Analysis of the current regulatory landscape for autonomous and remotely operated vessels in development and use by the Australian Defence maritime enterprise.

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Synopsis

The development and use of autonomous and remotely operated vessels ('autonomous vessels') is a focus area for militaries across the globe, including the Australian Defence Force. These vessels offer opportunities to extend naval capability, including by increasing reach and efficiency while reducing safety risks and environmental impact. In order to translate these opportunities into capability the vessels must be capable of compliance with applicable regulatory frameworks. This paper supports this outcome by analysing the existing applicable regulatory frameworks in Australia, identifying the unique regulatory considerations for autonomous vessels and adverse impacts of applying existing frameworks, and providing recommendations for Defence regulators to support efficient regulatory outcomes.

This paper identifies that autonomous vessels in Australia used for or in connection with a Defence purpose are subject to regulation under the same regulatory frameworks as traditional vessels. This includes under the Defence Seaworthiness Management System (DSwMS) and in some circumstances under Australian Maritime Safety Authority (AMSA) legislation. In addition, autonomous vessels are subject to State and Territory local waterways and environmental management requirements, local port requirements, and work health and safety obligations.

This paper identifies that the fundamental assumptions made by existing regulatory frameworks, for example that a human will be on board and supervising a vessel, and the fundamental differences between traditional vessels and autonomous vessels, for example their size and lifespan, gives rise to a range of regulatory considerations from a safety, environmental, and flag perspective, together with potential adverse impacts.

This paper draws on the conclusions reached regarding the current regulatory landscape for autonomous vessels, together with the experience of the authors, to put forward a series of recommendations for Defence regulators to consider in approaching and executing the regulation of autonomous vessels to ensure the opportunities presented by these vessels can be fully leveraged. These recommendations relate to (1) proactively seeking to enable test, trial and operation; (2) domestic and international collaboration; and (3) regulatory development.

Key words: Seaworthiness; Regulation; Emerging technology; Autonomous vessels

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1. Introduction

The development and use of autonomous and remotely operated vessels (autonomous vessels) is a focus area for militaries across the globe, including for the Australian Defence Force. These vessels are capable of supporting and extending existing capability, as well as establishing wholly new capabilities. The Royal Australian Navy (RAN) has recognised that "employing RAS-AI [Robotics, Autonomous Systems and Artificial Intelligence] will enable a more agile, resilient, and lethal fighting force, enhancing Navy's ability to Fight and Win at Sea." (Royal Australian Navy, 2022). In order to translate the potential offered by autonomous technology into operational outcomes, it must be capable of compliance with applicable regulatory frameworks. Inability or a high level of difficulty in understanding regulatory requirements and achieving compliance jeopardises the likelihood of successful translation of these disruptive new technologies into capability.

In an Australian defence context, autonomous vessels that are considered maritime mission systems are subject to the Defence Seaworthiness Management System (DSwMS). Understanding the regulatory landscape for autonomous vessels, the unique considerations and challenges, and identifying areas of future focus for regulatory development, is imperative. The conduct of this analysis will inform the Defence Seaworthiness Regulator (DSwR), being the steward of DSwMS, and her office, the Office of the Defence Seaworthiness Regulator (ODSwR), regarding whether regulatory reform activities are required to support the uptake of autonomous vessels within the Australian defence maritime community and what they could include. This analysis will also inform and possibly guide other defence regulators making the same assessments for their own regulatory frameworks.

This paper leverages the expertise of practitioners across the fields of regulation, flag administration, safety, and environment to analyse the current regulatory landscape for autonomous vessels used by the Australian defence maritime community, with a focus on the application of existing seaworthiness requirements. Drawing on the analysis conducted, this paper will argue that DSwMS is capable of successful application to autonomous vessels, particularly when supported by high quality guidance material, and strong, sustained engagement between DSwR and the regulated community. The paper will conclude by identifying a number of recommendations for Defence regulators to consider in approaching and executing the regulation of autonomous vessels.

2. What are autonomous vessels and why are they being used by defence forces

Autonomous and remotely operated vessels (autonomous vessels) utilise robotics, autonomous technology and artificial intelligence to operate with a spectrum of human involvement from hands on remote control through to limited or no supervision. Autonomous vessels have been in development and use since the 1970s, but rapid increases in capability and availability from approximately 2015 onwards has seen increasing use for commercial and defence purposes (Horne et al, 2023). These vessels, including both sub-surface and surface variants, are the subject of significant science and technology investment by militaries, including within Australia (Australian Government, 2024), the United States of America (Defense News, 2023) (DefenseScoop, 2024) and the United Kingdom (United Kingdom Parliament, 2023). The Royal Australian Navy (RAN) have recognised that "employing RAS-AI will enable a more agile, resilient, and lethal fighting force, enhancing Navy's ability to Fight and Win at Sea." (Royal Australian Navy, 2022).

Increased use of autonomous vessels by Defence could reduce the overall impact of maritime operations on the environment, for example by reducing emissions (CO_2, NO_2, SO_2) and pollutant discharges such as oil, fuel, sewage and garbage. (Grome, 2018) (McCarl, 2023) (Cross, 2023). Further, facilitating the use of autonomous vessels in Defence operations may accelerate Australia's transition to clean energy and contribute to its net zero greenhouse gas emissions target by 2050.[2]

In the 2020s the majority of autonomous vessels under development and use are small in nature, generally ranging from <0.1m up to 12m in length (Horne et al, 2022). This size reflects the dominant use cases, being hydrographic survey, mine counter measures and persistent surveillance, together with common understandings of existing domestic regulatory frameworks that scale regulatory requirements to specific size brackets (Horne et al, 2022). Larger autonomous vessels are in use in the United States of America (USNI News, 2023), and are expected to be integrated into the RAN in the future, including for undersea warfare (Australian Government, 2024) (Austal, 2024). **Figure 1** provides examples of autonomous vessels in use in a defence context.

[2] *Climate Change Act 2022* (Cth) s 10(1).

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Figure 1 Compilation image of autonomous and remotely operated vessels used by Defence by Dr Rachel Horne, individual images sourced from Defence Image Gallery April 2024.

3. The regulatory landscape for autonomous vessels used in defence contexts

Autonomous vessels are regulated under the same defence and civilian regulatory frameworks as traditional crewed vessels. This means they are subject to the DSwMS, which requires the Capability Manager (CM) or their delegate to have in place a Seaworthiness Case supported by a Compliance Strategy that addresses governance and management compliance obligations (GMCOs) and activity and condition based compliance obligations (ACCOs). Vessels must also be registered on the Defence Vessel Register, which is administered by ODSwR. For autonomous vessels not included in a Seaworthiness Case and Compliance Strategy there must be an Operating and Support Intent (OSI) and Safety Case[3] in place, and the vessel must be registered on the Defence Vessel Register or equivalent.[4] DSwR has issued guidance to support the regulated community to comply with these requirements.[5]

The new Australian Naval Classification Authority (ANCA) also forms part of the DSwMS, and has recently published the Australian Naval Classification (ANC) Manual. This Manual includes the ANC Policy, the ANC Rules, and ANC Design Notes. The ANC Rules are a prescriptive materiel ruleset similar to that of a class society, and will include a specific division for remote and autonomous systems[6] (ODSwR, 2024).

In some circumstances autonomous vessels used in a defence context are also subject to regulation by the Australian Maritime Safety Authority (AMSA), as either domestic commercial vessels under the *Marine Safety (Domestic Commercial Vessel) National Law Act 2012 (Cth)* (DCV National Law Act) or as regulated Australian vessels under the *Navigation Act 2012 (Cth)* (Navigation Act). AMSA's regulation applies by default where the autonomous vessel is a "vessel", unless a carve out provision applies, for example where the vessel meets the definition of 'defence vessel' in the DCV National Law Act, or 'naval vessels' in the Navigation Act. The key Australian maritime safety frameworks are depicted in **Figure 2**.

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[3] This Safety Case must demonstrate that efforts have been made to eliminate or minimise so far as is reasonably practicable (SFARP) hazards/risks to personnel, the public and the environment, as per: *Defence Seaworthiness Management System Guidance, Making a seaworthiness case for autonomous and remotely operated vessels (autonomous vessels) which are Maritime Mission Systems in the Defence context. 2024.*

[4] Note ODSwR, the steward of the Defence Vessel Register, are working to implement a Defence Autonomous Vessel Register for non-flagged autonomous vessels, which will sit alongside the Defence Vessel Register.

[5] For more information see: Royal Australian Navy, Office of the Defence Seaworthiness Regulator, Defence Seaworthiness Management System Guidance: Making a seaworthiness case for autonomous and remotely operated vessels (autonomous vessels) which are Maritime Mission Systems in the Defence context. 2024.

[6] For more information see: [Australian Naval Classification Authority | Business & Industry | Defence](#).

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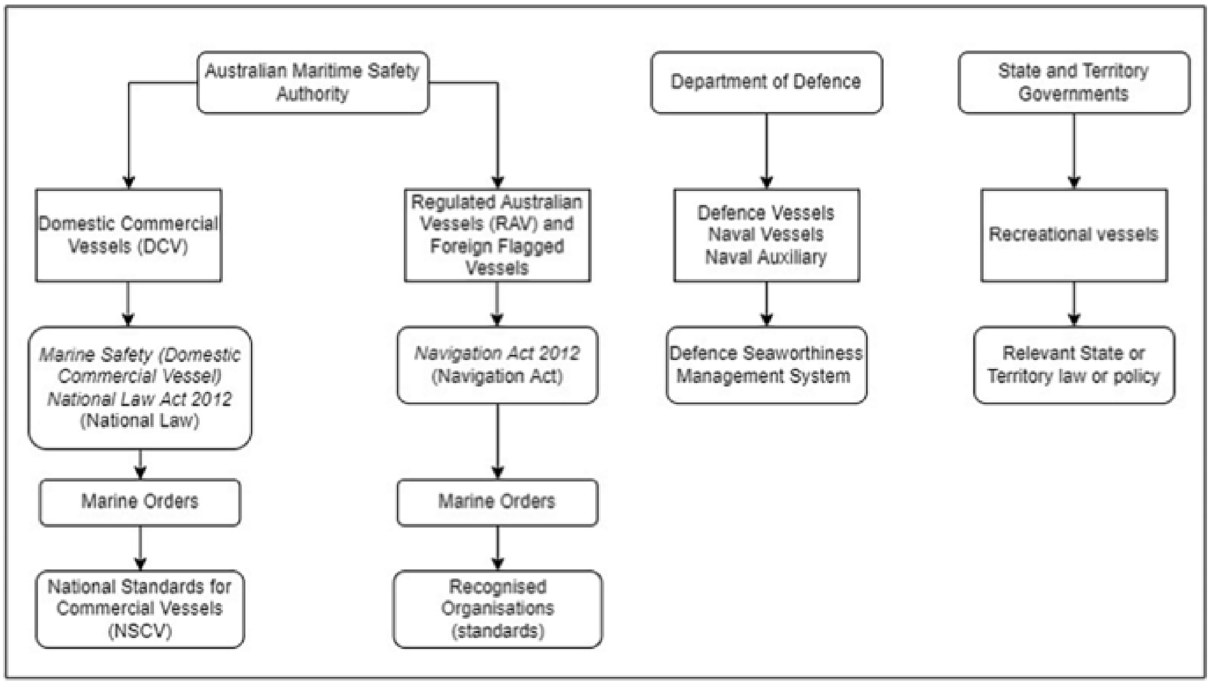

Figure 2 Four key maritime safety frameworks in Australia (Humphries et al, 2023).

a. The Defence Seaworthiness Management System (DSwMS) and how it applies

The DSwMS is a Defence-wide goals-based maritime risk management framework that applies to all maritime mission systems.[7] It provides the framework, policies and procedures that inform the actions and decisions of Defence personnel on the nature and scope of employment of mission systems, including ships, submarines, powered and non-powered vessels of any size, diving systems, unmanned underwater vehicles including remotely operated systems, and water borne drones.[8] The system is broad in its remit, regulating capability in a maritime context.

The intent of DSwMS is to support achievement of the Seaworthiness Outcome, which is defined as "to maximise the likelihood of achieving the specified operational effect for the defined tasking, where efforts have been made to eliminate or minimise so far as is reasonably practicable (SFARP), hazards/risks to personnel, the public and the environment."[9] It does this by supporting Defence to achieve operational effect by integrating hazard and risk considerations into decisions and activities across the entire Capability Life Cycle.

Notably the defence regulatory structure uses a three lines of defence model, whereby the third line directs how hazards and risks are to be managed in the context of the enterprise objectives (DSwMS); the second line provides the systems of hazard and risk control (for example through Navy's Safety Management Systems and Environmental Management Systems), and the first line conducts the core business.

DSwMS is codified in the Defence Seaworthiness Management System Manual[10], which includes volumes on system description, operations and administration; the GMCOs; the ACCOs; and independent seaworthiness management review. The core of DSwMS are the GMCOs and the ACCOs, as depicted in **Figure 3**.

The ANCA and ANC Rules support the attaining and maintaining of classification as part of achieving the Seaworthiness Outcome for new and existing vessels. The ANC Rules are a sovereign naval ruleset that combine best practice international shipping rules with Australian defence rules to comply with Australian requirements (Australian Government, 2024). The ANCA Handy Billy provides an accessible guide that explains the framework, how it applies, and the relevant processes.[11] The interface between the GMCOs, ACCOs, and ANC rules is being established collaboratively by ANCA and ODSwR, which sit side by side under the DSwR.

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[7] A maritime mission system is the element of a capability that directly performs the operational function, for example a ship or a distributed system such as a communications network.
[8] The Defence Administrative Policy ME2 – Defence seaworthiness management system, 04 December 2018.
[9] Defence Seaworthiness Management System Manual, Vol 002 Part 001, 04 December 2018.
[10] Defence Seaworthiness Management System Manual, Ed 3, 4 Dec 2018.
[11] For more information see: The Australian Naval Classification Authority Handy Billy published Feb 2024; and https://www.defence.gov.au/business-industry/industry-governance/australian-naval-classification-authority.

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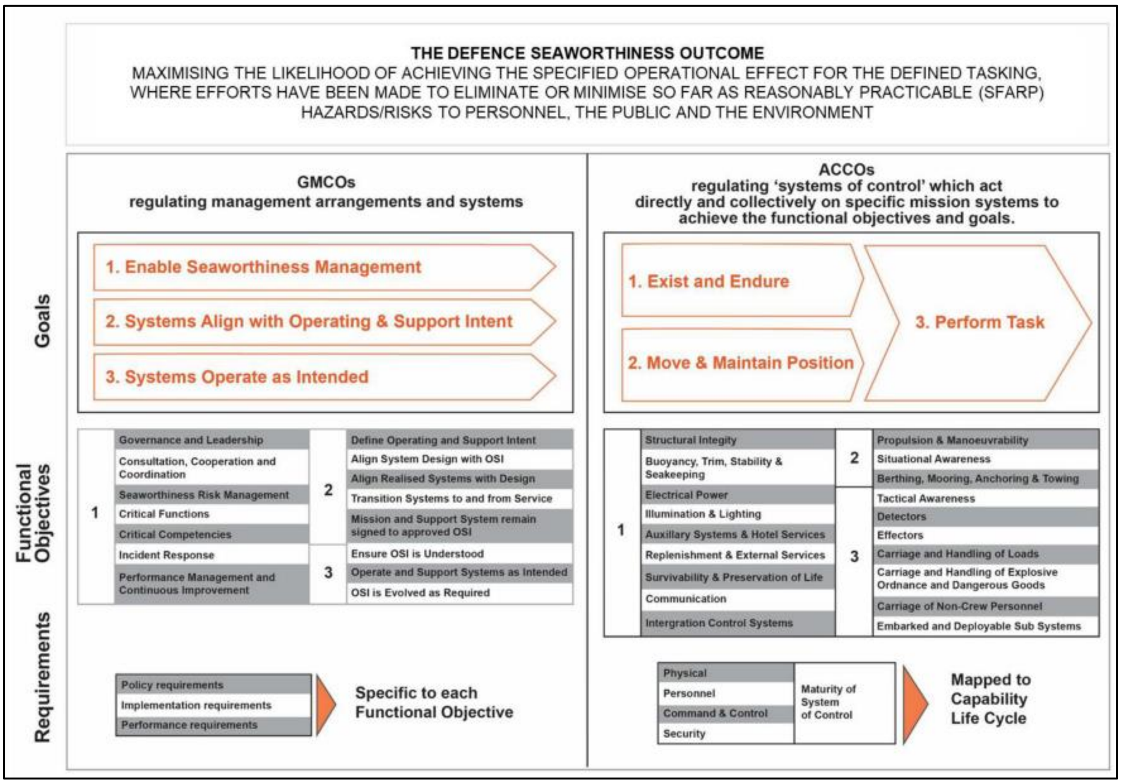

Figure 3 DSwMS Regulatory Framework

As mentioned above, the DSwMS requires each maritime mission system to be managed by the Capability Manager under a Seaworthiness Case, as depicted in **Figure 4**. This document is to be developed and managed in accordance with the Capability Manager's compliance strategy to DSwMS.[12] DSwR provides guidance on compliance with DSwMS through provision of fact sheets, case studies, training sessions, and consultation. ODSwR also conducts compliance and assurance activities to support compliance with DSwMS and achievement of the Seaworthiness Outcome.

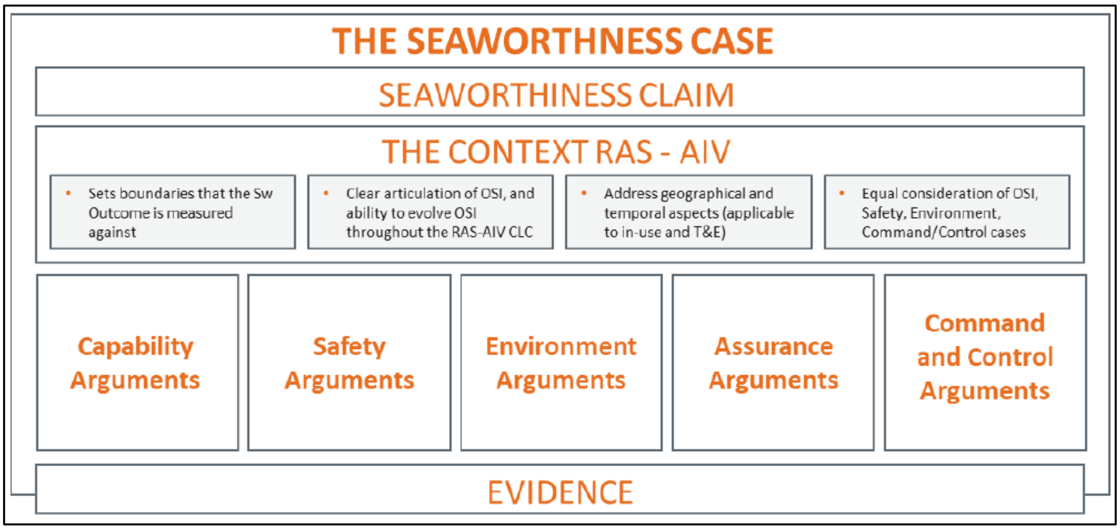

Figure 4 Structure of a Seaworthiness Case

[12] Defence Seaworthiness Management System Manual, Vol 001 Part 00, 04 December 2018.

b. Regulatory requirements under the DCV National Law Act and Navigation Act

Autonomous vessels used in a defence context are often subject to regulation by AMSA. This is either as a domestic commercial vessel under the DCV National Law Act or as a regulated Australian vessel or foreign vessel under the Navigation Act, as per **Figure 5.**

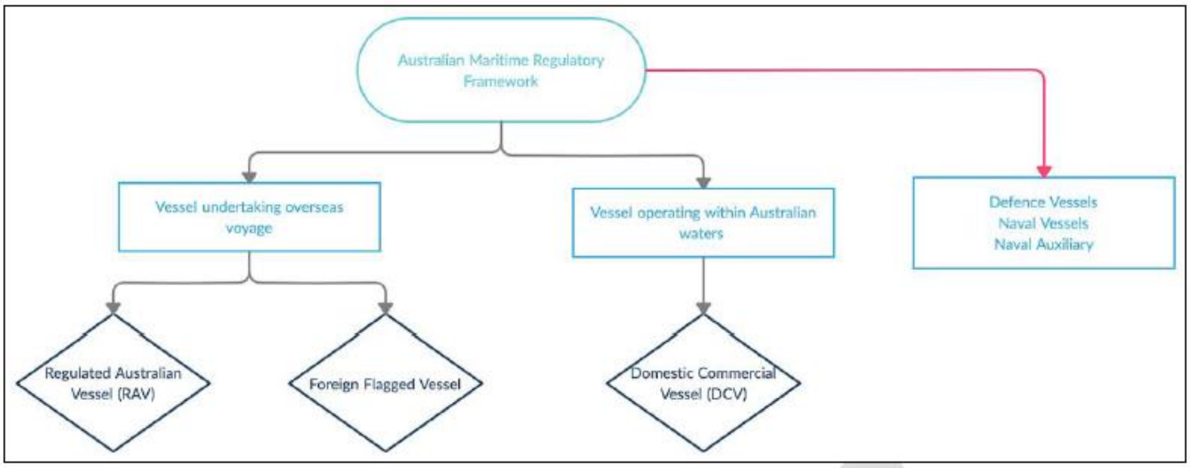

Figure 3 Categorisation of vessels in Australian maritime regulatory framework (Horne, 2024)

AMSA's regulation applies to a vessel used in connection with a commercial, governmental or research purpose unless a carve out provision applies, for example where the vessel meets the definition of 'defence vessel' in the DCV National Law Act, or 'naval vessels' in the Navigation Act.[13] The definition of 'defence vessel' requires that a vessel is:

(a) a warship or other vessel that

(i) is operated for naval or military purposes by the Australian Defence Force or the armed forces of a foreign country; and

(ii) is under the command of a member of the Australian Defence Force or of a member of the armed forces of the foreign country; and

(iii) bears external marks of nationality; and

(iv) is manned by seafarers under armed forces discipline; or

(b) a Government vessel that is used only on government non-commercial service as a naval auxiliary.

As there is no determination making power in either Act, AMSA cannot 'determine' if a vessel fits into the above definition but it can provide guidance to Defence. Only courts can determine the 'correct' interpretation of legislative provisions against specific circumstances. While it is undecided in a formal legal context whether autonomous vessels are capable of being 'defence vessels' or 'naval vessels', existing literature indicates they are (Horne, 2024). Commentary by Liivoja, Massingham and McKenzie indicate that "the command requirement does not necessitate direct oversight by a (human) commander for every decision made, but rather requires asking whether the system is fulfilling the intent of the commander." (Liivoja et al. 2022).

i. Requirements for domestic commercial vessels

Autonomous vessels that are domestic commercial vessels (DCVs) must comply with the requirements under the DCV National Law Act. Compliance requires:

- Vessels must:
  - have a Unique Vessel Identifier (UVI);
  - have a Certificate of Survey; and
  - be listed on a Certificate of Operation.
- The Master and Crew must have the required Certificates of Competency; and
- General Safety Duties must be complied with.

Flexibility mechanisms include specific and general exemptions, and equivalent means of compliance, which may be accessed to modify applicable regulatory requirements. All autonomous vessels to date have relied on exemptions to operate, noting regulatory requirements assume that humans are on board operating and supervising the vessel (Trusted Autonomous Systems, 2022).

[13] For more explanation of AMSA's regulatory framework see R Horne, T Putland, T Roberson and C East, (2022), Body of Knowledge: Assurance and Accreditation of Autonomous Systems in Australia, Edition 1, Trusted Autonomous Systems.

ii. Requirements for regulated Australian vessels

Autonomous vessels that are regulated Australian vessels must comply with the Navigation Act, Navigation Regulation 2013 (Cth), and Marine Orders 1 – 98. International convention requirements are incorporated into these instruments, including the International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL). For example, vessels must hold the required certificates, which may include:

- Certificate of class;
- Safety certificate/s and minimum safe manning certificate;
- Safety management system certificate;
- International oil pollution prevention certificate;
- International loadline certificate; and
- Maritime labour certificate.

Regulated Australian vessels over 12m in length must also be registered under the Shipping Registration Act 1981 (Cth).

The Navigation Act applies predominantly to large vessels that travel beyond the Australian Exclusive Economic Zone (EEZ) and it is not clear how this translates to small autonomous vessels. Flexibility mechanisms are limited, noting the specific international conventions under which specific requirements originate from may or may not allow a Flag State to grant an exemption from relevant requirements (Humphries et al, 2023).

c. Other regulatory requirements

All vessels, whether autonomous or not, must comply with applicable requirements arising from State or Territory legislation, such as local waterways management and environmental management requirements, together with work health and safety legislation and port-specific requirements.

4. Unique regulatory considerations for autonomous vessels under the DSwMS

There are unique regulatory considerations for autonomous vessels under both DSwMS and AMSA's regulatory framework. This paper is written in a defence context and will focus on the DSwMS. Applying the existing DSwMS framework to autonomous vessels is challenging because they are fundamentally different from crewed vessels. For example, autonomous vessels do not have humans on board to operate and supervise the vessel; instead they use sensors to perceive the operating environment and software programs to fuse and interpret data and make decisions (Horne et al, 2023) (Devitt et al, 2021). They are also often significantly smaller than crewed vessels, may be built using different materials, and may be iteratively developed with a short life span (Humphries et al, 2023) (Horne, 2021). There are also no tailored technical standards incorporated in existing Australian regulatory framework, which provide a best practice benchmark for these vessels, including from a safety and environment perspective (Horne, 2021). There is, however, a voluntary standard, the Australian Code of Practice for the Design, Manufacture, Survey and Operation of Autonomous and Remotely Operated Vessels, published by Trusted Autonomous Systems Defence Cooperative Research Centre (TAS), which may be utilised.[14] For all of these reasons, a range of unique considerations are required.

A Safety and Environment Case needs to be established as part of the Seaworthiness Case, which considers the unique risks associated with the operation of an autonomous vessel and identifies appropriate controls (ODSwR, 2024). The Safety and Environment Case contributes to achievement of the Seaworthiness Outcome by demonstrating that efforts have been made to eliminate or minimise so far as is reasonably practicable hazards/risks to personnel, the public and the environment. Specific considerations are set out below.

[14] 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).

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a. Safety considerations

There are unique safety considerations related to the operation of autonomous vessels. For example, the utilisation of an autonomous, semi-autonomous or remote operating system reliant on sensors and real time integration of data presents unique risks. Additionally, the varying ways that autonomous vessels are built, powered, and operated also creates unique risks. The lack of an agreed best practice technical standard that identifies and considers these unique safety risks increases the need to highlight these considerations. Examples relevant considerations are set out in **Table 1** below.

Table 1: Examples of Unique Safety Considerations

Issue	**Explanation**
Safe handling and storage	Proper handling, storage, and transportation of autonomous vessels, explosive ordnance and dangerous goods are essential for preventing conditions that could compromise safety. For example, additional fire detection and suppression systems in storage areas may be required to enhance on-board safety and mitigate the consequences of fires or explosions.
Integration of autonomous sub-systems	Integrating autonomous sub systems into larger vessels requires planning, coordination, and consideration of safety implications to ensure seamless operation. For example, the risk of overloading emergency response systems when integrating multiple novel autonomous systems onto larger vessels. It is crucial to conduct thorough, coordinated risk assessments to ensure that emergency response systems and capabilities are robust enough to control for the additional demands posed by the integration of deployable autonomous sub systems. This may involve upgrading emergency response equipment, changing designs, increasing storage areas, and implementing emergency redundancy measures. Further, additional training to personnel may be required to effectively manage emergencies associated with the integrated systems such as regular drills, simulations, and training exercises.
Safe access and egress	Providing safe access to critical components and systems for maintenance personnel is important for preventing accidents and injuries. Designing access points, walkways, and ladders in compliance with safety regulations and ergonomic principles ensures that technicians can perform tasks efficiently without exposing themselves to unnecessary hazards. Additionally confined spaces may be present on-board autonomous maritime vessels, posing unique safety challenges for maintenance personnel due to limited access, restricted ventilation, and the potential for hazardous atmospheres.
Lithium-Ion battery safety	With the increasing use of lithium batteries to power various systems on-board autonomous maritime vessels, ensuring their safe integration, storage and handling, and maintenance is paramount. Developing comprehensive emergency response plans and procedures for battery-related incidents, such as fires, thermal runaway, or smoke emissions, is key to safeguarding personnel, protecting property, and minimising environmental impact.
Training and certification	Maintenance technicians working on autonomous vessels require specialised training and certification to perform their duties safely and effectively. Training programs should cover relevant topics such as equipment operation, maintenance procedures, safety protocols, and emergency response techniques and any required high-risk work licensing requirements and certifications.
Notification of incidents	Reporting autonomous incidents to the Regulator is crucial for identifying potential trends, improving safety protocols, and preventing future accidents in maritime operations. Reporting thresholds are being considered, and should be set based on the severity and impact of incidents, considering factors such as injuries, environmental damage, property damage, and operational disruptions. A tiered system will be considered, with potential mandatory reporting to the Regulator for serious incidents such as collisions, groundings, or spills, while minor incidents may require internal documentation for review and tread analysis* [*Note this is speculative and, at the date of submission of this paper, has not been formally endorsed by the Defence Seaworthiness Regulator or Defence Seaworthiness Authority.]*

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b. Environmental considerations

There are unique environmental considerations related to the operation of autonomous vessels, for example based on materials used for construction and payloads, their power source, the areas they operate in, the possibility they are lost and remain in the ocean, and the potential for underwater collision with marine life. Examples of specific hazards and risks are set out in **Table 2** below.

Table 2: Environmental Hazards and Risks

Hazards and Risks	Consequences
Storage and transportation[15]	Fires and release of contaminants to the environment
Recharging of batteries or refuelling activities (Trusted Autonomous Systems, 2022)	Fires and release of contaminants to the environment
Loss of 'Command and Control' (Roberts et al, 2019)	A failsafe mode, loss or scuttling of the vessels, leading to the release of contaminants to the environment in short and long terms
Entanglement (Australian Institute of Marine Science, 2022)	Damage or loss of seagrass and other marine flora
Seabed damage (Royal Australian Navy, 2023)	Damage or loss of seagrass, other marine flora, and the seabed itself
Collisions with marine fauna (Australian Government, 2013)	Injury or death of marine fauna (Australian Government, 2017)
Propulsion system and undersea collisions with benthic substrates and reefs (Alcaide and Llave, 2020)	Damage or death of coral and sediment disturbance, causing erosion and/or turbidity in the water column
Biofouling/moving across different biological communities (Australian Government, 2009)	Introduce marine pests and disease translocation
Paints, anti-fouling coatings and biofouling cleaning procedures (Australian Government, 2015)	Contaminants and marine pests are released into the water column, which impact on water quality and biosecurity, respectively
Presence of other payloads and substances, including explosive ordnance, ozone depleting substances and synthetic greenhouse gases (Australian Government, 2021)	Explosions and/or the release of contaminants into the environment
Visual and noise disturbance (Australian Government, 2021)	Physiological effects from the propulsion systems and/or sensors, resulting in behavioural changes, injury or death of marine fauna
Disposal of autonomous vessels (Australian Government, 2023)	Release of contaminants to the environment

The DSwMS can enable the effective management of environmental risks posed by autonomous vessels, noting management of these risks is an embedded part of the framework. Additionally, the DSwMS requires a clear understanding of the Operating and Support Intent (OSI) of the capability, accountability frameworks to manage hazards and risks, and ensuring there is risk oversight and assurance. Further, the DSwMS and its compliance obligations can provide a means to address issues associated with deployment of autonomous vessels. These issues include the lack of on-board personnel to conduct organic level preventative maintenance and defect rectification, post-incident actions that would prevent or minimise harm to the environment, and dependence on non-detached and remotely located support systems for recovery or retrieval.

Through the OSI, DSwMS requires a clear articulation and understanding of the temporal and geographical operating aspects of autonomous vessels. For example, risks (including regulatory and reputational) can vary significantly in the presence of migratory species, within protected areas, and in areas deemed to have high social, heritage, and economic values (Royal Australian Navy, 2023). These temporal and geographical variations are a fundamental aspect of existing Defence maritime environmental controls, such as within the Maritime Activities Environmental Management Plan. The temporal and geographical operating aspects are also a significant factor in deploying autonomous vessels, especially regarding command and control, maintenance, emergency response and recovery/retrieval. Additionally, risks from externalities, which are heavily influenced by temporal and geographical factors (e.g. biofouling), should also be considered (Australian Government, 2022).

c. *Flag/Defence Vessel Register considerations*

Vessels within the Defence jurisdiction, which includes vessels owned and operated by Defence and used for or in support of a Defence purpose, are registered on the Defence Vessel Register.[15] Vessels on the Defence Vessel Register which are 'warships' fly the Australian White Ensign (AWE), and all other vessels generally fly the Australian National Flag (ANF). There are currently no autonomous vessels registered on the Defence Vessel

[15] For more information and to view the Defence Vessel Register see: https://www.defence.gov.au/business-industry/industry-governance/defence-seaworthiness-regulator/flag-administration-defence-vessel-register.

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Register which fly either the ANF or AWE*.[16] Doing so would generally indicate acceptance that the vessel is either a 'warship' or a 'naval auxiliary' as defined in the United Nations Convention on the Law of the Sea (UNCLOS). Notably, for an autonomous vessel to be subject to the rights and responsibilities entailed in UNCLOS for either warships or naval auxiliaries, they must be considered capable of meeting the relevant definitions (Liivoja et al, 2022) (Horne, 2024). The key problematic elements for warships is the definitional element "under the command of an officer duly commissioned by the government of the State" and "manned by a crew which is under regular armed force discipline." This definition is based on the premise that humans are on board the vessel, as either master and crew, special personnel, or passengers (Humphries, 2023) (Horne, 2024) (Trusted Autonomous Systems, 2022). Formal legal determinations are necessary to confirm an official position on this issue, however as stated above existing literature indicates the autonomous element is not insurmountable (Liivoja et al, 2022) (Horne, 2024). This understanding would entitle an autonomous vessel to fly either the AWE or ANF, and exercise the rights and protections that affords.

d. Other considerations: Cyber risk

A major risk related to the use of autonomous vessels is their susceptibility to cyberattacks, due to their heavy reliance on sensors, automation, and integration for operation. These components may be connected to the internet and satellites. Unauthorised interference with these automated systems can be achieved in various ways, including injecting malicious software into a navigation system, infecting the vessel's primary server with ransomware, and spoofing or jamming the vessel's Global Positioning System (GPS) or Global Navigation Satellite System (GNSS) (Akpan et al, 2022). If these critical systems are infiltrated, the vessel may lose its ability to navigate. For instance, spoofed GPS signals may enable hackers to reroute a vessel without triggering an alarm or alert (Hogg and Ghosh, 2016) (Starr, 2013). Unauthorised access to data may allow hackers to modify the data, resulting in misleading navigation information (Roberts et al, 2019). Expected consequences of these incidents could include collision, grounding, environmental damage, and defection (Alcaide and Llave, 2020). These hazards and risks must be identified in a Safety and Environment Case and appropriate controls identified and implemented.

5. Potential impacts of applying existing regulatory frameworks to autonomous vessels

As described above, applying existing regulatory frameworks to autonomous vessels is challenging because they are fundamentally different from crewed vessels and they do not fit the assumptions on which the regulatory framework is based – for example that a human will always be on board, operating and supervising the vessel, and that a vessel will have a life span of 10 years or more (Horne, 2021). These assumptions mean regulatory burden, including required risk controls and survey and certification processes, and associated time and cost implications, may not be reasonably calibrated to the actual risks presented. The potential impacts and consequences of applying existing regulatory frameworks to autonomous vessels are set out in **Table 3** below.

Table 3: Impacts and Potential Consequences

Impact	Potential consequences
Uncertainty regarding regulatory risk tolerance, pathways and requirements	- Slower, more expensive, less ambitious technology development (Horne et al, 2023) - Underutilisation of the full capability effects and benefits (including related to safety, efficiency and environmental impact) offered by autonomous vessels (Horne, 2024) - Increased difficulty leveraging industry expertise and effort due to the project budget and schedule risk caused by regulatory uncertainty
Potential inconsistency with risk based regulatory approach	- Cost and time of regulatory compliance could be inconsistent with risks being controlled
Uncertainty regarding how to adapt current systems safety, assurance, and test and evaluation approaches	- Slower pull through of technology into service (Devitt et al, 2021) - Makes it harder to generate trust in a technology (Horne et al, 2023) (Keane et al, 2022) - Slower decision making processes in terms of bringing technology into service and deploying it
No agreed benchmark for best practice (i.e. because there are no agreed technical standards to apply)	- Jeopardises trust and increases uncertainty (Horne, 2023) - Makes it more different to leverage the lessons learned/experience of other parties, i.e. who would otherwise have contributed to the technical standard
Increased burden for both the regulator and the regulated	- Use of resources to understand how the existing framework applies, how autonomous vessels can comply, and how to update the framework to support better integration
Jeopardised social licence	- Compromised Government, community, and general stakeholder support for autonomous vessel related projects and operations, less tolerance for incidents, higher risk thresholds represented in decisions

[16] **At the date of submission of this paper.*

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As Horne et al articulate, "Because of regulation assuming human oversight, often autonomous systems are either unable to operate legally, or they are subject to very limiting processes and restrictions, which fail to address the key issues that differentiate them from traditional systems." (Horne et al, 2023).

6. Key recommendations for Defence regulators

The analysis conducted in this paper, and the experience of ODSwR staff to date in supporting the uptake of autonomous vessels in the Australian defence enterprise, has enabled compilation of a number of key recommendations for defence regulators to consider in approaching and executing the regulation of autonomous vessels. These are set out in **Table 4** below:

Table 4: Key Recommendations for Defence Regulators

Topic	Recommendation
Proactively seek to enable test, trial and operation	1. Implement formal, repeatable flexibility mechanisms to enable development, test and trialling, and operation 2. Implement regulatory sandbox approaches to enable agile and iterative test and trialling (Humphries et al, 2023) 3. Ensure all approaches are scalable and flexible (Horne, 2023) 4. Elicit feedback and lessons learned from tests, trials and operations, and use it to adapt existing approaches 5. Establish the objective risk tolerance of decision makers and communicate that to relevant stakeholders, including in what circumstances that tolerance will change and the impact on decision making considerations and thresholds 6. Establish agreed objective ways to build trust in technology for different stakeholders in the capability life cycle (Horne, 2024) 7. Prioritise both short and medium term regulatory development so that technology is able to be used now, but a more tailored approach also becomes available as soon as possible 8. Publish clear guidance material identifying requirements and methods for compliance 9. Upskill the regulator workforce and associated stakeholders in autonomous technology
Domestic and international collaboration	10. Collaboration is critical and should be facilitated as a priority to enable the sharing of lessons learned and generation of new ideas. For example, in an Australian domestic context, in 2023 ODSwR established the Defence Robotic and Autonomous Systems Community of Practice, which has membership across all domains and services 11. In an international context consider establishing an International Defence Maritime Regulators Community of Practice (as advocated for by Dr Rachel Horne)
Regulatory development	12. Consider the degree of consistency required between the regulatory frameworks of Australia and its allies to facilitate interoperability 13. Consider the need to establish common language regarding autonomous systems across regulatory frameworks and domains (Horne, 2024) 14. Work with co-regulators to establish clear co-regulatory boundaries and where necessary put in place a tailored regulatory treatment to avoid delay and uncertainty for operators 15. Identify what a best practice regulatory approach looks like for the relevant regulatory context, which fits the risk tolerance of the organisation, and then work to implement it in a way that means autonomous vessels don't have to rely on exemptions/bespoke approaches beyond the short term 16. Consider the literature regarding regulation of emerging technology, and utilise the concepts that are relevant and appropriate. For example, Horne et al proposed 10 principles to base regulatory development and implementation on: Trust-centred; Collaborative; Risk-based; Evidence-led; Facilitate experimentation; Systems-focussed; Usable; Consistent; Adaptable and Reviewable. These are intended to collectively "…provide a domain and technology agnostic basis for a regulatory framework development and implementation approach that supports the design, manufacture and operation of safe and trusted autonomous systems." (Horne et al, 2023)

'Learning by doing' is one of the most successful way of identifying regulatory issues and gaps and workable short, medium and long term solutions (Humphries et al, 2023). For example, activities such as the Autonomous Warrior Exercise hosted by Warfare Innovation Navy[17], or the Trusted Autonomous Systems Maritime Showcase held at the ReefWorks test range in 2022[18], push the bounds of regulatory frameworks, build experience, and enable identification of key learnings to use to inform regulatory development.

[17] Note Warfare Innovation Navy transitioned into Maritime Integration and Systems Branch on 13 May 24.

[18] See TAS Maritime Showcase Report (December 2022) for more information: https://tasdcrc.com.au/reflecting-on-the-tas-maritime-showcase-demonstration-september-2022/.

7. Conclusion

This paper provided an analysis of the regulatory landscape for autonomous vessels being developed and used by the Australian Defence maritime enterprise. As an emerging technology, autonomous vessels are poised to revolutionise sea warfare in the coming decades thanks to their agility, resilience, and potential for lethality. This trend is reflected in the heavy investments made by countries such as Australia, the United States of America, and the United Kingdom. In light of these developments, the analysis in the paper is timely, highly informative and significant for the regulated community, ODSwR, and other Defence regulators.

The paper analysed the existing regulatory landscape for autonomous vessels developed and used by the Defence maritime enterprise, most notably the DSwMS. The DSwMS is an important framework for ensuring safe operation of autonomous vessels and facilitating achievement of their defined tasking in the defence context. Ensuring safe operation of these vessels brings with it practical challenges. Among the challenges are the lack of humans on board the vessels and their heavy reliance on sensors, artificial intelligence, as well as information and communications technology for operation. To overcome these challenges, Capability Managers must carefully consider issues such as safety, environment impact, flag and cyber security risks. These factors are equally applicable to crewed vessels. However, the unique nature of autonomous vessels requires closer monitoring and greater management of risks and hazards. Achieving these goals necessitates a fit for purpose regulatory landscape, supported by clear guidance materials for Capability Managers, their delegated personnel, and other stakeholders.

This paper offered recommendations to better facilitate the development and use of autonomous vessels in a Defence context. These were divided into three key topics: (1) Proactively seek to enable test, trial and operation; (2) domestic and international collaboration; and (3) regulatory development. It was also noted that 'learning by doing' is one of the most successful ways of identifying regulatory issues and gaps and workable short, medium and long term solutions. The application of these recommendations is expected to improve the integration of autonomous vessels into existing regulatory frameworks, while supporting the development of fit for purpose amended or new regulatory frameworks. This outcome will support the translation of the opportunities presented by autonomous vessels into capability, enabling realisation of the RAN's predication that "employing RAS-AI will enable a more agile, resilient, and lethal fighting force, enhancing Navy's ability to Fight and Win at Sea." (Royal Australian Navy, 2022).

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