a survey and the relevant inspection forms are not seaworthiness certificates.[17]

4.3.1 The PSC Directive and the Paris Memorandum of Understanding

The PSC Directive has the effect of making binding on EU Member States the system for coordinating inspections undertaken based on port State jurisdiction established by the Paris Memorandum of Understanding on Port State Control (the Paris MoU). The Paris MoU, like other regional agreements coordinating port States' undertaking of control inspections, is an agreement between States to coordinate inspections carried out by their national maritime authorities with the aim of enforcing international legal standards. First agreed in 1982 between the then EU Member States and Norway, the Paris MoU now has twenty-seven Member States including all EU Member States with seaports, the Russian Federation, Iceland, Canada and Norway.[18] Concretely, such regional MoUs on port State control entail the administration of databases recording results of past inspections and assigning risk profiles to individual ships based on those records; they outline procedures and parameters for how many inspections States Parties should undertake, how those inspections should be conducted and what should be inspected; and they facilitate the coordinated refusal of access to ports in the MoU region for ships failing to satisfy inspection standards or take remedial action. The regional system of MoUs has been criticized for failing to make consistent inspection practices between different MoU regions, and between States in the same MoU region, and for its non-binding character.[19]

As noted above, the EU would appear to have solved this problem, binding its Member States by layering its PSC Directive atop the arrangements made within the Paris MoU, and linking the practical operation of the Directive, for example with respect to the assignation of ship risk profiles, to the methods established by the Paris MoU.[20] With the international conventions enforced under the Paris MoU, the PSC Directive also coordinates Member States' enforcement of EU maritime legislation.[21] An exception made in the fortieth recital and in Article 3(1) of the Directive and related to MoU regions is addressed to France, permitting France's remaining colonies, the "overseas departments" listed in Article 299(2) of the Treaty

[17] Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (n 7). This remained the view of the Commission as of its publication of an Inception Impact Assessment of the operation of the PSC Directive in October 2020: "Port State Control is considered the third line of defence against sub-standard shipping, the primary responsibility laying with the ship-owner and the flag state (the state of registration of the vessel). However, as some owners and some flag states have shown an inability or an unwillingness to correctly discharge their responsibilities PSC is seen as a very important enforcement tool. Ensuring compliance with international rules and standards by vessels calling EU ports promotes a level playing field between ship-owners. In addition, increasing the quality of shipping in EU waters helps preventing big maritime accidents and its associated financial and environmental costs." Inception Impact Assessment: 'Port State control - Strengthening safety, security and sustainability of maritime transport', DG MOVE.D2 – Maritime safety (2020).

[18] Inception Impact Assessment: 'Port State control - Strengthening safety, security and sustainability of maritime transport', DG MOVE.D2 – Maritime safety (2020) (n 13). The other regional MoUs are: for Asia and the Pacific, the Tokyo MoU; for Latin America, the Acuerdo de Viña del Mar; for the Caribbean, the Caribbean MoU; for West and Central Africa, the Abuja MoU; for the Black Sea region, the Black Sea MoU; for the Mediterranean, the Mediterranean MoU); for the Indian Ocean, the Indian Ocean MoU; and the Riyadh MoU. The United States Coast Guard maintain the tenth PSC regime: https://www.imo.org/en/OurWork/MSAS/Pages/PortStateControl.aspx, accessed 10 March 2022.

[19] Armando Graziano, Maximo Q Mejia Jr. and Jens-Uwe Schröder-Hinrichs, 'Achievements and Challenges on the Implementation of the European Directive on Port State Control' (2018) *72 Transport Policy* 97, at p. 98 and criticism cited therein.

[20] Recitals 9, 13, 14, 15, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 3).

[21] *Ibid.,* Article 1(a), ibid.; Paris Memorandum of Understanding on Port State Control. Section 2, 'Relevant Instruments'; Vincent Power, *EU Shipping Law* (3rd edition, Routledge 2019), at p. 1305.

Establishing the European Community (TEC), now Article 349 of the Treaty on the Functioning of the European Union (TFEU), to be exempted from the port State control system applied pursuant to the PSC Directive, due partly to the fact that some of these territories are parties to different regional MoUs, as well as due to their geographical distance from Europe.[22]

4.4 Regulating in Response to Disasters

Briefly recalling the background to this contemporary legal landscape spanning multiple regimes is worthwhile because it contains salutary lessons for attempts to regulate shipping today. The 1980s and 1990s saw a series of significant disasters involving oil tankers and bulk carriers. Bulk carriers are used to carry huge quantities of loose dry cargo like grain, iron ore, or fertilizers. These vessels came into use in the post-war period, but in the early 1990s a large number of bulk carriers were wrecked after suffering catastrophic structural failures, in some cases simply breaking apart in heavy weather. Once these vessels failed they were frequently flooded and lost extremely quickly, with the consequence that all crew died.[23] Research into the problem revealed that bulk carriers are subjected to particularly serious structural strains due to factors such as the loading and unloading of heavy, loose materials; the movement of unevenly distributed loose cargo; accelerated corrosion of metal plates composing the hull due to the chemical composition of these cargoes; design flaws; and the increased use of thinner, high-tensile steel plates.[24] Age was also a central causal factor, with most of the bulk carriers lost in the early 1990s being over 20 years old.

Since the 1980s oil tankers had also been involved with some regularity in massive disasters that caused catastrophic environmental pollution, making up a considerable portion of total worldwide losses of ships.[25] Concern in Europe at this trend had initially prompted the 1982 agreement of the Paris MoU. The 1999 breaking in two of the Maltese tanker the ERIKA off the French coast and the 2002 wrecking of the Bahamian tanker the PRESTIGE off the Spanish coast prompted significant EU legislative packages focused on, among other topics, using inspections undertaken under port State jurisdiction to more vigorously enforce safety and maintenance standards with respect to foreign flagged vessels. Both the ERIKA and the PRESTIGE had broken in two, were over twenty years old, and had been inadequately maintained and surveyed.[26] A particular contributing factor to disasters involving tankers was the use of tankers of a single, rather than double hulled design.[27] This prompted the EU to adopt a regulation accelerating the timetable

[22] Recital 40, Article 3(1), Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 3); Article 349, Consolidated version of the Treaty on the Functioning of the European Union, OJ C 326.
[23] 'Bulk Carrier - Improving Cargo Safety' [2007] United Nations Atlas of the Oceans <https://web.archive.org/web/20070927063932/http:/www.oceansatlas.com/unatlas/issues/safety_at_sea/bulk_carrier/bulk_carrier.htm> accessed 10 March 2022.
[24] *Ibid.,* High tensile steel can allow metal plates composing a ship's hull to be thinner than mild steel. This has the consequence that corrosion becomes a structural threat more quickly.
[25] M A Nesterowicz, 'European Union Legal Measures in Response to the Oil Pollution of the Sea' (2004) 29 Tulane Maritime Law Journal 29, at p. 31.
[26] *Ibid.,* at p. 32, 39.
[27] Double hull tankers are designed with two layers of metal plates separating the oil they carry from the seawater. *Ibid.* at p 33, n 44.

specified by the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL) for the phasing out of the use of single hulled oil tankers.[28]

This spate of shipping disasters from the 1980s through to the 2000s, involving especially but not only bulk carriers and tankers, catalysed efforts to impose more stringent legal standards for the construction, maintenance and inspection of merchant ships. One important outcome of these efforts, which is of particular relevance to the focus of this article, were the 1993 guidelines adopted by the IMO Assembly, 'Guidelines on the Enhanced Programme of Inspections during Surveys of Bulk Carriers and Oil Tankers', on the basis of which amendments were made to the International Convention for the Safety of Life at Sea, 1974 (SOLAS, 1974), entering into force in 1996.[29] The guidelines mandate enhanced survey procedures be applied to bulk carriers and tankers during the surveys prescribed by the SOLAS, 1974, focusing on identifying corrosion; taking plate thickness measurements; how close up surveys should be conducted; who is qualified to conduct such surveys; and what documents ships must carry to demonstrate compliance with these requirements.[30]

Responsibility for ensuring compliance on the part of ship owners and operators with these legal instruments lies primarily with flag States. Those States will in turn ordinarily follow the longstanding practice of privatizing the responsibility of actually conducting the required surveys by contracting private companies to do so – classification societies.[31] However, the history of the development of these legal instruments shows that port States can also play a significant, and at times crucial role in ensuring their enforcement. Australia's tightening of port State control inspections in the early 1990s in response to disasters concerning ageing bulk carriers at first resulted in a large movement of bulk carriers from the Pacific to the Atlantic, apparently by owners seeking to protect their substandard vessels from Australia's more stringent inspection regime.[32] Subsequently, wider enforcement of standards concerning safety procedures, construction, design and maintenance of bulk carriers and tankers, alongside the agreement of IMO level guidelines, raised standards worldwide. When taken by port States in an economic and geographical position to do so, unilateral enforcement measures like those of Australia can contribute to raising standards more widely, including by prompting activity through the IMO.[33] The EU's speeding up of the phasing out of single hulled oil tankers in the early 2000s is another example of unilateral (in this case on the part of a regional body) regulation that went beyond internationally agreed standards and had the effect of helping to lift global standards.[34]

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[28] International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997 (MARPOL), entered into force on 2 October 1983, 1340 UNTS 61; Nesterowicz (n 21), at p. 33 and 35.
[29] IMO, Resolution A.744(18) adopted on 4 November 1993, Guidelines on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers; International Convention for the Safety of Life at Sea, 1974 (SOLAS, 1974), entered into force on 25 May 1980, 1184 UNTS 2.
[30] Relatedly, the EU has legislated to harmonise procedures for the safe loading and unloading of bulk carriers: Directive 2001/96/EC of the European Parliament and of the Council of 4 December 2001 establishing harmonised requirements and procedures for the safe loading and unloading of bulk carriers, OJ L 13.
[31] For analysis of the position of classification societies within the field of global maritime governance drawing on Bourdieusian sociological concepts, see: Raphael Lillillour and Dominique Bonet Fernandez, 'The Balance of Power in the Governance of the Global Maritime Safety: The Role of Classification Societies from a Habitus Perspective' (2021) 22 Supply Chain Forum: An International Journal 268.
[32] 'Bulk Carrier - Improving Cargo Safety' (n 23).
[33] Molenaar (n 2), at p. 226.
[34] The United States had previously taken unilateral action to phase out the use of single hull tankers: Oil Pollution Act of 1990, 104 Stat. 484.

Writing in 2004 of the EU's successive efforts to combat oil pollution resulting from disasters involving old, poorly maintained and surveyed oil tankers, Malgorzata Anna Nestorowicz summarized the situation in the following way:

> Even if the recent years have seen an important development in monitoring and control of the maritime traffic on the international level, they can hardly catch up with the potential dangers that shipping brings about. The mechanism established by the IMO granting a flag state major prerogatives over its ships is not effective anymore. The ownership of the registered tonnage is largely concentrated in new flag states where the IMO conventions are either not uniformly adopted or, if adopted, not properly enforced due to insufficient controls of ships by the flag state authorities. Moreover, many of the IMO resolutions are not legally binding. This allows many substandard ships to continue to operate under one of the flags of convenience where controls are not too strict. Employing an old, substandard ship constitutes for many importers a major reduction in fixed costs.[35]

The EU's efforts to harmonize how Member States assert port State jurisdiction, currently manifested in the PSC Directive, is yet another unilateral (regional) attempt to address this situation by better enforcing compliance with internationally agreed standards with respect to ships entering EU ports, as well as to enforce EU maritime legislation that goes beyond standards provided for in international conventions. This can be welcomed as a productive contribution to improving the safety of life at sea; the protection of community interests like the marine environment; and as a measure that reduces substandard shipping and removes a competitive advantage enjoyed by owners and operators that benefit from cutting costs by operating poorly maintained ships.[36]

From the truncated history of legal developments concerning ship construction, maintenance and inspection standards presented here, we can draw two significant lessons. First, as is often noted by commentators, an assertion of public regulatory power that may seem improbable today is often one disaster away from becoming an imperative and obvious priority of powerful actors keen to act and be seen to act. Second, these legal developments are often propelled through initial unilateral acts taken by powerful States or regional organizations. Departing from a perspective cognizant of these lessons, the following section examines the extent to which the employment of autonomous inspection robots could, or would constitute an innovation in the operation of port State jurisdiction from the perspective of EU law.

4.5 Inspection of Ship Structures under Current EU Legislation on Port State Jurisdiction

The PSC Directive is the latest iteration of EU legislation on how Member States undertake inspections based on port State jurisdiction. It consolidates and moves the law further than previous legislation on the subject, in response to events including those outlined in the previous section. As Vincent Power notes, the Directive embodies the fact that "PSC is best seen as an evolutionary regime."[37] The legal basis for the PSC Directive was Article 80(2) of the Treaty Establishing the European Community (TEC), now Article 100(2) of the Treaty on the Functioning of the European Union (TFEU). Article 100(2) falls under Title VI, which sets

[35] Nesterowicz (n 25), at p. 44.
[36] Molenaar (n 6), at p. 226; Recital 7, 16, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 7).
[37] Power (n 21), at p. 1307.

out a framework for a common transport policy, and gives the European Parliament and Council the power to "lay down appropriate provisions for sea and air transport." [38] The stated purpose of the Directive is "to help drastically reduce substandard shipping in the waters under the jurisdiction of the Member States", and in scope it applies to "any ship and its crew calling at a port or anchorage of a Member State to engage in a ship/port interface", with the possible exception of ports of French colonies noted above.[39] Member States are required to "take all necessary measures, in order to be legally entitled to carry out the inspections referred to in this Directive on board foreign ships, in accordance with international law", entailing national legislation be adopted by Member States to empower their competent authorities, and that those authorities be adequately staffed and equipped.[40] The Directive requires Member States to refuse access to ports and anchorages in their jurisdiction where a ship fails to satisfy inspection criteria on several occasions and after specified time periods, and to detain any ship exhibiting deficiencies "clearly hazardous to safety, health or the environment" until the deficiencies are rectified.[41]

A number of provisions of the PSC Directive establish a framework within which Member States' competent authorities could choose to employ autonomous inspection robots when fulfilling their obligations to assert port State jurisdiction. The central point from the perspective of this article is that the Directive, and the Paris MoU on which it draws in significant respects, requires Member States' competent authorities to inspect the inner and outer structures of ships in specified circumstances. Under the terms of the PSC Directive and the Paris MoU ships are selected for "periodic inspections" at intervals determined by a system of assigning risk profiles to individual vessels, and taking into account past performance of flag States; recognized organizations ("a classification company or other private body, carrying out statutory tasks on behalf of a flag State administration"); and companies responsible for operating a ship.[42] Ships can also be subject to "additional inspections" regardless of the time period since their last periodic inspection where "overriding or unexpected factors arise".[43] Such factors include issues like ships having been suspended or withdrawn from their class since their last inspection in the Paris MoU region; having been the subject of a report or notification by another Member State; having been involved in a collision on the way to port; carrying certificates issued by a recognized organization that is no longer recognized; and so on.

Having been selected for inspection, a ship may first be subject to an "initial inspection", during which a Port State Control Officer (PSCO) verifies the ship is carrying documentation certifying compliance with international conventions relating to safety and security, as well as EU maritime legislation; checks whether deficiencies identified during a prior inspection have been rectified; and assesses "the overall condition of the ship".[44] However, a "more detailed inspection" may be conducted where there are "clear grounds", after an initial inspection, to believe a ship does not meet the relevant requirements of a convention.[45]

[38] Consolidated version of the Treaty on the Functioning of the European Union, OJ C 326 (n 18).
[39] Article 1, 3(1), Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 7).
[40] *Ibid.,* Article 4(1), 4(2).
[41] *Ibid.,* Article 16, 19.
[42] Quoting *Ibid.,* Article 2(19), on selecting ships Article 12 and Annex I, on risk profiles and frequency of inspections Article 10 and 11 respectively, ibid.; the Directive draws language and procedures from Annex 7 (risk profiles) and Annex 8 (on selecting ships for inspection), Paris Memorandum of Understanding on Port State Control (n 17).
[43] Article 12, Annex I, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 7).
[44] *Ibid.,* Article 13(1), Annex IV.
[45] *Ibid.,* Article 13(3).

Among the examples of “clear grounds” specified in Annex V to the PSC Directive is: “Evidence from the inspector’s general impression and observations that serious hull or structural deterioration or deficiencies exist that may place at risk the structural, watertight or weathertight integrity of the ship.”[46]

A focus on the inner and outer structure of ships is also a component of a further inspection category, that of “expanded inspections”.[47] Expanded inspections are carried out on ships of certain types with certain risk profiles. Among other categories, “Passenger ships, oil tankers, gas or chemical tankers or bulk carriers, older than 12 years of age” are prioritised for expanded inspections.[48] Annex VII to the Directive specifies risk areas to be given particular attention, including a ship’s “structural condition”; “weathertight condition”; and “pollution prevention”.[49] Commission Regulation No. 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships offers yet further detail concerning specific items that should be verified during an expanded inspection. The annex to this implementing regulation specifies that with regard to appraising a ship’s structural condition, the specific items to be verified during an expanded inspection referred to under Article 14(4) of the Directive include: for all ships the condition of the hull and deck; and for bulk carriers and oil tankers the verification of documentation certifying compliance with the ESP (discussed above), and examination of the condition of bulkheads, coamings and ballast tanks within the cargo area, with the possibility that at least one ballast tank may need to be inspected from the inside.[50]

Finally, a focus on inspecting the inner and outer structure of ships is also evident in the criteria on the basis of which a PSCO is required to make a professional judgment as to whether a ship should be detained. These criteria are referred to in Article 19(3) and listed (non-exhaustively) in Annex X, grouped by reference to the international conventions to which they relate. Alongside broadly delineated “main criteria” concerning the general safety and ability of a vessel to proceed to sea, criteria of particular relevance for the purposes of this examination include: under SOLAS, 1974, failure to carry out the ESP, which in turn could be a ground for a more detailed inspection as per Article 13(3) and Annex V; and under the 1966 International Convention on Load Lines, “Significant areas of damage or corrosion, or pitting of plating and associated stiffening in decks and hull affecting seaworthiness or strength to take local loads…”.[51]

The provisions of the PSC Directive highlighted here all require a PSCO to undertake some level of visual inspection of the outer and inner structure of vessels of all types. With regard to bulk carriers and tankers, visual inspection for structural defects is given added priority, due to the particular risks associated with these vessels and their history of involvement in significant disasters, outlined in the previous section. Drones or submersibles operating autonomously to identify structural defects could offer significant advantages in such scenarios. Submersibles offer the possibility of visually inspecting underwater parts of a ship’s hull with relative speed and without the use of divers. Drones also offer the possibility of inspecting difficult to access parts of massive vessels. The autonomous navigational capabilities of drones currently under development enable the systematic visual appraisal of enormous areas of steel plating in a way that

[46] *Ibid.,* Annex V Part A (13).
[47] *Ibid.,* Article 2(11), 2(12), 2(13), Article 14.
[48] *Ibid.,* Article 14(1).
[49] *Ibid.,* Annex VII.
[50] Annex Part A(a) and (b), Part B(b), Part E(a) and (b), Commission Regulation (EU) No 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships (n 7).
[51] Article 19, Annex X, Points 3.2 and 3.5, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 7).

a human eye would be unable to replicate. This level of methodical, systematic inspection conducted at relative speed would increase the likelihood of areas of plate corrosion, pitting and cracking being identified. Drones are also well suited to inspection tasks within the large internal compartments of vessel hulls, for example the inspection of bulkheads in a bulk carrier.

One conclusion that can be drawn from the above analysis is that it would be possible for national competent authorities to use autonomous inspection robots to conduct inspections based on port State jurisdiction within the legal framework provided by the PSC Directive as it stands. Judgment as to how, and in what scenarios such technologies may be useful would be a matter for the national competent authorities, and at the most immediate operational level for the PSCO undertaking a particular inspection, depending on the procedures established at national level. The professional judgment of the PSCO with respect to the best way to appraise whether a ship satisfies standards of relevant EU maritime legislation and international conventions is emphasized in the Directive.[52] From a technical and operational perspective, the European Maritime Safety Agency (EMSA) could offer support and coordinate Member States' adoption of autonomous inspection technologies. EMSA has the responsibility of supporting Member States' with the aim of ensuring "the convergent and effective implementation of the port State control system" by, among other tasks, assessing the port State control procedures established by individual Member States; and managing the THETIS and SafeSeaNet databases, which record ships prioritised for inspection and the results of those inspections, and collate information on vessel movements to and from EU ports respectively.[53]

These new technologies can be viewed simply as new tools that can allow old inspection tasks to be completed in new, quicker and (it is hoped) more effective ways. However, they can also be viewed as technologies that alter the character of old tasks by making it possible to inspect in ways not considered feasible previously. The PSC Directive caveats the scope of detailed or expanded inspections on the basis of "practical feasibility or any constraints relating to the safety of persons, the ship or the port".[54] It may prove to be the case that the employment of autonomous inspection robots will change what is and is not considered safe and feasible in the context of inspections conducted under port State jurisdiction. With respect to feasibility, the speed offered by autonomous inspection robots may simply permit inspections to include more extensive and rigorous examination of ship structures than is currently possible through human, visual inspection. With respect to safety, one concrete example that may be noted concerns expanded inspections of oil tankers and bulk carriers. Notwithstanding the requirement under Article 14 of the PSC Directive read together with the annex to its implementing Regulation No. 428/2010 (examined above) that as part of an expanded inspection, the condition of bulkheads be examined in the case of bulk carriers, and that ballast tanks within the cargo area be examined and possibly entered in the case of both bulk carriers and oil tankers, feedback from PSCOs suggests that in practice it is rare for a PSCO to enter cargo holds or tanks.[55] The use of inspection drones could help to reduce this discrepancy between law

[52] E.g. *Ibid.,* Annex X, Point 1.
[53] *Ibid.,* Recital 10; Power (n 21), at p. 1305-1306; Regulation (EC) No 1406/2002 of the European Parliament and of the Council of 27 June 2002 establishing a European Maritime Safety Agency, OJ L 208.
[54] Annex VII, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control (as amended), OJ L131/57 (n 3); A similar caveat is found in: Recital 1, Commission Regulation (EU) No 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships, OJ L 125 (n 50).
[55] I am grateful to the members of the BugWright2 'Senior Advisory Group' for this observation.

and practice. As noted above, drones are well suited to inspection tasks within the large internal compartments of vessel hulls, for example the inspection of bulkheads in a bulk carrier or of ballast tanks.

4.6 Possible Changes to EU Legislation on Port State Jurisdiction

At the time of writing in March 2022, a number of EU legislative proposals that could support the possible increased use of autonomous ship inspection robots under port State jurisdiction are at various stages of development. The most significant of these are the Commission's plan to review and potentially revise the PSC Directive; and the 'Fit for 55' legislative package, so called because it aims to reduce EU net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. The implications of each of these significant initiatives merits brief examination.

In October 2020 the Commission announced its intention to review the PSC Directive, after which a public consultation took place. The Commission is expected to publish a legislative proposal in June 2022. Upon announcing its intention to review the Directive, the Commission published an Inception Impact Assessment outlining problems and policy options, on the basis of which it intended to develop a legislative proposal. One set of policy options, proposed on the basis of perceived problems with the functioning of the PSC Directive, envisaged requiring Member States to conduct "more substantive, ship based inspections", concentrating "on operational issues rather than being just a document check"; charging EMSA with training PSCOs to be "more pro-active" in their approach to safety, security and pollution prevention; supporting Member States that have difficulty fulfilling their inspection commitments due to limited resources including with respect to staffing; and encouraging Member States' to digitalize their inspection procedures, including by making provision for the acceptance of electronic certificates of compliance with international standards and preparing port State control procedures to accommodate autonomous shipping.[56] From these proposed policy options, an impetus can be discerned in favour of moving towards more substantive inspection procedures, carried out in a uniform way by all Member States, which instrumentalise and adapt to greater levels of automation, of ships themselves and of their associated technologies. Review of the Directive aims to incorporate "new tools and political priorities" into this legal framework.[57] The autonomous inspection robots discussed here fit comfortably with this impetus, and could contribute to the achievement of aims sought by revising the Directive, including the improvement of "maritime safety, security, [and] pollution prevention".[58]

A second leitmotif of the Commission's proposed policy options with respect to the PSC Directive is a focus on mitigating the shipping industry's contribution to GHG emissions. The Inception Impact Assessment identifies as a problem the fact that the current inspection targeting system does not allow for emphasis to be placed on environmental aspects aimed at rewarding "greener" vessels, and notes that environmental issues connected to decarbonising maritime transport "will have to be looked at from the enforcement perspective."[59] Review of the Directive is framed in part as a response to the European

[56] Inception Impact Assessment: 'Port State control - Strengthening safety, security and sustainability of maritime transport', DG MOVE.D2 – Maritime safety (2020) (n 13), Part A and B; 'Legislative Train Schedule: Review of the Port State Control Directive' <https://www.europarl.europa.eu/legislative-train/theme-promoting-our-european-way-of-life/file-port-state-control-directive-review> accessed 10 March 2022.
[57] Inception Impact Assessment: 'Port State control - Strengthening safety, security and sustainability of maritime transport', DG MOVE.D2 – Maritime safety (2020) (n 17), At Part 2.
[58] *Ibid.,* at Part A.
[59] *Ibid.,* at Part A.

Council Conclusions endorsing the 'Opatija Declaration' of March 2020 on the *EU Waterborne Sector – Future Outlook: Towards a carbon-neutral, zero accidents, automated and competitive EU Waterborne Transport Sector,* a declaration that instantiates a belief that digitalization and automation, climate sustainability and the EU's economic competitiveness are intertwined.[60] This focus on 'greener' shipping is shaped by the broader context of the EU's assumption of an increasingly active role with respect to regulating GHG emissions from ships, and its vying with the IMO on this topic, as noted at the outset of this research. The 'Fit for 55' legislative package announced in July 2021 fits into the 'European Green Deal', the overarching initiative that aims to make the EU the first climate neutral continent by 2050, and contains a number of much discussed proposals of relevance to shipping including its inclusion in the European Emissions Trading System (ETS); a proposed FuelEU Maritime Regulation; and the proposed Alternative Fuels Infrastructure Regulation.[61]

While at this stage the Commission's vision of how a legislative proposal based on its review of the PSC Directive should practically connect to environmental goals pertaining to shipping is not clear, it could be suggested that one possible connection concerns biofouling. As noted above, accumulated organic matter on a ship's hull significantly reduces fuel efficiency by increasing friction between the surface of the hull and the water. Cleaning such biofouling from a ship's hull can result in a reduction in fuel consumption of 10% to 30%. This could be visualized as approximately half a swimming pool of heavy fuel being saved on a return trip across the Atlantic.[62] The lower energy density of non-fossil alternative fuels means that maximizing fuel efficiency will remain an important concern for non-fossil fuel burning vessels. Biofouling also risks the introduction to new habitats of alien invasive species. This is widely recognized as a serious threat to biological diversity, and the EU has adopted legislation (not limited to the maritime sphere) on alien invasive species, as well as a series of instruments focused on improving and protecting the quality of EU waters and marine habitats.[63]

One way to combat biofouling is by painting ship hulls with anti-fouling paints, although it is recognized that such paints do not completely prevent the accumulation of biofouling.[64] Another option is to physically clean hulls, brushing them free of organic matter. While the EU has adopted legislation prohibiting the use of anti-fouling paints harmful to the environment, no EU legislation currently exists that prescribes acceptable levels of biofouling for ships entering Member State ports, or requiring national authorities to

[60] Council Conclusions on 'EU Waterborne Transport Sector – Future outlook: Towards a carbon-neutral, zero accidents, automated and competitive EU Waterborne Transport Sector' 2020.

[61] Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2015/757 in order to take appropriate account of the global data collection system for ship fuel oil consumption data COM/2019/38; Proposal for a Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC COM/2021/562; Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council COM/2021/559.

[62] 'Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks' (BugWright2), Description of the Action, EU Horizon 2020 grant agreement No. 871260, Cédric Predalier (n 10).

[63] Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species, OJ L 317; Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), OJ L 164; On implementation of the MSFD Directive see: Rían Derrig, 'Report on Irish State Practice on the Law of the Sea 2020' (2020) XV Irish Yearbook of International Law (forthcoming publication).

[64] IMO, Resolution MEPC.207(62) adopted on 15 July 2011, 'Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species'.

address biofouling in the context of inspections under port State jurisdiction.[65] Such legislation can be found in jurisdictions outside the EU, for example in Australia, New Zealand, and in some US states.[66] In certain Australian ports for example, biofouling is an object of inspection, while the state of California has recently developed an inspection programme that will use remotely operated underwater vehicles to examine the hulls and difficult to access areas of vessels entering port to ascertain their compliance with state level mandatory biofouling regulations.[67]

A revised PSC Directive could address biofouling in a similar way, requiring Member States to inspect for acceptable levels of biofouling on ships entering their ports. Alongside inspection, cleaning hulls of biofouling can also be undertaken robotically. The magnetic wheeled crawlers described in the second section above can be fitted with brushes and can navigate autonomously across the entire surface of a large hull, brushing organic matter free above and below water. It is worth noting that if ships were cleaned in this way with sufficient frequency, biofouling could be eliminated completely and only gentle brushing would be required during each cleaning. This reduces the possibility that anti-fouling paints are brushed free along with organic matter and released into the marine environment. Given the EU's focus on investing in port infrastructure to support decarbonization aims under the 'Fit for 55' legislative package, resources could be committed to making such robotic cleaning systems available in ports.

4.7 Conclusion

This research has analysed the extent to which the aims pursued by EU legislation on port State jurisdiction – the improvement of "maritime safety, security, [and] pollution prevention" – could be supported by the employment of autonomous inspection robots that are currently under development. Based on a close reading of the primary piece of EU legislation governing port State jurisdiction, Directive 2009/16 of the European Parliament and of the Council of 23 April 2009 on port State control, alongside the problems and policy options identified in the context of the Commission's significant ongoing work on the revision of this Directive, the research has argued that these technologies could support the completion of inspection tasks conducted under the current version of the Directive in significant ways.

One conclusion that has been drawn from this analysis is that it would be possible for national competent authorities to use autonomous inspection robots to conduct inspections based on port State jurisdiction within the legal framework provided by the PSC Directive as it stands. The analysis undertaken here also suggests that autonomous inspection technologies could prove even more useful to Member States implementing a revised version of the Directive focused on more proactive, substantive inspection procedures that incorporate both automated technologies and sustainability and environmental protection aims to a greater extent than is currently the case. From the perspective of EU law, an

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[65] Previously, anti-fouling paints frequently contained organotin compounds, active biocides intended to prevent organisms from attaching to the hull that had significant negative effects on the marine environment. In 2003, the EU legislated to prohibit ships bearing such anti-fouling paints from entering Member State ports, a unilateral regulatory act that is considered to have prompted enough States to ratify the International Convention on the Control of Harmful Anti-fouling Systems on Ships to ensure its coming into force in 2008: Regulation (EC) No 782/2003 of the European Parliament and of the Council of 14 April 2003 on the prohibition of organotin compounds on ships, OJ L 115. On this see: Lena Gipperth, 'The Legal Design of the International and European Union Ban on Tributyltin Antifouling Paint: Direct and Indirect Effects' (2009) 90 Journal of Environmental Management.

[66] C J Zabin et al., 'How Will Vessels Be Inspected to Meet Emerging Biofouling Regulations for the Prevention of Marine Invasions?' (2018) 9 Management of Biological Invasions 195.

[67] *Ibid.,* at p. 199.

appropriate way for the Commission to ensure Member States employ autonomous inspection robots would be through a new regulation implementing provisions of a revised PSC Directive that require physical inspection of ship structures, or through a revised version of Regulation No. 428/2010 implementing Article 14 of the PSC Directive.[68] The purpose of such a regulation, directly effective in national law, would be to specify what means Member States should use to implement a particular requirement of the Directive. In this case, those means would be autonomous inspection robots.

As suggested above, mandatory minimum biofouling standards offer a logical point of intersection between sustainability and biodiversity protection aims, and ship inspection practices, which might profitably be addressed by the Commission's revision of the PSC Directive. Mandatory minimum biofouling standards could also be laid down by means of a regulation, similar to the manner in which the EU prohibited the use of organotin compounds in anti-fouling paints used on ship hulls.[69]

The intersection between the construction and maintenance quality of ships, and sustainability and biodiversity aim, is significant. This will only become more so as regulators seek to pressure older fossil fuel burning ships out of the global fleet through more stringent enforcement of existing legal instruments, and potentially the introduction of new, higher standards. Increasingly automated enforcement procedures may play a significant role in this effort.

5. Regulatory Blueprint

5.1 Setting the Scene[70]

This part amalgamates specific strands and co-related blocks of influences (for semi-autonomous platforms) to form of a harmonised regulatory blueprint. In this process, researchers have taken into account the "elements for regulatory blueprint" highlighted in the international arrangements, national comparative analysis and European Regional Analysis parts. It bears mention that the work pertaining to the blueprint-framework satisfies the primary objective of BUGWRIGHT2 (as found in p. 4 of Annex I to the Grant Agreement: Description of the Action): "bridge the gap between the current and desired capabilities of ship inspection and service robots by developing and demonstrating an adaptable autonomous robotic solution for servicing ship outer hulls". Researchers assert that, as technological breakthrough continues, bridging all potential gaps will require strategic techno-regulatory governance founded on critical safety, security, quality, performance, and efficiency standards developed in a cooperative and common effort.

At the outset, researchers also note that the blueprint is, in essence, aligned with IMO's strategic directions: (SD 1) aiming at the effective, efficient and consistent implementation and enforcement of the provisions of the IMO instruments; (SD 2) aiming at integrating and advancing technologies in the regulatory framework; (SD 5), aiming at enhancing facilitation and security of international trade; and (SD 6), which aims at ensuring that a universally adopted, efficient, international regulatory framework is in place and

[68] Commission Regulation (EU) No 428/2010 of 20 May 2010 implementing Article 14 of Directive 2009/16/EC of the European Parliament and of the Council as regards expanded inspections of ships (n 7).
[69] Regulation (EC) No 782/2003 of the European Parliament and of the Council of 14 April 2003 on the prohibition of organotin compounds on ships (n 65).
[70] This part of the report has been used (subject to minor modifications) in the forthcoming publications: Johansson, T.; Skinner, J; Dalaklis, D.; Klenum, T. and Pastra, A. (2022 forthcoming) Harmonizing the Maritime Service Robotics Techno-regulatory Regime: Six Blocks of Influence for Good Environmental Stewardship in the *10th European Union Law Forum Book*, Intersentia, Cambridge, UK, ©Intersentia.

consistently implemented, embracing and integrating new and advancing technologies, without causing unnecessary burdens.

RIT, in this context, represent systems based on machine learning that offer time-efficient and perhaps cost-effective alternatives to existing manual-driven survey and maintenance operations. Remote inspection can be conducted with UAVs, ROVs and magnetic crawlers. UAVs perform global visual inspections (GVI), Ultrasonic Thickness Measurements (UTM), and close-up surveys for ships undergoing intermediate and renewal surveys. Magnetic crawlers can conduct UTM, scan plates when they are not accessible from a vessel's interior and perform hull cleaning. ROVs can perform underwater surveys without the need for divers. In the last years, several flag State administrations have approved RIT for vessel inspections on a case-by-case basis after receiving approval from recognized organization (RO). National flag state authorities, classification societies and ship owners are steadily adapting to RIT-based solutions, especially during the COVID-19 pandemic and the special challenges and limitations of human-presence on board ships. Moving forward, efforts to maintain good environmental stewardship, especially at the EU level, will not only require the seamless integration of RIT, but also a guarantee that all techno-regulatory elements vital to the semi-autonomous platform are streamlined into policy through international multi-stakeholder consultation.

5.2 Strands of Influence

5.2.1 First Strand: Compelling Evidence of RIT & Remote Survey Paradigm Shift

Shipping performance at the highest level of efficiency is the principle that drives the world fleet's operation. But constraints highlighted by researchers indicate "hull resistance" negatively impacts hull performance which hinders a ship's optimal performance (Deligiannis, 2017). Among many sub-factors affecting hull performance; hull fouling or biofouling most significantly contributes to increased global shipping emissions (Adland et al., 2018). In technical terms, hull fouling increases water resistance and in so doing also increases energy usage, a very significant concern for the shipping industry, while also impacting scheduling and maintenance costs (McClyay, 2015; Schultz, 2010; Wang and Lutsey, 2013). Preliminary findings from a Global Industry Alliance (GIA) report stressed the importance of "maintaining a smooth and clean hull free from biofouling" to avoid increase in Greenhouse Gas (GHG) emissions (Global Industry Alliance, 2021).

For vessel survey and inspection, including maintenance of bulk carriers, stakeholders are currently focused on two technology-related aspects: RIT and remote survey. The published documents and online articles are evidence of the noteworthy shift towards technology-based alternative solutions due to their manifold advantages.

Table 29: Twofold Needs Documented: Stakeholders Supporting RIT and Remote Survey

Year Published	Published by/Authored by	Title (RIT)
2017	Registro Italiano Navale	Surveys with Remote Inspection Techniques: A New Digital Efficient Tool without Burden of Time, Money and Resources
2018	Det Norske Veritas	Remote Technology Points to Cost Efficiency and Quality Gains

2019	Safety4Sea	Remote Inspection Techniques on the Rise
2019	Det Norske Veritas	Survey by Remote Inspection Techniques – Use of Approved Service Suppliers
2020	SEADRONE	Class Societies' Steady March to Remote Inspection Technologies and Techniques
2020	Astri Haukerud	Remote Inspection Methods Improve Efficiency, Safety
2020	Bureau Veritas	Technology and Necessity are Pushing Marine and Offshore Toward More Remote Possibilities
2020	Seatrade Maritime News	Maritime Industry Responds to Covid-19 with Faster Uptake of Remote Inspections
2020	The Royal Institution of Naval Architects	Remote Inspection at Large During the Pandemic Period
2020	Riviera	Coronavirus: class reveal remote inspection and e-learning platform
2021	Bureau Veritas	Proving the Value of Remote Inspection Techniques
2021	Bureau Veritas	Remote Inspection Techniques: Exposing Myths and Exploring Potential
2021	Seatrade Maritime News	Enhancing Remote Inspection Techniques
2021	International Shipping News	Bureau Veritas Proves Value of Inspection Technologies on Oceanbulk Ship
2021	Det Norske Veritas	DNV – Maritime: Response to the Coronavirus (COVID-19) Outbreak
2021	Homeland Security Today	COVID-19 Effects, Tech Vulnerabilities Challenge Marine Inspectors
2021	Maritime and Port Authority, Singapore	Remote Inspection on Singapore Registered Ships
2021	BIMCO	BIMCO Supports IMO Development of Global Remote Inspection Guidelines
2021	TIC Council	Remote Inspections: Meeting the Dynamic Demands of Conformity Assessment Activities
2022	Lloyd's Register	Are you making the most of remote inspection technologies? Reap the safety, efficiency and cost advantages of new remote inspection and surveying techniques.
2022	European Commission (CORDIS EU Research Results)	A Big Step Forward for Ship Remote Inspection Technologies
Year	**Published by/Authored by**	**Title (Remote Survey)**
2020	Bureau Veritas	Embracing Digitalisation During the COVID-19 Pandemic: Successful Trial of Remote Surveys in SEMBCORP Marine
2020	International Institute of Marine Surveying	The elephant in the room: What do remote surveys mean for the marine surveying profession?

2020	Det Norske Veritas	First Movers Benefit from Remote Surveys for CMC in COVID-19 Conditions
2020	Naida Hakirevic Prevljak	Shipping Industry sees Growth in Remote Surveys in times of Coronavirus Crisis
2020	Craig Jallal (Riviera)	Liberia Conducts First Remote Annual Safety Inspection due to Covid-19
2020	Safetyy4Sea	Remote Surveys on the Rise: Pros and cons
2021	Safety4Sea	PSC Inspections during COVID-19: Key Considerations and Developments
2021	Safety4Sea	Pandemic spurred advancement of remote surveys, says IACS
2021	Hellenic Shipping News	Seafarers Zoom in on Remote Surveys of Ships
2021	Splash (online)	Remote Surveys are the New Reality – but we will meet again
2022	Lloyd's Register	Remote. And Present – Remote Surveys from LR
2022	Bureau Veritas	Remote and Augmented Surveys

As noted in the document titled "Remote Technology Points to Cost Efficiency and Quality Gains" by DNV: AI-based alternatives are projected to save ship's operation time that make up a significant portion of running costs [DNV, 2018]. This is further confirmed by BV in an online article published in 2021 titled "Proving the Value of Remote Inspection Techniques" [BV, 2021]. Noteworthy are the "capex and opex" benefits that include: "Reduced travel/accommodation costs; Shorter response times; Potentially quicker inspection and survey activities; Greater scheduling flexibility; Instant access to deep technical expertise; and less operational downtime" [Haukerud, 2020]. In terms of the economy side of things --- a cost-benefit analysis for RIT-assisted survey was performed by the members of the EU project titled ROBotics technology for INspection of Ships (ROBINS) (ROBINS, D 9.2, 2021). RIT-in-focus included UAV for close-up Inspection, Magnetic Crawler for thickness measurement and ROV for close-up inspection/thickness measurement for hull inspection. The following costs were calculated in the analysis:

- Direct costs for the means of accessibility such as cherry pickers and temporary staging or portable ladders; and
- Indirect costs which include i) the improvements in the safety of the personnel in monetary terms (Probability of Fatal Accident, Probability of Non-Fatal accident, Compensation for Fatal Accident and Compensation for Non-Fatal accident) and ii) the opportunity cost which is the time the ship stays idle.

Table 30 serves as an example for calculating the total benefits for the ship-owners (in relation to large bulk vessels during a Special Survey I/ Intermediate Survey II and Special Survey II/ Intermediate Survey III). It is evident from the table that at later stages of a vessel's lifecycle, the benefits for the ship-owners are even greater.

Table 30: Financial benefits for the ship-owner per type of vessel per survey

	Handymax Bulk Carrier SS1/IS2	Handymax Bulk Carrier SS2/IS3	Panamax Bulk Carrier SS1/IS2	Panamax Bulk Carrier SS2/IS3	Capesize Bulk Carrier SS1/IS2	Capesize Bulk Carrier SS2/IS3
Cost Savings						
Means of Accessibility	€ 4.647	€10.346	€ 5.939	€ 14.835	€ 7.496	€ 27.254
Total Cost Savings	€ 4.647	€10.346	€ 5.939	€ 14.835	€ 7.496	€ 27.254
Cost Avoidance						
Opportunity Cost	€ 18.000	€ 90.000	€ 22.800	€ 114.000	€ 27.750	€ 194.250
Total Cost Avoidance	€ 18.000	€ 90.000	€ 22.800	€ 114.000	€ 27.750	€ 194.250
Other Benefits						
Safety of the Personnel	€ 67.19	€ 179.18	€ 89.59	€ 238.90	€ 111.99	€ 373.29
Total other Benefits	€ 67.19	€ 179.18	€ 89.59	€ 238.90	€ 111.99	€ 373.29
Total Benefits Per Vessel Per Survey	€ 22.714,19	€ 100.525,18	€ 28.828,59	€ 129.073,90	€ 35.357,99	€ 221.877,29

Source: ROBINS EU project, D 9.2, 2021, p. 34

Since 2020, COVID-19 provided an impetus to test RIT for conducting statutory and classification surveys remotely. However, the integration of RIT raises concern for the viability of common minimum standards developed by international organizations, especially from an environmental perspective. The initial findings unveiled at COP26 stressed the need to mitigate biofouling build-up which explicitly contributes to increased greenhouse gas emissions. Therefore, niche sources and technological tools for environmental excellence cannot be overlooked.

5.2.2 Second Strand: Template Definitions

IACS makes an effort with s. 1.1 of Recommendation 42 to list equipment types that currently serves as the minimum standard definition of RIT. Considering the evolving nature of innovation, those types will inevitably branch out into other expeditious complex systems, necessitating the development of unified definitions for each and every type of permissible techniques. Researchers further assert that the procedural rules and requirements ought to be founded on concrete product-definitions.

No two techniques are built following a standard pattern, although certain tangible components may be the same. It is also observed that different types of techniques manoeuvre in different environments.

Techniques also differ in terms of tasks and outcomes. However, for all types, the trait shared in common is incorporating innovation towards full-autonomy. Depending on how innovation progresses in relation to each individual acceptable techniques; technological and other differences will stay discernable despite the amalgamated placement of all types under the common term “Remote Inspection Techniques”.

Moving forward, notable template definitions already exist, and can be found in, for example, section 2 of ISO 8373:2012, section 3 of ISO 19649:2017, and sections 1.1, 1.3 and 1.5 of Guidance Notes developed by the American Bureau of Shipping (ABS):

2.2 Autonomy

Ability to perform intended tasks based on current state and sensing, without human intervention (ISO 8374:2012)

2.6 Robot

Actuated mechanism programmable in two or more axes (4.3) with a degree of autonomy (2.2), moving within its environment, to perform intended tasks (ISO 8374:2012)

~~**2.10 Service Robot**~~ Currently not applicable

~~Robot that performs useful tasks for humans or equipment excluding industrial automation applications (ISO 8374:2012)~~

~~**S. 3.1.1 Mobile Robot**~~ Currently not applicable

~~Robot able to travel under its own control (ISO 19649:2017)~~

2.17 Operator

Person designated to start, monitor and stop the intended operation of a robot or robot system (ISO 8374:2012)

2.30 Validation

Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use have been fulfilled (ISO 8374:2012)

2.31 Verification

Confirmation by examination and provision of objective evidence that the requirements have been fulfilled (ISO 8374:2012)

1.1 Unmanned Aerial Vehicles (UAVs)

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot onboard. The UAV can be remotely controlled or programmed to fly a predetermined route using information on a specific asset’s condition to target known areas of concern. It can collect visual data (such as still images, live-stream and recorded video) from difficult-to-reach structures and areas (ABS, 2019)

1.3 Remotely Operated Underwater Vehicles (ROVs)

An ROV is an unmanned unit designed for underwater observation, survey, inspection, construction, intervention or other tasks. Similar to UAVs, an ROV can be remotely controlled or programmed to travel a predetermined route using information on a specific asset’s condition to target known areas of concern. It can collect visual data, perform Non-destructive Testing (NDT), and measure plate thickness in difficult-to reach areas (ABS, 2019)

1.5 Robotic Crawlers

A Robotic Crawler, commonly referred to as a "crawler", is a tethered or wireless vehicle designed to "crawl" along a structure by means of wheels or tracks. Crawlers are often equipped with magnets which allow them to operate on a vertical surface or hull structures in air or underwater (ABS, 2019)

5.2.4 Third Strand: RIT v. Remote Survey

The former (RITs) comes with reference to acceptable technologies or techniques that could be used in situ when carrying out prescribed surveys in the presence of the surveyor, and the results of which require the acceptance of the "attending surveyor". In other words, s. 1.2 of IACS Recommendation 42 clearly stipulates those inspections using RIT should be done in the presence of a surveyor, which requires the attending surveyor to remain on board. Moreover, the verification/confirmatory part of RIT-based results pursuant to section 1.3 of IACS Recommendation 42 certainly requires surveyor to remain on site at selected locations. However, the above provisions are in sharp contrast with the definition of RIT found in IACS's proposed Amendments to the 2011 ESP Code views RIT as enabling surveys without the need for direct physical access of the surveyor.

In the absence of an IMO-established definition, IACS and flag States, in terms of the latter, have defined "remote survey" according to respective viewpoints. In the 2021 Information Paper issues by IACS, remote survey is viewed as "… the use of remote inspection techniques may be deployed to assist the surveyor in the survey process, and certain aspects of the survey process may be delegated to appropriately qualified ships' staff, for example under approved planned maintenance arrangements where a confirmatory survey by the surveyor will verify the maintenance records. A 'remote survey' is then a survey where the verification is undertaken, or partially undertaken, without attendance on board by the surveyor" (IACS Information Paper, 2021). In other words, "remote survey" denotes a survey conducted via remote technology off-site, and does not require the physical presence of the concerned surveyor.

Moving forward, researchers assert that the following points should be taken into account in future discussions:

- The inherent differences between RIT and "remote survey" must be preserved so as to refrain from using the two terms interchangeably;
- S. 1.2 of IACS Recommendation 42 should be revised so as to allow remote surveys using RIT to be conducted without the physical presence of the surveyor being mandatory. The word "attending" should be taken out, and the word "may" be replaced with "should" so as to provide sufficient flexibility. Given that remote surveys could be surveys conducted using RIT, it is advised that RIT-procedures concerning the engagement of surveyor be left open-ended.

Considering the above, an all-embracing definition of RIT, remote survey and remote audit, according to the researchers, could be as follows:

Remote Inspection Techniques (RIT) may include:

(i) The use of unmanned robot arm, remotely operated vehicles (ROVs), climbers, drones, or any other techniques acceptable to the Society (ref: IACS Recommendation 42, s. 1.1);

(ii) A robust system governing the deployment of the above techniques, which include a control station, connectivity equipment, a platform to display and replay visual data, and a platform to collect and display non-destructive evaluation (NDE) data (ref: ABS, 2019); and

(iii) Inspections performed using (a robust system governing the deployment of) techniques mentioned in (i) may be carried out in the presence of the Surveyor (ref: IACS Recommendation 42, s. 1.2).

Remote Survey

Remote Survey is an off-site survey conducted:

(i) Without surveyor's attendance on board ships for verifying conformity with both statutory and classification rules and requirements; and

(ii) For obtaining similar information obtained from survey on site through physical presence, by applying digitals systems and acceptable remote inspection techniques, in a safe, secure, effective and efficient manner.

Remote Audit/ Verification

"Remote Audit" means a process of systematic and independent verification without being physically present at the site of the audited party, and through the collection of objective evidence through available online tools, to determine whether the Safety Management System (SMS) complies with the requirements of the ISM Code and whether the SMS is implemented effectively to achieve the Code's objectives (modified with ref. to: s. 1.1.1 IACS, Procedural requirements for ISM Code Certification).). A similar process may be used for ISPS verifications for ships and ports (ISPS certification)

5.2.4.1 Third Strand Block 1 (RIT): Operational & Technical Considerations Based on Variety

As discussed earlier, individual RIT are marked by operational and technical differences. Therefore, this requires the introduction of operational and technical considerations that complement mandatory procedural requirements. Operational and technical considerations are beyond the purview of IACS, hence their exclusion from the scope of UR Z17. Such standards, however, are important for setting a baseline for determining operational limitations, to establish timelines for the initiation of "confirmatory surveys" (where surveyors proceed to examine abnormal damage and deterioration manually pursuant to s. 1.3 of IACS Recommendation 42). Fortunately, however, classification societies, such as ABS for example, have developed operational considerations for UAV, ROV and Robotic Crawlers (which are termed as Remote Inspection Vehicle (RIV) as opposed to the common minimum standard term RIT that is used widely at the EU level) (ABS, 2019). These could very well serve as model operational considerations for RIT:

Pre-operations: Items to-be discussed during the short briefing session, such as, reviewing weather forecast (AUV), confirmation of enclosed space free of sediments (for ROVs), reviewing RIV maintenance records, reviewing emergency escape/evacuation plan, reviewing identified risks and associated mitigation, verifying the responsibilities of all personnel, assessing field conditions and amending operation plans as deemed fit, and confirming the work-scope of intended RIT operation, and as a part of job safety analysis on the date of the field operations, but prior to the; commencement of the RIV operations, inter alia (ref: ABS, 2019);

In-operation: Items to be included, e.g., checklist clearance, RIT Launch and Recovery Zones, Communication, Documentation, Visual Line of Sight for UAVs, Deconfliction for UAVs, in the Standard operation Procedure by the Service Provider (ref: ABS, 2019); and

Post-operation considerations including logging and maintenance (ref: ABS, 2019)

Given an inherent vulnerability to risk, “risk assessment” is an important feature of operational standards. It is worth noting that surveys using aerial drones, unlike crawler and ROVs, can easily be compromised due to humidity, lighting, and air turbulence. Furthermore, hybrid RITs that have the potential to conduct biofouling cleaning, in addition to survey operations, require limiting all possible risks prior to deployment. The ABS promulgated Guidance Notes also include the following sound methodologically construed categories of risk-assessments, founded on operational standards, for the three preferred types of RITs:

> **Explosion risks in hazardous areas**
>
> **…**
>
> **Dropped object risks:**
>
> **…**
>
> **Collision risks (e.g., with other RITs)**
>
> **…**
>
> **Lost link risks (e.g., network compromise)**
>
> …
>
> **Other risks** consisting of high-risk working areas, risk associated with other parallel operations and emergency situations (ref: ABS, 2019)

China Classification Society (CCS) in its document titled Guidelines for Use of unmanned Aerial Vehicles, describes in detail the technical standards for UAVs (CCS, 2018). These standards focus on:

> **Safety performance**
>
> **…**
>
> **Operation performance**
>
> **…**
>
> **Enduring capacity**
>
> **…**
>
> **Data transmission and communication**
>
> **…**
>
> **Data storage (e.g., video and image resolutions and video and photo formats)**
>
> **…**
>
> **Requirements for airborne cameras**
>
> **…**

Technical standards, according to the authors, close the circle of procedural rules and requirements in so far as they ensure safety and reliability, and enable interoperability by providing a common language to evaluate performance. CCS promulgated *Guidelines for Use of unmanned Aerial Vehicles* could serve as a model for developing technical guidelines for crawlers and ROVs.

5.2.4.2 Third Strand Block 2 (RIT): Degree of Autonomy Redux

Vocabularies found in the document titled ISO 8373: 2012 (en) Robots and Robotic Devices – Vocabulary developed by the Technical Committee ISO/TC 184 sets a number of useful definitions relevant to both industrial and service robots. In defining the term "robots", ISO keeps the performance facet open-ended appreciating "the degree of autonomy", loosely translated as the level of a systems' reliance on human intervention in the execution of pre-determined tasks when operating within the programmed pathway. Important to note here is that while the definition of *operator* acknowledges the integration of human intervention to "start, monitor and stop the intended operation"; it does not proffer any further clarification on what the term "monitor" entails (ISO 8373: 2012)

RITs, have built-in image sensors that convert photons into electrical signals that are then viewed and analysed by operators engaged in commercial inspection activities. Therefore, according to s. 2.12 (professional service robot) when read together with s. 2.17 (operator) - monitoring intended operations could be viewed as pertaining to "inspection function" being undertaken, or "inspected," through the RIT's image sensors. In other words, the current system portrays a model built on semi-autonomy or supervised-autonomy. Bearing in mind the aims of realizing full-autonomy, the RIT systems today could undergo strategic re-categorization in a fashion similar to what has been accomplished in relation to Maritime Autonomous Surface Ships (MASS) (IMO Doc. MSC 100/20/Add, 2018). It is necessary to emphasize that such a categorisation from the get-go could help keep track of many graduations toward-autonomy and thereby assist classification societies with future revisions:

Table 31: Categorisation of RIT Based on MASS Degree of Autonomy (hypothetical comparison)

Degree/Level of Autonomy	MASS	RIT
First Degree	Ship with automated processes and decision support with seafarers on board to operate and control the systems. Systems are partially automated, unsupervised with seafarers on board ready to assume control.	RIT-survey conducted in the presence of the attending surveyor. This degree aligns explicitly with IACS Recommendation 42 and IACS UR Z17.
Second Degree	Remotely controlled ship with seafarers on board.	Remote class survey with the possibility of surveyor to intervene, if necessary.
Third Degree	Remotely controlled ships without seafarers on board.	Remote class survey without attending surveyor
Fourth Degree	Fully autonomous ship.	RIT with automated processes and Artificial Intelligence-based machine learning operating systems to support decision-making.

Source: IMO Doc. MSC 100/20/Add. 1, Annex 2

5.2.4.3 Third Strand Block 3 (RIT): Data Management & Security

Data acquisition is at the heart of all RIT-interventions. Stakeholders involved in this process include non-human actors, e.g., technological tools and infrastructure, and human actors, i.e., service providers, classification societies and ship owners (end-users). The latter is aptly known as "human-in-the-loop" with supervisors, operators and surveyors remaining engaged during data storage and verification of data collected through RIT-based visual inspection and close-up surveys. In essence, the RIT infrastructure communicates data to "human-in-the-loop" via five independent layers: hardware, network, internet, infrastructure and application.

Within the RIT multi-stakeholder landscape, "control of data" has received due attention in s. 5.2.6 of IACS UR Z17, which, unfortunately, dwells only on service suppliers' duty to confirm computer software's ability to acquire, record, report, store, measure and monitor data. Corroborated by interview respondents, the *status quo* inadequacy does not create any privacy contentions for EU Member States since non-personal data, such as ones that are acquired by RIT, fall outside the scope of EU's Regulation 2016/679 on the General Data Protection Regulation (GDRP) (GDPR, 2016). That being said, RIT acquired data is attached to the vessel-history as it informs surveyors (conducting periodical surveys) about maintenance tasks previously completed. As such, asset-related information in shipping has been traditionally met with utmost confidentiality to protect ship owners from unforeseen threats caused from breaches in cyber security.

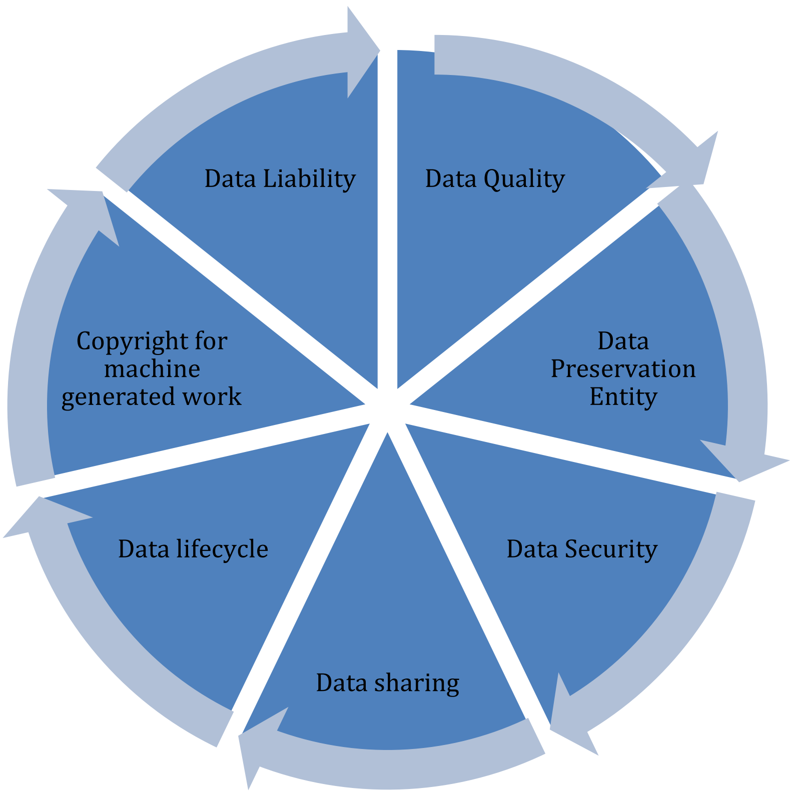
Data governance and management are topics of great concern, especially in relation to the topic of trustworthiness of RIT, as a number of individual entities, namely, ship owners, service providers, and classification societies are involved in the inspection process. Admittedly, data protection remains significant as the vessel's information is processed with it. Remote inspection data should be reviewed in real-time or submitted to the attending surveyor as agreed in the survey planning stage. Data terms should be included in the form of a contract signed by the relevant parties (owner/operator, class, and service supplier) about data quality, data ownership and copyright, data collection, preservation entity, storage, security measures of data preservation entity, data post-processing and report (Figure 18). The roles and responsibilities for data ownership, quality, storage, security and sharing of information remains uncatered and requires an in-depth review of all private contracts developed by service suppliers; thus, reliable mechanisms by service suppliers that ensure the long-term usability of data and metadata are of utmost importance. Parties in the remote inspection planning, operation, and reporting stages should ideally utilize a trusted data platform to safeguard the data generated by the remote system and its sharing. Data security and the effectiveness of data collection, data processing, and distribution of analysis outputs need to be demonstrated if RAS platforms are to achieve the desired level of trustworthiness among the stakeholders of the business model. The key questions that should be addressed in a contract between the service supplier, classification society and ship owner are:

- Who should retain the copyright ownership of data gathered from RIT?
- What are the main characteristics of data quality?
- How should data be shared between the key stakeholders?
- What provisions on data control and data security should be considered?
- What responsibilities do each party have to the other regarding data control and data security?
- What is the duration of preservation of data and image from close-up and in-water surveys?

- Should there be any safeguard mechanisms for service providers against third-party liability?

Individual efforts to govern non-personal data management and data security are noted in various guidelines articulated by individual classification society members. For example, data calibration and analytics has received attention in the RIT-specific document titled Remote Inspection Technique Systems (RITS) Assessment Standard for use on LR Class Surveys of Steel Structure issued by LR. Issued by the same society, data capture and treatment considerations have also been prioritized in *Guidance Notes for Inspection using Unmanned Aircraft Systems*. In this document, key provisions on data encapsulated in s. 8 entitled "Inspection Data" covers important recommendations on "data security principles, standards and methods" against "manipulation or unwanted distribution". DNV has also advanced rules and requirements that are found in the document titled *Approval of Service Supplier Scheme* illustrates concrete effort to regulate RIT-data storage. Section 16.1.4 of Appendix A obliges service suppliers to store data in an orderly fashion whereby the files should be made available upon request for a duration of five years. This provision is quite unique as common minimum standards do not address questions, such as: who should be responsible for data and image preservation, and how long does individual survey data and image need to be preserved?

Figure 19: Data elements to be included in the Contract between service suppliers, classification societies and asset owners/operators



Source: Authors

A striking feature of the *Guidance Notes on the Use of Remote Inspection Technologies* developed by the ABS, are criteria for RIV post-operation data review and processing tasks. Also in this document, RIT data governance criteria is infused in sections 4.9 and 4.11 as well as all essential elements integral to the data decision domain. A strong emphasis on "data security policies and procedures" can be found in section 4.11.1.1(h). On the Asian front, CCS has provided similar emphasis on data acquisition, data processing, and data security in in section 3 of their Guidelines for Use of Unmanned Aerial Vehicles for Surveys. Collectively, all of the provisions briefly discussed above provides a settled discourse on non-personal data integrity for a semi-autonomous system.

Table 32: Data Management Provisions for Inclusion in the Formal Agreement between Service Supplier & Client

Data governance stages for RITs and ROVs	Provisions for inclusion in the Formal Agreement
Collection of Data	- In the formal agreement, provisions should be included to indicate the copyright ownership of data and the terms under which the data may be produced, reproduced, distributed, edited, copied and used by its customer; - Digital data collected (picture and video quality) by the service supplier is to be reviewed in real-time and/or submitted to the attending Surveyor as agreed in the survey planning stage; - Visual data collected should be continuous and uninterrupted, with stable quality. If there are any gaps in the data, the Surveyor and owner/operator should be notified; - Data cannot be used for marketing reasons by the service supplier, without prior approval from the asset owner.
Storage	- The Service Provider should have data security policies to ensure that data and metadata is stored in a secure way that has minimum vulnerability to unauthorised manipulation and distribution; and - Each party in the agreement should have data storage and infrastructure policies for effective organisational data management.
Processing	The raw data and related metadata should be stored separately from any post processed data.
Using	Data protocols governing data use and third user access should be put in place by each party.
Sharing	- Utilization of a secure industry platform to ensure secure data transfer between data owners and users, when saving and sharing the video stream from the remote survey; - If the Remote Inspection Service Provider provides the data management system for remote access to data, then adequate security of the remotely accessed data is to be ensured (data encryption to protect digital data confidentiality may be applied); - Third-party sharing provisions should be included in the agreement; and The use of Universal Serial Bus (USB) for data sharing is not recommended.
Destroying	Specify when data is authorized for deletion.

5.2.4.3 Third Strand Block 4 (RIT): Safety & Liability

'The computer programmer is a creator of universes for which he alone is the lawgiver. No playwright, no stage director, no emperor, however powerful, has ever exercised such absolute authority.' (Weizenbaum (1976), p. 115.)

Legal scholars dealing with RAS issues have concluded that there are no philosophical or legal grounds to refer to technology as a "subject" or a "being" from an ontological context (Bertolini, 2015). From a producer standpoint, both industrial robots or service robots are manufactured through an action or a process and refined for sale. Focusing on the keyword "manufacture", it is posited that all RAS, whether autonomous vessels, autonomous vehicles or RIT, are merely "products" that are offshoots of a cascade of applied science-related innovations. The functional approach is to apply a legal framework to govern the usage of products (Alexandropoulou, 2021). This is perhaps because service robots need to possess a high degree of autonomy because their modus operandi takes place in an "unconstrained, human-centered environment".

Safety and liability are interrelated concepts. As noted by the European Commission, higher levels of safety symbolize minimal risk of harm while ensuring adequate compensation for damages (European Commission, 2020). Existing and emerging applications of complex varieties of RIT (as discussed earlier) will demand a concrete safety-net that could protect end-users from third party liability. Consequently, authors do not consider it feasible to include a new RIT liability provision within common minimum standards, rather submit the proposition that a reference, in brief, be made to the national liability regime within the scope of the MS requested international guidelines. Off-site remote surveys bear risks of damage to physical assets. Risks ranging from dropped object, collision or lost link, and defective products, *inter alia*, call the need to solve RIT-induced liability issues through existing regional or national policies so as to remove a major barrier that could potentially inhibit the market growth of RIT.

The above nexus would prove to be advantageous for EU MS given that the proposition would allow liability incurred from the usage of RIT to be governed by EU Product Liability Directive 85/374/EEC (EU Product Liability Directive, 1985). RIT used in remote surveys are operated using (battery-produced) "electricity" --- that is viewed as a product pursuant to Article 2 of Directive 85/374/EEC. The producer or manufacturer can resort to the defense mechanism found in Article 7: "[…] having regard to the circumstances, it is probable that the defect which caused the damage did not exist at the time when the product was put into circulation by him or that this defect came into being afterwards; or […] that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered […]" (EU Product Liability Directive, 1985). Alternatively, in the case of strict product liability, the manufacturing company will most likely acquire insurance, and manage to exploit the economies of scale by distributing costs along the value chain. The liability circle for RIT will be closed.

Based on the discussions and all the issues identified in the preceding sections, researchers forward the following elements for consideration:

RIT Standards: It is important to consider the notion/feasibility of establishing an EU RIT Agency or any open system that could contribute to developing RIT standards by taking into account EU wants and needs --- until a state-of-the-art regulatory code is developed at the international level. Developing effective and detailed regulatory standards could serve as a stepping stone in developing the much-needed liability regime for RITs;

Stakeholder Consultation: The EU RIT stakeholders in consultation with IMO and IACS should carve out pertinent items that could be placed within an overarching tailor-made RIT regulatory Code of Conduct framework. While critical aspects, e.g., definitions including a refinement of IMO's definition of close-up survey as found in Harmonized System of Survey and Certification (HSSC), data governance and data protection, trust and ethics, should receive the much-needed consideration; filling out the current void in relation to liability is in order;

Opting for a Clear Pathway: Develop a methodology that could guide the projection of the direction "liability" could take from RIT deployment, and simultaneously ensure that Tort law and Product Liability Regulations do not overlap as a result of human-RIT interactions. The methodology should be robust enough to provide guidance not only in the semi-autonomy/ "human-in-the-loop" phase, but also once RIT autonomy reaches its peak;

Determining Types of RIT Liability & Developing a Safety Net: As part of future research activities, exploring in detail all categories of liability with respect to actions by ship owners, producers/manufacturers and any other entities involved should follow swiftly. This would also entail highlighting aspects that could exempt the entity involved in RIT operations from liability. Whether or not an RIT/smart insurance system should be initiated --- is a matter to be determined jointly by producer/manufacturer, service suppliers and insurance companies. The notion that that an RIT/smart insurance system safety-net could serve as an important incentive which would allow innovation to grow without being stalled by incidental issues is also expressed here.

5.2.4.4 Fourth Strand Block 5 (RIT): Environment[71]

At the international level, the primary forces driving outer hull inspection cleaning and maintenance are twofold: (1) to inspect the biofouling status of a ship; and (2) to address elevated risks that could result in safety and environmental concerns. These twofold motivations reside at the crux of IMO's work reflected in the 2011 Guidelines (2011 Guidelines).

The 2011 Guidelines is designed to facilitate the implementation of the IMO's BWM Convention and AFS Convention in conjunction with SEEMP. Recognizing the significance of evidence-based studies which concluded that all ships contribute to some degree to biofouling after immersion in water, the 2011 Guidelines prescribes "in-water" inspection, cleaning and maintenance procedures as additional measures for anti-fouling installation and maintenance.

Specific provisions of in-water inspection, cleaning and maintenance can be found in s. 7 of the 2011 Guidelines. As the first step, the 2011 Guidelines prescribes inspection of niche areas (of the ship) that have high probability of prolific build-up of the hard-shell fouling allowing operators to optimize target zones for cleaning and maintenance. In this context, the 2011 Guidelines suggest a twofold option for conducting inspections; use of human divers; or Remotely Operated Vehicles (ROVs). Considering the absence of a pre-set definition of ROV within the framework of the 2011 Guidelines; it is reasonable to assert that ROVs deployed in hull inspections belong to "inspection-class ROVs" that is consistent with the ISO definition of "professional service robots" which are monitored by an operator. These types of robots are essentially real time "acoustic eyes" with a smaller footprint when compared to "intervention-class ROVs" that are not typically equipped with tooling equipment.

Post inspection, Member States (MSs) are advised to perform risk assessments prior to cleaning and maintenance to minimize environmental threats associated with cleaning actions, e.g., biological, toxic effects from employed substances. While the 2011 Guidelines did not anticipate the use of ROVs for those tasks, if there had been such a provision, the high operational costs associated with deploying "intervention-class ROVs" would likely be debated. All in all, the 2011 Guidelines emphasizes the need to exercise due diligence to provide a continuous cycle of cleaning and maintenance to ensure clean and safe future operations.

Recently, the Baltic and International Maritime Council (BIMCO) took the lead in the development of standards for in-water cleaning. The document titled *Industry standard on in-water cleaning with capture* (version 1.0) was the result of a three-year effort to set strategic guidance for ship owners (BIMCO, 2021). The objective, as stated in the document states that the standards so developed could ensure "that the in-water cleaning of a ship's hull, and niche areas including the propeller, can be carried out safely, efficiently and in an environmentally sustainable way" (BIMCO, 2021, p. 2). ROV-specific cleaning standards are well documented in the section titled "operating requirements of the cleaning system with capture" that

[71] This section has been used verbatim in the forthcoming publication: Johansson, T. (2021 in press) Advances in Robotics and Autonomous Systems for Hull Inspection and Maintenance (2022) in "Emerging Technology and the Law of the Sea" (James Kraska and Young-Kil Park, (eds.)), Cambridge University Press, © Cambridge University Press.

provides the following important measures, which could be taken into account in international discussions on the development of RIT and remote survey guidance:

<u>9 Operating Requirements of the Cleaning System:</u>

1. When choosing the cleaning equipment, careful consideration should be given to the information received from the AFS manufacturers and/or ship to ensure the performance of the AFS is not impaired.

2. The cleaning unit must be able to safely reach the section of underwater area that has to be cleaned and be able to remove visible biofouling.

3. Procedures must be in place to avoid accidental releases into the water and the cleaning system shall capture the dislodged material. If a cleaning unit accidentally releases material into the sea, it shall be assessed to find the root cause. In case of consecutive malfunctions or when a malfunction results in the release of captured materials to the marine environment, the cleaning equipment shall be taken out of service and tested. Any accidental release should be recorded in the cleaning activity log with the contingency measures taken and the relevant authorities should be alerted of the incident.

4. Pictures and/or videos shall be used to document the effectiveness of the cleaning. The photographs and videos should conform to the specification mentioned in Annex 3 of this *industry standard*.

Annex 3 Standards of Photographs and Videos

Photographs and/or videos taken by a diver or ROV should follow certain specifications to conform with this standard. The purpose of the photographs/videos is to support the diver/ROV inspection and to document the biofouling and AFS condition.

Photograph of reference areas:

1. The photograph should depict the general condition of the area and should, if visibility permits, cover the entire reference area. In the event of restricted visibility, the reference area can be photographed using a mosaic of photographs.

2. The diver/camera operator should carefully choose the camera settings to ensure proper lighting, exposure, focus, colour, tone etc. for capturing an accurate image.

3. The angle of the picture should be chosen carefully to ensure a true reflection of the marine growth and/or damages to AFS system, if any. The correct angle, without use of IT programs to compensate, is perpendicular to the surface.

The reference area number should be identifiable on the photograph. This may be done either during

filming or later during the editing process.

NACE International has published a standard, SP21421 – 2017, for underwater evaluation of biofouling degree on ships hulls, which is designed to facilitate descriptions of degree of biofouling. This standard uses pictures with examples of high quality and gives standards for scale etc.

Video specification:

1. Speed: The diver or the cleaning supervisor should determine the speed keeping the following factors in mind:

a. size of the field-of-view in video b. sunlight and associated glare

c. area of the ship being videoed d. video equipment's capability.

2. In any case, the swimming speed over the hull should not exceed 30 cm/s (0.6 knots) to prevent blurring of the image in individual frames.

3. The reference areas should be captured within the video. If the video camera is unable to cover an entire reference area in one run, a system should be in place to enable sampling of recordings to show the entire reference area ((BIMCO, 2021, Annex 3)

9.3 Post Cleaning Inspection

… Systems, which use ROVs as cleaning equipment, may not have to conduct a separate post cleaning inspection but instead use strategically mounted cameras on the ROV that photograph the cleaned hull. Thus, the inspection is completed at the same time as the cleaning. However, it is essential that the photos and videos can clearly depict the exact condition of the hull: existence of any biofouling if there is any and the condition of the anti-fouling coating. Images must live up to the specifications required by the industry standard for in-water cleaning with capture. If the ROV's photographs are not to specification, a diver or other equipment will have to be employed for the task.

The cleaning report and post cleaning inspection report may be combined into one report, providing all the necessary details have been sufficiently captured. This report will provide the ship with proof of compliance with various local regulations (BIMCO, 2021, p. 56)

9.4 Post Cleaning Safety and Environmental Requirements

After the following procedures have been completed, a post cleaning meeting must be held:

1. After completing all in-water cleaning activities, the equipment should be removed from the water and brought back to their original positions.

2. All underwater gratings shall be safely restored to their original state.

3. All remaining material in the in-water cleaning system including the hoses, separation and treatment units shall be contained and disposed of in a safe manner. The cleaning company shall ensure the material does not find its way into the local marine environment.

4. When confirmation has been received that all cleaning equipment and personnel have been removed from the water, the ship can be made operational by releasing locked out or tagged out systems (BIMCO, 2021, p. 24).

9.5 Service Report after Cleaning

This service report contains basic information about the cleaning that was carried out. The cleaning company shall hand over the service report to the master or another representative of the ship at the post cleaning meeting and before the ship's departure (BIMCO, 2021, p. 24).

9.6 Cleaning Report

… The cleaning report shall contain information based on documentation from reference areas or other areas if available about the biofouling observed prior to cleaning, details of the cleaning performed plus the state of the AFC before and after cleaning.

Further, it shall provide detailed information about the location of the cleaned areas to enable another in-water cleaning company to continue the cleaning if necessary.

Cleaning reports shall be retained for a period of two years on board the ship and thereafter with the shipping company until at least five years have elapsed since the date of the cleaning.

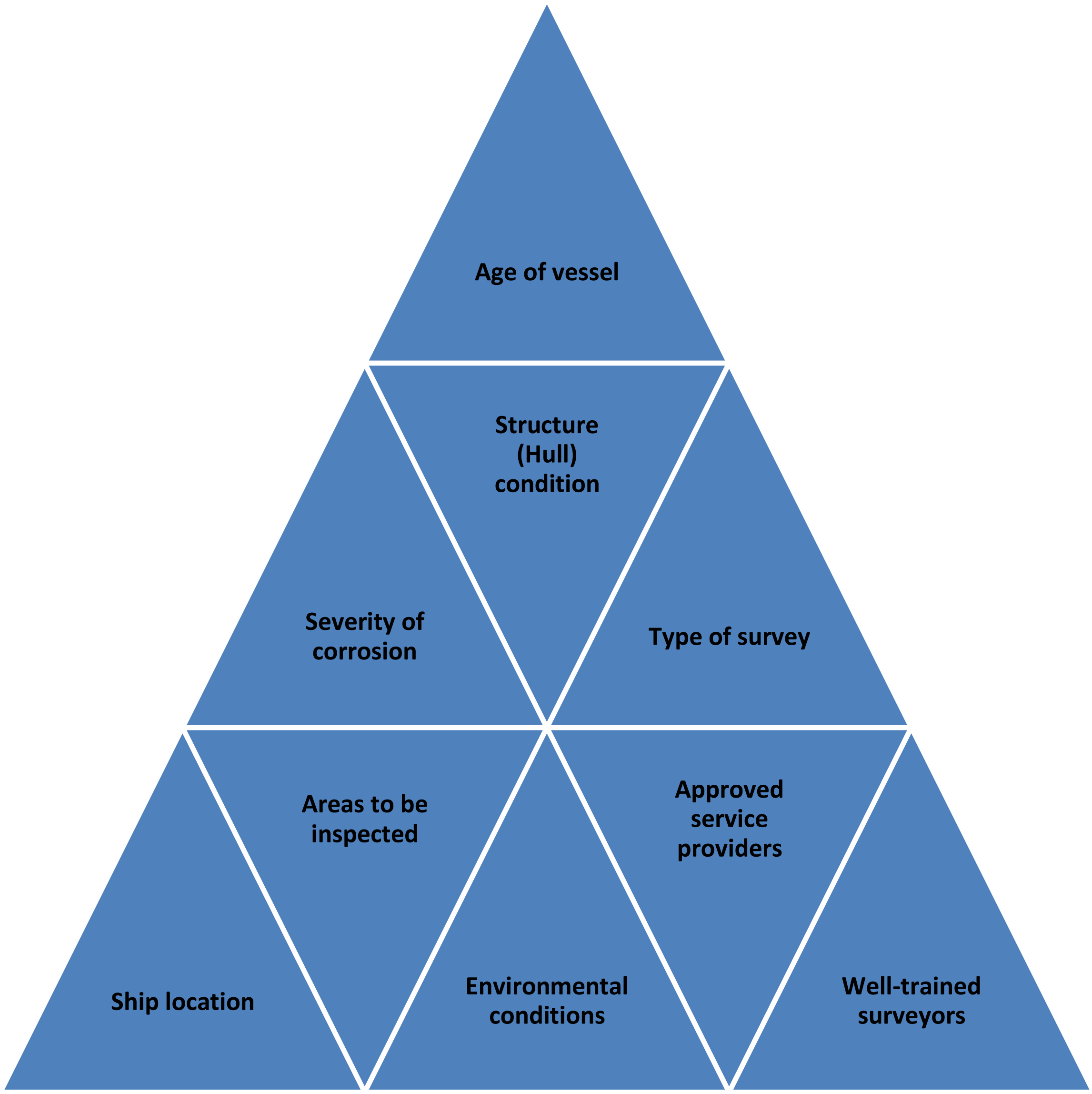
5.2.4.2 Fifth Strand Block 6 (Remote Survey): "Proof of Concept" using Regulatory Sandbox

Remote surveys should be considered with the objective of achieving at least equivalent results from in situ survey, with "safety" being the primary consideration, especially during *force majeure*. Adequate testing should be carried out in controlled environments that will allow for the strategic development of the desired methodologies for remote survey operations, both on the external and the internal areas of a vessel, as required. Researchers deem this as an important step for determining a "proof of concept" of the functionalities of remote survey. Researchers also note that flag States and Classification societies could engage in extensive testing using the "regulatory sandbox" methodology to establish "proof of concept" for remotely conducted inspections (with the possibility of surveyor to intervene and without the possibility of surveyor to intervene) to ensure that these techniques/technologies provide safer and even higher-quality evidence in the survey process whilst offering optimum benefits to ship-owners and operators. The findings could, consequently, inform internationally initiated scoping exercise on the subject matter.

5.2.4.3 Fifth Strand Block 7 (Remote Survey): Risk Assessment Framework for Determining the Feasibility of Remote Survey

A strategic risk assessment process (See figure 20) could assist in determining whether a physical inspection is necessary. A common risk assessment framework for eligibility for remote survey should be developed based on the age of the vessel, hull condition, severity of corrosion on hull structure, type of survey, areas to be inspected, ship location, environmental conditions in the area, approved service supplier and well-trained surveyors on remote technologies. Remote survey should ideally be dealt with on a case-by-case basis. For instance, specific criteria should determine whether a bottom survey carried out whilst the ship is afloat is a realistic alternative to a bottom survey in dry-dock. If a remote survey is to be conducted, this will be stated in the Survey Planning Document, where each party should acknowledge the risks associated with the conduct of such inspection.

Figure 20: Considerations when assessing feasibility of remote survey



Source: Authors

5.2.4.3 Fifth Strand Block 8 (Remote Survey): Common Minimum Standards for Remote Survey & Audit

Markedly, there is no international guidance that covers the conduct of remote surveys/inspections, remote audits and verifications. The above statement is explicit in the following submissions that have received the attention of the Maritime Safety Committee (MSC):

- Submission from Republic of Korea: MSC 104/15/3 - Proposal for developing guidance on the remote surveys;
- Submission from Austria et al.: MSC 104/15/6 - proposing a new output on regulating remote surveys and audits;
- Submission from Austria et al. – MSC 104/15/12 - proposing the development of guidelines for remote inspections and verifications in the field of maritime security; and
- Submission from China: MSC 104/15/24 proposing to undertake a scoping exercise of the framework and developing technical requirements for remote surveys, together with document

MSC 104/INF.2 (China) providing information on the application of new technology in remote surveys of ships.

Researchers being cognizant of ongoing preparations in relation to forthcoming discussions on the new output titled “Development of guidance on assessments and applications of remote surveys, ISM Code audits and ISPS Code verifications” (as scheduled in the biennial agenda of the III Subcommittee for 2022-2023 and the provisional agenda for III 8), table the following items for consideration:

Preliminary Considerations:

1. Remote surveys may be applied to satisfy both statutory and classification requirements during normal situations and *force majeure*. In normal situations, remote surveys could accompany the option of intervention from surveyor;

2. Consider amending the Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), 2021, where appropriate, with reference to IACS rules and requirements (ref: IACS Recommendation 42) to streamline the usage of remote inspection techniques. This would serve the purpose of establishing a strong foundation for moving forward with the conduct of remote surveys since remote inspection techniques remain at the crux of all surveys conducted off site;

3. Consider developing matrix to indicate time-trajectory under the HSSC prescribed surveys, and confirm how much time is being saved, if any;

4. Consider harmonizing existing flag State-initiated practices given that all IMO rules and requirements concerning survey/inspection are aimed at flag States that can then delegate responsibilities to classification societies. Fragmentation in methodologies for remote survey must be avoided;

5. Indicate, at the outset of all procedures, the need to assess feasibility of remote survey adopting a case-by-case approach. This would primarily depend on:

- The type of vessel;
- Age of vessel;
- Records and reports from previous surveys;
- Areas to be surveyed/inspected (depending on vessel location);
- Types of RIT to be deployed;
- Types of RIT previously deployed (if deployed previously) and if confirmatory (manual) surveys were conducted;
- Risk-assessments;
- Proper verification of safety and security management system and quality management system of company engaged in survey/inspection; and

6. Consider the development of training and certification requirements for personnel involved in the conduct of remote surveys and audits. It should be stressed that the current IACS rules and requirements

for RIT take into account the role of attending surveyor, which is different from remote surveys given that physical presence of the surveyor is not obligatory.

Robustness of Systems

Remote systems for survey should operate safely, reliably and consistently whereby the manufactures and artificial intelligent developers have the responsibility to ensure the technical robustness of these products and foresee the potential risks associated with the design phase. This is connected to the safety element of crew members on board. For robust systems, two conditions are relevant: a) technical robustness; and b) data quality.

Technical Robustness Challenges with UAVs, ROVs and Magnetic Crawlers

For technical robustness, the integrity of the system is of paramount importance since the remote application should be reliable and work properly every time it is needed. Reproducibility of the results is also crucial, and the system should produce consistent results if the operation is repeated. Besides, the system's usability is a factor that should be considered since it must prove itself that is easier and cheaper than a traditional mode of survey.

There are various challenges with drones flying in confined spaces such as: a) problems related to the obstacles detection, b) electromagnetic field disturbances between RAS platforms and onboard electronic systems, c) stability challenges affected by the air turbulence caused by its own propellers in narrow spaces where the airflow tends to circle back towards the drone and d) beyond visual line of sight of the operator flights (Poggi, et al, 2020). Localization for drones is another important concern since surveyors need to be aware of the robot's location in relation to its surroundings during the inspection process. Localization can be achieved either through onboard sensors that enable operators to observe its environment and its motion or with a receiver that provides an estimate of its location based on a Global Positioning System (GPS). For drones flying in a confined space and storage tanks, a GPS signal may not be available; therefore, their trustworthiness can be enhanced with GPS-denied drone technology which includes: a) advanced visual sensors that enable the stabilization of a drone and obstacle avoidance sensors that can provide a drone with reference points, or b) a SLAM system (Simultaneous Localization and Mapping) that comprises of multiple sensors that algorithms can map its surroundings in real-time.

For ROVs, there are three main obstacles:

1. Understanding what you have inspected (vs. not inspected);

2. Visualising the data in a meaningful way; and

3. Sending the data to stakeholders in a meaningful way.

The first obstacle is related to the location of the inspection. GPS positioning systems do not work underwater as they can travel only a couple of inches through the water. One potential solution is the utilization of technology such as the Underwater Positioning System (USBL), which provides a position of the ROV using acoustic positioning. USBL consists of a transceiver mounted on the vessel and a transponder mounted on the ROV, which jointly cooperates to communicate the ROV's position in relation to the vessel. However, there are cases that USBL on its own does not work well because the vessel is an obstacle for acoustics to communicate from the dunking transducer to the ROV's transponder. USBL is also inherently inaccurate by 20 cm, making autonomous motions difficult and unreliable using just USBL. Companies should explore methods for getting positioning and allowing for autopilot functionality.

The second obstacle is the visualization of the data in a meaningful way. Like a diver's eyes, video has a limited field of view to give positional context to the images the surveyor is seeing. A 3D rendering or model allows the surveyor to analyse the aggregate of the data points collected during an inspection. Currently, underwater 3D models are too time-consuming, require expert-level expertise, and their technology remains prohibitively expensive. The three main technologies that can be used to create 3D models and overcome obstacles are: sonar, laser and photogrammetry.

The third obstacle is related to the proper interpretation of the data. With the divers, the surveyors usually rely on their expertise to confirm the vessel's condition. In contrast, an ROV allows video streaming or video recording where stakeholders can monitor the inspection process. However, there are many hours of footage to comb through to get the answers needed for the surveyor. The operator of the ROV should still be certified and experienced in hull inspections to identify issues. If the surveyor can monitor the inspection process next to the pilot, the quality of the report could be increased. A hull survey report engine must enter the inspected data and then produce a PDF report with photos of points of interest and easy access to key milestones during the video with text added for additional detail.

An important challenge with magnetic crawlers is that they encounter difficulties to overcome obstacles such as rust or achieve stable climbing capabilities on surfaces with deposits like salt, oil and dust. Therefore, reliable climbing abilities are required to enhance the capabilities of magnetic crawlers.

Data Robustness for Remote Audits

Data quality, including video and images, is one of the most crucial factors for remote audits. The quality of data is affected by various parameters, including lighting conditions, distance to the object and vehicle motion. Recorded data should be of high quality and uninterrupted; otherwise, the surveyor and owner/operator should be notified. Industry standards for video and image resolution should be followed. For HD video resolution and image resolution the minimum acceptable standards for a meaningful assessment of the hull structure are 1080p (1920×1080 progressively displayed pixels) and 3840×2160 pixels accordingly. High-definition cameras, artificial lighting and high precision sensors on UAVs and ROVs are paramount for detecting defects in the vessel's structure. Advanced image and data processing can be achieved with data localization, defect recognition and 3D models reconstruction. 3D scene reconstruction of particular damages, via the use of high resolution visual, thermal, LIDAR and SONAR images, facilitates the identification of crack or damage localization and thicknesses in the hull structure.

Clear Allocation of Roles & responsibilities:

Devise clearly allocated roles and responsibilities of relevant parties (Figure 20). An example is provided in the following:

Pre-inspection:

- Approved service providers should possess all applicable certificates of authorization from recognized national/local authorities and have internal Quality Management System, Safety Management System, Safety Risk Management, Safety Assurance and competent personnel.
- The service provider should maintain high-quality standards for the selection and maintenance of the equipment.
- Competent and trained personnel should be employed to perform remote surveys/inspections.
- The owner should provide all documents and drawings related to the work scope to the selected provider, approve the remote inspection plan, and set the Survey Planning. The provider at this stage should develop the inspection plan that includes the different types of RIT to be used coupled with the results of risk assessment.
- The classification society shall review the Survey Planning Document to verify that the survey plan satisfies the applicable rules (ref: preliminary considerations (2)).

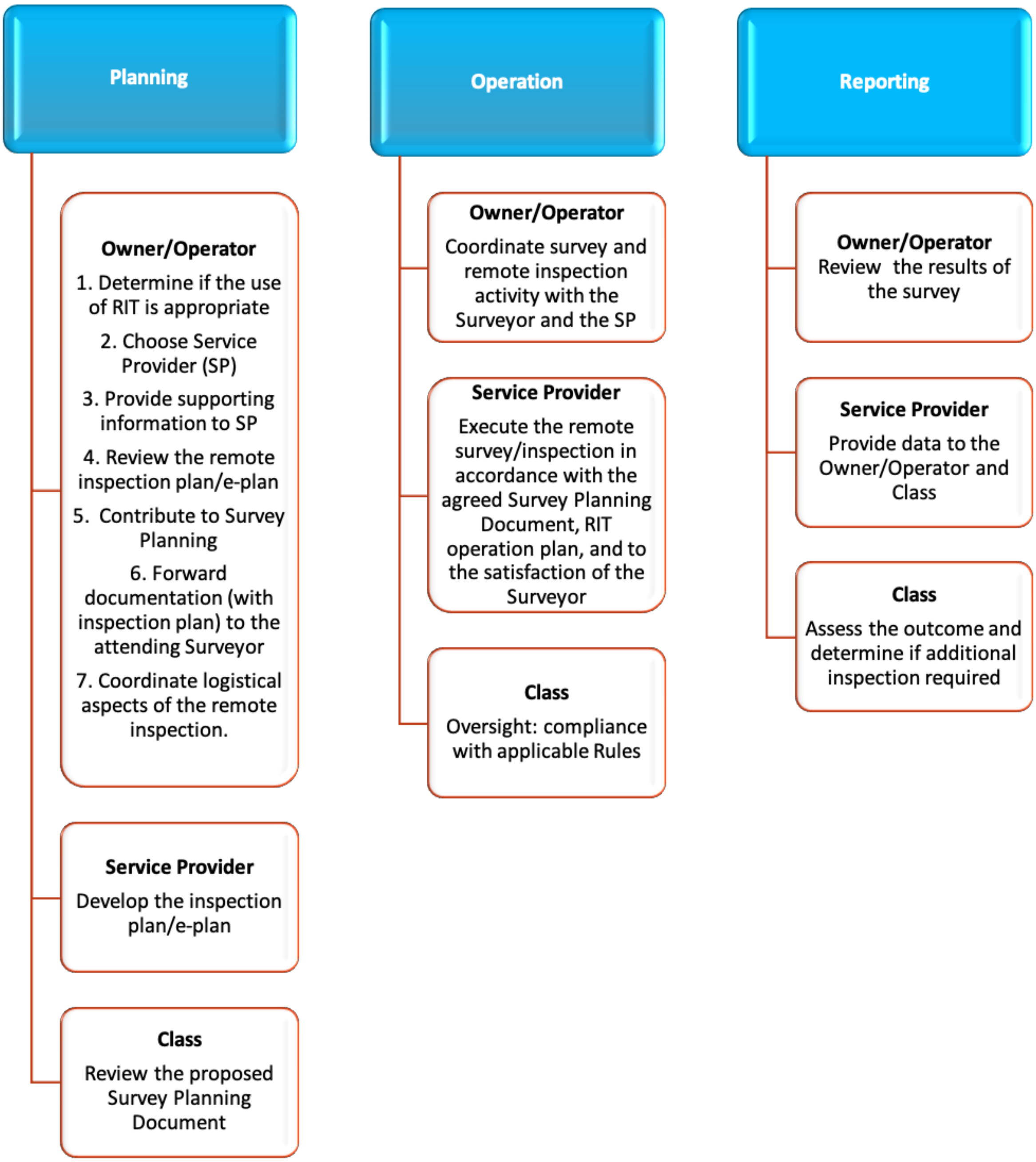
During-inspection:

- During the operation, which is the second stage of the inspection process, the owner shall coordinate with the surveyor and the service provider.
- The service provider shall conduct the inspection according to the Survey Planning Document, RIT operation plan, and statutory/class requirements.
- The attending class surveyor ensures that the RIT operation-team conducts the survey according to the relevant requirements.

Post-inspection:

- During the reporting phase, the service provider shall send the report and data to the asset owner and class.
- The class surveyor will assess if an additional inspection is required.

Figure 21: Roles & Responsibilities at Different Stages of Remote Survey



Scope of Remote Statutory Audit/Verification/Inspection:

Determine the scope of remote audits that could serve as an alternative to in situ audits, and whether they could extend beyond the remit of the following (confirmed audits/verifications/inspections that could be conducted remotely):

- Renewal and annual Document of Compliance (DOC) audits at the company's office;
- Renewal and intermediate Safety Management Certificate (SMC) audits on board the ship;
- Renewal and intermediate International Ship Security Certificate (ISSC) verifications on board the ship;
- Renewal and intermediate Maritime Labor Certificate (MLC) inspections on board the ship;

- Verifications of interim SMC, DOC, ISSC and MLC audits; and
- Additional audits.

In the conduct of remote surveys, adherence to the requirements found in paragraph 4.12 of IMO Res.A.1118(30) entitled “Guidelines on the implementation of the International Safety Management (ISM) Code by Administrations” is advised.

Protecting the Remote Audit Regime Against Cyber-threats

The audio, visual and data-sharing of confidential information by remote means requires adequate protection against cybersecurity threats. In the process of developing common procedures, it is important to consider this element with reference to the following five concurrent functional elements that bolster support to effective cyber risk management:

Identify: Define personnel roles and responsibilities for cyber risk management and identify the systems, assets, data and capabilities that, when disrupted, pose risks to ship operations.

Protect: Implement risk control processes and measures, and contingency planning to protect against a cyber-event and ensure continuity of shipping operations.

Detect: Develop and implement activities necessary to detect a cyber-event in a timely manner.

Respond: Develop and implement activities and plans to provide resilience and to restore systems necessary for shipping operations or services impaired due to a cyber-event.

Recover: Identify measures to back-up and restore cyber systems necessary for shipping operations impacted by a cyber-event (IMO, 2017)

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