Designing in reconfigurability and adaptability to deliver lean and mean naval combatants

H. Schweidler, Bsc (Hons), CEng, MRINA, M. Howard, MEng (Hons), CEng, MRINA

Synopsis

As an enterprise we need to deliver naval combatants that can pack the biggest punch for the lowest cost whilst taking the strategic advantage of emerging and developing technologies. Modularity has been hailed as a key enabler in achieving this due to increasing requirements for the use of off-board systems, uncrewed assets, and the need to re-role naval combatants.

Terms such as modular, adaptable, flexible, and reconfigurable have been used in the context of warship design for decades, but what is meant by these is sometimes confusing. As an enterprise we need to learn the lessons of their adoption to repeat the good and stop the bad.

In the current climate where the threat is fast evolving and highly diverse the need to operate ships that can maximise capability across several different and often conflicting missions is highly desirable. The conflict in Ukraine along with recent issues in the Red Sea, show how traditional methods of war fighting and protection of commercial routes is in danger of becoming cost ineffective. For example, it is not economical to expend million-dollar missiles for the defence against small low-cost drones. How does this relate to requirements for further modularity and reconfigurability, and does flexibility and adaptability play a part in solving these issues?

This paper looks to discuss modularity and reconfigurability along with key enablers such as adaptability and flexibility, to establish what this means for design and associated impacts on the holistic cost of capability. It aims to promote the use and standardisation of definitions in the context of modern naval ship design and explore the breadth of these features to expose how a holistic approach to integrating systems is required to ensure they remain more than buzz words. If collective enterprise-wide agreement can be sort in defining what is truly meant by modularity and reconfigurability, a more collaborative and coherent wholeship design approach can be provided to increase efficiency when implementing these adaptability and re-configurability paths.

Keywords: Adaptable; Flexible; Reconfigurable; Modular; Arrowhead 140

1. Introduction

Over the past 20 years the need for naval ships that can undertake multiple roles and provide utility across a broad spectrum of operations has been made clear, with many new ship procurement programmes requiring multi-purpose or adaptable ships. Examples include the T31 General Purpose Frigate and T26 Global Combat Ship both of which are marketed as modular and adaptable.

The war in Ukraine and recent attacks to allied navies in the Red Sea, seem to validate the push towards technologies such as drones / un-crewed systems, which are now being used in conjunction with ani-ship missile and new ballistic missile threats, requiring a change in the defensive approach. These fast developing and rapidly changing technologies therefore impart a demand on the current and next generation of naval vessels to be flexible enough to carry high end radar and interceptors for the hypersonic and ballistic missile threat, as well as cost effective methods of dealing with the drone threats. This can provide a challenge to customers who specify the capability required for the vessels but whose design and build programmes are overtaken by rapid developments in technology. Therefore, it has become common to hear reference to terms such as modular, adaptable, flexible and re-configurable used in ship specifications, requirements and marketing literature, giving acknowledgement that future warfighting capabilities will need to evolve at a pace faster than the procurement cycle of vessels and that these requirements are largely unknown. This gives rise to vessel designs that must allow for the ability to change their topside arrangement, operational spaces and mission spaces to account for current unknowns and uncertainties associated with future sensor, communications, command & planning and weapon systems to keep pace with their technological developments.

Harry Schweidler A Senior Engineering Manager at Babcock UK Marine Engineering with responsibilities including day to day management of the Concept Engineering Team, continued development of the Arrowhead Family of designs, future ship concept design and ship design consultancy support.

Matt Howard Shipbuilding Technical Director responsible for the export of the Arrowhead 140 design, which has been selected for both the Indonesia and Poland (MIECZNIK) programmes (at the time of writing). His previous role was the Type 31 Frigate Chief Engineer, 2017 to April 2022, which included Design Authority responsibility for the platform and gun systems. His tenure as T31 Chief Engineer included the Competitive, Basic, Functional and Detailed Design phases.

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As an enterprise of ship designers, builders and equipment suppliers we all have our own understanding of what is meant by modular, adaptable, flexible and re-configurable. However, with little agreed common definition it can be easy to focus on the key equipment enablers necessary to embark 'modular' systems i.e. allowing Space, Weight and Power (SWAP), but lose sight of the holistic ship design required to fully support and operate a series of changing systems over the period of a vessel's life. As a result some of the core tenets of ship design often get overlooked, i.e. integration with communications, combat management, bridge and platform management systems. The importance of integration is becoming more widely acknowledged as demonstrated by the first Sea Lord coining the term *"Digital Integration"* (Allison, 2024) at the 2024 Sea Power conference.

As customers strive to identify the new technologies and systems needed to fight the changing landscape of war, it is likely that the demand for vessels with even more modularity, flexibility, adaptability, reconfigurability and interoperability will be required. This approach allows the unknowns and uncertainty associated with identifying future capabilities at the time of a ship procurement programme to be mitigated, resulting in a change in mind set from designing ships based on past conflicts and a fixed capability requirements, to designing vessels capable of meeting future threats, where the requirements are more ambiguous.

As this demand increases an effort should be made to agree on the key definitions of the terms that may govern the requirements of the future and draw out how they impact the design of a vessel, so as not to lose sight of the wholeship impacts that these requirements place on the naval designer. Afterall put a system in a box is just the first step, fully integrating that system into the ship to provide reliable capability over a series of campaigns should be considered the complex part.

This paper is intended to promote a series of existing definitions, which could be agreed and cause a pause for thought over the impact of integrating new technologies within a vessel. A further aim is to aid in informing future specifications or requirements, that allow the naval ship designers to offer a more collaborative and coherent wholeship design approach, which can be provided to increase efficiency when implementing these adaptability and re-configurability paths for our navies.

2. A definition of terms

The terms *Modular*, *Flexible*, *Adaptable and Reconfigurable* appear all too often in marketing literature associated with ship design and within requirements from navies for new ship procurement projects, including recent example such as the UK Defence Ministers announcement for 6 new Multi-Role Support Ships (UK Royal Navy, 2024). The inclusion of these features is clearly regarded as highly important in delivering capability to modern navies and allowing them to leverage new technologies on their ships. However, the definitions of these terms vary as shown through research across some key published standards and publications, for example:

- Lloyd's Register Naval Ship Code Technical Committee – Ship design and applications – Modularity (Draft);
- NATO ANEP 91 & 99;
- Royal Navy Maritime Modularity Concept; and
- DSTL Proposed way ahead on modularity.

What becomes apparent when reviewing the meaning of these terms and subsequently discussing them with learned colleagues is the overlap of the potential definitions or interpretations, modularity being a prime example. Used as an umbrella term modularity can have a series of different meanings covering either the way a vessel is constructed leading a ship to be described as modular build, a feature in a vessel that allows modules to be used e.g. a large mission bay or refers to a systems or equipment within a box that can be transported and embarked on a vessel, i.e. a modular system. Each of these can be argued to be a form of modularity that also overlaps with adaptability, flexibility and re-configurability.

The UK Royal Navy defines modularity within their Maritime Modularity Concept (UK MOD, 2022) as: '*adaptation through the timely addition or substitution of specialist or new capabilities at home or deployed; fully integrated to execute specified missions.*' This definition is further explained with the use of five subcategories of modularity: Build Modularity, Integral Modularity, Installed Modularity, Team Modularity and Digital

Modularity. In each instance a description provides some context as to what is meant by the term however these descriptions fall short of an unambiguous definition. These terms also overlap with others, for example Integral Modularity is stated to be a capability with a defined boundary both in application and installation. It relies on locations within a vessel designed specifically to accommodate modules allowing the capability to be fitted or removed depending on the mission demands, for example the Danish STANFLEX System. However, this could just as easily be described as either adaptability or re-configurability.

Therefore, to progress on a common understanding, it important that we become specific in the use of our terminology when describing features and function of the ships we design and systems we which to embark. To help this the following definitions are recommended based on the discussions held and publications examined.

In reviewing the aforementioned publications the definitions as stated within Dr Courts' paper (M.D.Courts, 2014) (Table 1) stand out as a comprehensive set of terms that are well bounded and meet with the authors' experience within the context of ship design. However, it is worth noting that modularity as a definition is not included, as these terms were intended to support the description of what was holistically meant by 'modularity'.

Term	Description	Example
Producibility	A measure of the ease with which a design can be manufactured and assembled. This may be enabled by both reducing work content and improving the efficiency of the work required. This may be achieved by breaking items down into sub-assemblies that can be built and tested separately before coming together or by re-designing assemblies to have fewer components requiring little effort to assemble.	- Structure with few components and weld lengths - Raft mounted engineering and auxiliary systems
Operability	A measure of the ease with which a ship or system can be operated by its crew.	-Ship that has easy access to all manned areas and living spaces separate from spaces allocated to fight and move functions.
Supportability	A measure of the ease with which a ship can be supported by maintaining equipment in situ or by removal and replacement.	- Clear vertical removal routes that can be opened easily. - Access for maintenance around equipment
Flexibility	Describes the ability of a complete entity to perform more than one function without major change.	- General purpose frigate able to contribute effectively against all threats in a battle space.
Reconfigurability	Describes the ability of a complete, or part of an, entity to be easily altered during its life to perform different functions.	- Deck space that can accommodate functionally complete portable containerised systems.
Adaptability	A measure of the ease with which a ship or system design can be changed to produce	- Ship design that has spaces already allocated

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	variants optimised to perform additional or different functions.	for in-service additions together with in-built system capacity to support such additions.

It becomes apparent that in defining these terms, modularity becomes mostly redundant as a descriptor of ship capability and that it is in fact simply an enabler of re-configurability, flexibility, and adaptability. However, if the term modularity is replaced by re-configurability both the terms of modular and module do not become redundant and can be simply defined as stated in Table 1.

Term	Description	Example
Modular	Describes a system or capability, which can be assembled or constructed from multiple standardised parts or modules.	- A field hospital capability constructed from individual medical modules, e.g. labs, CT scanner, wards, stores, sanitary facilities etc
Module	Describes a defined item constrained to a size envelope, which can be transported and integrated to a larger assembly or host to enhance capability.	- Equipment installed within a container or standardised interface specification.

Table 1: Modularity definitions

3. Reconfigurability Case Studies

The following case studies provide examples of reconfigurability within a ship design that have enhanced capabilities and are reviewed to learn the lessons of their adoption to repeat the good and stop the bad.

RFA Argus

RFA Argus demonstrates reconfigurability at probably one of the extreme ends of the scale. Originally launched in 1981 as a commercially owned and operated freight, RORO and container ship, it was taken up from trade during the Falklands War and converted (adapted) for use as an aircraft transport before further conversion (adaptation) in 1985 to an aviation training ship with extended accommodation, flight deck and aircraft lifts. In 2009 further changes were made to incorporate a primary casualty receiving facility (PCRF) (UK MOD, 2024). The key enabler for this dramatic change in role was the overall size of the vessel and arrangement, which allowed for the reconfiguration of the design adapting it to the unique capability it now has.

The first PCRF adaptation of the vessel was achieved by reconfiguration of existing spaces within the vessel and in installation of a modular containerised hospital capability. This was completed during a re-fit period and within the bounds of the existing weight and stability limitation of the design. After being in service for several years the modular containerised hospital section was identified as being sub-optimal in layout and suffering from deterioration, but the value of the capability had been demonstrated and there was a wish to make the capability permanent. Implementing the improvements and making the PCRF fit permanent, resulted in a change to the classification of the ship, from class VII cargo ship to passenger ship requiring significant changes to provide sufficient escape and evacuation routes. This illustrates the need to consider the holistic impact of adapting a vessel with a modular fit and consideration if a system may become permanent, requiring a more holistic design approach from the outset including safety and certification.

This example also shows that reconfigurability is not necessary a short term or transient thing and with adaptable and flexible designs substantial change during a vessel's life is possible.

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Figure 1: RFA Argus (image credit Wiki commons)

RDN Absalon and Iver Huitfeldt Classes

The Royal Danish Navy's Absalon class and later designed Iver Huitfeldt class were designed from the outset as flexible and adaptable vessels, utilising a 'wide beam' design mentality, which provides additional volume beyond that required by the as built capability. This allows ease of maintenance and future reconfigurability of spaces. HDMS Absalon has a large flex-deck capable of accommodating multiple different vehicle types, stern ramp for launch and recovery and a large flight deck. In addition the vessels also utilised the Danish STANFLEX modular weapon systems. Designed from the outset as frigates opposed to auxiliary vessels enabled a credible combat capability as well as the inherent ability to change role, an example of which being the reclassification in October 2020 as Anti-submarine Warfare (ASW) Frigates through fitment of towed sonars and ASW helicopters (U.S Naval Institute, 2021).

The Iver Huitfeldt followed a progressive development on from the Absalon design providing an Anti-Air Warfare (AAW) primary capability, but also embraces reconfigurability through a number of means including utilising a mission bay capable of hosting four twenty-foot ISO standard sized containers and the integral design for interchangeable STANFLEX modules. The versatility has been seen firsthand by the authors whilst visiting HDMS Niels Juel, where the level of flexibility of the design becomes apparent as well as the level of integration that was required to enable the complex weapons (STANFLEX modules) to function. Discussions with the crews highlighted the process required to integrate these modules once they are fitted to the ship and although this now represents a streamlined process, the complexity of the design to allow integration with the combat system, communications system and ships sensor systems was clear.

Figure 2:HDMS Absalon (Left) HDMS Iver huitfeldt (Right) (Images credit wicki commons)

Arrowhead140

The Arrowhead 140 has evolved from the HDMS Iver Huitfeldt design adopting the wide beam design methodology and incorporates modern classification and NATO standards, along with increases to ship survivability. These ships have purposefully been designed to allow reconfigurability through life via a spiral capability acquisition programme, or to embrace the ability for the baseline design to be customised by the customer Navy, this can be seen when open source specifications for the UK RN Type 31 and Polish Miecznik programme vessels are compared.

The design has the ability to be reconfigured through a series of options to enhance capabilities such as Anti-Surface Warfare, Anti-Air Warfare, Anti-Submarine Warfare, Land Strike, as well as provision to embark modular capabilities e.g. Humanitarian Aid and Disaster Relief (HADR) or Mine Countermeasures (MCM), etc. Designed

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with a substantial adaptability margin the AH140 can facilitate significant capability changes (Howard & Johnson, 2022) (Babcock International Group, 2024) . These integral design features provide reconfigurability options that consider a wide variety of system interfaces allowing for the interfacing and addition of critical supporting systems beyond the primary capability, e.g. provision for additional HVAC and chilled water associated with a mission system equipment upgrades, which may be necessary for the inclusion of advanced radars or Mk 41 Vertical Launch Systems. The design also considers aspects such as the Integrated Platform Management System (IPMS) within the adaptability margins to ensure whichever system enhancements are selected the IPMS can be integrated.

In developing a variant of the AH140 tailored towards embarkation of modular systems, a series of discussions were held with Lloyd's Register to establish the most appropriate means of meeting safety regulations for large enclosed multi-use mission bays. The conclusions of these discussions were that the rules do not currently consider these spaces in the new manner of which they could be used. Instead, they are reliant on extant regulations for vehicle decks or hangars to cover elements such as firefighting, etc. They do not fully consider simultaneous stowage of hazardous materials (e.g. batteries, fuels, munitions etc) or the requirements for general access/ egress / escape and evacuation through these spaces. Therefore it was key in the development of the AH140 that the solutions and safety case for the vessel consider these aspects in order to deliver a platform that is safe to operate without overly restricting the use of modular systems.

Figure 3: Arrowhead 140

4. Reconfigurability in the context of a ship design

To fully exploit a design and ensure that it can be reconfigured it is important to understand the different ways reconfigurability can impact a design. Broadly speaking these can be divided into two categories, Embarked and Integrated, which cover the different aspects of reconfigurability.

Embarked reconfigurability:

Embarked reconfigurability is where a vessel's capability is reconfigured or supplemented through the embarkation of systems and equipment. This leverages the use of standardised modular system concepts, which conform to common design and integration standards e.g. NATO ANEP 99 (NATO, 2019) and NATO ANEP 91 (NATO, 2017) or utilises embarked vehicles or vessels e.g. drones. These systems are embarked into mission bays to either enhance the ship's capability or be used to enhance the overall naval / military capability, through deployment from the ship. In order to be effective the ship must be designed to both accommodate and facilitate their operation by supplying key services to them (water, power, cooling, networking, etc) and accommodating the operators and/or maintainers. It is this form of reconfigurability that has been more widely known as modularity.

The benefits of providing embarked reconfigurability are well documented and the use within multi-role vessels established. However, the ability to host a module should only be regarded as the first step in true reconfigurability of capability, as the module and more importantly the equipment and systems hosted within must be fully integrated into the ship systems beyond allowance for Space, Weight and Power (SWAP) to function effectively.

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This leads to a key trait of reconfigurable modular systems, which is that for the benefits to be fully realised they are reliant on being capable of being shared across multiple vessels and in some instances between navies, and therefore be designed to a single interface standard. This may sound obvious, however the ability to gain multi-organisation and multi-nation agreement on highly complex system design is fraught with difficulty. For example, the task of agreeing the size of a module, build standards and interfaces (ANEP 99) took NATO a significant number of years, and this was based on well-established ISO Containers. With standards for communications, interfacing and network infrastructures still to be decided amongst a wide variety of competing systems from both industry and government research institutes alike, the realisation of true interoperability of capability via a reconfigurable fleet is very much a continued journey.

These can be short cut through adoption of a common system by many customers, thus making it the adopted standard e.g the use of Hendrickson Hook for quick release boat, although this is a prescribed standard many navies and small vessel manufactures have adopted it or are compatible with it. Another approach could be a single 'best for navy' approach where one navy adopts a system and does not worry about the ability of sharing capabilities with other nations, e.g. the Danish STANFLEX system (DANYARD, et al., 1992). However, this approach brings a significant development cost for a nation compared to leveraging a wider pool of research and development from other nations and the wider equipment supplier market. This approach also blurs the line between embarked and integrated reconfigurability.

Integral reconfigurability

Reconfigurability of a vessel can also be facilitated through bespoke integral design solutions for systems and equipment in a single ship or class of ships. This can either be through specific design features that allow alteration of the vessel to meet different capability demands and uses, e.g. large office spaces that can be subdivided with partitions, additional space to fit either extra or larger equipment e.g. chiller plants, or specific interfaces for a particular system type, e.g. fit to receive a Lockheed Mk 41 Vertical Launch Silo, or the Danish STANFLEX system.

There are many advantages of integral reconfigurability from provision of flexible accommodation and planning areas to the ability to cost effectively add capability such as upgraded radars or weapon systems, without significant modification to the ship during refits. Having a design with integral reconfigurability provides the benefits of ship commonality for training, maintenance and spares whilst allowing the provision of capability differences, e.g. different vessels in a fleet geared for different mission types. There is also no reliance on the need to gain international agreement of standard interfaces or conform to large boxy volume requirements when smaller equipment can be accommodated, saving space.

The principal disadvantage associated with integral reconfigurability lies in the potential extended time to reconfigure ships if a standardised system is not used. Although reconfigurable in design the nature of the integral reconfigurability inevitably has a cost impact when compared to embarked reconfigurability due to the up-front development costs, therefore it is important that the solutions are thought through so the capability gains outweigh the associated cost burden.

Integrating reconfigurable spaces need to be carefully considered as they can affect ship size and cost of procurement to accommodate this specific feature. There is also a risk that, this capability may only be utilised once or twice during the lifetime of the ship or not at all e.g. fit to receive towed array sonar bay. This type of reconfigurability can also bake-in the interface requirements or standards for modules and systems that may not be adaptable for future technology developments, e.g. energy magazines for Directed Energy Weapons (DEW).

In summary regardless of the type of reconfigurability utilised within a vessel design, careful thought is needed on how it will interface with the ship. Which systems need to be provided? Where the additional design margin is required? How will a change of role / capability be undertaken so the associated costs are manageable and proportionate to the capability increases envisioned?

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5. Reconfigurability impact on Cost

With little empirical data available to compare across the different vessels that provide reconfigurability in different ways it is difficult to draw fully factual conclusions. However, in the experience of the authors, elements such as mission systems equipment, survivability requirements and the required rules and standards typically make up the principal elements of a ships cost during the initial procurement. Reconfigurability therefore can aid in reducing this by allowing spiral acquisition programmes to be effective in adding capability at a later stage during a ship's life cycle noting equipment can make up to 60% of the ships cost. This can be applied to both types of reconfigurability provided that the holistic integration considerations are addressed effectively, and all future integration risks are mitigated.

The cost of reconfigurability at the design stage varies depending on the approach taken in design. Vessels that leverage a high degree of Embarked reconfigurability would expect to have costs that vary / scale proportionate to the volume of mission bay, as this forms the principal vessel size driver. Vessels that utilise Integral reconfigurability is more sensitive to the equipment cost of items designed into the vessel e.g. Missile or ammunition costs and the requirements to integrate these systems which are more significant than that of the platform costs.

Through life costs however will vary between the two types of reconfigurability as the investment will need to be either placed in the design of the embarked equipment i.e. modules, their transportation, stowage and maintenance (Harris & Thatcher, 2023) or invested during refits of a vessel, where integral reconfigurable spaces are modified to integrate new equipment and systems. The important factor in both cases is that reconfigurability provides the customer multiple options to manage the cost of the capability over the lifetime of a vessel.

6. Conclusion

The terminology associated with a ship's ability to be reconfigured is currently ambiguous and confusing. In order to provide succinct communication of requirements and capability an enterprise-wide agreement of common terms such as adaptable, reconfigurable, flexible, modular, etc. should be agreed. The term modularity is particularly misleading and only seems to cover part of a broad spectrum of capability drawing focus on embarked systems as opposed to the many ways a vessel design can facilitate changes in roles or capability.

This paper therefore recommends that as an enterprise we use the term reconfigurability in place of modularity and categorise it as either Embarked or Integral as it is the key enabler for adaptability and flexibility. The following statement aims to conclude the relationship of the common terms in the context of enhancing a naval capability:

'To provide a cost-efficient naval capability, the ship designer and builder should ensure high producibility, supportability and reconfigurability, which in turn allows for an operable, adaptable and flexible naval platform capable of exploiting modular systems.'

It is also important to realise that although it is easy to focus on the new technologies being developed and embarked via modules and their associated handling systems, to truly leverage an increase in capability and provide reconfigurability the wider ship design aspects must be fully understood and considered. Aspects such as integration to the combat system, platform system and communication system cannot be overlooked or underestimated in complexity. Appreciation of the way large internal reconfigurable spaces can be operated and designed safely has also not been fully tested, with classification rules dependant on requirements for either vehicle decks or hangars to manage multi-use mission spaces. This means that the design of any reconfigurable spaces needs to carefully consider the safety challenges and justifications for their muti-use, the level of effort of which should also not be underestimated.

Many aspects associated with common integration of modular capabilities are yet to be defined or agreed resulting in an inability to fully standardise embarked reconfigurable capabilities. Therefore, it is key that the ship design and system integration beyond simply the physical aspects is fully considered in future reconfigurable designs and that integral reconfigurability can also provide substantial capability increases without the reliance on modular systems.

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8. References

Allison, G., 2024. *UK Defence Journal: Historian Dan Snow Talks to the First Sea Lord.* [Online] Available at: https://ukdefencejournal.org.uk/historian-dan-snow-talks-to-the-first-sea-lord/ [Accessed 20 05 2024].

Babcock International Group, 2024. *Arrowhead 140.* [Online] Available at: https://www.arrowhead140.com/ [Accessed 01 May 2024].

DANYARD, NobelTech & TERMA, 1992. *StanFlex 300 The True Multi-role ship.* [Online] Available at: https://www.marinehist.dk/orlogsbib/h/StanFlex.pdf [Accessed 22 May 2024].

Harris, A. & Thatcher, C., 2023. *The Challanges in Supporting modular capability, today and in the future.* Bristol, IMarEST - EAAW.

Howard, M. & Johnson, J., 2022. *Type 31 Frigate: Complex Warship Design for a Dynamic Operational Environment.* s.l., IMarEST.

M.D.Courts, D., 2014. *DTSL/TR75915 Proposed UK Way Ahead on Modularity.* 1 ed. s.l.:Defence Science and Technoloy Laboratory.

NATO, 2017. *Allied Naval Engineering Publication 91: Standard Interfaces for Mission Modules,* s.l.: NATO.

NATO, 2019. *Allied Naval Engineeriung Publication 99: Design and Infterface Stabdards for Containerised Mission Modules,* s.l.: NATO.

U.S Naval Institute, 2021. *U.S Institute November 2021 Proceedings Vol. 147/11/1325: Denmark's Absalon-class Flexible Frigates.* [Online] Available at: https://www.usni.org/magazines/proceedings/2021/november/denmarks-absalon-class-flexible-frigates [Accessed 01 May 2024].

UK MOD, 2022. *Maritime Modularity Concept.* s.l.:UK Ministry of Defence.

UK MOD, 2024. *Royal Navy organisation units and squadrons RFA Argus (A135).* [Online] Available at: https://www.royalnavy.mod.uk/organisation/units-and-squadrons/support-ships/rfa-argus [Accessed 01 May 2024].

UK Royal Navy, 2024. *Royal Navy: Six new amphibious warships to be built for Royal Marines operations.* [Online] Available at: https://www.royalnavy.mod.uk/news-and-latest-activity/news/2024/may/14/20240514-six-new-amphibious-warships-to-be-built-for-royal-marines-operations [Accessed 14 May 2024].

 https://doi.org/10.24868/11172

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