OPPORTUNITIES FOR ENHANCING DEFENCE CAPABILITY GENERATION: THE FOURTH INDUSTRIAL REVOLUTION

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ABSTRACT

The current and future threat environment in which the Royal Australian Navy (RAN) will operate is becoming increasingly congested, lethal and asymmetric. To ensure that the Australian Defence Force 'keeps pace' with the industrial and commercial sectors while remaining ahead of its adversaries, there needs to be a constantly evolving, agile capability program that leverages from the fourth industrial revolution, Industry 4.0.

Defence industry has historically driven a significant number of the cutting-edge technologies that are used every day - from canned foods through to the internet. Ever more advanced technologies are becoming prevalent in areas of operations and regions of interest. The tempo at which these threat systems can emerge is a significant challenge to RAN's ability to acquire, certify, commission and employ capabilities that effectively counter the threats before they can evolve. The acquisition system of the future must be agile and minimally impacted by unnecessary complexity, inconsistent application of policy, or industry engagement limitations.

This paper presents a tiered framework for capability acquisition that matches the exponential growth of technological capacity. Defence 4.0 is a paradigm shift in the way capability is employed and generated. This framework has been modelled around the OODA loop and is comprised by the following four pillars: 1) Observe – Technology Intelligence Horizon Scanning, 2) Orient – Test and Evaluation, 3) Decide – Rapid Acquisition Process, and 4) Act – Deployment of Solution.

1. INTRODUCTION

Australian Department of Defence (Defence) have laid out broad innovation and reform plans for an Australian ship building capability to 2040, in the Naval Shipbuilding Plan, 2017 [1], and the 2016 White Paper [2]. The plan commits to maximising Australian industry involvement in naval shipbuilding in Australia and throughout the capability life cycle for new naval capabilities. There are tangible programs to bring together industry, academia and Defence research through initiatives such as the Centre for Defence Industry Capability (CDIC), the Defence Innovation Hub (DIH) and the Next Generation Technologies Fund (NGTF).

The Naval Shipbuilding Plan and initiatives are part of a broader objective and recognition that older styles of undertaking capability development and acquisition are not up to the task of keeping Defence capabilities effective against the rapid technological advances being adopted by adversaries.

The fourth industrial revolution, referred to as Industry 4.0, is a term that originated in Germany and defines the fundamental shift to cyber-physical systems [3]. Exciting new technological developments from Industry 4.0 are emerging such as:

1. Advanced automation and robotics;
2. Artificial intelligence (AI) and machine learning;
3. Additive manufacturing such as 3D printing; and
4. The Internet of Things (IoT).

The great promise of Industry 4.0 can only be realised if Defence has an agile capability acquisition system that works in concert with industry and academia. This paper will examine a broad view of Defence capability acquisition with a focus on the Naval context, and the application of Industry 4.0, which will be referred to as Defence 4.0.

Defence 4.0 is a paradigm shift in how capability is employed and generated. The framework has been modelled around the Observe-Orient-Decide-Act (OODA) loop and is comprised of the following four pillars:
1) Observe – Technology Intelligence Horizon Scanning,
2) Orient – Test and Evaluation,
3) Decide – Rapid Acquisition Process, and
4) Act – Deployment of Solution.

The loop is designed to illustrate how the capability phases flow into and loop back to create an organic model, as shown in Figure 1.

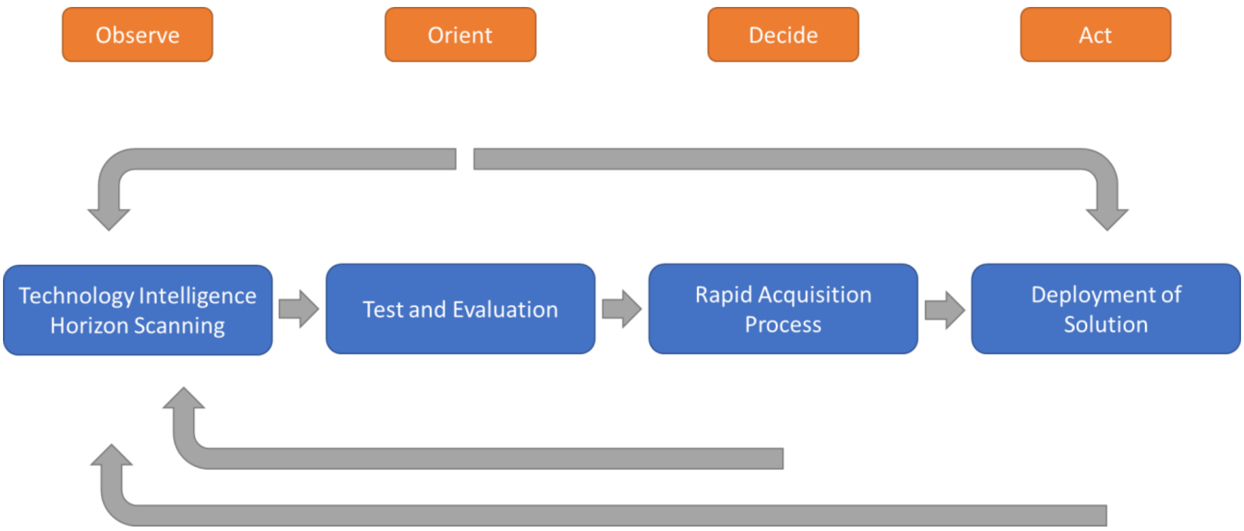

Figure 1: Defence 4.0 Capability Loop.

2. OBSERVE – TECHNOLOGY INTELLIGENCE HORIZON SCANNING

The purpose of horizon scanning is to identify and predict important global trends. Technology intelligence is a component of horizon scanning that focuses on identifying technology that can disrupt future growth. This section will explore technology intelligence horizon scanning activities being conducted by the Defence community (with a focus on RAN) and provide recommendations on how RAN can strengthen their technology intelligence.

2.1. Horizon Scanning in Defence

Defence uses several mechanisms to assist with horizon scanning, as illustrated in Figure 2. As part of Vice Chief Defence Force (VCDF) Group's Force Design Process, VCDF methodically analyses the current force structure for gaps and opportunities [4]. Defence also relies heavily on DST Group for advice. DST identified the task of scanning the environment to understand emerging threats and opportunities as one of its key roles [5]. To capture ideas from industry and academia, initiatives such as the DIH and NGTF have been established. These programs help Australia identify potentially disruptive technologies, enabling these areas to be proactively evaluated.

On an international level, Defence participates in The Technical Cooperation Program (TTCP). TTCP is an alliance between defence scientists from Australia, Canada, New Zealand, United Kingdom and the United States (Five Eyes Alliance). It is Australia's strongest tie to defence-related research being conducted in partner nations, encouraging idea sharing and open platforms. TTCP recognises that member nations do not have the individual resources to completely cover every area of defence research and that all partners can enhance their national defence at reduced cost through collaboration [6, 7].

These principles need to be applied in Defence's relationship with industry and academia. The private sector's research investment into areas such as "Big data" (managing large datasets) and AI can be leveraged by RAN. The DIH and NGTF are initiatives of the 2016 Defence Industry Policy Statement [8] that provide funding to companies and organisations to develop technologies that have been identified as being important to Defence. Another initiative was the Emerging Disruptive Technology Assessment Symposium (EDTAS) [9]. EDTAS are a series of presentations and workshops that have been run since 2015 and are co-hosted by DST, academia and industry. They explore the potential for technology to disrupt areas of interest to DST and provide guidance on priority areas for the NGTF. These programs are a step in the right direction, but more can be done to engage the broader Defence community enabling collaborative research.

As advanced threats are rapidly manifesting, RAN's ability to develop and bring into service new capabilities will be reliant on an increased capability for horizon scanning. Plan Pelorus 2022 outlines the direction of RAN from Chief of Navy's Senior Advisory Committee and aims to prepare RAN for future engagements. The Centre for Innovation (CFI) is designed for the RAN workforce to trial and develop ideas [10]. The CFI has also hosted Launch Pad events, which have successfully engaged industry and given them a platform to showcase to RAN [11]. The Navy Fleet Air Arm (FAA) hosts Shark Tanks at HMAS Albatross as part of FAA Innovation Program. The program gives RAN aviation personnel a platform to present ideas to improve capability [12].

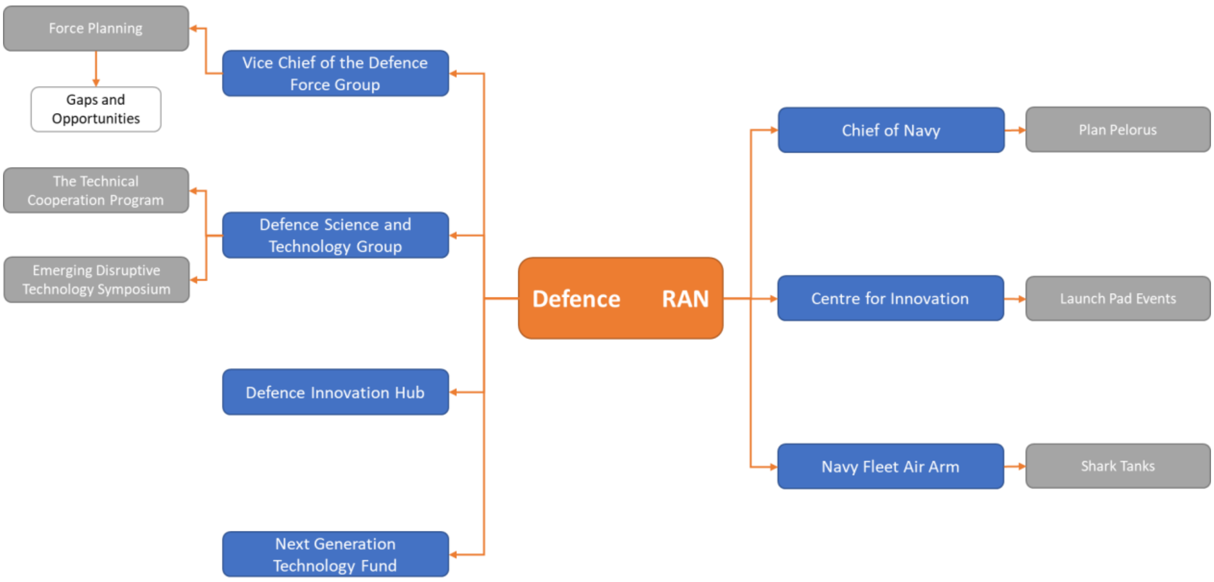

Figure 2: Defence and RAN Organisations for Innovation.

2.2. Harnessing Industry 4.0 to Improve Technology Intelligence

Horizon scanning is conducted in industry to drive innovation and help maintain a competitive edge. An important component of this is Internal Research and Development (IRAD) and research labs. Investment into research areas is guided by technology forecasting but also supports the prototyping of innovative concepts that can lead to disruptive technology. RAN encourages internal innovation, but the opportunity exists to refine and institutionalise efforts to engage with, and hence leverage, industry research. This is particularly true of international Primes who can seek to provide access to large (particularly United States) IRAD programs.

Defence benefits from engaging academia, which provides the ability to monitor the fundamental research conducted by universities (blue skies research) and recognise when the idea is mature enough to invest in. However, the pace of technology evolution is such that rather than trying to structure defence expectations around 20 to 30-year predictions, emphasis should be placed on the 10-year time horizon. Using technology readiness levels (TRLs) Defence should be aiming to support university research once it reaches TRL 4 or TRL 5 – laboratory breadboard or laboratory testing of integrated/semi-integrated system [13].

2.3. Recommendations

The following recommendations aim to develop a truly collaborative Defence-Industry relationship and maintain a competitive edge in the technology intelligence field:

- Establish a Naval Innovation Day – inspired by Army Innovation Day [14]. Yearly calls for proposals could be made, inviting industry and academia to showcase R&D activities that would enhance RAN capability. This event could focus on RAN high-priority interest areas. The aim of this day will be forging closer links with industry, encouraging/celebrating new ideas and a means to identify new concepts worthy of further investment;
- Structure within Defence how technology assessment is applied to university research. Encourage dialogue between universities by sending out Defence personnel to universities with the intent of creating an "Open Day" where universities can present research directly to Defence. Another initiative are joint research labs between Defence and universities. An example of this is the Jericho Smart Sensing Lab [15], which is a collaboration between the Royal Australian Air Force (RAAF) and the University of Sydney;
- Maintain and increase active involvement in the DIH and single service initiatives – reducing turnaround times; and
- Ensure involvement as stakeholder in the DST led NGTF programs.

3. ORIENT – TEST AND EVALUATION

To continually improve how Defence develops requirements and acquires capability, the technology options identified in horizon scanning need to be processed, analysed and synthesised into viable solutions that align with the high priority areas of Defence and RAN. The acquisition process relies heavily on the Test and Evaluation process (T&E). T&E informs decision makers of risk areas in cost, schedule and capability. It provides insight into how these risks can be managed or eliminated [16]. The following phases of T&E, shown in Figure 3, run alongside the capability life cycle:

- Preview T&E – supports the processing and assessment of options;
- Developmental T&E – supports design and development of system during acquisition;
- Acceptance T&E – verifies that the system is compliant to requirements; and
- Operational T&E – validates that system capability satisfies mission requirements.

This section will cover the preview and developmental T&E that inform how Defence sort and select options. The acceptance and operational T&E will be covered in Section 5 – Act, which will examine the verification and validation process (V&V).

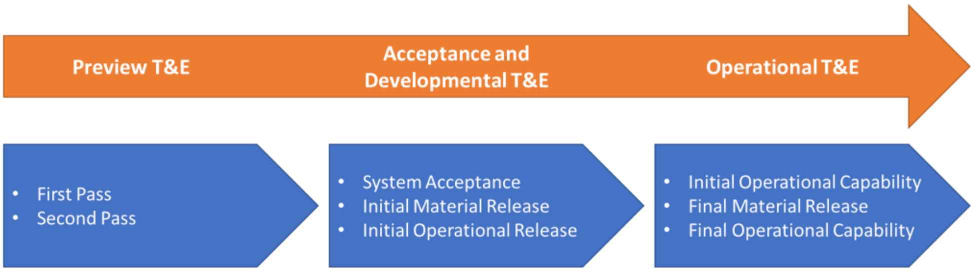

Figure 3: Capability life cycle showing how the T&E phases align with the acquisition milestones [16].

3.1. Current Test and Evaluation Process

The Australian Defence Test and Evaluation Office (ADTEO) was established in 2007 to be the central authority for Defence T&E [16]. ADTEO provides support for Defence during the entire acquisition process, from helping to refine options during First Pass government approval through to Final Operational Capability.

One of the roles of the Force Integration Division of the VCDF Group is to oversee the Joint Test and Evaluation. This maintains that T&E is consistent across Defence. The Defence Test and Evaluation Roadmap 2008 [17] emphasised the need for centralised T&E as the current organisations within Defence could not cover all phases of T&E over the capability life cycle. The 2012 Senate Inquiry into Defence Procurement Procedures [16] recommended improved T&E capability to better identify and control risks pre-First Pass.

The Royal Australian Navy Test and Evaluation Authority (RANTEA) and the Aircraft Maintenance and Flight Trials Unit (AMAFTU) conduct the T&E activities within RAN. In 2015 the Australian National Audit Office (ANAO) released a report investigating Defence T&E [16]. One of the case studies used in the report was the Landing Helicopter Dock (LHD), HMAS Canberra, where the report highlighted that due to workforce vacancies capability risk had been transferred to RAN. The report recommended that T&E training is strengthened and becomes more centralised so that Defence can have a complete overview of the organisation's T&E capability.

3.2. Integrating Industry 4.0 with Test and Evaluation

As acquisitions of complex systems increase, T&E tasks will become more critical. The 2008 Roadmap [17] outlined the important role of industry in conducting T&E and providing Defence with independent test facilities. It highlighted that obtaining information from industry was an issue that impeded T&E. The 2018 Department of Defense (DoD) Digital Engineering Strategy [18] recommends that one option to increase industry engagement is by integrating virtual environments to allow easier transfer of information such as digital design and lifecycle management embodied by the digital twin concept. A digital twin is a dynamic and functioning virtual representation of a physical system. This helps to inform decision making by increasing design transparency and mitigates risks around systems complying to standards. RMIT University recently proposed the Virtual Design, Optimisation and Testing framework (VDOT), which is a system using AI that will be able to process the increasing amount of data available to Defence [19].

The technological developments in AI and digital design that can optimise T&E will not be able to be realised without more investment in a T&E workforce that has consistent training across Defence.

Recommendations

The following recommendations would help Defence improve agility and risk management in the T&E process:

- Feedback mechanisms from T&E must take priority in Defence 4.0 system engineering frameworks;
- A strong, centralized T&E force that is capable of surging to meet project needs;
- Industry should be given more transparency into the T&E process to build trust and open pathways to data sharing; and
- Incorporating end-to-end digital environments.

4. DECIDE – RAPID ACQUISTION PROCESS

The Observe phase of the Defence 4.0 cycle gives data-driven insights into the decisions that are needed. However, these observations only drive probabilistic recommendations. A decision must still be made, and the capability acquisition, and sustainment gears must begin turning in order to align a new capability with Defence's existing systems and assets.

4.1. Current Acquisition Process

Traditional acquisition processes and cycles are not prepared for the demands of timeliness and quality that will be needed by Defence 4.0. Contemporary efforts to modernise the acquisition cycle through Capability Acquisition and Sustainment Group (CASG) have trialled different project administrative strategies, such as the DDG alliance. CASG current goals include implementing First Principles Review (FPR) recommendations, to align strategic partnerships with industry, and to improve relationships with owners (Government) and customers (Capability Managers).

Implementing the Smart Buyer process is an example of modernising the acquisition phase of the capability life cycle. Yet modern acquisition strategies are still aimed at supporting technology available circa 2020. The acquisition process must continue to evolve in order to be able to integrate modular, sophisticated technologies into existing and future systems.

4.2. Rapid Acquisition Processes Under Defence 4.0

The Australian Standard for Defence Contracting (ASDEFCON) suite of contracting templates are used to provide a standardised set of documents of procurement [20]. Under Defence 4.0, rapid acquisition processes will need to be adaptable. In the same manner that the Observe phase recommends which capability to acquire; suitable acquisition contracts must be matched to that capability. Future contracts can adapt to the technology or system being acquired based upon 1) its TRL [13], 2) trust in the supplier (based off past performance and other metrics such as the company scorecard), and 3) capability priority and urgency.

The commitment to the fourth wave of deterrence research, that has emerged from the mid-1990s, demonstrates the scale and scope of the spectrum of future technologies that will need to be integrated [21]. Specialised technologies will require increasingly niche skillsets to acquire and implement. It is imperative for Defence 4.0 as a whole that this is achieved, so that capability managers will have trust in their system when Acting (deploying solutions). ASDEFCON will be automatically matched to the technology under consideration, critically reducing time and resources required. Standardised T&E techniques and measures will become a critical framework providing system feedback.

Matching an acquisition with a suitable contract structure should be the perfect 'task' for existing machine learning technologies. A key risk however will remain data quality, in that any recommender system is only as good as its inputs, and it will only deliver outputs asked of it. The proposal herein is certainly not intended to be a complete solution, it is intended to assist human decision makers in order for them to make better decisions in a timelier manner. Notwithstanding, this concept will likely prove to become a critical component of capability acquisition. This will be driven by necessity where complex software refresh cycles must be integrated into hardware and software lifecycles with vastly different requirements.

An emerging disruptive technology to acquisition capability is blockchain. Blockchain defines digital records (blocks) that are stored in a public database (chain). In 2018 it was announced that AUCloud will partner with Quant Network to develop a blockchain operating system for the Australian Government [22]. This system will be used by Defence and has the potential to significantly improve the efficiency of the acquisition process by allowing smart contracts between industry and Defence. A smart contract would be committed to the blockchain and be executed automatically by the computer. This allows for the construction of contracts from standard templates by AI.

A shake-up to the traditional acquisition model employed by the United States Intelligence community is the use of the independent venture capital firm, In-Q-Tel. The firm is backed by the Central Intelligence Agency (CIA), and has disrupted how the United States Intelligence community conduct their scanning, partnering and acquisition process. The Australian Government has formed a partnership with In-Q-Tel to allow Australian agencies access to emerging technologies acquired by In-Q-Tel [22]. The NGTF is an example of Defence scanning and acquiring emerging technology, however this has focused on mid to large scale programs. The DIH provides an avenue for start-ups to submit proposals to receive Defence funding whereas the In-Q-Tel model proactively seeks out start-ups that have technology that can be ready for use within 6 to 36 months [23].

4.3. Recommendations

Defence has taken the first steps toward mastering the 21st century acquisition environment, however, adoption and evolution of Defence 4.0 rapid acquisition processes is critical. Some techniques have been proposed, however new innovations should be continually be assessed. The following recommendations would add value to CASG in the short-medium term:

- Immediate focus on ability to acquire software and robotics systems of increasing autonomous sophistication;

- Put T&E at the core of the capability life cycle;
- Continually incorporate new information from the Observe phase to maximise the likelihood that adequate resources are available to acquire and implement new capabilities;
- Launch an Australian version of In-Q-Tel; and
- Implement blockchain-based contracts and use AI to automate their construction from ASDEFCON templates, reducing cost and time of acquisition.

5. ACT – DEPLOYMENT OF SOLUTION

The final phase, once the course of action has been decided, is the rapid deployment of the solution. Prospective threats are changing ever more rapidly, and the combination of longer lead times to develop new equipment, coupled with the increased rate of change of threats, is a significant concern for military planners. Rapid deployment relies on understanding the situation and workforce management – as vehicles and equipment become more complex the user group needs to be selected, trained and retained so that deployed systems have maintained support.

5.1. Current Transition from Acquisition to Operational

The maritime industry is not immune from the increasing length of time required to develop new equipment. There are big challenges to bringing new systems online after the acquisition phase. Currently Defence needs to integrate new technology into legacy systems, interconnect networks and collaborate with contractors. Defence is respected as a leader in providing consistent structure to certification, V&V and intellectual property (IP) strategy but as start-ups, new industry partners and academia are increasingly involved in Defence projects more can be done to streamline these processes and build strong relationships between industry and Defence.

Defence strategy recognises that innovative technologies require significant effort and funds to develop, and there needs to be trust that industry IP will be protected at the end of the acquisition cycle. In 2016 an IP strategy was released [24] to encourage industry to participate in the DIH. Coordination of cross-disciplinary environments across Defence, academia and industry will streamline each stage of a project life cycle and create an intuitive feedback loop back into generating new capability.

RAN has initiated a large investment in innovation, this includes many unit level initiatives to embrace Industry 4.0 such as additive manufacture trials [10]. Additive manufacture allows RAN to replace parts and experiment with solutions while at sea. This is done in workshops modelled off the CFI mentioned in Section 2.1.

5.2. Rapid Deployment using Defence 4.0

Current Defence capability generation within the Australian maritime domain could be arguably described as reactive. Data collected through the Observe phase informs the acquisition cycle on where there are gaps and opportunities, but there is also an immense amount of data being collected from intelligence, surveillance and reconnaissance (ISR) that can inform decisions at the deployment stage. A large step that is needed in processing ISR data is the standardisation of data formats, communication architectures and enhanced, automated meta-data tagging (e.g. automatic generation of semantic labels for entities in satellite imagery). This will not only be useful in the identification and evaluation of threats but in the sustainment and optimisation of systems to combat the threats. An example of this is the Global Fishing Watch [26] which connects data from Automatic Identification Systems (AIS), satellite imagery and IoT to determine a vessel's purpose. Primarily this has been used in the identification of illegal fishing vessels, one of the RAN's busiest constabulary tasks. The data gathered using these techniques can then also inform horizon scanning and acquisition.

Operational data can also be paired with game theory to provide modern tactics or be used in simulation software/equipment and serious games for training the Defence workforce. Serious games or gamified training creates an engaging and motivating learning experience. Simulation software and equipment such as augmented reality provide new ways to easily process large amounts of information through visualisation and enable collaboration between remote sites.

Open source data, standards and architectures enhances collaboration between industry, academia and Defence. This allows rapid responses to emerging problems and threats leveraging extant data sources and simulation capability. Free and open source systems are often supported and reviewed by larger communities than proprietary systems, increasing the likelihood that defects and vulnerabilities are detected earlier. The challenges of IP and security policy also apply here and would need to be closely managed by the data manager who is the single source of truth. The importance of open systems is supported by the memorandum signed by the Secretaries of the United States military, which stated that a Modular Open Systems Approach (MOSA) is imperative to mission success [27].

V&V and the sustainment of operational assets would both be helped by using a digital environment, as introduced in Section 3.2. Digital environments allow the creation of a digital twin, which is a digital representation of the physical system. Digital twins are continually updated with the physical system's performance and maintenance data throughout its life cycle. This is currently utilised in monitoring physical health of systems such as aircraft engines and Formula 1 cars [25] for accurate engineering fatigue and maintenance requirements and would offer high value to RAN for materiel seaworthiness.

5.3. Recommendations

The following recommendations would help the rapid deployment of an acquisition:

- Increased emphasis and high-level support for standardisation of data formats and architectures;
- Defence policy supporting collaboration with industry is critical to stimulate the industry investment into the disruptive technologies;
- Defence resources are allocated to include mentoring startups and new industry partners through the certification and V&V phase;
- V&V is supported by digital twins; and
- Defence workforce is supported by gamified training.

6. CONCLUSION

The motivation for designing Defence 4.0 around the OODA loop was to demonstrate how each phase of capability development informs the next but also has the potential to improve those preceding it. The recommendations put forward in the four phases: Observe – Technology Intelligence Horizon Scanning, Orient – Test and Evaluation, Decide – Rapid Acquisition Process, and Act – Deployment of Solution, could have significant impact on how Defence generates capability by leveraging the technological developments of Industry 4.0.

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