# The Future Naval Battlespace and implications for Key Enablers

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## Synopsis

The impact of ongoing global events, from AUKUS to increased tension in the straits of Taiwan, South China Seas and Baltic, highlight profound changes in the global strategic context that places the maritime domain at the heart of efforts to maintain freedom of trade and manoeuvre. Globalisation means the Sea Lines Of Communications (SLOCs) are vital to the economies of the world, pressure on natural resources and climate change will mean contests in the world's Seas and Oceans will escalate including asymmetric and semi-deniable (grey zone) attacks alongside more traditional blue water peer to peer naval combatant operations and humanitarian aid requirements. The future Naval Battlespace is hard to predict with the rate of technology change, it is safe to say that uncrewed vehicles, drone swarms, Artificial Intelligence (AI), powered autonomous elements, low observables, hypersonic weapons, Directed Energy Weapons and cyber capabilities will all feature, requiring the structure and composition of naval forces to evolve rapidly. Energy usage and the maintenance of freedom of manoeuvre through energy supply and resupply will be critical. Many of these threats are also opportunities and through pursuing these opportunities the threat will be better understood and mitigated, but economic balance must also be pursued. The paper will look at the Platform, Marine Engineering and Combat System aspects that will need to develop in order to enable improved effectiveness in the future battlespace and will draw out key threads that should lead to virtuous cost-effective development cycles to prepare naval forces for the future. Uncrewed vehicle launch and recovery, survivability, operability, modularity and reduced crewing are themes that will be looked at in the platform. Future fuels and energy management, environmental performance and availability will be considered through the Marine Engineering aspects and the Combat Systems will cover future effectors, network enabled capability, sensor integration, open architectures as benefit and threat, operator workload and combat system automation. Cross functional aspects will be explored such as the future of survivability, management of damage control in lean manned and autonomous vessels, automation of currently manpower intensive operations and how this may affect personnel and organisational structures.

Keywords: Naval, Future, Battlespace, Combatant, Uncrewed, Survivability

## 1. The current geo-political climate and its impact on the Sea

The world is in a great competition, between the West, China, Russia and other actors who would seek to control the Sea Lines of Communications (SLOCs) and other means of affecting the world-wide economy and power to their advantage. These actors are already in a form of Total War using all means at their disposal including but often short of Kinetic action. These forms involve Cyber, Social Media influencing, Economic power through coercion and aggressive investment, Diplomatic warfare and grey zone (military actions short of war – such as the Chinese taking of reefs in the Pacific) actions. Power comes through economic means and the building of military forces, something that is happening extremely quickly in China.

### *1.1. Naval Blockades and Globalisation*

The power of the blockade has been shown in strategic pinch points, whether that be the deliberate blockading of the coast of Ukraine, The Evergreen obstruction of the Suez Canal or the COVID created blockage of Shanghai and other Chinese ports.

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**Authors' Biographies**

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**Matt Bolton** had a long career in the Royal Navy spanning almost 4 decades and following retirement in 2020 he established MTWB Consultancy Ltd, offering independent consultancy services to the maritime defence enterprise. In September 2021 he also started a part-time role with United Kingdom Naval Engineering, Science & Technology (UKNEST), promoting the engineering, science and technology interests of UK Naval Defence. Matt is chair of the IMarEST's Naval Engineering Special Interest Group.

**Iain Tall** is a Naval Combat System Engineer with over 3 decades of experience. He is currently Commander Weapon Systems at Maritime Capability Trials and Assessment, where he leads a team of 80 specialist engineers conducting Test and Evaluation (T&E) trials globally on RN sensor, weapon, information system and communications equipment. Iain is chair of the IMarEST Engine as a Weapon International Symposium Technical Advisory Committee and is the RN representative to the IMarEST Naval Engineering Special Interest Group.

The humanitarian, economic and industrial impacts of these events are significant for tens of millions of people and many economies. Thus the ability of Naval Forces to control or free pinch points or SLOCs has been highlighted again.

### *1.2 The Grey Zone*

Actions short of war or Grey Zone related activities are being more commonly used to upset the rules-based order. Naval Forces are being used to instigate, support and to police these actions. Advantage can be gained using the Naval domain as part of multi-domain capabilities and integration needed to counter Grey Zone activities. Others are attempting to undermine the rule of law and gain benefits across the world. The Naval domain with the right connected assets can be used to identify threats, then support cross-governmental operations to counter that threat whether it be by cyber, Special Forces, uncrewed vehicles, support to other governmental agencies or diplomatic efforts.

### *1.3. Sea based resources*

Naval forces through history have raided, blockaded, captured and defended economic targets at sea including: merchant shipping, fishing fleets, port infrastructure, oil rigs and now added to that list are undersea pipelines and cables whether for electrical power or internet connections and thus financial transactions. Thus, both offensive opportunities and defensive protection are highly significant aspects of war and Grey Zone activities. Sea bed based financial targets and resources are now coming within reach of technology such as uncrewed submarines, ROV's and specially designed weapon systems. Naval Systems need to develop to provide the protection to allied resources and assets as well as put the enemies' systems and assets at risk, thus maintaining deterrence based on the capability and will to fight should it be necessary.

Hypersonic weapons are starting to become reality with the consequence of much reduced reaction times for targeted forces. Greater sensing range and layered defence is the only way to defeat this threat as well as maintaining vulnerability reduction technology.

The naval world has changed, hence the need to use asymmetric capabilities just as much as adversaries do, there are technological solutions to this that can work hand in hand with more developed and nuanced doctrine. Technological response must use far more agile procurement techniques alongside new doctrine. The defence industrial base needs to be able to react quickly to emerging threats, enabling technology and new materials to give the battle-winning edge.

Climate change and energy markets are both threats and opportunities. The ability to provide energy more efficiently and economically to naval forces is a capability edge. The ability to keep conducting operations in a changing world is critical to any future ability to manoeuvre and sustain operations.

### *1.4. Naval forces change*

Naval forces must change in order to maintain the winning edge. Uncrewed air, land & sea systems will enable naval forces to see further with greater definition and with much more presence than before. Therefore, it will always have to be assumed that components will be seen. Navies must be able to carry, launch and recover uncrewed systems efficiently. If this can be achieved in poorer weather conditions or more quickly than an opponent, military advantage is gained.

Due to the increasing coverage of these more persistent systems, High Value Units will need to operate further off the coast, reducing the ability to influence the littoral without having some level of superiority in the uncrewed littoral domain.

Fossil fuels may become less available, which has implications for naval capability and reach but Naval forces are unlikely to be technology leaders. The effects on supply, logistics and vessel performance need to be thoroughly understood in order to be prepared.

Achievement of Information Superiority has significant technology implications in order to be gained and then maintained in a multi-domain environment. The use of digitalisation/AI is a threat and an enabler. Naval forces can add to the information flow, through distributed mobile and persistent sensor networks. Disaggregation of forces will be necessary in the future due to threats such as hypersonics. This mobile disaggregation brings in the use of more uncrewed systems in support of more traditional units, albeit more lean-crewed than previously.

In order to work with the availability of crew due to demographics, increased automation will need to be developed. This has other implications of creating more space onboard either to carry more uncrewed vehicles or to allow easier maintenance, storing and improved vulnerability protection. More operator/maintainers will be required for servicing uncrewed vehicles. It will be important to have common, multi-role uncrewed vehicles to reduce the burden on the agile Uncrewed Systems Corps in training, support and operation. Autonomy systems should be as common as possible to reduce Defence Lines Of Development (DLOD) impact. Electrification will be a key enabler for the future to improve availability and for increased efficiency of energy usage across propulsion, supporting systems and energy-based weapons. With the sheer diversity of possible technology options enabled by uncrewed systems, the optimisation of the system of systems will come from better analysis of options such as modularity, commonality and multi-role platforms and systems enabling the through-life agility required to field the latest technology easily. Uncrewed systems have great potential across many roles, the determination of whether they are disposable or maintainable and the associated trade-offs for complementing and ship size for spares etc. must come into the analysis of the optimal System of Systems.

## 2. Power & Propulsion

### *2.1. Sustainability*

It is inevitable that Western Navies at least will be required to demonstrate compliance with sustainability goals and contribute to net zero targets. This has particular challenges, not least in terms of equipment selection but also the fundamental logistic burden for the storage and movement of different fuels and the potential implications for platform speed and endurance. Unfortunately, fossil fuels offer the best energy density whilst the commercial marine sector has been using and experimenting with Liquid Natural Gas, Methanol, Ammonia and Hydrogen; none of which are without their limitations. Of significant concern are considerations such as flash point and toxicity in addition to energy density. In addition, NATO navies are accustomed to F76 Dieso for marine propulsion and F44 Avcat for aviation, whose standardization and availability across NATO enables full interoperability. By way of example, taking the Type 45 Destroyer with a published endurance of 7000 nm at 18 kts, using the same tank capacity for fuels with lower volumetric energy density, the impact is quite stark (Fig 1). Whilst this ignores the effect of overall system efficiency (i.e. a warship using hydrogen fuel cells might be more efficient than a one using heat engines), improvements to endurance would be marginal compared to the impact of energy density.

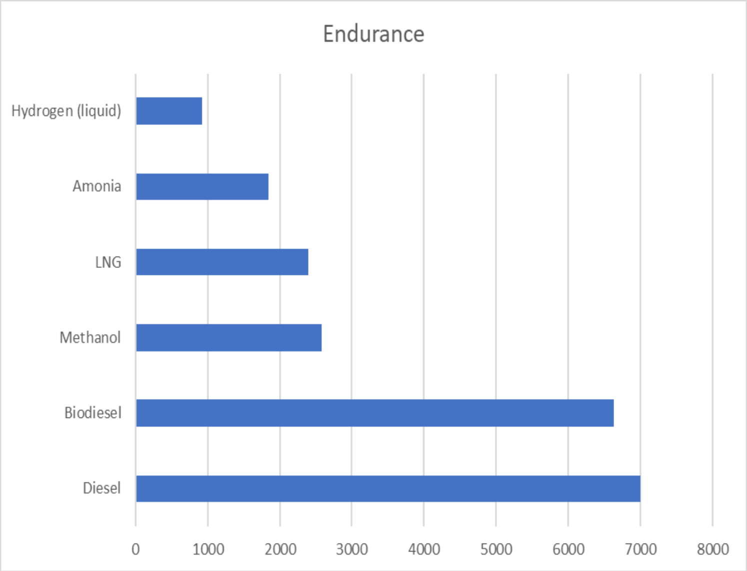

Fig 1: Predicted endurance for different fuel types

It is possible that navies will find different ways to offset their carbon footprint, perhaps by taking a wider enterprise approach. Alternative propulsion solutions may also become more prominent, for example, nuclear propulsion in surface warships may become a more serious contender, especially if micro-reactors become more of a reality. But this does not solve all of the problems, especially if we consider offboard systems, unless they all become fully electric (using battery energy storage) or perhaps hydrogen powered, where fuel is electrolysed on board. The question that remains is will the naval community be a leader or a follower? Given that the transport of goods on the high seas is never likely to be dispensed with in the foreseeable future, these may be the trends that navies emulate. Alternatively, navies may follow developments in aviation where Sustainable Aviation Fuel (SAF) made from refuse, used cooking oil or plants could be the future. This can reduce the carbon footprint of the industry by up to 80% and over 200,000 flights have taken off with SAF since 2016. However, the aviation industry alone needs 7Bn l/yr. It remains to be seen whether naval solutions will follow merchant marine or aviation experience, but it is unlikely to lead the revolution.

### *2.2 Autonomy*

Greater use of autonomous offboard systems is already a reality, but the automation of larger, more complex naval assets is a very different question. The leaner crewing of naval ships has been a prominent feature of naval ship acquisition for decades, largely driven by a recognition that people are expensive; to recruit, train, retain and even keep in retirement. Sadly, there is little evidence that any dividend reaped from employing fewer people at sea has been invested effectively in technology. Whilst removing human beings from harm's way is undoubtedly a laudable aim, doing so puts at risk the inherent adaptability that humans provide. Greater autonomy or automation and hence reductions in crew size is likely to be a continuing trend but the implications must be carefully thought through. Different crewing models may be necessary that require maintenance crews, of more highly skilled personnel ably supported by diagnostics and prognostics, operating on different employment cycles to the "operators". Greater electrification, referred to later, will be a key enabler as will very careful consideration of reliability and redundancy. There are some fundamental questions that emerge from a marine systems perspective on the path to autonomy; will platforms be simple, cheap and disposable? Or will more complex platforms require far greater levels of system reliability, redundancy or reconfigurability in order to be persistent and guarantee mission success? On 5 Jun 22 the Mayflower autonomous ship (Fig 2) arrived in Halifax, Nova Scotia, after completing her 3500 mile voyage; an enormous success, which was suspended at the Azores due to a failed isolation switch and the first attempt was aborted in June 2021 after the failure of a flexible coupling. With no-one on board to repair relatively innocuous faults, the only option in each case was to abort or delay the mission.

Fig 2: The Mayflower Autonomous Ship (Image: IBM Newsroom)

### *2.3. Electrification*

The Royal Navy has often led the way with Type 45 and QE Class as significant examples of a step change in a naval approach to integrated electrical propulsion. Type 45 delivers exceptional propulsion efficiency when the power station concept is properly applied although the lack of energy storage has been an Achilles heel, currently being remedied through the addition of more diesel generator prime movers but drifting away from the original design intent. In QE we see the design freedom afforded by electrification, uniquely siting large gas turbine alternators in the sponsons, thereby maximizing hangar space. These design freedoms and benefits will remain important to ship designers but we have probably still yet to see the full weaponisation of electrical power through the deployment of higher power sensors, effectors (rail gun, coil gun) or launchers. These will come and the platform design and marine systems must be available to supply and support them. Electrification has yet to be fully exploited in the simplification and control of auxiliary systems. Electrically actuated steering gear, stabilisers, engine starters and valves have all been trialed successfully, without any widespread adoption. Warships continue to be proliferated with high pressure hydraulic and pneumatic systems, which might be low risk and low cost upon acquisition but have a significant through life overhead and is one of the impediments to crew reductions in technical branches. Whilst not only reducing the maintenance burden, electrification enables health and performance monitoring leading to optimized maintenance planning and intervention. This easier integration with digital platform systems provides for greater control and monitoring, enhancing situational awareness in capability terms and enabling the adoption of highly reconfigurable systems. Energy storage remains key to unlocking the benefits of electrification; whether for enhancing efficiency, providing ride through or boosting weapon systems, and continued development will be crucial. Fuel cells have deliberately not been mentioned (they are a prime mover not an energy store) but they will inevitably be more widely employed when the challenges of catalyst contamination and fuel reformation or supply are satisfactorily overcome.

### *2.4 Modularity / Adaptability*

The inclusion of Mission Bays in platform design is not only commonplace it is becoming a standard requirement. From a marine systems perspective this requires careful consideration in terms of ship services, mechanical handling and interface management. Whilst work is in hand within NATO there is not yet an agreed standardization for such interfaces although the consensus is that modular systems should be based upon the dimensions of standard 20 and 40 foot containers to ease integration with established logistic services (Ref 1).

Almost anything can be put in the modular box, the host platform just needs to provide the necessary electrical power, cooling, HVAC and data interfaces, although this is not trivial. There are already a number of novel solutions to mechanical handling using deck pivots rather than overhead cranes to minimize top weight and to enable modules to be shuffled within a mission bay.

Fig 3: Mechanical Handling for Modular Mission Systems (Images: SH Defence)

It is also envisaged that any particular modular capability will be accompanied by the appropriately skilled personnel to operate and maintain it; this places a demand upon hotel services that must also have an element of flexibility within the platform design. This is nothing particularly new; ship's Flights have traditionally only embarked when the aircraft is on board, similarly Boarding teams with additional boats and equipment or UAV operators with their UAV and launcher.

### *2.5 Thermal Management*

Traditionally, chilled water systems that ensure a continuous flow of treated water for HVAC and combat system cooling, with the latter being particularly sensitive to temperature and flow fluctuations. Hence the chilled water system is a crucial component in sustaining operational capability and is a notably precious system when faced with damage control activity. Furthermore, if electrification is to enable high energy weapon systems such as rail guns, the inherent system inefficiency will require significant cooling and thermal management. Marine engineers may need to look at alternative solutions such as phase changing techniques to provide the necessary capacity along with more distributed systems to improve survivability.

### *2.6 Digitalisation*

Digitisation and digitalization of marine systems are key enablers that cut across many of the observations above. Warships that are digital by design and digitally configured through life will enable optimization of support and increases in platform and equipment availability., also enabling reduced crews by providing maintainers with the information they need. It is also a key enabler to decision support for operators, especially where platforms are adaptable, modular systems are swapped out and offboard systems are being managed, to ensure equipment and system performance and availability are understood in the context of mission success. The golden rules set out in the RN’s MarSIX Strategy (Ref 2) remain true and if adhered to will provide the basis for an optimized platform and support digital system.

## 3. Sensors and Effectors

The historic cat and mouse game between offensive and defensive maritime missile technology has swung, for the moment decisively, in favour of offence with the advent of hypersonic missiles. This will cause many Navies to reconsider how, and indeed if, they concentrate their forces and reinforces the importance of a swift, effective, likely hypersonic, counter-strike capability. At the same time the current Russian invasion of Ukraine has demonstrated that legacy Anti-Ship Missile technology, particularly when tactically combined with effective use of emerging affordable UAS, is still a credible threat to High Value Units. (Ref. 3)

Fig 4: Ukranian Navy Bayraktar TB2 (Image: Ukranian Navy)

### *3.1 Nowhere to hide*

To compound this challenge, emerging sensor technology combining Low Earth Orbit Satellites (LEO), High Altitude Pseudo Satellite (HAPS) drones and other surface and sub-surface autonomous capability provides a ‘see, sense, and connect’ capability that increases current C4ISTAR capability exponentially, particularly when combined with fifth and sixth generation communications processing techniques and Artificial Intelligence based Command and Control.

This means that the ability of Naval Forces to remain undetected, particularly in the surface environment, in the initial stages of any conflict will be severely compromised. In a total sub-nuclear war scenario, or even a large-scale regional conflict between major powers, future combatants must either be able to survive until enemy ‘find’ capability has been significantly degraded by their own effectors or be so disaggregated that they are not a viable cost effective target for high cost hypersonic effectors. In both instances the ability to survive against both the existing legacy air, surface and sub-surface threat and emerging UXV capability remain critical. Similarly, the ability to operate in a degraded environment once both sides have defeated or significantly degraded the opposing sides satellite capability, by removing communications and geospatial satellites, is critical to strategic victory.

### *3.2 Affordable defence?*

The economic and logistical aspects of naval warfare begin to play a role at this point; utilising a ≈2 million dollar Anti Air Missile to defeat a ≈200 thousand dollar UXV is neither tactically prudent or financially viable. An effective, affordable counter UXV system will be a key enabler for the survivability of future surface combatants. Developing technologies offer a number of potential solutions from hard kill using a ship-based rail gun or Directed Energy Weapon (DEW) through to soft kill via Electronic Warfare Counter UAS technology.

A layered, blended approach using each of these technologies is a possibility in the future but in the near term it is likely that Navies will focus on soft kill and small to medium calibre gunnery systems linked to both organic and external sensors with Threat Evaluation and Weapon Allocation (TEWA) carried out by the next generation of Command / Combat Management Systems. It is likely that the requirements of quantum computing (Faro, Johnson, Gambetta, IBM) (Ref. 4) will drive technology ever closer to true real time computing with attendant benefits for Command System latency either as a result of the realisation of a usable quantum system or the improvements to real-time classical computing necessary to develop quantum computing being applied to combat system equipment.

So what will this mean for the design, integration, operation, defect diagnosis, maintenance and repair of these systems? Many current fundamentals of equipment delivery will not change, open standards and the use of 'secure by design' principles will remain key to delivering effective combat system integration whilst degrading the impact of the cyber threat. Following design for support principles will be critical to meeting availability targets, particularly where autonomous systems are operating at reach. There is likely to be fewer operators required as data fusion and decision making become increasingly automated. The requirement for engineers, at all stages of the equipment lifecycle is initially likely to increase as increasingly complex systems require integration, test and evaluation, maintenance and repair. Basic naval engineering principles such as alignment of weapon system datums and accurate system timing data will further increase in importance as tolerances decrease as Navies seek to defeat faster moving, smaller threats.

One area that must change for many Navies however, if they are to maintain technological equivalence with peer and near peer competitors, is the ability to move equipment from the experimental programmes into main equipment procurement with the minimum of bureaucracy and therefore delay. Commercial and financial rules, intended to allow fair competition and ensure probity of public money often combine to delay or worse stop new capability being provided. Similarly, software and hardware obsolescence of existing equipment should be exploited as an opportunity to maintain operational advantage via spiral development rather than in service equipment and new capability being kept as entirely separate financial entities. Finally, the tendency to focus only on a 5-year spending cycle which drives short term financial decisions at the cost of availability and longer term affordability must be overcome if technological parity is to be maintained

## 4. Platform

### *4.1. Survivability*

Whilst the future battlespace may be full of drones and uncrewed vehicles giving visual indications and radar pictures, low signatures and vulnerability protection will still be required for a mixture of more current heavier weapons and lighter but more numerous swarm type UXVs. Signatures still matter to prevent bigger weapon targeting. Vulnerability protection and reduced susceptibility will become more important to protect sensors, defensive systems and crewed spaces. Layered defences using uncrewed vehicles hosted by naval platforms, independent uncrewed vessels and platform based defences will enable the higher value units to survive and thrive by rolling back the enemies crewed and uncrewed systems.

### *4.2. Damage Control*

Damage control and recovery will become more important, naval vessels will be hit more often. More automation, including damage sensing, in Damage Control will be required on more lean manned vessels, this will need to combine; internal communications, human location and health status, damage sensors and automated means of making a difference to fragmentation, flood and fire damage.

### *4.3. Lean Crewing*

Having said that future ships will be leaner crewed, this cannot always be the case as they conduct many human intensive operations such as humanitarian aid, Military Interdiction Operations (MIOPS) with boarding parties, Commando or Marine raiding groups, training teams and the uncrewed vehicle operator/maintainers. Flexibility will be required in the design to allow for the fluctuation of personnel. An optimised payload matrix that describes the mixtures of people, vehicles, boats, spares etc. will enable the most cost effective and adaptable design. Whilst it is not possible to think of everything for the future, the delivery of space in the right places with access to above and below the water for a range of vehicles is entirely necessary.

### *4.4. UXV Launch and Recoverability*

The ability to carry, launch and recover uncrewed vehicles will be a game changer. To do this with greater capacity, volumetric efficiency and the ability to recover bigger and heavier vehicles in higher sea-states and wind than the adversary gives a military advantage. To do this will mean the ability to carry, maintain, update and refuel/rearm/recharge the vehicles in the best location for them with a method that is either tailored to each vehicle type (and volumetrically efficient) or universal. The most effective system has yet to be accepted.

### *4.5. Topside Optimisation*

In order for the combatant or ship-based task group, made up of the primary vessel and its sub units, the uncrewed vehicles', to remain effective, communication rather than primary ship sensors will now be the priority. They will need to be high bandwidth, redundant and separated. This has significant arrangement and power system implications for the platform, as well as Electromagnetic Interference minimization, there will also need to be more effective power system zoning and supply.

### *4.6. Modularity*

Modularity is an enabler to the more efficient and fast fielding of new technology, whether this is at system or sub-system level. The platform designer needs to assess the most effective modular architecture to meet the needs of the payload matrix and look to gain mass and cost effectiveness through agreeing that modularity across assets and allies.

### *4.7 Non-lethal Defenses*

Force protection will be needed in non-war scenarios in order to prevent grey zone incidents such as the theft and reproduction or backwards engineering of uncrewed vehicles and other high-tech systems. In these incidents the use of non-lethal systems will be necessary to ensure the event remains in the grey zone and is not considered an act of war. The systems will need to operate alongside the lethal systems and will vie for high priority positions.

## 5. Conclusions

### 5.1 *The More Things Change*

This paper discusses a wide range of current and future technologies that the authors believe will shape the future naval battlespace but it is possible, indeed likely, that a key disruptive technology that will significantly impact naval warfare has not yet evolved or been created. What is certain is that to utilise any emergent technology effectively in the naval environment will require it to integrate with or operate alongside existing platform, system and power and propulsion technology. The policy and processes to do this exist and are enshrined in a number of international standards and policy documents, such as UK DEFSTAN, NATO STANAG and US MILSTD. New technology frequently fails to deliver operational effect because design, support and integration standards have been compromised, occasionally in the name of innovation, but more usually in the need to deliver affordability. Attempting innovation in all areas simultaneously has thus far not always been successful. But navies must innovate to maintain a battle-winning edge over peer and asymmetric adversaries in a geopolitical climate that is continually shifting in emphasis. This introduces many dilemmas, not least regarding levels of investment and collaboration, the balance of survivability and risk to human life and the extent to which obligations to international agreements such as those associated with climate change impact decision-making. As such a set of guiding principles might be useful.

### 5.2 *The More They Stay the Same*

The authors believe that the following guiding principles are key to effectively delivering key enablers to shape the future battlespace:

- Stop thinking about platforms, rather a force mix of complex or simple, crewed or uncrewed assets to meet capability needs. Enable and incentivise private solution-led development, not Operational Analysis developed exquisite requirements.

- Design for support and digital by design, exploiting platform data to drive availability and mission success. Use space created on platforms through automation to improve maintainability and survivability.

- Design for flexibility and superiority through modularity, automation, crewing, improved UXV launch and recovery and redundant, survivable communications systems.

- Only reduce crews if balanced by investment in technology and be serious about different crewing options.

- Electrify and digitalise where possible and consider the true cost and value of thermal management.

- It is better to be an active follower than lead technology trends when strategically unnecessary.

- Survivability is becoming more important as well as enhanced Damage Control capability. The constraints of the maritime warfare environment must be a key design consideration, for example; shock, reliability, corrosion, long range bandwidth, endurance.

- Develop procurement rules to incentivise rapid and effective private investment to facilitate operational advantage. Enable faster exploitation of new technology and concepts.

- Follow 'secure by design principles' and design information architecture to capture high quality data, process it at source and transmit high quality information to optimise bandwidth, whilst optimising the energy usage at source processing in near real-time computing.

- Ensure any capability constraints emerging from compliance with international agreements such as net zero obligations are fully understood and mitigated.

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