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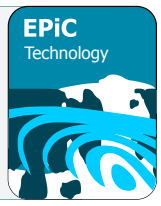

A Case Study in the Application of Trusted Autonomous Systems (TAS) Australian Code of Practice to the Design, Construction, Survey, and Operation of New Build Autonomous & Remotely Operated Vessels

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Abstract

The emergence of autonomous vessels presents opportunities and challenges for the maritime industry. Regulations relating to crewing or manning, safety equipment, watchkeeping, etc., normally applicable for crewed vessels, do not apply to Autonomous Surface Vessels (ASVs) which operate without onboard crew and are controlled, supervised or monitored by software or remote operator. Due to their nature, ASVs should have new standards developed to address risks relating to lack of onboard crew. The International Maritime Organization (IMO) is responsible for making rules that apply to all oceangoing vessels, including ASVs, and are working through those updates (International Maritime Organization, 2021). The Australian Maritime Safety Authority (AMSA) has provided an interim framework of exemptions and guidance notices, and a dedicated support team to work with industry in navigating the uncertainty in application of extant principles, rules, and standards to ASVs. The Trusted Autonomous Systems (TAS) Defence Cooperative Research Center has developed a suite of tools to guide builders, owners and operators in the design, build and certification of ASVs; and advocacy groups such as the Australian Association for Uncrewed Systems (AAUS) are working to provide industry recommendations and "promote a professional, safe and commercially viable uncrewed systems industry" (Australian Association for Uncrewed Systems, 2023). This paper discusses the regulatory challenges experienced in Gibbs & Cox Australia's new build Environmentally Powered, Modular Autonomous Platform System (EMAPS) project and the project experience navigating the regulatory misalignments and published

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guidance documents. The solutions (exemptions and equivalencies) are straightforward but rely on best practices rather than explicit requirements where regulations are misaligned.

Keywords: Autonomous Surface Vessels, Survey

1 Introduction

International and Australian national maritime rules and regulations are largely based on international rules laid down in the 1970's: International Maritime Organization (IMO) Convention on the International Regulations for Preventing Collisions at Sea (COLREGS) and human safety International Convention for Safety of Life at Sea (SOLAS) and may not be completely relevant to uncrewed autonomous surface vessels.

In Australia, ASVs are likely to fall under one of two regimes, both administered by AMSA, neither of which is well-suited to the features, risks, and hazards of ASVs:

The Navigation Act 2012 (Cth) – applies to Regulated Australian Vessels (RAVs), which are non-recreational vessels that are proceeding, or will proceed on an overseas voyage (outside Australia's Exclusive Economic Zone (EEZ)). The Navigation Act implements IMO conventions in Australia, including certification requirements, for RAVs; and The Marine Safety (Domestic Commercial Vessel) National Law Act 2012 (Cth) (National Law Act) – applies to domestic commercial vessels (or 'near coastal' vessels) and applies separate certification requirements. Some convention requirements apply to domestic commercial vessels. Recognizing that ASV's need coverage under national law and regulations, the Australian Maritime Safety Authority (AMSA) has developed a "Guidance Notice – Small unmanned autonomous vessels" but has not yet updated the National Standard for Commercial Vessels (NSCV) or associated standards to reflect small or large ASVs. Trusted Autonomous Systems (TAS) also have recognized the challenges in obtaining approvals for the operation of ASVs and as a result have produced "The Australian Code of Practice for the Design, Construction, Survey and Operation of Autonomous and Remotely Operated Vessels, Edition 1 (published April 2022 by Trusted Autonomous Systems)" aiming "to achieve practical outcomes, create a sustainable industry, and – through our common good activities – deliver resources for ethics, law, and assurance of autonomous systems in Australia". (Trusted Autonomous Systems, 2023). Authorizations to operate small Autonomous Surface Vessels (ASV) on navigable Australian waters are driven by the AMSA enforcement of international and national laws and regulations.

1.1 International Maritime Organization (IMO)

IMO is working through a process to identify new requirements and requirements that need to be revised in SOLAS, COLREGS and other international standards and procedures. (International Maritime Organization, 2021). A June 2021 IMO Regulatory Scoping Exercise Complete Outcome of the Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS) identifies areas of misalignment between conventional and autonomous vessels and provides recommendations for further assessment and development of proposed changes (International Maritime Organization, 2021).

1.2 Australian Maritime Safety Authority (AMSA)

AMSA is Australia's national maritime safety authority, and is the regulatory authority for Australian maritime safety, protection of the marine environment, and maritime aviation search and rescue (Australian Maritime Safety Authority, 2023). AMSA regulates Remotely Operated and Autonomous Surface vessels in three categories:

1. Domestic Commercial Vessels which operate within Australian exclusive economic zone;
2. Regulated Australian Vessels which operate in international waters; and
3. Foreign Vessels which operate within Australian exclusive economic zone.

EMAPS is considered a domestic commercial vessel applying both AMSA and TAS guidance. A domestic commercial vessel must generally, unless exempt:

1. be marked by a unique vessel identifier
2. have a certificate of survey, and be subject to the relevant survey regime
3. be operated under a certificate of operation
4. be operated by crew with the requisite certificate of competency

Additionally, domestic commercial vessels, including ASVs must be operated in accordance with a safety management system.

1.2.1. Key Principles for Autonomous Surface Vessels

AMSA policy key principles include (Australian Maritime Safety Authority, 2023) the imperatives that the owner/master are responsible for ASV safety and that their ASVs must be as safe as manned vessels, considering risks to safety of people, other vessels, and the environment. EMAPS was designed with these three principles as primary design criteria.

1.2.2. National Standard for Commercial Vessels (NSCV)

NSCV is the Australian national standard for design, construction and operation of domestic commercial vessels and enforced by AMSA in its' application to domestic commercial vessels, including Autonomous Vessels, and includes Australian electrical safety standards by reference. The NSCV is typically applied to a vessel or operator through certification, or as a condition of an exemption. EMAPS is designed and built in accordance with the NSCV insofar as an ASV can comply, aligned to AMSA key principles to minimize the exemptions required, simplifying the ability to obtain a certificate of operation.

1.2.2.1. Certificate of Survey vs Exemption

The designer of ASVs must consider the vessel size, capabilities, intended use, operating areas and conditions that their vessel will operate in. These factors in turn determine whether the vessel can obtain a certificate of survey (compliant with the survey regime) or whether an exemption is required.

AMSA and TAS guidance both indicate that Small ASVs <12m with operational speeds of <10 kts can likely be exempted from survey requirements. EMAPS is 5.85m and has an operational speed of 6kts but operates up to 17 kts. TAS guidance provides a kinetic energy matrix for Survey Exempt Vessels which indicates that based on EMAPS 1200kg full load weight and 17 kts maximum speed would exceed the 100,000 KJ of kinetic energy for a survey exempt vessel (Trusted Autonomous Systems, 2022, p. 51), however EMAPS operational speed at 10kts, full load weight of 1,200kg renders a kinetic energy of 60,000 kj (Mass/2 * Velocity ^2) which is less than the 100,000 kj criteria.

Accordingly, TAS and AMSA Guidance implied that EMAPS requires a certificate of survey, but discussion with AMSA concluded that EMAPS should seek exemption from survey requirements, in accordance with the Guidance Notice – Small Autonomous Surface Vessels (Australia Maritime Safety Authority, 2021).

It is worth noting that a vessel that is not fully compliant with certification requirements, can apply for certification with conditions rather than an exemption from certification. The best approach should be discussed with an accredited marine surveyor and may require consultation with AMSA.

1.2.2.2. Certification & Exemptions Process

"The Australian Code of Practice for the Design, Construction, Survey and Operation of Autonomous and Remotely Operated Vessels, Edition 1 (published April 2022 by Trusted Autonomous Systems)" (Trusted Autonomous Systems, 2022) guides the reader through the process of determining whether a vessel should apply for a certificate of survey or exemptions to survey requirements and references the "AMSA Guidance Notice – Small Unmanned Autonomous Vessels" (Australia Maritime Safety Authority, 2021) which applies to EMAPS.

The TAS Design Record was a useful tool for identifying EMAPS compliance with COLREGS, and an internal assessment of NSCV compliance provided the balance of the assessment of EMAPS compliance to code. The examples of compliance that TAS provided for the 5m and 6m WAM-V vessels were most useful in assessing compliance. The WAM-V examples of compliance provided confidence that the EMAPS had checked the right factors and provided an indication that the EMAPS solutions were fit for purpose.

1.2.2.3. Exemptions and Generic Equivalent Solutions

AMSA has developed national law exemptions and Generic Equivalent Solutions (GES) for Domestic Commercial Vessels, but not for ASVs. Generic Equivalent Solutions were developed to "facilitate innovation, modernization and emerging technologies" (Australian Maritime Safety Authority, 2023) and are directly relevant to some ASVs. Trusted Autonomous Systems discusses AMSA Exemptions in depth but does not refer to AMSA's Generic Equivalent Solutions. As the GES are directly relevant to identifying equivalence solutions in ASVs, they should be discussed within the TAS guidance documents.

The process and standards for obtaining AMSA certificate of survey (applicable to vessels to be built as "Survey Vessels") or Exemptions (for vessels not built to code (Survey Exempt) are clear, but the process for determining what Exemptions should apply, and what equivalent solutions are acceptable for the new build EMAPS ASV required a comprehensive review of existing Generic Equivalent Solutions (GES) and assessment of EMAPS compliance with COLREGS, SOLAS, NSCV and NSCV referenced standards. This review contributed to a determination of the exemptions and equivalences that would be applied to EMAPS and provided excellent examples of the type of equivalences that would be acceptable.

Two kinds of exemptions are available from AMSA:

1. General exemptions: are instruments with general application that apply to a specific class/es of vessel/s or person/s. Some are available 'as of right' – so that no application or permission from AMSA is required to use the general exemption – whereas some require an application, consideration, or determination from AMSA in order to access the flexibility provided by the general exemption. General exemptions include Marine Safety (Temporary operations) Exemption (EX07), which – among other things – provides exemptions from certification requirements for certain temporary purposes.
2. Specific exemptions: are instruments that relate to a specific vessel/s or person/s and require an application by the applicant to AMSA.

An exemption may exempt a vessel or person from any part of the National Law – as long as the exemption (together with any relevant conditions) does not jeopardise a vessel or person.

EX07 offers exemption from certification requirements in certain circumstances. Temporary operations exemptions provide valuable short-term flexibility for testing and evaluation purposes. However, processing times can be lengthy, applicants need to clearly outline the nature of the vessel and its operation so that AMSA can be sure that the issue of the approval will not jeopardise safety.

EMAPS will be seeking a Division 3 application for an initial 14 day sea trials period, to be followed by application for a Division 2 application to continue prototype trials until such time as the vessel is able to complete activities that the EMAPS team have deemed are essential for submission of application for an specific exemptions to survey requirements:

1. Division 2 (Temporary operations – operations without certificates): offers an exemption from the requirement for a unique identifier, certificate of operation, and/or certificate of survey for – essentially – any temporary use. A temporary exemption under EX07 is valid for 90 days from approval and may be subject to conditions imposed by AMSA. Consecutive or subsequent temporary operations applications may be made; however, there is no guarantee that it will be issued.
2. Division 3 (Temporary operations – sea trials): offers an exemption for a maximum period of 14 days for the purpose of undertaking sea trials. The vessel must have undergone survey by an accredited marine surveyor, who must in turn give the owner and AMSA a signed document to the effect that the vessel can be operated safety during sea trials. This assumes that the designer or operator will be able to engage a suitable accredited marine surveyor who is familiar with and able to undertake surveys for ASVs (this is more likely where a vessel complies with the NSCV).

1.3 TAS Support

Trusted Autonomous Systems (TAS) have developed best practices and guidance documents that "guides people who design, build, manufacture, own, operate or regulate these vessels and aims to assist in achieving certification under the Australian maritime regulatory framework. TAS created three documents and supporting reference material that were very useful in the EMAPS assessment AMSA requirements:

1. "The Australian Code of Practice for the Design, Construction, Survey and Operation of Autonomous and Remotely Operated Vessels, Edition 1 (published April 2022 by Trusted Autonomous Systems)" (Trusted Autonomous Systems, 2022);
2. "Guidance Materials to support the Australian Code of Practice for the Design, Construction, Survey and Operation of Autonomous and Remotely Operated Vessels" (Trusted Autonomous Systems, 2022); and
3. COLREGs Operator Guidance Framework (Trusted Autonomous Systems, 2023).
   These three documents were invaluable in assessing the process and compliance of the EMAPS ASV and understanding of the right AMSA processes and steps required.

1.4 AAUS Support

Organizations such as Australian Association for Uncrewed Systems (AAUS) (Australian Association for Uncrewed Systems, 2023) and Trusted Autonomous Systems (TAS) (Trusted Autonomous Systems, 2023) are independently advocating for, and facilitating advancements in the autonomy space, including the ethical, legal, regulatory and technology domains.

2 Materials and Methods

This paper was developed as a case study, documenting the real-life experiences of Gibbs & Cox Australia's (GCA) 2023 EMAPS Autonomous Surface Vessel (ASV) R&D project. GCA used The Australian Code of Practice for the Design, Construction, Survey and Operation of Autonomous and Remotely Operated Vessels, Edition 1 (published April 2022 by Trusted Autonomous Systems) (Trusted Autonomous Systems, 2022), associated Guidance Materials (Trusted Autonomous Systems,

2022), and COLREGs Guidance Framework (Trusted Autonomous Systems, 2023) to understand and guide EMAPS' AMSA certification and entry to service. EMAPS was designed and built to AMSA standards with the aim to obtain approvals to operate in Australian waters[†]. This paper offers conclusions and recommendations for the Australian maritime industry and associated regulatory and advisory bodies.

3 Discussion

A significant challenge for the EMAPS project has been to identify what construction standards apply to the build of the EMAPS ASV and what certifications, infrastructure and operator training are required to operate the EMAPS vessel.

Primary EMAPS design considerations as relate to standards and regulation compliance were:

1. The safe design of the vessel, and parameters that would allow its safe operation for operators in Australia and world-wide.
2. Understanding which NSCV and IMO requirements that EMAPS, as an autonomous uncrewed vessel, would not, could not or should not apply.
3. Understanding AMSA survey requirements and approaches that would apply to certifying the EMAPS ASV for use in Australian waters.
4. Understanding the guidelines, forms, and approach that TAS CRC has documented in their efforts to support the certification and entry into service of domestic commercial vessels for use in Australian waters and how TAS documentation relates to AMSA documentation; and
5. Understanding the delta between Australian and International standards to support development of a vessel that can be built and operated in other jurisdictions.

3.1 TAS Process to Determine In-Survey or Exempt

The process of determining whether a vessel is "In Survey" or "Survey Exempt" is driven by a variety of factors based on the size and speed of the vessel, whether it will carry passengers and crew. TAS Australian Code of Practice indicates applicability to autonomous surface vessels (a) less than 12 meters in length; and (b) limited to an operational speed of 10 knots – this is consistent with AMSA guidance. EMAPS is 5.85m long and has a speed of up to 17 knots, so according TAS and AMSA Guidance would apply for certificate of survey, but discussion with AMSA concluded that the intent of the Guidance assessment would direct EMAPS down the path of exemption from survey requirements.

3.2 Assessment of Compliance to Code

The following steps are specified in the TAS Guidance Materials and Code of Practice (Trusted Autonomous Systems, 2022, p. 20) and are intended to assist with determining compliance to AMSA standards. The EMAPS SMS captures the Concept of Operations, Design Risk Assessment, Operations Risk Assessment, Emergency Plan, COLREG compliance and Crewing Assessment in the EMAPS Safety Management System.

1. Prepare a Concept of Operations.
2. Prepare a System Design Risk Assessment.

[†] At the time of writing, EMAPS exemptions have been drafted but not yet submitted for approval

3. Prepare and implement a Safety Management System.
4. Prepare an appropriate crewing assessment in accordance with Marine Order 504.
5. Ensure that the vessel complies with applicable COLREGs requirements.
6. Complete the Design Record Template to assist with COLREG compliance assessment; and
7. Comply with the Chapters of the Code identified in (Trusted Autonomous Systems, 2022).

3.3 Risk Assessment

TAS Australian Code of Practice for Autonomous and Remotely Operated Vehicles (Trusted Autonomous Systems, 2022, p. 54) indicates that the builder should conduct a Risk Assessment using a "recognized methodology" for undertaking the risk assessment and references MSC-MEPC.2/Circ.12/Rev.2 Revised Guidelines for Formal Safety Assessment (FSA) (International Maritime Organization, 2018).

EMAPS risk identification was performed during the development of the EMAPS Safety Management System (SMS) and through the process of identifying operating procedures and emergency procedures elicited more risk areas than through use of the prescribed FMEA process. The act of developing and documenting operating procedures and emergency plans was better at identifying failure modes and effects and creating controls than the FMEA activity which can be a somewhat arbitrary procedural necessity that does not elicit the necessary critical thinking. The greatest value of the FMEA was to identify areas that were not considered during SMS development.

3.4 AMSA Vessel Category for ASVs

AMSA applications for EMAPS exemption to survey requirements necessitate identifying the category of vessel. EMAPS does not cleanly fit any existing AMSA vessel categories, and many ASVs and USVs because of their novel design solutions similarly do not fit the conventional classifications, or even the accommodations recently made for Novel Vessels. There is currently no ASV category, nor is there a category for environmentally powered vessels other than Sailboats. Although EMAPS is "novel" (different from the mainstream), the term has a specific meaning to AMSA "autonomous vessels greater than twelve meters in length, or those intending to carry people" or, Vessels with electric propulsion and installed battery power exceeding 30kWh – EMAPS is not Novel in AMSA's definition of the term. (Australian Maritime Safety Authority, 2022).

3.5 AMSA Accredited Marine Surveyors

The project considered deferring surveyor engagement and CoS/exemption costs to 2024 by deferring the CoS and exemptions plan review and applications. Deferring certification or exemptions would only introduce unnecessary design change and additional costs later, so the project engaged accredited platform and electrical Surveyors to provide early, objective verification of the design, to apply for exemptions, and to guide the project through applications for exemptions. The EMAPS experience with engagement of AMSA and the EMAPS Surveyors has been extremely positive. The AMSA team have been very responsive and provided excellent advice in terms of the process, design requirements, and exemptions applications. Survey was conducted in three phases:

1. Plan Review
2. Construction Survey
3. Commissioning Survey

3.6 Safety Management System

The EMAPS Safety Management System (SMS) was developed to include all details associated with the Vessel Details, Concept of Operations, Certification Process, Operating Procedures, Risk Assessment and Emergency Plan as recommended in the TAS Australian Code of Practice for Autonomous and Remotely Operated Vehicles chapters and Marine Order 504 (Federal Register of Legislation, 2023). The Safety Management System was used as a collector for all EMAPS Design Decisions, Risk Assessment, Operational Procedures, and Emergency Procedures. It has been a critical document for the design of the EMAPS vessel and will be maintained and used in perpetuity for future design and operations. The process of creating the EMAPS SMS also identified risks that require controls and was a useful exercise in developing and validating the EMAPS design and operating procedures.

3.7 Concept of Operations

EMAPS is designed as an environmentally powered Autonomous Surface Vessel (ASV). As a prototype vessel, EMAPS will always be under remote control, although the vessel autonomy software will control all systems and the vessel maneuvering under supervision of the operator at the Shore Control Station (SCS).

The SCS operator will have a full situational awareness (cameras, AIS, Radar (production vessel), Lidar (production vessel) and the ability to take positive control at any instant. Development of the Concept of Operations in the Safety Management System was an essential contributor to the EMAPS COLREG Compliance Assessment, Operational Procedures, Safety Design Elements, Operational Risk Assessment and to Autonomy Software design parameters. The EMAPS Project is training one “competent person” through an Australia Maritime College (AMC) Unmanned Surface Vessel (USV) Operator Course to support test and trials.

3.8 AMSA Exemptions & Equivalences

Exemptions are an alternative to obtaining a certificate of survey and require comprehensive documentation of vessel design, Concept of Operations and Safety Management System. EMAPS will seek exemption from survey requirements. EMAPS required several clarifications and equivalences to clarify EMAPS NSCV and COLREG compliance in areas relating to responsibilities between vessels, visual watch, and shore control.

3.9 AMSA Certificate of Operation

In addition to certificate of survey or exemption from survey requirements, AMSA requires a certificate of operation for the vessel which is applied for in parallel with the certificate of survey or application for exemption to the crewing requirements of Schedule 1 of Marine Order 504. (Federal Register of Legislation, 2023, p. Division 2).

Marine Order 504 requires, as a condition for a certificate of operation, that the owner or operator undertake an appropriate crewing evaluation and that a crew member have a certificate of competency per Marine Order 505. For uncrewed ASVs, an exemption from the requirement to have crew on board is typically warranted, but the ASV will still require remote crew with an appropriate certificate of competency. This is consistent with IMO guidance for remote operated vessels.

The EMAPS project has addressed this requirement and exemption application by documenting a crewing evaluation in the EMAPS SMS. The EMAPS crewing assessment identifies crew competencies and requirements, including minimum crew requirements for launch, recovery and safe operations of the vessel, and associated shore control station ASV operator requirements, which are

based on curriculum currently in development by the Australian Maritime College with the Royal Australian Navy and AMSA.

4 Conclusions and Recommendations

The EMAPS project concluded through review of TAS and AMSA documentation, discussion with AMSA staff and AMSA Accredited Surveyors that the EMAPS project should:

1. Apply for exemption to survey requirements
2. Seek a certificate of operation
3. Train at least one team member to monitor and control the EMAPS ASV

Project deliberations and preparations of certification artefacts yielded several lessons and resultant recommendations that can be addressed in AMSA regulatory framework and TAS guidance documents:

1. Develop an ASV certification framework in consultation with industry and TAS.
2. Incorporate TAS Guidance & examples in AMSA documentation set.
3. Adopt TAS COLREGs Guidance Framework. (Trusted Autonomous Systems, 2023).
4. Develop a process for certifying Autonomy Software and Shore Control Stations.
5. Safety Management System (SMS) assessed for quality and content in Initial Plan Review.
6. Develop a Vessel Category for ASVs, based on size and kinetic energy.
7. Develop Standards for ASV Autonomy Software and Control Systems Functionality.
8. Develop Standards for ASV Software Assurance and Cyber Security.
9. Create ASV Generic Equivalent Solutions (GES) and reference them in TAS Guidance.
10. Create GES for situational awareness sensors and processing capabilities.
11. Incorporate Risk Identification and Controls in Safety Management System requirements.
12. Rationalize and simplify Risk Assessment between TAS and AMSA.
13. Establish requirements for Safe States and Vessel Identification, including visible markings, radar reflectors, AIS reporting, manoeuvring behaviours (e.g., full stop).
14. Establish requirements relating to behaviours in loss of communications, loss of power / propulsion, unsafe behaviours by other vessels.
15. Codify a USV Operator Course as a requirement for operation of small ASVs.
16. Develop an incremental certification process for developmental vessels aligned to IMO four-tier definition of Autonomous Ships (International Maritime Organization, 2021).

IMO is undertaking its own review and update of COLREGS and SOLAS rules. AMSA should align to IMO update plans regarding Maritime Autonomous Surface Ships (MASS) (International Maritime Organization, 2021):

Issue		Planned activities and result
1	**Consideration of a holistic approach to MASS operations in IMO instruments**	
	Development of a goal-based MASS instrument	Consideration on how to develop a new MASS instrument and draft amendments to the applicable instruments through which it can be made mandatory
	Definition of MASS	Consideration on the need to revise definition and/or degrees and if revision is deemed necessary, agreeing on the definition and/or degrees
	Terminology for MASS operations in the IMO regulatory framework	Consideration on the need of supplementing terminology, and if deemed necessary, agreeing on such terminology
	High-priority common gaps and themes in relation to MASS operations and IMOs regulatory framework: - Meaning of Master, crew or responsible person - Remote control station/centre - Remote operator designated as seafarer	Consideration of the high-priority common gaps and themes
	Non-mandatory instrument	Consideration of the development of guidelines for MASS operations such as guidelines for installation and guidelines for system application

Figure 1: AMSA should align to IMO Maritime Safety Committee planned updates

In summary, the maritime autonomy community needs a clear, concise and cohesive pathway for autonomous surface vessels certification and operation. The right approach will allow flexibility in initial and periodic survey requirements and processes, especially as relate to novel designs, but also for extant systems. The TAS tools – COLREGS tool, RAS Gateway and Code of Practice (CoP) – are a great start but should be integrated into the AMSA ecosystem and aligned to impending IMO and AMSA developments.

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