Is Regulation really the barrier? Exploring the Opportunities and Challenges in Certifying Maritime Systems with Increased Automation and Autonomy

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Synopsis

In recent years there has been a huge drive to apply new and novel technologies across industry and in the maritime sector, centred around the application of automation and autonomy. The potential applications are far and wide and cover every type of maritime vessel. The application of these new technologies challenges the conventional adherence to some of the fundamental maritime conventions, specifically International Regulations for Preventing Collisions at Sea 1972. In an industry that is traditionally underpinned by prescriptive regulations, the ability of the Regulations to keep pace with the evolving technical landscape is continually tested. But is it fair to blame Regulations for the constraints on certifying vessels with ever increasing levels of automation and autonomy? This paper looks at the current commercial approach, which typically takes a more traditional prescriptive approach and compares it to the defence industry that operates in the same environment and undertakes similarly complex operations, but has goal-based regulations and utilises risk based methodologies to demonstrate compliance. The authors' are not advocating any one solution, but comparing two differing approaches to look at opportunities and to examine the question “is Regulation really the barrier”.

Keywords: Automation, Autonomous, Regulations, Assurance

1 Introduction

The potential application of new and novel technology in the maritime domain, specifically automation and autonomy, is progressing at a pace rarely seen with regards to technology development/ insertion. The use of automation and autonomy is pushing the technical boundaries and hence regulatory frameworks with a concurrent requirement to understand how their adoption can be assured robustly and consistently.

Development of regulations always takes considerable time, and technology exploitation will always outstrip development of regulations in timescales. As a result, regulations often get blamed for hindering technical development, but is this fair?

It is important to note that the paper is agnostic of vessel size; the challenges posed are common and thus the paper’s question is equally applicable. It is also worthy of note that where we discuss safety “...and environment” is implicit.

Great care needs to be taken in the use of terminology, both in terms of ensuring a common/ pan industry understanding, but also to ensure a true reflection of the capability without inadvertently being misleading. The paper does not go into variations on Remote Control or Autonomy, but uses the following core definitions, Remote Control “the vessel is controlled and operated from another location by a person” and Autonomous “the vessel assesses its environment, makes decisions and determines actions by itself to fulfil its mission”.

This paper asks the question “Is Regulation really the barrier?” to the adoption of novel technology specifically in the context of automation and autonomy. To examine this question the authors, draw on their respective

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Mr Steve Pearson served 38 years in the RN including Command at Sea and Captain Portsmouth Flotilla. He was the first Head Defence Maritime Regulator, introducing the widely recognised as exemplar Defence Maritime Regulations for Defence Maritime activity. He joined Safeguard Engineering Limited as Principal Safety and Environmental Protection Consultant in 2021.

Mr Ashley Stehr qualified with a master’s in mechanical engineering and a seasoned consultant with extensive experience across various sectors, including both commercial and defence. Formerly an Assistant Director at the MCA, where he established and led the Maritime Future Technologies team, focusing enabling the safe adoption of novel technologies within regulatory frameworks. Currently, he serves as Director and Principal Consultant at Stehr Consulting Ltd.

 https://doi.org/10.24868/11198

experiences in the commercial and defence maritime sectors to compare differing approaches to the challenges posed by the adoption of such novel technologies.

The authors are not suggesting that any one model is the answer, but by comparing two industries that both operate in the same environment, both undertaking similarly complex operations and both pushing the adoption of new and novel technology in automation and autonomy, useful comparisons can be made.

2 Sector Landscape

To be able to draw comparison between Commercial and Defence industries, it is first important to understand where the respective regulations have come from, how they have developed and their current status. This section provides that overview.

2.1 Current Industry Landscape

There has been a significant increase in interest and uptake of remote control and autonomous surface and subsurface vessels in recent years across both Commercial and Defence applications, both internationally and within the UK. The press is full of new and novel applications, from the small, sub 6 metres, to the full-scale ships, e.g. 200 meters plus.

This paper considers the application of new and novel technology in the round to the maritime environment and does not focus on any particular example.

2.2 Current Regulatory Framework Context

2.2.1 Commercial Context

The regulatory and standards landscape in the commercial maritime sector is complex and continuously evolving. Traditionally, maritime regulations have been inherently prescriptive, consisting of a broad array of international and national rules, conventions, guidelines, and standards. These are primarily designed to ensure safety, security, and environmental protection. The International Maritime Organization (IMO) plays a pivotal role in creating and implementing these international standards, with member states adopting these standards on a multilateral basis. This top-down regulatory approach details the obligations and rights of Flag States, vessels, and seafarers, setting minimum technical and operational standards that dictate ship design, operation, and performance.

Compliance with these regulations varies significantly across different regions, with some areas showing high levels of compliance and others much lower, partly due to the existence of Flag States that impose less stringent requirements.

Nationally, countries like the UK have their own domestic maritime regulations, overseen by the Maritime and Coastguard Agency (MCA) (an executive Agency of the Department for Transport (DfT)).

The prescriptive regulatory model faces increasing pressure as the maritime sector enters an era marked by rapid technological change and diversity, where traditional prescriptive approaches often fall short. The current regulatory framework, although effective for incremental changes, struggles to accommodate the fast evolution and complexity of new systems, leading to significant regulatory barriers and gaps for emerging technologies.

To address these challenges, regulatory bodies are adopting more tailored, case-by-case approaches for vessel certification. These make use of existing mechanisms like Exemptions, Equivalence, or Alternative Design and Arrangements (AD&As) to facilitate the introduction of new technologies, though they are traditionally intended for minor deviations and the processes are not designed for more substantial, system-wide changes. Within the UK, the MCA has just recently updated the Workboat Code Edition 3 (WBC3) [Ref. 1] to cater for Remote Controlled vessels, and has also published Marine Guidance Note (MGN) 664 ‘Certification Process for vessels using Innovate Technology’ [Ref. 2] which is a goal-based approach and has only relatively recently been introduced.

Similarly, industry via the various trade bodies is also developing supporting information to contextualise how to demonstrate compliance for autonomous platforms. For example, Maritime UK have developed the Maritime Autonomous Systems (MASS) UK Industry Conduct Principles and Code of Practice [Ref. 3].

There is, however, due to commercial nature of projects, little publicly available to allow industry to understand “what good looks like” or what has been successful in seeking certification, a common theme across commercial and defence industries. To be able to rapidly develop, sharing knowledge, is key.

 https://doi.org/10.24868/11198

2.2.2 Defence Context

As with the commercial maritime space, defence maritime has its roots very much in the prescriptive regulatory space. Similarly, whilst this approach has allowed it to embed lesson learnt into the regulations and standards applied, it can struggle to keep pace with evolving technology application.

In 1996 the UK Ministry of Defence (MOD) issued, what can be considered by today's standards to be the first Safety Management System, Joint Service Publication (JSP)430 [Ref. 4]. This was developed and issued as a result of various reviews and parliamentary investigations into a series of accidents ranging from the Piper Alpha Oil Rig Fire 1988, to the capsize of the Herald of Free Enterprise 1987 and the Clapham Rail Disaster 1988. The various investigations, inquiries and Coroners Court findings associated with these events led to changes in the law, the creation of the Corporate Manslaughter Act and the specific requirements for Safety Cases. The then UK MOD Ship Safety Maritime Office (SSMO) developed and issued JSP430 [Ref. 4] in response, to provide initial regulation and guidance to the UK Defence Maritime Sector.

JSP 430 Issue 1 [Ref. 4] set the overall objective of "*The overall MOD Ship safety objective is that levels of risk of accident death or injury to crew or other third parties and damage to property and the environment due to MOD shipping activities are as low as reasonably practicable*."

Importantly the forward of JSP 430 [Ref. 4] was signed by the then Secretary of State for Defence, establishing a clear commitment from the very top of government with respect to establishing a robust Safety Culture. Promoting policy at the highest level creates the working environment and conditions individual behaviour [Ref. 5].

JSP 430, also set out two important fundamental concepts for the application of safety management within defence:

1. "…*that where MOD has been granted exemption from specific regulations, health and safety standards and arrangements will be, as far as is reasonably practicable, at least as good as those required by statute*"; and
2. "*Safety management is to commence at the first consideration of a new design*…".

These points still remain extant today, and whilst they have been developed further within the current set of Defence Regulations, DSA02 – DMR [Ref. 6], the fundamentals remain the same; simply put demonstrate that the platform/ system is "Safe to Operate" and is "Operated Safely". As noted, the basis of defence safety is demonstration via a risk-based approach. This poses a number of challenges:

- what is an acceptable level of safety when it is assessed subjectively?
- how do you maintain consistency in approach? and
- how do you maintain consistency in level of rigour and fidelity in analysis?

Whilst the Defence Maritime space might have been applying a risk-based approach for circa 28 years, these concerns remain at the forefront of thinking and result in a body of guidance and training. They are similarly applicable to the commercial space as it embarks on risk based methodology.

The UK Defence industry adopts the As Low As Reasonably Practicable (ALARP) principle, Edwards v. National Coal Board in 1949. MOD generally adopts a Risk Class Matrix approach, which in the majority of cases, takes due regard for the risk tolerability levels defined in the Health and Safety Executive (HSE) guidance document Reducing Risk and Protecting People (R2P2) [Ref. 7]. .

Since the inception of the risk based approach in 1996, there has been a development in internal guidance to support a common baseline of what should typically constitute a Safety Case, for Defence Maritime, most notably the pan defence Acquisition Safety and Environmental Management System (ASEMS) and various supporting publications supporting the Naval Authority Regulations, in effect "Defence Codes of Practice", for lack of a better collective term.

In addition, the UK MOD has developed and applied structured training, accredited to professional institutions to ensure consistency in understanding and application. This with a use of forums to assess risks with relevant stakeholders, the application of a Suitably Qualified and Experience Person (SQEP) forums supports the provision of consistency in risk assessment.

The UK MOD Regulator has evolved from the early days of the SSMO and JSP430 [Ref. 4] into the Defence Maritime Regulator (DMR), within the Defence Safety Authority (DSA) with an aligned set of regulations in DSA DMR 02 Defence Maritime Regulations [Ref. 6] that dovetail with the HSE and the MCA. This evolution

 https://doi.org/10.24868/11198

started in 2016 post the Haddon Cave Report [Ref. 7] that reset the whole of UK Defence's approach to regulation. That change created the Defence Regulators, aligned to the UK Government's Regulators Code and empowered those regulators to drive and shape the regulatory framework across the domains. For DMR that led to a much closer relationship with the MCA and HSE and endorsement from both of those statutory bodies for the DMR Regulations. The regulator's intent was and remains to provide a sensible handrail to allow defence to deliver its outputs and develop new equipment and technologies in a way that achieves legislative compliance within a safe operating envelope.

The International Naval Safety Association (INSA), responsible for the development and maintenance of the North Atlantic Treaty Organisation (NATO) Naval Ship Code, Naval Boat Code, and NATO Naval Submarine Code, has established a working group focused on unmanned and autonomous systems. This group is working to update the Naval Boat Code to incorporate unmanned and autonomous functionalities under the 'Special Functions' provisions. Furthermore, the group is developing a goal-based performance standard for Autonomous Navigation Systems that could be implemented on remotely controlled or autonomous naval vessels of various sizes. This initiative is cognisant of the IMO MASS Code (to be issues), the UK WBC3 [Ref. 1], and other navy and industry standards, and strives to align with these standards where suitable for naval vessels.

The UK Naval Authority & Technology Group (NATG) have also published, amongst others, the Maritime Acquisition Publication (MAP) No. 01-151 Certification of Autonomous Vessels [Ref. 9] in October 2023. This embeds the provision of a risk-based approach, whilst ensuring compliance with statutory regulations the defence objective of "...at least as good as..." mentioned earlier. In addition to this, it provides consideration and a framework to support progressive proving on novel technology.

Other areas within the MOD are also looking at what safety case models could look like to provide a standard construct for the demonstration of the remote control and autonomous vessels. As with the commercial space, there is considerable work being undertaken, and due to the structure of UK MOD and the complexities of commercial and security arrangements, not necessarily visible to all parties, thus restricting knowledge sharing.

3 Regulation vs Assurance

Through time the application of rules and legislation to systems and activity has evolved and methods of assessment and measurements of compliance have evolved with them, often leading to sustained debate about what is regulation and what is assurance. Regulation is simply the controlling of an activity or process, usually by means of rules, while assurance is simply a positive declaration intended to give confidence. The key difference being that regulation requires adherence, while assurance focuses on the provision of a body of evidence to provide confidence that an activity can be undertaken safely.

The critical challenges in the maritime sector associated with remote control and autonomous platforms has primarily evolved around adherence to International Regulations for Preventing Collisions at Sea (COLREGS) in enabling the vehicle to act in a way appropriate to the maritime condition, establishing and identifying the role of the "Master" in an autonomous vehicle and developing appropriate emergency equipment fits for autonomous vehicles. The situation awareness challenge for over the horizon activities and the understanding and identification of other vessels around an unmanned/ autonomous vessel conducting activities has presented significant challenges to the community as a whole, both within commercial and defence sectors.

The risk-based model adopted can be represented as depicted in Figure 1. The application of prescriptive requirements, whether embedded in regulations, or standards, is a key control to hazards and risks identified. Where novel aspects are considered, either in operations that don't fall under any standards, or the application of novel technology, the risk based model allows consideration of safety from first principles; but importantly building on a sound body of initial assessment against prescriptive standards, ensuring the inherent lessons learnt are captured and not lost. This approach also identifies and addresses any emergent risks that may not have previously been present.

 https://doi.org/10.24868/11198

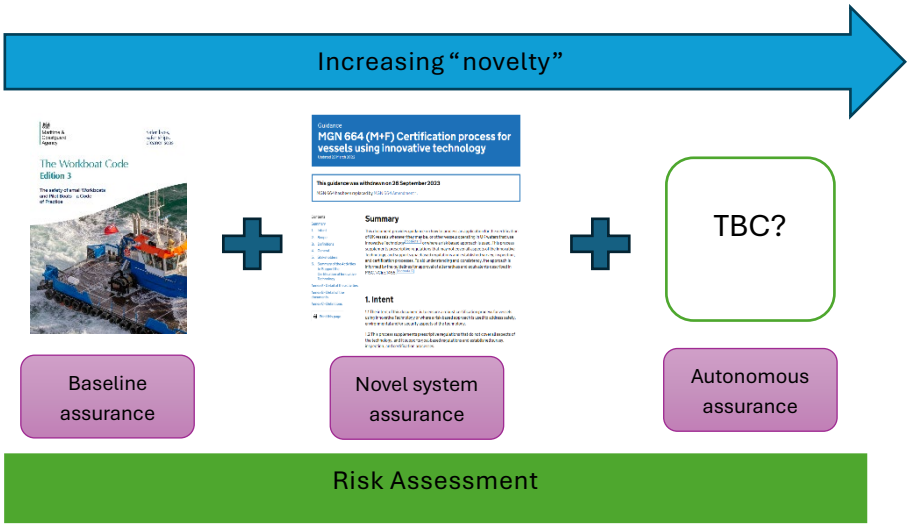

Figure 1 – Risk Based Safety Assurance Model

This approach allows the regulator to seek assurance within a defined construct, which does not stifle innovation, but is cognisant of the activity and how novel technology/ operations are intended to be applied. With this understood, a measured risk-based framework can be developed that enables the development of appropriate assurance for novel systems.

With a thorough understanding and engagement from the community, the regulator can also provide assurance to the accountable persons that all reasonable precautions are in place and applicable procedures developed to allow ALARP to be achieved in activities. This reflects a unique set of conditions that are not necessarily present within the commercial maritime environment, specifically a community with a common understanding and acceptance of tolerability of risk, as baselined in R2P2 [Ref. 8], and environmental with defined training.

However, whilst it may be argued that 28 years of application of a risk based approach within the defence maritime industry generates a community with common understandings and expectations on assessment methodologies and fidelities, the challenges of personnel churn within a small, relatively speaking, community cannot be underestimated.

It is the authors' experience that it is widely acknowledged that the commercial maritime industry as a whole (industry and regulators) are struggling to transition from what is a traditional prescriptive approach, e.g. guardrails shall be a minimum of 1000mm above deck level, to a risk based approach considering controls to mitigate the Hazard of "personnel fall overboard" or "personnel fall from height". In addition to defence, other industries have made, or are making this transition, e.g. O&G initiated by Piper Alpha, and UK building industry is current progressing as a result of Grenfell Towers. The commercial maritime industry has already made some strides in this area with the introduction, at the international level of the ISM Code as a result of the Zeebrugge disaster. Whilst this does not progress a risk-based safety assessment methodology, it does introduce aspects of subjectivity and assurance of the process rather than the product, e.g. what level of fidelity should be in an Emergency Response Plan? Whilst at the national level the UK has MGN 664 [Ref. 2], for novel technologies predicated on a risk-based approach.

The authors propose that there is substantial learning from the risk-based approach, adopted by defence (and other sectors) that can be utilised within the commercial space to alleviate the challenge of lag in regulation/ standards development, whilst maintaining a robust assurance oversight. The fundamentals to allow this to be achieved are already in place, e.g. MGN 664 [Ref. 2]. There are however a set of challenges, which we have characterised as "challenge themes" to the adoption of the risk-based approach. These "challenge themes" span both the Regulator and Industry alike, and thus in answer to the papers question "Is Regulation really the barrier?" the answer is no, it is a shared responsibility with the sector overall, both Regulator and Industry.

Challenge Theme 1 – Necessity for a consistent understanding and connection of the regulation to the hazards and risks being managed.

Commercial maritime regulation is characterised by a complex array of codes, each designed to manage specific risk profiles. These regulations, predominantly prescriptive and technical, have evolved over time, often in

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response to lessons learned from past incidents and accidents. There is a notable absence of goal-based regulations, and the existing technical requirements frequently lack a clear connection to the hazards and risks they aim to mitigate. This disconnect poses significant challenges when assessing novel technologies. To evaluate such technologies, it is necessary to first understand the original intent of the regulatory requirements. Only then can consideration be given to exploring alternative compliance methods, such as equivalence, or Alternative Design and Arrangements (AD&A). This will also allow for the consideration of any potential emergent hazards and or risks being introduced by the novel technology. A more effective regulatory framework could be achieved by structuring future requirements to highlight overarching goals, with prescriptive measures serving as acceptable means of compliance. This approach would simplify the integration of novel technologies into the maritime sector by making it much easier to demonstrate and articulate alternative means of compliance.

Challenge Theme 2 - Clear safety benchmarks defined in maritime regulation.

In addition, for the need for clear and consistent goals, Theme 1, there is also a need for a consistent understanding of the acceptable level of safety. The importance of defining 'how safe is safe enough', where proportionality is essential and consistent application is fundamental. Commercial maritime lags in adopting such baselines for risk tolerability as those proposed in R2P2 [Ref. 8] prevalent in other sectors. Whilst this can be applied in a national context, due to the common acceptance of risk levels, application on an international basis will pose considerable challenges, as evidenced by the application of varying degrees of rigour in the prescriptive standards. Transitioning to a risk-based approach necessitates an evaluation of risks - from well-understood to emergent - using first principles to establish a baseline of safety. This process involves either deducing the level of safety provided by existing controls and requirements (which are not often apparent or clearly defined) or applying the principles of ALARP. Variations have been adopted in some other countries noting there can therefore be differing interpretations of "reasonably practicable", thus posing particular challenges for adoption worldwide.

Challenge Theme 3 – Specific challenges with assuring high degrees of autonomy

In addition to the challenges with more bespoke assurance of novel and complex systems, there are some additional specific assurance challenges presented by introducing higher degrees of autonomy. Many of these are not unique to maritime, and other arguably more advanced and well-funded sectors are also trying to grapple with these challenges. These challenges range from needing to consider the shift from product to the inclusion of process based assurance, and operational risk versus system risk. An example are the specific challenges with assuring Machine Learning which can be used as a key enabler for some autonomous systems (e.g. for processing and understanding Electro Optical/Infrared Imagery which can be used in contact classification). Industry wide, established baselines are required to define acceptable levels and methods of assurance to demonstrate the robustness of non-deterministic methods such as Machine Learning. This includes, what tests scenarios and methods are required and how many iterations are necessary to demonstrate that a Machine Learning autonomous system will behave as expected?

Challenge Theme 4 – Increase in SQEP capability and capacity required to implement a risk-based approach.

The transition from a prescriptive to a risk-based approach to safety assurance marks a significant shift in the maritime industry. This change offers greater flexibility, but also presents considerable challenges in terms of the technical skills and capabilities required to manage increased subjectivity, including the need for Suitably Qualified and Experienced Personnel (SQEP). Traditionally, the commercial industry has relied on a model where specialists develop technical standards for generalists to implement. However, a risk-based approach demands the involvement of these specialist skills in every project, posing challenges for both industry and regulatory bodies. Furthermore, the adoption of highly adaptable systems that allow significant post-manufacture modifications through software updates necessitates the need for more comprehensive through-life safety management. This includes oversight through life of the design, construction, maintenance, and modifications, with a demand for ongoing expert involvement and oversight.

Challenge Theme 5 – Shift in safety culture and approach.

The shift from a prescriptive to a risk-based approach in maritime safety assurance represents a fundamental change in the regulatory paradigm, notably transferring more risk management responsibility from regulators to the industry (and other third parties). This alteration significantly impacts the required safety culture and the level of trust between these entities. In a risk-based framework, the industry assumes greater responsibility for identifying hazards and risks and for identifying appropriate controls to either eliminate these risks or mitigate them to ALARP levels. Establishing trust in the industry's commitment to safety is crucial, yet challenging,

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given the diversity of stakeholders and a safety culture that will be subject to considerable change from prescriptive to risk based. This transition demands a robust, collaborative effort, by all stakeholders to reinforce trust and ensure a shared commitment to safety excellence, knowledge and good practice.

4 Conclusions

At the start of this paper, we asked ourselves the question "is regulation truly the primary barrier to innovation?". While recognising specific regulatory challenges - which we do not intend to diminish - we believe that many of the core issues extend beyond mere regulatory frameworks. Instead, they are closely linked to the complexities of demonstrating safety assurance in an efficient and effective manner. Thus, the answer to our initial question is no, but it is not straightforward.

The paper identifies that the primary hurdle involves demonstrating safety and environmental assurance of novel and complex technologies through ensuring effective risk management within an existing and inherently prescriptive regulatory environment. This paper has explored various dimensions that transcend traditional regulatory challenges, extending into broader 'assurance' issues that require attention and resolution.

Anecdotally, industry often hastily blames regulatory bodies for obstructing the adoption of innovative technologies. However, many of the challenges we have highlighted are as significant for the industry as they are for regulators, who are tasked with maintaining appropriate safety and environmental standards. It is crucial to acknowledge that regulatory functions vary across different contexts. In the commercial maritime sector, many technical requirements are positioned at a higher level within the regulatory ecosystem than in other industries.

Key challenge themes identified in our paper include:

- 1 – Necessity for a consistent understanding and connection of the regulation to the hazards and risks being managed;
- 2 - Clear safety benchmarks defined in maritime regulation;
- 3 – Specific challenges with assuring high degrees of autonomy;
- 4 – Increase in SQEP capability and capacity required to implement a risk-based approach; and
- 5 – Shift in safety culture and approach;

In conclusion, while Regulation is often perceived as a barrier, our view is that often the real challenges lie in the broader context of assurance and the readiness of industry as a whole to meet these challenges. Moving forward requires a collaborative, balanced approach that not only reevaluates regulatory frameworks, but also enhances industry practices and the collaborative dynamics between regulators and the industry.

5 Acknowledgements

With thanks to Dr Paul Hogan for his guidance in focusing the challenge themes of this paper.

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