CHAPTER 20

Towards an International Guideline for RIT End-Users: Spearing Through Vessel Inspection and Hull Cleaning Techno-Regulatory Elements

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1 Introduction: Setting the Scene

Over the last few years, discussions have taken place at various international fora in regards to RIT in performing inspections of steel structures on ships and floating offshore. Primarily, RIT represents systems based on machine learning that offer time-efficient and conceivably cost-effective

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alternatives to existing manual-driven survey and maintenance operations (Johansson, 2022). What is certain is that manual inspections could be replaced through the usage of UAVs, ROVs, magnetic crawlers, and any other technological apparatus approved by classification societies.

From a specific-functionality standpoint, UAVs are capable of performing general visual inspection (GVI), ultrasonic thickness measurement (UTM), and close-up surveys on ships requiring statutory and or classification surveys. On steel plates, magnetic crawlers could conduct UTM for scanning plates should there be restrictions to access a vessel's

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interior. Crawlers are also designed to perform hull cleaning. Finally, ROVs are tethered, maneuverable underwater robots that could perform tasks below water without the need for divers.

Noticeably, RIT have been approved by several flag State administrations on a case-by-case basis. National flag State authorities, classification societies, and ship owners are slowly but steadily adapting to RIT-based alternatives, especially during the COVID-19 pandemic that engendered special challenges and limitations of human-presence on board ships.

Currently, RIT mass deployment, should it continue to remain an international objective, calls for a holistic governance framework that could optimally dissipate fragmented methods and dissimilar procedural matters. In other words, the smooth integration of RIT alternatives for the conduct of dull, dirty, and risky tasks requires for the development and implementation of uniform international standards (Johansson, 2022). Targeting uniformity, generally speaking, means developing standards, policies, and guidelines that could stimulate innovation and safeguard people from risks emanating from automated technologies (Smuha, 2021). Given that the RIT governance framework is at nascent stages of development, the authors (of this chapter) assert that a blueprint covering all essential elements could help overcome regulatory barriers that may hinder RIT deployment resulting in a substantial and well-founded impact on the field.

Evidence-based research also indicates that efforts to maintain good environmental stewardship, principally at the EU level, will not only require seamless technical integration of RIT but also a guarantee that all techno-regulatory elements vital to semi-autonomous platforms are built into an international stand-alone *guideline for end-users* through international multi-stakeholder consultation. Ideally, all efforts should be aligned with the EU "Next Generation Digital Commission" of 2022, which aims at optimizing processes and automating workflows through the usage of digital technologies, products, and services with the view to increase productivity and digital sovereignty.

Against the foregoing, this chapter presents critical findings derived from project BUGWRIGHT2 which aspires to change the EU landscape of robotics for vessel structure-inspection and maintenance. The research-findings provide important insights into key elements that constitute a harmonized regulatory blueprint that could serve as a foundation for the anticipated international stand-alone *guideline for end-users*—bridging all potential gaps through cooperation-based strategic techno-regulatory governance founded on critical safety, security, quality, performance, and efficiency standards with regards to maritime semi-autonomous platforms.

2 Main Elements of a Regulatory Blueprint

At the outset, it is important to note that the threads of individual elements discussed below are tied to International Maritime Organization's (IMO) Strategic Directions (SDs):

- (SD 1) aiming at the 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 3) intending to respond to climate change by reducing greenhouse emissions;
- (SD6) addressing human-element-related issues including consideration of new technologies and human-centered design; and
- (SD7) ensuring regulatory effectiveness in the development of advancing technologies (IMO, 2022, Resolution A.1149 (32)).

All elements have been carefully extracted based on the exposition of legal texts, international instruments, relevant scholarly literature, academic and professional journals containing legal opinions and expert commentaries, industry standards, procedures, requirements, and the likes. Expository research, i.e., an essential component of the doctrinal methodology, serves as the primary methodology employed in the research leading to this chapter. It is used to analyze the extant law (*de lege lata*) pointing out its drawbacks and deficiencies that has been 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.

2.1 Element 1: Compelling Evidence Redux

Effective and efficient environmental performance is the main principle that drives the world fleet's operation (Johansson, 2022). Observing increased fuel consumption and higher emissions emanating from the accumulation of harmful micro-organisms, the adverse effects of biofouling on ship performance and energy efficiency have been well documented (Adland et al., 2018; Coraddu et al., 2019; Deligiannis, 2017; McClay, 2015; Moser et al., 2016). The United Nations (UN) Climate Change Conference of the Parties (COP26) in Glasgow (2021) also stressed the need to mitigate biofouling build-up, which explicitly contributes to increased greenhouse gas emissions, together with technical and operational measures to reduce them. Therefore, niche sources and technological tools for environmental excellence and hull cleaning cannot be overlooked. It should be noted that IMO conventions are subject to continuous amendments. The introduction of risk assessment techniques, such as formal risk assessment or goal-based standards, paves the way for a new regime that might even embark on a decision to carry out surveys depending on risk profiles (Núñez, 2016). Secondary sources confirm that novel data detection methods, machine learning modeling techniques, and new technologies to diagnose hull and propeller fouling enable better asset management—giving the owners the means to predict hull condition and suggest the best time for hull maintenance work (Coraddu et al., 2019).

For vessel survey and inspection, including maintenance, stakeholders are currently focused on two technology-related aspects: RIT and remote survey. Inspection using RIT, for example, by default, requires physical verification through interaction with associated components. It goes without saying that the majority of vessel's class and statutory surveys require the physical attendance of class representatives. Remote verification, on the other hand, is an option that is exercised when physical attendance is not feasible or the extent of survey is deemed limited.

Published documents and online articles are a confirmation of the noteworthy shift towards technology-based alternatives due to their manifold advantages. For instance, it is noted in the document titled "Remote Technology Points to Cost Efficiency and Quality Gains" by Det Norske Veritas (DNV), AI-based alternatives are projected to save ship's operation time that makes up a significant portion of running costs (DNV, 2018). This is further validated by Bureau Veritas (BV) in an online article published in 2021 titled "Proving the Value of Remote Inspection Techniques" (BV, 2021). Patently, the outbreak of COVID-19 pandemic provided an impetus to test RIT. Nonetheless, the integration of RIT raises concern for the viability of common minimum standards developed by international organizations, especially when it comes to guaranteeing the same standard of safety and environmental protection, which is also related to liability.

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 economical aspect—a cost–benefit analysis for an RIT-assisted survey was conducted 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 include (a) 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 (b) the opportunity cost which is the time the ship stays idle (ROBINS, 2021).

According to the analysis developed solely for the market of large Bulk Carriers, a staggering €190 million could be saved by shifting to RIT-based alternatives (ROBINS, 2021). In sharp contrast, remote verification, dubbed as "remote survey", is contingent on information and communication technology (ICT) and has no direct correlation with costs.

Further research reveals that "remote survey" is, for the moment, associated with consideration of the following factors:

1. Instant accessibility and examination of the initial condition and assessment if physical attendance is required (or not);
2. Data record tracking and condition comparison with past maintenance records;
3. Sharing of data with multiple recipients and affected entities in real time;

4. Development of archives that maintain the data and can be used for research purposes (by shipyards, classification societies' technical teams, etc.), and
5. "Flag state acceptance" in case of statutory Surveys and that before any classification society can take a decision.

It is recalled that in shipping, the term "inspection" entails a plethora of dimensions. Some inspections are conducted for simple operational reasons, i.e., to improve the efficiency, while others bear a more commercial connotation, especially when it comes to chartering, insuring, or purchasing a ship.

Another important aspect concerns the understanding of "ship classification". In general terms, it is considered as being the development and worldwide implementation of a set of standard published rules and regulations that set and maintain quality and reliability. It is compliance with specific *class rules* that determine the class notation assigned to a ship and recorded in the register book. With that in mind, *classification* is a partnership between the flag state, class society, owner, and operator that collectively ensure the correct application of rules to endorse the:

- Structural strength of all essential parts of the hull and its appendages;
- Safety and reliability of the propulsion and steering systems; and
- Effectiveness of all features and auxiliary systems that have been built into the ship in order to establish and maintain basic conditions onboard, so that personnel and cargoes can be safely carried at all times.

To this end, class ensures that surveyors maintain the above through periodical visits to the ship with a view to carrying out corresponding periodical surveys to determine compliance with mandatory rules and regulations.

Relevantly, Enhanced Survey Programme (ESP) requires a close-up survey of defined structures in addition to an overall survey (see Fig. 1 below). It also requires an enhanced number of scantling thickness measurements. In order for these to be conducted properly, prior planning is in order so that tanks and holds are sufficiently clean with well-ventilated and suitable access arrangements provided. Considering the risk of entrance in confined spaces and the time required for those

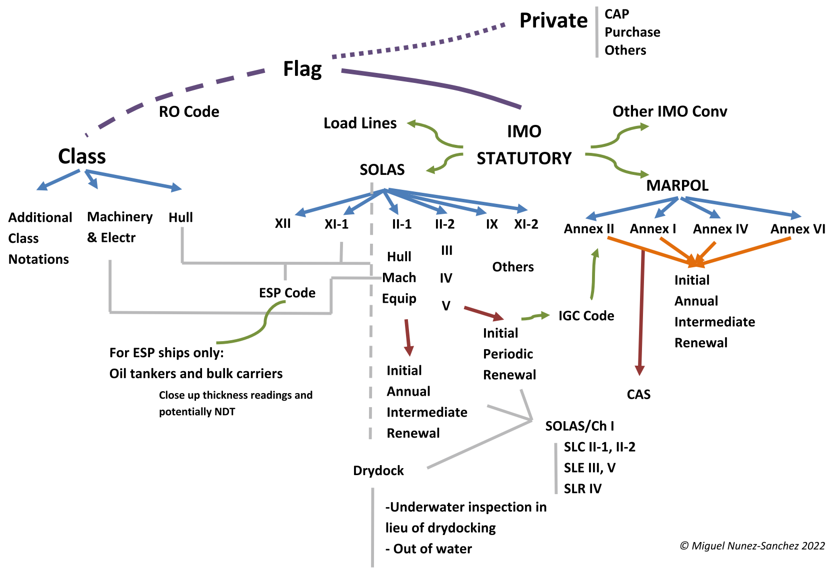

Fig. 1 Diagram synthesizing IMO's Statutory Survey Regime (*Source* Authors) *Note* **Remote Inspection Techniques** for underwater inspection, thickness readings, close-up and non-destructive testing with a need for planning, approval of service providers, validation, and certification; **Remote Surveys** with extreme due care or non-acceptance for structures with coating with a poor condition; and **Remote Survey Techniques** for all statutory and class inspections; and Remote Audit Techniques for verification audits

spaces to be effectively ventilated, as well as the associated costs, alternative methods of remote inspections are taken into account. Taking advantage of the digital tools and processes that are the byproducts of the fourth industrial revolution, DNV and other classification societies have incorporated drone surveys into class services. It should be underlined that drones used for these inspections are intrinsically safe for gas hazardous areas, and operated by trained surveyors. Drones are equipped with high-definition cameras and are able to provide high-resolution video and images even in the absence of light.

The biggest advantage of remote inspection using drones is the opportunity to carry inspection in real-time. The results are reviewed and recorded by the surveyors and vessel's representatives in a safe environment. Obviously, if the inspection reveals issues of concern, then there is a provision that enables surveyors to revert back to traditional physical inspection.

The statutory survey, if carried out by a class surveyor, is being conducted on behalf of the Flag Administration for the country with which the ship is registered. The class survey is carried out on behalf of the classification society itself.

The requirements of the statutory survey are governed by the flag administration and not classification society promulgated rules and requirements. As with statutory surveys, all associated services such as approval of intact and damage stability and approval of safety equipment arrangements offered by the classification society are conducted on behalf of the flag administration.

In most cases, the statutory instruments used for the survey of ships are based on the internationally adopted codes and conventions covering subjects such as safety construction, safety equipment, safety of navigation, pollution prevention, load line, and safety management. It is worth noting that even countries that have adopted international convention codes may, in addition, develop and implement respective national requirements that are commonly known as "flag requirements" (Fig. 1).

The practice of taking thickness readings in conjunction with close-up and hull inspection is delegated to companies authorized either by the Flag administration or the classification society in compliance with the International Association of Classification Societies' (IACS) unified requirement (UR) Z17. The surveyor progresses rapidly during the inspection and with results of the thickness readings reviewed only after a few hours—most likely on a daily basis. With regards to the underwater survey, the divers are normally on the spot and there is visual and audio communication with the surveyor that is on board, or in case of broadcasting in front of his computer, to certify the inspection of the underwater body in case the ship has not been drydocked.

2.2 Element 2: Uniform Definitions

The minimum standard definition of RIT has been specified in s. 1.1 of IACS Recommendation 42. Taking into consideration the evolving nature of innovation, the current types of RIT endorsed by IACS will inevitably branch out into other expeditious complex systems, making the development of unified definitions necessary for each and every type of technique that maneuver in different environments (Johansson, 2022). Table 1 (below) provides a summary of the definitions that currently exist and ones that could set the pragmatic basis for umbrella/uniform definitions for all future varieties.

Table 1 Summary of existing definitions relevant to RIT

Autonomy	*Ability to perform intended tasks based on current state and sensing, without human intervention (ISO 8373:2021)*
Robot	Programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning (ISO 8373:2021)
Operator	Person designated to start, monitor and stop the intended operation (ISO 8373:2021)
Validation	Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use have been fulfilled (ISO 8373:2021)
Verification	Confirmation by examination and provision of objective evidence that the requirements have been fulfilled (ISO 8373:2021)
Unmanned Aerial Vehicle (UAV)	An aircraft with no pilot on board that is controlled remotely or can fly autonomously based on a predefined flight route and/or using dynamic automation systems. The industry may refer to Unmanned Aerial Vehicles as "drones", Remotely Operated Aerial Vehicles (ROAVs), or Unmanned Aircraft Systems (UASs) (ABS, 2022)
Remotely Operated Underwater Vehicles (ROVs)	An ROV is an unmanned unit designed for underwater observation, survey, inspection, construction, intervention, or other tasks. Like UAVs, an ROV can be remotely controlled or programmed to travel a predetermined route using the 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. (ABS, 2022)
Robotic crawler	A robotic crawler, commonly referred to as a "crawler", is a tethered or wireless vehicle designed to "crawl" along a structure using wheels or tracks. Crawlers are often equipped with magnets to operate on a vertical or inclined surface or hull structures in air or underwater (ABS, 2022)

Source ISO 8373:2021; ABS, 2022

2.3 Element 3: Remote Survey vs RIT

The main IMO Conventions such as International Convention for the Safety of Life at Sea, 1974, International Convention for the Prevention of Pollution from Ships (1973/1978) (MARPOL) and the International Convention on Load Lines, 1966 (CLL) do not deal with "remote survey" because, by default, surveyors should be physically present on board to carry out inspections. While this does not hinder resorting to "remote survey", however, there are legal aspects for consideration due to the fact the ship is certified by flag administration.

The role of recognized organization (RO) surveyors acting on behalf of flag administrations was befittingly reflected in the Protocol of 1988 relating to the International Convention for the Safety of Life at Sea, 1974, the Recognized Organization (RO). It is also stressed that the administration bears all responsibilities even when the work is delegated to a RO. Therefore, the concept of remote surveys could be extended to statutory surveys but it should, nevertheless, remain grounded within the IMO Conventions. Firstly, the use of low-level voluntary instruments, such as circulars with interim guidance might be extended to voluntary resolutions, and, at the latter stage, into mandatory ones once the system is in place and safeguards safety and environmental protection level remain the same. The above serves as important information in the context of "remote survey".

To ensure that all classification societies have uniform guidance on the concept of remote surveys, IACS developed UR Z29 titled "Remote Classification Surveys" (that will enter into force on 1 January 2023), which conceptualizes remote survey as a "process of verifying that a ship and its equipment are in compliance with the rules of the Classification Society where the verification is undertaken, or partially undertaken, without attendance on board by a surveyor" (IACS UR Z29, 2022). In short, and as briefly mentioned before, a "remote survey" denotes the survey conducted via the use of ICT, such as email and zoom, without the requirement of the physical presence of the surveyor. In the process, a remote survey should provide the same level of assurance as a survey with physical attendance on-board of a surveyor.

It is also important to bear in mind that certain audit activities, known as verifications, are carried out by the flag administrations or the RO acting on their behalf. These are mainly connected to safety aspects in relation to the ship and the company (document of compliance) under

SOLAS IX and the International Safety Management Code, and *security* aspects under SOLAS XI-2 and the International Ship and Port Facility Security Code, 2004 (ISPS Code). Since there exist several standards for remote audits—they could be also carried out for ships and companies, provided that risk assessments permit them. According to the authors, the same approach towards their introduction in SOLAS and MARPOL should prevail.

When the focus is on RIT, one could turn to s 1.1 of IACS Recommendation 42 that provides: "Remote inspection techniques may include the use of: Divers; Unmanned robot arm; Remote Operated Vehicles (ROV); Climbers; Drones; Other means acceptable to the Society". Section 1.2 further stipulates that external and internal examinations require the presence of a surveyor. In short, RIT could be identified as technologies that allow external and internal examinations through close-up surveys and thickness measurements (where applicable) without the need for direct physical access of the surveyor. Authors observe that currently, both RIT and "remote survey" are used interchangeably, although the former refers to robotic platforms, and the latter being survey via ICT, and as such does not entail mobile robotic platforms. Moving forward, researchers assert that the following points should be taken into account in all future discussions:

- The inherent differences between RIT and "remote survey" must be preserved so as to refrain from using the two terms synonymously. A way forward could be to develop separate all-embracing definitions on RIT, remote survey and remote audit (see Table 2 below);
- S. 1.2 of IACS Recommendation 42 should be revised and/or complemented with other IACS instruments so as to allow remote surveys using RIT to be conducted without the physical presence of the surveyor being mandatory, for classification purposes. The word "attending" should be omitted, 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; and
- Remote surveys and audits for IMO statutory certification, either total or partial also need to be agreed upon at the level of the IMO after careful consideration following a step approach (Table 2).

Table 2 Conceptualization of RIT, remote survey and remote audit

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) The use of: Divers, Unmanned robot arm, Remote Operated Vehicles (ROV), climbers, drones, other ther means accepted. (ref: ABS, 2022); 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	A "Remote Survey" is a process of verifying that a ship and its equipment are in compliance with the rules of the Classification Society where the verification is undertaken, or partially undertaken, without attendance on board by a surveyor (ref: IACS UR Z29, s. 1.2.1)
Remote audit	"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)

Source Adapted from ABS, 2022; IACS recommendation 42; IACS UR Z29 and IACS, Procedural requirements for ISM Code certification

2.4 Element 4: Operational and Technical Considerations Based on Variety

The operational and technical differences that stem from the different types of RIT should be considered when developing standards for these technologies. The objective here is twofold: (i) to set a framework for determining operational limitations; and (ii) as a minimum to get the same level of results that a physical inspection would provide. It is important to note that the American Bureau of Shipping (ABS) has identified different operational challenges for UAV, ROV, and robotic crawlers, which might serve as a model framework should discussions, at any time, lead towards the development of an international stand-alone *guideline for end-users*:

- **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 workscope 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, 2022);
- **In-operation**: Items to be included by the service Supplier in the Standard Operation Procedure (SOP) for each RIV, 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, 2022); and
- **Post-operation** considerations including logging and maintenance (including launch time, operation duration, recovery time, and the type of work completed) (ref: ABS, 2022).

What is noteworthy is that there are various hazards associated with UAVs, magnetic crawlers, and ROVs that should be considered while expanding operational standards. ABS (2022) has categorized the risk areas as follows: explosion risks in hazardous areas, dropped object risks, Collision risks, Lost link risks, other risks consisting of high-risk working areas, risk associated with other parallel operations, and emergency situations. China Classification Society (CCS) has also specified technical standards for UAVs that touch upon safety performance, operation performance, enduring capacity, data transmission and communication, and data storage (CCS, 2018). The Risk Assessment Report, according to CCS, should be compliant with the ship's hazardous area plan and agreed upon by the shipowner/operator class society and service supplier prior to the commencement of inspection. A noteworthy technical issue (related to operation performance) that needs to be addressed is one that concerns "connectivity". RIT-based remote surveys require high-speed internet connection, which to date, remains a challenge on board vessels, especially in certain trading areas.

2.5 Element 5: Degree of Autonomy

The degree of autonomy is relevant to systems under progressive autonomy. The current technical system governing RIT, as of 2022, is not fully autonomous and requires intervention from the human element. The current stage of RIT is subject to "supervised autonomy" or "semi-autonomy" given that an operator is involved in operating the technology in question remotely. In order to keep track of progress (towards full autonomy) and in order to harmonize standards based on categories and types of RIT (followed by future amendments, if required)—the "degree of autonomy" or the "level of autonomy" for the current system should be conceptualized.

It is noted that RIT could be fully autonomous in the not-so-distant-future, and be able to function without human involvement. The "degree of autonomy" is a stress on carving out the level of the autonomous systems in a fashion similar to what has been done for maritime autonomous surface ships (MASS) (IMO Doc. MSC 100/20/Add. 1, Annex 2). Such categorization (Table 3 below) or assigning RIT to a certain "degree" could help keep track of the advancements towards full autonomy, thereby, assisting classification societies with future potential revisions (Johansson, 2022).

2.6 Element 6: Data Governance and Cyber Security

High-definition cameras, artificial lighting, high-precision sensors, and 3D scene reconstruction models are paramount to data quality. High-quality data plays an important role in detecting vessel's structural defects (Pastra et al., 2022). In digital data such as photos, live-stream, and recorded video, data are the predominant outcomes of conducting inspection using RIT. In this process, "metadata" could also be generated which includes time/date stamps, GPS location, camera orientation, focal length, shutter speed, aperture setting, ISO level, camera type, and lens type (ABS, 2022, 9).

Based on the different types of data generated, authors assert that a data governance framework could be developed to establish provisions and processes that could offer adequate and appropriate protection to data-assets as they are relayed between and among the different stakeholders (Al-Badi et al., 2018; Sarsfield, 2009).

Table 3 Categorization 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 Authors (with reference to IMO Doc. MSC 100/20/Add. 1, Annex 2)

Data governance has been conceptualized by the Data Management Association (DAMA) as "the allocation of authority and control and shared decision making over the management of data assets" (Earley et al., 2017). By way of explanation, data governance is related to decisions in regards to the allocation of responsibilities, access, control, and use of data, as opposed to data management, which is primarily linked to data collection and protection, as well as the implementation of governance-related decisions (Johansson et al., 2021).

Johansson et al. (2021) underscore that data quality, data ownership, preservation entity, security measures, sharing, data lifecycle, copyright, and data liability are the terms that should be included in the contract-form that is executed by ship owners, classification societies and service suppliers (Fig. 2 below). The roles and responsibilities concerning data ownership, quality, storage, security, and sharing of information currently remain uncatered for and requires an in-depth review of all private contracts developed by service suppliers. What is currently absent is a

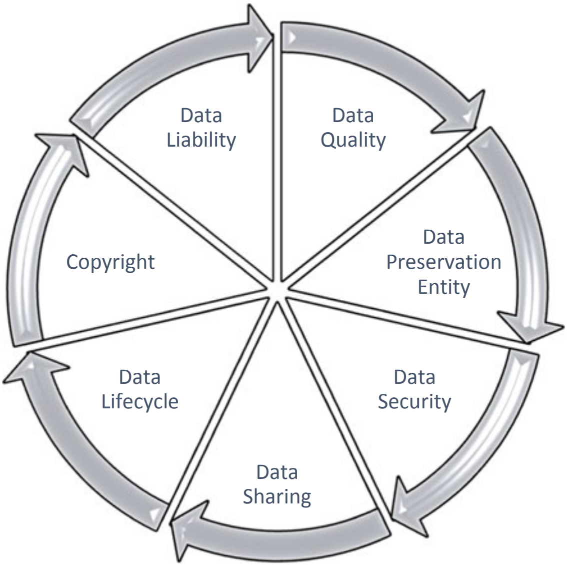

Fig. 2 Data elements to be included in the Contract between service suppliers, classification societies, and asset owners/operators (*Source* Johansson et al., 2021)

reliable instrument that ensures the long-term usability of data and metadata and protection from being misused by third parties (Johansson et al., 2021). Furthermore, the key parties in RIT inspection planning, operation, and reporting stages are advised to utilize a trusted data platform to safeguard the data generated through the systems. Data security and the effectiveness of data collection, data processing, and distribution of analysis outputs need to be demonstrated through further tastings and checks in order for RIT platforms to achieve trustworthiness among the stakeholders of the business model (Johansson et al., 2021; Pastra et al., 2022).

Additionally, data-sharing of confidential audio and visual information by remote means requires sufficient protection against cybersecurity threats. To avoid unforeseen challenges pertaining to non-personal asset-data, it is important to consider the above 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; and
- **Recover:** Identify measures to backup and restore cyber systems necessary for shipping operations impacted by a cyber event (IMO, 2017).

The same would also apply for the protection of the integrity of the data when surveys and audits are carried out via remote means with audio and video end-products. For instance, when SOLAS XI-2/ISPS security verifications are executed, there are documents, such as the ship or port security plan, which are confidential in nature. If those are discussed via video conference, the integrity of the ship or the port facility being audited or inspected may be compromised in the absence of stringent measures against cybersecurity threats. It should also be mentioned that IMO Resolution MSC.428(98) requires actions to ensure that safety management systems take into account cyber risk management in accordance with the objectives and functional requirements of the International Safety Management (ISM) Code, no later than the first annual verification of the company's "document of compliance" after 1 January 2021.

2.7 Element 7: Liability and Safety

There is also a crucial narrower focus: policymakers ought to shape the regulatory conditions having the best interest of end-users in mind so as to ensure accountability for software and product development. Product safety and product liability are two complementary mechanisms that ensure high levels of safety and minimal risk of harm to users. Robotics and Autonomous Systems (RAS), such as autonomous vessels, autonomous vehicles, or RIT, are merely "products". Defective products, incur liability, and ergo, the functional approach could be to apply a legal framework to govern the usage of products (Alexandropoulou et al., 2021).

Risks ranging from dropped objects, collision or lost link, and defective products, inter alia, make it more urgent to solve RIT-induced liability issues through existing regional or national policies, for example, the EU Product Liability Directive 85/374/EEC (EU Product Liability Directive, 1985; Johansson, 2022). RIT is operated using (battery-produced) "electricity"—that is viewed as a product pursuant to Article 2 of Directive 85/374/EEC (Johansson, 2022). Although this needs to be further substantiated, the preliminary connection is clear. According to Article 1 of the Directive, the producer shall be liable for damage caused by a defect in his product. Article 7 of the Directive gives resorts to the defense mechanism of manufacturers, stating that the producer shall not be liable as a result of this Directive if he is able to prove:

a) that he did not put the product into circulation; or
b) that, 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 afterward; or
c) that the product was neither manufactured by him for sale or any form of distribution for economic purpose nor manufactured or distributed by him in the course of his business; or
d) that the defect is due to compliance of the product with mandatory regulations issued by the public authorities; or
e) 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; or
f) in the case of a manufacturer of a component, that the defect is attributable to the design of the product in which the component has been fitted or to the instructions given by the manufacturer of the product (Directive 85/374/EEC).

The original equipment manufacturers (OEMs) of RIT could follow internationally agreed and accepted requirements for safe commercial operations, such as standards developed by the International Organization for Standardization (ISO). Whether a manufacturer is liable will depend on the circumstances and whether relevant international or industry product specification standards have been violated. During the design phase, manufacturers of RIT should exercise due diligence to ensure that connectivity will, under no circumstances, compromise safety (of the product) or data accuracy. In tandem, manufacturers should ensure transparency, accountability, and responsibility for all intelligent information systems that are developed. Certified products following international standards should be provided by manufacturers and subsequently, deployed by end-users. From an RIT perspective, service providers/suppliers should ensure prescribed equipment safety standards for hardware and software. All systems should be rated against the intended operational environment (intrinsically safe in hazardous areas, operational wind speed, etc.).

At this juncture, it is important to note that any progress in terms of "degree of autonomy" inevitably raises the question of who is responsible if RIT should violate a contractual obligation; therefore, clarity on responsibility in connection with the use of remote systems is a requisite. Clearly, embedded provisions in the contract should specify the liable party (manufactures, developer of the AI system, or pilot of the drone) in different scenarios when an RIT operated by a pilot, or fully autonomous RIT drops, crashes, and causes damage. The different scenarios include but are not limited to collisions with asset structures, collisions due to malfunction of the equipment, or unexpected or unforeseen incidents occurring in cases where visual line of sight (VLOS) is not maintained.

Regardless of how provisions on liability take shape in the long run, service suppliers should secure third-party public liability insurance and professional indemnity insurance for protection against legal liability for third-party property damage or injury while using RIT.

2.8 Element 8: Determine "Proof of Concept"

Improving technical reliability and confirming/determining the "proof of concept" of functionalities of the remote survey could be achieved after conducting more live experiments in a controlled environment. Classification societies, once RIT witnesses mass deployment, should ensure that these technologies are robust, and are able to accomplish quicker, safer, and more efficient ship inspections. In short, the validity of these systems will be concretely substantiated if technical robustness and data quality are demonstrated (Pastra et al., 2022). For the former, i.e., technical robustness, systems should function properly and be able to reproduce the verbatim results if the operation is repeated should that fall under the scope of "confirmatory survey" in the future, timeliness, completeness, and credibility (Johansson et al., 2021; Khatri & Brown, 2010). The final step could be to initiate validation of the final output through a series of tests on different types of vessels during close-up inspections and statutory surveys. The results should be compared and contrasted with data gathered through results gathered from physical surveys.

2.9 Element 9: Risk Assessment Framework for Determining the Feasibility of Remote Survey

A strategic risk assessment process could be adopted whereby a common risk assessment framework for the eligibility of remote survey should consider the following elements: the age of the vessel, port state control history, class history, hull condition, and 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 (Fig. 3 below).

The feasibility of carrying out statutory inspections with RIT should not only depend on ship parameters, e.g., age, historic records, and sister ships, but also on company aspects, e.g., records of deficiencies and trust between the company and administration. Considerations ought to go beyond legal risk parameters. In the case of statutory surveys, for example, there is a need to ensure that all is in good order conditions for carrying out a remote survey satisfactorily. In terms of complexity, stakeholders should be cognizant of whether any special planning is required bearing in mind the "special planning" prerequisites for special surveys with regard to oil tankers and bulk. The survey planning for the above takes into consideration how and where close-up inspections, together with thickness measurements will be carried out. The document is signed or accepted by the company so as to allow for the survey to start. When it comes to remote surveys, planning becomes even more critical because of the need to ensure that the results would be equivalent to the results obtained from manual/physical inspection. Failure to provide the desired quality would increase risks that will have a negative implication on costs.

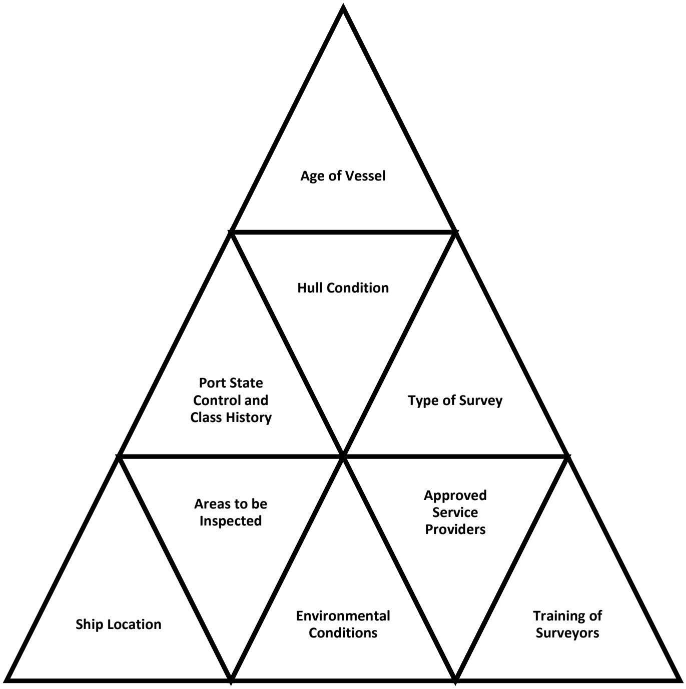

Fig. 3 Considerations when assessing the feasibility of the remote survey (*Source* Authors)

2.10 Element 10: Allocation of Responsibilities

Each party during the different stages of the remote inspection process (planning, operation, reporting) should have clear roles and responsibilities. For example, during the planning pre-inspection phase, the ship owner/operator must determine, in consultation with the class, if the use of RIT is appropriate, and if this is the case, then a recognized service supplier should be appointed (ABS, 2022). The supplier ought to develop the inspection plan that includes the different types of RIT to be used coupled with the results of the risk assessment, whereas the class should review the "survey planning document" provided by the ship operator and verify that the survey plan satisfies the applicable rules (ABS, 2022).

During the second stage of the inspection process, the service provider should conduct the inspection according to the “survey planning document”, and the attending class surveyor must ensure that the RIT operation team conducts the survey according to the relevant requirements (ABS, 2022). In the reporting phase, the service provider shall send the report and data to the asset owner and class to assess if a physical or additional inspection is required (ABS, 2022).

3 Conclusions

RIT includes the possibility of effective examination of vessel structure without the need for direct physical access by the surveyor. Remote surveys may be applied to satisfy both statutory and classification requirements during normal situations and force majeure. Markedly, currently, other than procedural requirements stipulated by IACS, no specific international guidance covers the fundamentals of remote surveys/inspections, remote audits, and verifications.

IMO has recently embarked on the development of guidance for assessments and applications of remote surveys, ISM Code audits, and ISPS Code verifications, with 2024 as the target completion year. This may likely result in amendments to current instruments such as Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), 2019 (Resolution A.1140(3)), or guidelines to other security-related instruments, where appropriate, with reference to IACS rules and requirements (ref: IACS Recommendation 42 and IACS UR Z29) 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 RIT remain at the crux of all surveys conducted off-site.

It should also be noted that IACS UR Z29 on remote survey, which was issued in March 2022 and will be uniformly applied by IACS Societies for remote surveys commenced on or after January 1, 2023, could set the foundation for suitable procedures and instructions for RIT under the purview of its regulations. It is essential to proceed with a different mindset that could assist stakeholders to comprehend the topic, explore different ways to approach it, set a strategic basis for RIT, and finally, move forward towards class certification.

In parallel to the above, policymakers could consider developing and 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 surveys must be avoided at all costs. Uniformity contributes to certainty that in turn, is an acknowledgment that technology-policy interface developments are keeping pace with innovation.

The authors stress the need to assess the feasibility of remote surveys adopting a case-by-case approach. In that very process, it would be important to develop training and certification requirements for personnel involved in the conduct of remote surveys. The current IACS rules and requirements for RIT take into account the role of the attending surveyor, which is quite different from remote surveys given that the physical presence of the surveyor is not obligatory.

In conclusion, service robots pave the way for a service revolution that will dramatically improve customer experience, service quality, and productivity (Wirtz & Zeithaml, 2018). Within this context, responsible innovation practices and measures, call for strategic stakeholder engagement (Leenes et al., 2017). Through the process of testing, learning, and reflection, different stakeholder groups should join forces to fill the current vacuum (identified in this chapter) by drafting an international stand-alone *guideline for end-users*. Innovation cannot be contained. As it progresses, a guideline would certainly assist in governing niche incidental areas that could otherwise detract from unleashing the full potential of the byproducts generously bestowed by the fourth industrial revolution. The maritime and ocean community could certainly benefit from autonomy-renaissance. Much work lies ahead.

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