Artificial Intelligence: The Challenges and Opportunities for Future Naval Platform Design

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Synopsis

When looking at the future of naval platforms and the purpose they serve, artificial intelligence presents immeasurable opportunity for exploitation when the potential of the technology is explored. This paper studies the impacts of the introduction of artificial intelligence on naval platform design and where the direction of travel the discipline may follow in the future. Adopting a bottom-up approach based on the functional breakdown of a typical naval combatant, focus is drawn to six functional groups – navigation, warfare, platform management, recoverability, maintenance and logistics. A comprehensive derivation of functions and sub-functions formed the foundation for the study's research. Each individual function was assessed to identify its limitations and constraints as well as its potential to realise a marked improvement in performance with the introduction of intelligent technologies be that creation of a fully autonomous system or a calculated human-machine teaming arrangement including identifying specific artificial intelligence classes which could provide the desired effect. This phase of activity generated a series of challenges and opportunities spanning multiple domains and disciplines, outlining what adoption of such technology would mean for wider defence enterprise. There is no question that artificial intelligence has a game changing contribution to make to naval warfare both in terms of supporting and protecting the operator and generally improving how navies conduct their business both at home and overseas. However, there are significant challenges within technical, regulatory, societal and political spheres to overcome which require collaboration and expertise not only across defence enterprise but the wider industry base in order to define a framework within which highly intelligent naval platforms can operate safely, securely and effectively. First, we must frame the question we are trying to answer with artificial intelligence before designing this framework and taking decisions with conviction. This paper takes an initial step on that journey.

Keywords: Artificial Intelligence, Design, Evolution, Intelligent, Naval, Technology

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1. Introduction

Naval platform design is a complex activity so could the blueprint for typical naval platform designs as we know them today be simplified somewhat by harnessing emerging technological opportunities?

Artificial Intelligence offers a wealth of potential and possibility. Looking to the future and the potential of current technological advances in the context of naval platforms and their associated systems, design of such could undergo a transformation in order to realise improvements in areas such as safety, system performance, personnel efficiencies and availability.

This paper studies the potential impacts of maturing intelligent technology on the spectrum of functions typically undertaken by a naval combatant platform as well as detailing the considerations required to ensure effective implementation.

2. Study Approach

The first phase of this study centred around decomposing the functions performed by a typical naval platform such as a frigate or destroyer. Initially, a comprehensive derivation of functions and sub-functions was undertaken to form the underpinning basis of this study's research and this led to a focus on six core high level functional groups – navigation, warfare, platform management, recoverability, maintenance and logistics. Each individual function within these groups was assessed with the aim of identifying technical and operational limitations and then for its potential to realise enhancement in performance with the introduction of intelligent technologies. Specific classes within the artificial intelligence field were attributed to each functional application, considering both narrow and general types, to provide an initial view on how artificial intelligence could be introduced into systems as we understand them today. The potential opportunities and associated challenges are not one-

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dimensional in nature and so these were defined, spanning technical, commercial and societal axes and work has examined the magnitude and complexities of these challenges and opportunities, their relation to other platform domains and what it means for wider defence enterprise.

3. The Six Function Overview

The six core functional groups identified during the initial phase of activity provided the foundation for the study and so the following sections outline the narrative behind these groups and their applicability within this research.

3.1. Navigation

There is a clear safety benefit by means of reducing occurrences of human involvement and dependency throughout performance of the navigation function. Many of these benefits come from reducing the cognitive burden required during complex and fast-paced evolutions, but also during more mundane assignments whilst still maintaining a high level of executive decision-making concurrently with required levels of attention and focus. Navigation planning is inherently prone to human error; it is a complex process that requires high levels of attention for extended periods. The introduction of intelligent methods to undertake navigation planning can improve its quality and reduce the likelihood of introducing human error and uncertainty.

Defensive manoeuvres are challenging for a human operator to firstly co-ordinate and then undertake. The emphasis on selecting the most appropriate manoeuvre for the warfighting aim at hand and subsequently executing this manoeuvre in a short time frame places significant demand on cognitive capability and capacity given the highly stressed nature of the working environment. With accuracies and velocities of future threats ever increasing and levels of covertness improving, this loading on the human will also increase, demanding they make defining decisions in ever shorter timescales, timescales which may just be too short for a human to perform within. Artificial intelligence offers the potential to manage these ephemeral events effectively and efficiently, automating defensive manoeuvres such as hypersonic missile and torpedo evasion or swarm attack.

Tactical manoeuvres are similar in nature to defensive manoeuvres in that they can be complex to undertake. Operators are highly skilled and must be able to make effective decisions based on multiple streams of intelligence. As with defensive manoeuvres, artificial intelligence could provide advice or indeed take full ownership of these evolutions to ensure the course of action taken is of the best credentials under the circumstances.

3.2. Warfare

Command and control featuring increased levels of automation could deliver a seismic step change in warfighting protocol. Artificial intelligence is defining a new algorithmic warfare battlefield that has very loosely defined boundaries. Therefore, intelligent systems are becoming a critical part of modern warfare and are expected to assume a central role within military capability across the world. Military systems equipped with AI are capable of handling and acting upon larger volumes of data more efficiently when compared with conventional systems. Artificial intelligence improves self-control, self-regulation and self-actuation of combat systems due to its inherent computing and decision-making capabilities.

Tactical mission planning is a complex logistical task with multiple, often conflicting factors and considerations. The increasing opaqueness of the battlespace means that the warfighter must be smarter and sharper. There is a need to support the decision-making process by providing dynamic data fusion from the best sensor suite available at the right time. Artificial intelligence provides the ability to prioritise aims, remove clutter, select the most appropriate weight of effect, provide command support or enable full autonomy. Particular applications include –

- Rapid analysis of large voice and communications data volumes.
- Rapid assessment of sensor data to identify and classify objects, signals and geographic information.
- Improved tracking data.
- Improved targeting speed and accuracy.
- Active signature management.
- Improved refinement of the ‘need-to-know’ basis.

Today, human and machine work very closely to manage the battlespace and the effectiveness of the human-machine team has improved over many years through multiple iterations of combat system implementations, however the onus remains very much on the operator to make high profile warfighting decisions with potential for serious ramifications. The systems at the operator’s disposal will continue to grow more capable and more versatile and this could ultimately end up in an era whereby the operator is relieved of these ‘do or die’ decisions and the responsibility is passed on to their new team mate.

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3.3. Platform Management

Management of platform systems is a critical function to enable the warfare functionality of a naval platform and represents a driver in both personnel and procurement cost. It is both mission and safety critical in terms of providing power, propulsion and manoeuvring functions as well as other services central to supporting the effective and efficient use of the military capability available.

Intelligent systems could improve platform operating efficiency, reduce operator workload, reduce manual and menial workloads and ultimately reduce numbers of personnel required to operate a platform through enabling heightened machine control autonomy and providing a significant suite of decision support aids. Highly intelligent platform management is a necessity to delivering unmanned platforms, especially beyond small and short endurance boats.

The efficient management of power generation provides consumers with a significant challenge to enact due to the constantly varying load demands and an inability to predict, over the course of an operation or transit, a comprehensive chain of events and the durations for which they are expected to last. Architecture design of power generation and distribution relies upon the estimation of load magnitudes and consumption utilisation over the course of the role profiles the platform is expected to perform. Data from legacy systems can be referenced to better inform the required design characteristics of a new system, however this would demand a wealth of data which presents challenges in accumulation and management and is still heavily based on estimates and assumptions. Artificial intelligence techniques could go some way to refining the system design by understanding the supply-demand plot and employing automation to subsequently both match supply and smooth demand as necessary. The ability of the intelligent system to learn from experience enables it to continually refine its demand plots for instance when role profiles are amended and in cases of the unexpected.

Given the nature of the domain, power distribution introduces significant challenges for a naval platform. High Voltage switchboards, cable route planning and protection, fault detection and load shedding all require continual monitoring under highly stringent management process and procedure. Clearly, there is much benefit in lowering or even removing human intervention in this domain and so artificial intelligence and automation provide a gateway by which to achieve this through providing distribution control & management as well as fault finding and resolution provision.

3.4. Recoverability

Recoverability is the final phase of platform survivability. When the barriers forming the platform's susceptibility have failed, the design features that contribute to the platform's vulnerability credentials have been tested and the platform has sustained damage which can be in the form of kinetic, blast or shock impact. Platform recoverability can be delivered in many ways, depending on the needs of a particular platform and the procurement capital available.

Artificial intelligence could be used to support and compile an accurate damage control picture, whilst also providing actuation or decision support for the automated control of damage control and firefighting activity. Additionally, machine learning techniques can support prediction of damage spread depending on the nature of the cause and it's magnitude and suggest and enact the most suitable platform configuration and recovery actions to limit the impact and therefore the magnitude of remedial action. This capability provides the command with a full understanding of the health status and availability of platform systems thereby informing mission planning and personnel deployment. Implementation of intelligent technology in this space is likely to markedly improve response times for damage control scenarios thus reducing damage magnitude and periods of sustainment culminating in a platform with greater availability.

3.5. Maintenance

Maintenance of onboard systems and equipment is essential to enable the platform to achieve deployment and sustained operations in theatre over a period of time. It is expected that improvements in system reliability will continue apace and maintenance regimes will continue to contract however the activity of maintenance in planning, management and conduct continues to account for a significant proportion of crew time. That said, the employment of artificial intelligence for machinery and equipment failure prediction promises to deliver benefits in the timely and accurate prediction of failure using sensors on equipment and a deep richness of legacy equipment operating data from which trends and patterns can be identified and design remedies implemented. The result will likely be that fewer unforeseen failures occur resulting in improved maintenance planning and a significantly reduced need for reactive maintenance activity and ultimately minimised in-theatre disruption. This culminates in a lower personnel demand.

Artificial intelligence-assisted planning could more accurately schedule maintenance tasks and minimise lost active platform days. The grouping of tasks in a more intelligent manner and intimately linking the scheduled maintenance with a robust resource, stores and tools plan, will maximise platform availability by minimising any maintenance and non-fleet time. It is beholden on the platform designer and the system designers to continue to adopt design rationale which lowers the need for intervention, particularly that which is unexpected and therefore unplanned. It is acknowledged that reaching a 'bulletproof' state will not always be possible but having the capability to predict in good time what could happen and the remedial action required to correct the wrongs enables firmer planning and instils confidence in those relying on the capability that it is available when needed.

3.6. Logistics

Logistics functions contribute to sustaining the capability of a platform over time, be this through sustaining the needs of the crew, providing consumable stores or liquids to maintain the operation of the ship or provisioning spares for maintenance and thus there exists much opportunity to improve the efficiency of this activity set.

Application of artificial intelligence, predictive learning and long short-term memory provide the tools to enable the monitoring and prediction of onboard/offboard inventory of stores, spares, munitions, provisions, fuels and other consumable items to optimise holdings and track use. Intelligent systems could also be employed to conduct handling of stores including replenishment at sea, embarkation from shore and transits onboard. The system could also have the capability to perform 'what if?' scenarios to quickly understand the logistical impact should the platform mission profile change or resources be lost due to an adverse event.

4. Opportunity and Challenge Provided by Artificial Intelligence

4.1. Opportunity Themes

As this paper has identified, the potential wealth of opportunity presented by these emerging intelligent technologies is very rich and some of the possibilities have been highlighted thus far. This section outlines a selection of some of the most significant and impactful possible benefits that the technology could offer to the naval domain:

- Reduction or elimination of error and uncertainty.
- Shortening of decision times and hence delay.
- Sharing of accountability and responsibility between human and machine.
- Iteration of teaming arrangements to optimise output – 'bringing the best out of one another'.
- Identification and exploitation of human and system latent capability.
- Reduction in the cognitive stress and strain burden.
- High potential to reduce personnel numbers.
- Widening and broadening of platform operating envelope.
- Functional performance optimisation.
- Effective countering of evolving large and unpredictable asymmetric swarm threats.
- Improved cross-platform collaboration.
- Potential for competitive advantage in highly contested and congested environments.
- Simplify naval platform designs through the de-escalation of designing for 'standard'.

4.2. Challenge Themes

The opportunities cited above do not come without their challenges for implementation and these span multiple domains, some of which demand a concerted effort across industry, discipline and politics. The following have been identified as being amongst the most challenging of the themes uncovered as part of this research, many of which are naval domain agnostic:

- Defining a route to realisation of the benefits identified in the preceding section.
- Data quality – particularly in respect to current systems' ability to record data and data of usable quality to 'educate' learning systems.
- Introducing and employing intelligent systems in high complexity, high interdependency system-of-systems.
- Exaggeration in artificially intelligent systems of existing, known concerns in traditional software systems.
- Assuring and understanding system transparency and certainty.

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- The ability of intelligent systems to consider all possible permutations.
- Determining demarcation of accountability and responsibility within a human-machine team – 'striking the optimal balance'.
- Avoidance of the human undermining or second guessing the machine and vice versa.
- Protracted test & assurance regimes with difficulty in defining an 'end' – the point at which system self-sufficiency and self-sustainability is deemed to have been achieved.
- Clear, concise and timely evolution, and in some cases revolution, of legislation and regulation.
- Achieving accreditation and certification, especially where the system is making safety-critical decisions in terms of accountability and safety integrity levels.
- System networking philosophy demanding complex and convoluted architectures posing significant security design challenges.
- Heightened levels of vulnerability and susceptibility through increased connectivity and system-to-system integration.
- Potential magnitude of platform margins considering system complexity and levels of required redundancy and resilience.
- Dependency on onshore support networks.
- 'Ripple Effect' throughout the adopting enterprise across all lines of development.

4.3. Evolutionary & Revolutionary Transformation

The functions evaluated as part of this study can generally be grouped into two categories when reviewing the predicted level of transformation expected following the introduction of artificial intelligence – evolutionary and revolutionary. Many have the potential to deliver an evolutionary transformation enabling optimisation of operations based on recommending actions to, or advising, the operators, essentially acting as a decision support cast. These are relatively straightforward to deploy as they do not demand the intelligent systems assume the role of a responsible decision maker, which removes the risks associated with accreditation and certification of systems as well as alleviating concerns around trust and confidence in depending on systems to deliver the 'correct answer, every time'.

Conversely, some artificial intelligence-charged functions where intelligence is empowered as the decision maker and awarded authority would induce a revolutionary change to current understanding and philosophy. Such change is likely to culminate in higher risks for certification, architecture design complexity, testing and validation, demand on network infrastructure and acquisition cost growth. Thus, from a naval platform design perspective, such a 'revolution' is likely to demand a platform that is purpose-designed to support the use of intelligence, likely to exhibit marked deviations from current design principles and conventions. It is possible, even likely, that the quest for an unmanned platform will drive many of these perceived 'revolutions' into design, with the technologies being subsequently applied to manned platforms, optimising the human-machine working relationship.

Figure 1 provides an illustration based on the insights of this research on how a selection of the functions explored are judged to impact platform design by providing an outline qualitative assessment. The lower end of the scale represents those functions, that with the introduction of intelligent technologies, likely to enable adaptation or modification to current design protocol. The higher end of the scale represents those functions likely to induce revolutionary change in current design convention.

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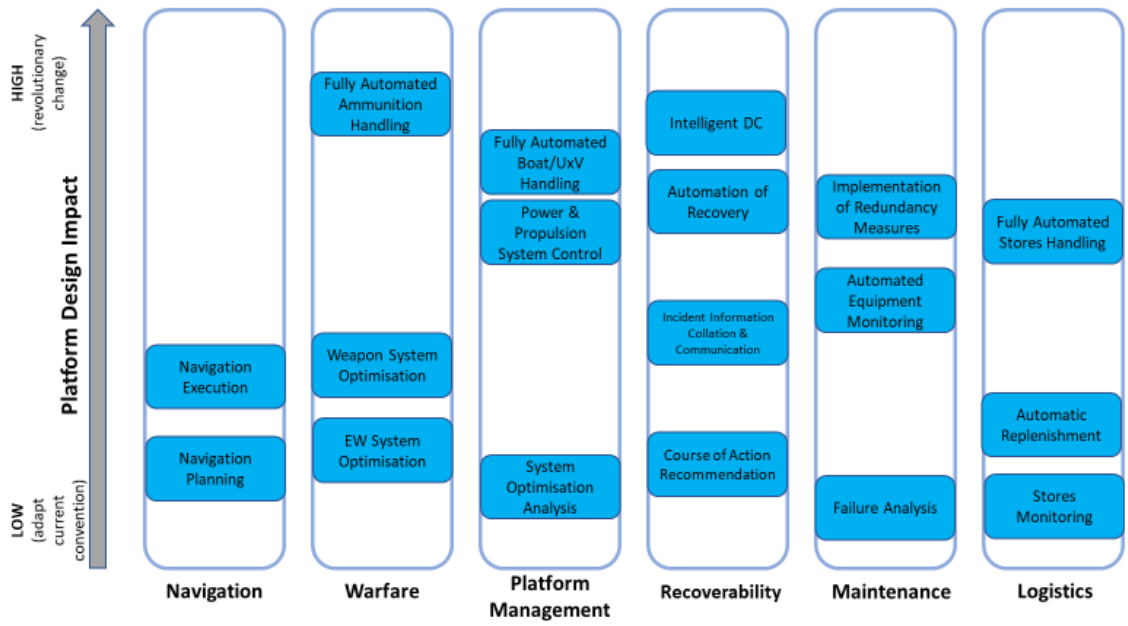

Figure 1: Qualitative Assessment of Impact Magnitude on Platform Design

5. Conclusions

In the context of naval platform design, artificial intelligence offers a wealth of possibility and opportunity to transition the naval enterprise into a new paradigm where the hypersonic threat can be successfully neutralised and the days of sending many hundreds of people are consigned to history. Looking across the six core functional groups, it is clear that they could all benefit from the introduction of intelligent technologies, be that in an advisory, support capacity as part of a human-machine team or as a fully autonomous task owner. It is recognised that it is likely that any system attaining fully autonomous status will have to go through evolutions working alongside the human as part of a team or organisation before being declared fully autonomous in order to build up the necessary trust and transparency within the stakeholder community that it is capable of fulfilling its responsibilities safely and securely. That said, there can be no doubting the potential potency of a carefully crafted human-intelligent machine team and the capability such a concept could nurture within the naval world.

However, to make such scenarios a reality, defence enterprises will need to evolve, and in some cases revolve, with a vast spectrum of questions requiring some carefully crafted answers. These answers need to be sought from across multiple axes to enable planning for this new age to begin and ensure that the promise shown by these technical advancements can be realised without losing the ‘glint’ within the gold that this technology can offer. Equally, we should not allow those challenges highlighted within this paper to stymie or heavily constrain the potential of the technology either. Any adopting enterprise must be clear on their aims and aspirations for artificial intelligence implementation. Whilst there is great potential which will only grow, much of this comes with significant cost attached and the consequences must be understood to ensure that intelligence is the correct all-round solution to their identified problem.

Upon review of how to advance the concepts discussed within this paper, a number of work themes were derived:

- Confirmation of the technical viability of employing maturing techniques to achieve the functional enhancements described.
- Undertake quantitative assessments and generate estimates on the impacts to the physical platform of enacting such technology changes and highlighting the key design drivers.
- Investigation into the required changes to network architecting philosophy in order to accommodate collectives of offboard assets for those functions which could be enhanced by their employment.
- Quantitative analysis of the challenges and risks and attribute these to specific functions to understand the magnitude of the opportunity.
- Review of the security implications on system design where levels of integration, connectivity and system-system collaboration is greater and determine suitable design measures to address.

There can be no doubting the significant challenge that delivering sufficient output to these themes presents and those challenges arise from numerous sources however, these steps will be necessary in order to ensure currency

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with innovation and maintain the ability to effectively counter increasingly capable disruptive threats. The most important consideration is that of time and by when adequate progress on these matters must have been made such that it is not too late.

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