NAVY

RAS-AI STRATEGY 2040

WARFARE INNOVATION NAVY

OUR VALUES

SERVICE COURAGE RESPECT INTEGRITY EXCELLENCE

www.navy.gov.au

FOREWORD

On 1 July 2020, the Prime Minister launched the *Defence Strategic Update 2020*. This highlighted that we are experiencing the most consequential strategic realignment since the Second World War. Consequently, our Navy must be able to meet the emerging challenges of regional military modernisation, the risk of state-on-state conflict and technological disruption, to maintain our ability to ***Shape*** the Maritime Environment, ***Deter*** actions against our national interests in the Maritime Domain, and ***Respond*** with credible Naval Power to defend our Nation, and our National Interests.

Robotics, Autonomous Systems and Artificial Intelligence (RAS-AI) are transforming every aspect of our lives. As a Fighting and Thinking Navy, we must leverage these advances to also transform, and improve, our ability to *Fight and Win at Sea*.

I am therefore pleased to release Navy's *RAS-AI Strategy 2040*, which nests within Navy's capstone strategic documents – Plans MERCATOR and PELORUS, and supports the achievement of each of the five Navy Outcomes.

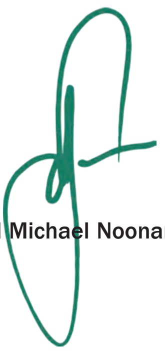
RAS-AI Strategy 2040 sets out the challenges and opportunities that these technologies present and explains to Navy, our Joint Force colleagues, the broader Defence Organisation, our allies and industry the benefits we seek from RAS-AI, and how we aim to realise them. To fulfil our potential, we need to engage in constant experimentation, and encourage collaboration and innovation at all levels. This will enable us to leverage RAS-AI to enhance Navy's capability by strengthening our ***Force Protection***, increasing our ***Force Projection*** in the maritime approaches of our near region, improving our Joint Integration through ***Partnership***, maximising our ***Force Potential***, and ensuring ***Australian Control***.

Just as our people and machines must operate in teams to enhance their strengths and overcome weaknesses, we must team with Defence as a whole, industry, academia and our international partners, to achieve the potential of these technologies. My vision is for Navy, industry and academia to build upon our established transformational partnerships, allowing us to address the challenges outlined in this strategy, together.

Make no mistake; the pace of change is increasing and will challenge us all at some point. To meet that challenge, all that I ask, is that each of us focus on being a little better – every day.

In embracing technology, we must remember that warfare is, and will remain, a fundamentally human activity. Our people will be at the core of our technological advances, and we must design systems with them at the centre. RAS-AI will make our people better warfighters, and will enable us to achieve expanded reach across the region, however it is our people who remain our competitive edge.

The race in autonomous warfare has already begun. Doing nothing, or waiting for allies to solve our requirements, is not an option. I commend the RAS-AI Strategy to you all and challenge each of you to think about how you can contribute to it.



Vice Admiral Michael Noonan, AO, RAN
Chief of Navy

Contents

EXECUTIVE SUMMARY

The Chief of Navy describes the Australian Navy as a world class fighting system, not just a collection of platforms. This strategy therefore, is not a standalone plan for Navy's adoption of RAS and AI technologies but an enterprise wide approach describing the challenges and opportunities that RAS-AI present; the benefits that Navy seeks; and lines of effort Navy will pursue to achieve them.

The first part of this strategy addresses the context in which Navy is developing RAS-AI. It outlines the distinct limitations & constraints, and opportunities, that the Australian maritime domain poses to the adoption of RAS-AI. Military-off-the-shelf (MOTS) capabilities from allies or other domains are not always suited to address these unique factors which include Australia's geography, maritime and strategic environments, and the Defence ecosystem.

The technology context provides an assessment of the driving forces, common trends, and challenges that RAS-AI present maritime forces. These factors underpin projections of the mission sets that RAS-AI offer above, on and below water. As a strategy, this document avoids singling out specific technologies but identifies common enablers that will be required to make Navy 'RAS-AI ready'.

The RAS-AI vision expands on the RAS-AI effects of greater Force Protection, Projection, Partnership, Potential and Control (4PC) described in Chief of Navy's message. Navy's RAS-AI strategy is to continually increase these effects between now and 2040.

Design principles describe how a *Thinking, Fighting & Australian* Navy must approach RAS-AI. They provide a framework for defining how new capabilities should be developed and employed to complement the maritime fighting system. They can be thought of as a starting point towards the vision.

This strategy sets out four lines of effort (LOE) which connect Navy's design principles to its vision: People, Discover, Develop & Deliver. These LOE address many of the common challenges that RAS-AI adoption faces and key enablers that it will require. These include training and workforce transformation; research & development; and building collaborative partnerships with industry and allies to design and demonstrate RAS-AI capabilities. They also address important legal and ethical issues, as well as the need to build trust and assurance in autonomous systems and develop a sovereign common control system.

As a document that addresses a field of rapid development and disruption, the RAS-AI strategy will be reviewed in 2024. It will be supported by a campaign plan that will set out milestones; key performance indicators; and metrics along the four LOE, over that period. Although this document describes a 20-year vision, this strategy is a plan for Navy to become 'RAS-AI ready' now.

As Chief of Navy says, "waiting is not an option."

THE AUSTRALIAN CONTEXT

There are many limitations & constraints, and opportunities, for an industrialised nation inhabiting an Indo-Pacific continent for the adoption of RAS-AI, which MOTS capabilities from allies, or other domains, are not always suited to address. Consequently, Navy needs marinised Australian RAS-AI capabilities which address factors including geography; the maritime and strategic environments; and the national Defence ecosystem.

GEOGRAPHY

DISTANCE Operating over a wide area and generating mass locally requires cooperation through agile control systems, the ability to task organise and generate a common operating picture, assured long-range communications and reliable supply, repair and recovery.

DISPERSION RAS-AI need to generate massed effects in multiple locations and timely collection, processing and dissemination of data. Systems must be able to operate independently but also complement crewed fleet units.

ENVIRONMENT

DIVERSITY Need to meet Australian conditions including current, temperature extremes and complex CLEAR[1] systems. Platforms designed for benign conditions, or the air or land domains, must be adapted for the marine environment.

DISASTER Operate in dynamic environments in the wake of natural disasters such as tsunami and volcanic eruptions which include turgid water, obstacles and changing seabeds.

RESPONSIBILITY Autonomous capabilities must minimise risk to the environment, both in normal operations or in the event of a system failure whether it be loss, hull fracture etc.

STRATEGIC ENVIRONMENT

REGIONAL MODERNISATION Even 'game changing' technological advantage is only temporary. Programs need to be agile to allow hardware and software to be continually developed and upgraded in a process known in the ICT sector as 'Evergreening'.

STRATEGIC WARNING Reduced warning times means no time to gradually adjust capability and preparedness. RAS-AI must deliver persistent presence across a wide area of interest and capabilities that can be forward or rapidly deployed.

Figure 1 The Australian Context

1 CLEAR is the Coastal, Littoral, Estuarine, and Riverine operating environment.

NATIONAL ENTERPRISE

WHOLE OF DEFENCE APPROACH
Effective, rapid introduction of RAS-AI capabilities into Navy requires close cooperation with other groups and services and a whole of Defence approach to enablers.

WARFIGHTING CULTURE our values & culture adhere to Australia's legal, ethical and policy obligations. RAS-AI systems must encode these while remaining interoperable with partners. Data and algorithms that underpin Navy's system of control must be trusted and sovereign.

NAVAL SHIPBUILDING RAS-AI capabilities must deliver force level effects to Navy's future fleet. Programs must use this national enterprise to enhance the speed of development (as well as the size and complexity) of systems.

INDUSTRY PARTNERSHIPS
An 'Evergreening' approach will be contingent upon groups of partners in long-term relationships with Navy to allow continual development and enhancement of RAS-AI capabilities.

GEOGRAPHY

Distance: As *Plan MERCATOR* highlights "Australia's maritime jurisdictional area alone amounts to more than 10 million km^2 – almost twice the size of mainland Australia – and our area of direct security interest encompasses more than 10 percent of the Earth's surface". The simple act of deploying from homeports to a domestic exercise or operational area is, by the standards of many of our coalition partners, an expeditionary task.

- Systems must be able to operate over a wide area, generate mass locally and be persistent. They need the ability to cooperate through agile control systems that allow them to task-organise and share information to build a common operating picture. They must be underpinned by assured long-range communications and reliable supply, repair, and recovery.

Dispersion: Navy is growing its surface fleet through programs such as the Hunter-class Frigate and the Arafura-class OPVs. These systems, however, will require supplementation by RAS-AI to increase presence across Australia's maritime interests.

- Capabilities will need to generate concurrent effects in multiple distributed locations with the ability to collect, process and disseminate data in a useable and timely manner.

Navy will require systems that can operate independently but also complement crewed fleet units.

ENVIRONMENT

Diversity: The size of our maritime domain means operating conditions for the Navy are varied, from the cold waters of the Southern Ocean to the tropics of our northern approaches with distinct and demanding currents, tides and other challenging characteristics.

- RAS-AI systems must be capable of performing effectively in a variety of conditions that characterise the Australian theatre, including strong currents, Antarctic through to tropical water (and air) temperatures and complex CLEAR systems. Capabilities designed for more benign marine conditions will need to be adapted for Australian employment.
- Likewise, platforms in service with Army and Air Force will likely need to be marinised to cope with the demands of the maritime environment and the challenges of operating on board a ship, or in company with a Naval Task Group.

Disaster: Defence's proud history of responding to regional natural disasters has demonstrated the need for systems to operate in dynamic maritime environments encountered in the wake of natural disasters such as cyclones, tsunami and volcanic eruptions.

- Navy will require systems that can survive in these environments, which include turgid water, obstacles and changing seabeds.

Responsibility: Some of Defence's most significant operational and training areas are located within or adjacent to locations of global environmental significance – such as the Great Barrier Reef. Navy takes all reasonable steps to avoid damaging the marine environment and ecosystems wherever in the world it operates, both at sea and ashore. Navy RAS-AI systems will also be compliant with relevant Australian legislative and regulatory requirements for safe operation and adhere to Navy governance frameworks.

- Autonomous capabilities must minimise risk to the environment, both in normal operations or in the event of a system failure whether it be loss, hull fracture etc. and comply with the *Maritime Activities Environmental Management Plan*.

STRATEGIC ENVIRONMENT

Regional Modernisation: The *2020 Defence Strategic Update* describes the growing pace of regional military modernisation with new weapons being introduced that place Australian military forces at greater risk over longer distances. To maintain its competitive edge, Navy will pursue disruptive RAS-AI technologies that have the potential to be 'game changing'. Any technological advantage over a pacing threat will, however, be temporary.

- Capability programs need to be sufficiently agile to allow hardware and software to be continually developed and upgraded in a process known in the ICT sector as 'Evergreening'. RAS-AI capabilities require a system-of-systems acquisition methodology that is not platform centric. Moreover, a 'tool box' approach (systems that can be tailored to deliver flexible mission packages) will be required to suit varied and dynamic operating environments.

Strategic Warning: The *2020 Defence Strategic Update* makes clear that growing regional military capabilities, and the speed at which they can be deployed, mean Australia can no longer rely on a timely warning ahead of conflict occurring. Reduced warning times mean defence plans can no longer assume Australia will have the opportunity to gradually adjust capability and preparedness in response.

- Navy requires RAS-AI that can deliver persistent presence across a wide area of interest, complemented by capabilities that can be rapidly developed, tested, forward deployed (or rapidly deployed) and adapted in situ.

NATIONAL ENTERPRISE

Whole-of-Defence Approach: Many of the enabling elements of emerging RAS-AI capabilities require enterprise-wide coordination. These include, but are not limited to, research & development; experimentation; test & evaluation; data; architectures; algorithm assurance; and systems of control.

- Effective, rapid introduction of RAS-AI capabilities into Navy requires close cooperation with other groups & services and a Whole-of-Defence approach to enablers.

Warfighting Culture: Navy reflects national values and culture while adhering to Australia's legal, ethical and policy obligations.

- RAS-AI systems should encode these values, policies and operational approach while remaining interoperable with coalition partners. Navy may employ a variety of platforms and payloads but the data and algorithms that underpin its system of control must be governable, trusted, assured, lawful and traceable. Human Command must maintain responsibility for RASAI decision-making.

The Force Structure Plan: Sets out a commitment to continuous naval construction enabled by shipbuilding and sustainment infrastructure, workforce, and an industrial base. It includes plans for the acquisition or upgrade of up to 23 different classes of Navy and Army maritime vessels through to 2040.

- RAS-AI capabilities must complement and integrate with the Navy's future fleet to deliver force level effects. Programs need to leverage this national enterprise in order to enhance the speed of development (as well as the size and complexity) of RAS-AI systems.

Australian Industry Content (AIC) & Partnerships: Navy has begun to establish long-term, multi-party teaming arrangements with industry, such as the Combat Management Systems Enterprise (CMSE) for the surface fleet. This model reflects Navy's relationship with industry and will be an important factor in RAS-AI.

- An 'Evergreening' approach will be contingent upon *groups* of partners in long-term relationships with Navy to allow continual development and enhancement of RAS-AI capabilities. Navy will seek AIC which, for new and emerging technologies, will require investment in Australian R&D.

THE TECHNOLOGY CONTEXT

RAS is a term used by academic, scientific and technology communities to describe the physical (robotic) and cognitive (autonomous) aspects of a system (or platform).[2] Defence uses this term to describe systems that perform a function on their own by being either physically remote from a human operator, performing cognitive functions on behalf of a human operator or, (increasingly) both.

Artificial Intelligence (AI) is not a specific technology but rather a collection of computational methods and techniques that include algorithms, machine learning and deep learning. This document employs the *Defence AI Strategy* definition that states, “AI is a collection of interrelated technologies used to solve problems and perform tasks that, when humans do them, requires thinking.”[3] This strategy encompasses both combat AI and enterprise AI applications.

The terminology used in the RAS-AI field is new and emerging and, in the absence of standardised definitions, can cause confusion. For clarity, the glossary at the end of this document sets out the most common terms used by Navy until a Defence-wide lexicon is agreed.

DRIVING FORCES

There are a number of driving forces that will shape the environment within which Navy will need to operate out to 2040. These include:

Rapid technology development: Areas of importance include machine learning, natural language processing, energy harvesting and storage, propulsion and aerodynamics, augmented reality, cybersecurity, robotic sensing, manipulation and movement (including swarming), cloud computing, Internet of Things, and communications.

Time and space compression: Ongoing increases in the speed and range of weaponry are occurring at the same time as an exponential increase in accessible data. The volume of data, speed of engagement and variety of courses of action available, will mean that decisions must be made faster than can be feasibly managed by any human alone or even teams of humans.

Increasing threat and lethality: The advent of new weapon propulsion technology and precision enabled by advances in position, navigation and timing systems, combined with adversary RAS-AI capabilities, has significantly increased the threat to Navy assets. This may be exacerbated where adversaries have different ethical standards in their application of RAS-AI effects. Reducing risk to sailors will require alternatives to the use of only crewed vessels and avoiding the concentration of capabilities in limited numbers of platforms.

Competition for skills: The skills Navy will need are already some of the most highly sought after in the workforce. If Navy is to build, sustain and retain the workforce it needs, it will be essential to develop or win skills (such as software engineering and data analytics) over from other industry sectors or identify new novel ways of accessing these skills on an as-needs basis.

Growing costs: The cost of conventional military capabilities continues to increase at higher rates than inflation. Regardless of the increasing capability being delivered in high-end military systems, they are associated with a reduction in mass and redundancy. RAS-AI systems offer more affordable technology that can augment or replace some of the functionality of crewed capabilities.

COMMON TRENDS

A number of different trends are emerging across a range of technologies that will enable more effective RAS-AI systems to be incorporated into the force at a lower cost. Some technologies will play a role in improving operations across a range of crewed and uncrewed systems. These include improved propulsion; novel means and modes of communications; materials that reduce the need for maintenance during maritime missions of long duration; and improved methods of generating, harvesting, and storing energy. Other advances seem especially critical for RAS-AI including:

Vision systems: Object recognition, navigation, and see-and-avoid capabilities are already enabling autonomous operations in crowded and congested environments.

Teaming & Swarming: RAS cooperation and swarming supports effective human-machine teaming and machine-machine teaming to generate mass, apply distributed affects and aid in safe and effective operations.

Launch & Recovery Systems (LARS): Allowing reusable RAS across a broader mission area and working in support of fleet specific tasks.

Additive Manufacturing (AM): Also known as 3D printing, is likely to allow repairs at sea with rapid production of replacement components, enabling greater use of local ‘repair through replacement’.

AI technologies: The use of artificial intelligence technologies will continue to be democratised thus empowering ‘non-experts’. This means a higher proportion of a given workforce can take a more active role in data utilisation, visualisation and maximisation.

2 US Joint Chiefs of Staff, *Joint Concept for Robotic and Autonomous Systems*, 2016

3 This definition is in turn adopted from the *2019 Australian Council of Learned Academics Report*

TECHNOLOGY FORECASTS

The Defense Science Board *Sense; Think/Decide; Act; Team* framework[4] is useful in understanding how to disaggregate advances in autonomy. Key capabilities in these areas, based on a review of the current technology and estimated developments, are highlighted in *Figure 2*.

What is apparent is that many RAS-AI technologies are already at a high Technical Readiness Level (TRL). Many components with maritime military applications are being employed in different contexts in the private or non-Defence sectors. Adaption for employment in the maritime domain represents project and commercial risk, as opposed to technical risk, to adapt and integrate systems.

COMMON ENABLERS

Analysis of the technology forecasts and a review of hundreds of sources indicates certain key technology enablers Navy will need for effective introduction and deployment of RAS-AI systems namely:

- Big data access and management;
- Secure computing and trusted algorithms;
- Systems of control;
- Assured communications;
- Trusted and dynamic spectrum management; and
- Networking based on modularity and open architectures.

MISSION POTENTIAL

Figure 3 summarises a wide body of research into what maritime missions can be accomplished in three horizons: today's technology; those that appear likely in the near-term; and those that likely require significant development out to 2040. For those accomplished with today's technology, there are a number of systems available now as either a fully developed system or as a prototype that could be developed into an operational role.

COMMON CHALLENGES AND THE LINES OF EFFORT (LOE)

An analysis of the technology forecast in *Figure 2* and the mission potential in *Figure 3* identified a number of common challenges to the adoption of RAS-AI into Navy. These challenges were further refined when considered in the Australian context. The four LOE set out in this strategy, *People, Discover, Design, Deliver*, address these common factors to provide a roadmap for the adoption of RAS-AI into Navy.

---

4 See: Office of Secretary of Defense (2016) *Summer Study on Autonomy*

TECHNOLOGY FORECASTS

The Defense Science Board Sense; Think/Decide; Act; Team framework helps disaggregate advances in autonomy. Key capabilities in these areas, many at a high technical readiness level (TRL), are highlighted in this RAS-AI Technology Forecast. While it is difficult to give an exact timeline the trends highlighted here are consistent across the literature. Many components with maritime military applications are already being employed in different contexts in the private or non-Defence sectors.

	TODAY 2020	LIKELY NEAR-TERM	POTENTIAL 2040 FAR-TERM
	Mature technologies available for integration into projects, albeit with the need for adaptation to military applications or the maritime environment.	*Technologies that are on a path to maturity and are expected to mature in time for projects currently in planning.*	*Technologies that will require further research and development before their applications are fully understood and they are available for military use.*
AUTONOMY	▪ Able to carry out simple and well defined missions with human oversight	▪ Able to independently carry out missions based on general information and automatically adapt to changing circumstances	
SENSE	▪ Object recognition; full spectrum sensing	▪ Additional sensing; integrated perception	▪ Scene understanding
THINK / DECIDE	▪ Rule based decisions; learning from training data	▪ Anomaly detection; values-based reasoning	▪ Abstraction; judgement; ideas-based reasoning
ACT	▪ Routing navigation	▪ Obstacle-avoidance; agility	▪ Navigation in dense and dynamic environments;
TEAM	▪ Human oversight of machines	▪ Emergent swarming behaviour; armed wingman	▪ Fully adaptive coordinated swarms; understanding of intent
INTER-OPERABILITY /COMMUNICATIONS	▪ Current C2 standards; stove-piped systems ▪ Centralised data management	▪ Seamless C2 support for human-machine and machine-machine collaboration ▪ Onboard data processing; smart push of data to the right user	
SECURE COMPUTING /NETWORKING	▪ Cyberdefence in depth ▪ Stovepiped RF systems; selected LPI/LPD; static network paths	▪ Autonomous cyberdefence; cyber-resilient design ▪ Efficient and agile use of RF spectrum; pervasive LPI/LPD; self-healing mesh networking paths	

Improvements in other technologies will also enable more efficient RAS-AI operations across a wider range of missions

- Propulsion
- Energy storage and harvesting
- Sensor technology (size, type, sensitivity, resolution)
- Materials and methods to enable long-term remote operations on and below the surface
- Underwater communications

Figure 2 RAS-AI Technology Forecast

MISSION POTENTIAL

The Mission Potential summarises likely maritime missions that could be accomplished with today's technology, appear likely in the near-term, and those that require significant development. For those accomplished with today's technology, there are a number of systems available today as either a fully developed system or as a prototype. These judgements were based upon a review of the available technology, environment, applicability to RAS-AI and other operational challenges.

	TODAY 2020	LIKELY NEAR-TERM	POTENTIAL 2040 FAR-TERM
	Missions that could be accomplished with today's technology, albeit with the need for adaptation to military applications or the maritime environment.	*Missions that could be accomplished with near-term technologies and are expected to be available for projects currently in planning.*	*Missions that can be accomplished in the far term and will require significant technological development.*
UAV MISSIONS for RAN organic operations	▪ Communications relay ▪ ISR in permissive environments + Counter piracy + Search and rescue ▪ CBRN detection ▪ Small scale cargo delivery in permissive environments	▪ Cargo delivery in hostile environments ▪ Maritime interdiction ▪ ASW tracking ▪ Air defence	▪ C4ISR in contested environments ▪ Medium endurance ISR ▪ Counter surface vessel
USV MISSIONS	▪ ISR in permissive environments ▪ Mine sweeping ▪ Search and rescue	▪ Mine countermeasures ▪ Armed escort ▪ Military deception/EW ▪ ASW sanitisation ▪ Air and missile defence (sensing, non-kinetic operations) ▪ Counter fast attack craft (remote operations)	▪ ISR in hostile environments ▪ Mine laying ▪ Counter fast attack craft (autonomous) ▪ Ground attack ▪ Air and missile defence (kinetic operations)
UUV MISSIONS	▪ Mine countermeasures ▪ Counter deployed sensor/sensor array ▪ Near-land monitoring ▪ Oceanography ▪ Undersea infrastructure monitoring ▪ Inspection/identification of hulls and piers ▪ Communications relay ▪ UUV decoys	▪ Tracking of submarines in support of ASW ▪ Long endurance ISR ▪ Navigation and networking ▪ Counter surface vessel	▪ Short timeline time critical strike (TCS) from a submerged UUV against a land-based target

Figure 3 Potential RAS-AI enabled missions

VISION

Navy's vision is for RAS-AI to enhance the ability to Fight and Win at Sea by enhancing five fundamental effects – Force Protection, Projection, Partnering, Potential and Control.

FORCE PROTECTION

RAS-AI will protect our people by providing new alternatives to traditional methods of maritime combat that help keep our sailors out of harm's way resulting in a more survivable force through increased combat mass and distributed critical functions.

PARTNERED FORCE

RAS-AI systems that are integrated by design with the Joint Force and prioritise interoperability with strategic partners deepening our capabilities and relationships.

AUSTRALIAN CONTROL

An Australian common control system (CCS) will support trusted human command and machine control of multiple robotic, autonomous, intelligent assets across a coalition force in a contested environment.

FORCE POTENTIAL

Human/Machine teaming will maximise Navy's human potential by allowing us to do things better and do better things.

Smarter systems will enhance our decision making while allowing our people to find new and better ways to conduct and sustain operations.

FORCE PROJECTION

Autonomous Systems allow Navy to generate mass and tempo on a scale it otherwise could not achieve, enabling a presence in Australia's maritime reaches that crewed platforms could not, on their own, maintain resulting in greater operational reach.

NAVY RAS-AI VISION

Force Protection, Projection, Partnering, Potential and Sovereign Control (4PC)

Navy must be able to contribute to complex joint missions in order for Australia to efficiently, safely and securely access and defend the maritime domain now and into the future. Employing RAS-AI will enable a more agile, resilient, and lethal fighting force, enhancing Navy's ability to Fight and Win at Sea through five fundamental effects – Force Protection, Projection, Partnering, Potential and Control. These are not end states but descriptions of the enduring benefit that RAS-AI will increasingly deliver through 2040 and beyond.

FORCE PROTECTION

RAS-AI will protect our people by increasing situational awareness and providing innovative alternatives to traditional methods of maritime combat that help keep our sailors out of harm's way. This will result in a more survivable force through increased combat mass and distributed critical functions which, in turn reduces the number of friendly high value or high pay-off targets available to threat targeting systems. Navy will use RAS-AI as a means to counter adversary RAS-AI.

FORCE PROJECTION

Autonomous Systems allow Navy to generate mass and tempo, on a scale it otherwise could not achieve, enabling a presence in Australia's maritime reaches that crewed platforms could not, on their own, achieve. RAS-AI capabilities enhance Navy's persistent ISR coverage, situational awareness and operational reach in all domains and the full spectrum of operations.

FORCE PARTNERSHIPS

The RAN prepares Naval Power in order to enable the Joint Force in peace and war. Navy RAS-AI systems will be integrated by design with the Joint Force and prioritise interoperability with strategic partners.

The shared employment of RAS-AI will further deepen Navy capabilities and relationships. RAS-AI enhance Navy's ability to Fight and Win at Sea through a strategy that is complementary to joint and coalition concepts.

FORCE POTENTIAL

Human/Machine teaming will maximise Navy's human potential by allowing us to do things better and do better things. Blended capabilities will enhance existing warfighting functions while delivering novel ways to conduct and sustain operations in the future which could not be delivered by either alone.

AI will reduce the cognitive load on our people, helping them make sense of the increasing volumes of big data to achieve improved situational awareness and deliver enhanced decision-making. Better use of data will also enhance training, simulation and force level planning which will in turn improve concepts and operating procedures.

SOVEREIGN CONTROL

Navy's RAS-AI system of control will protect our sovereign data and allow the rapid task-organisation of multiple RAS-AI assets across air, land, sea, space, and electromagnetic domains. This will enable a model of human command/machine control suited to Navy, Joint and Coalition forces. New UxVs will be able to 'plug and fight' and be operational within days not years.

RAS-AI DESIGN PRINCIPLES

Navy's RAS-AI design principles, derived from Chief of Navy's command themes – A Fighting Navy, a Thinking Navy and an Australian Navy – provide a framework for defining how new capabilities should be developed and employed to complement the maritime fighting system.

THINKING NAVY

"Success will increasingly depend on the quality of our thinking and our agility in decision-making."

USER CENTRED DESIGN

The number, variety and sophistication of Navy RAS-AI capabilities will rapidly increase from the present through 2040 and beyond. These capabilities will be employed in increasingly dynamic and potentially dangerous environments meaning systems must make human command easier. User centred design requires:

- systems designed for ease of use and rapid introduction into service;
- interfaces and controls that are intuitive as tasks and capabilities become more complex;
- an iterative design and upgrade approach to improve user experience, leveraging RAS-AI's ability to provide real-time data-driven feedback informed by users;
- an agile Integrated Logistic Support (ILS) system; and
- automating repetitive processes to allow operators to focus on mission command and the tactical picture.

DECISION SUPPORT

Already the array of highly capable sensors across the fleet have the potential to overload decision-makers while new capabilities offer the potential to exponentially increase the volume of data collected and options available.

RAS-AI systems must reduce the cognitive load on commanders and operators, allowing them to achieve greater shared situational awareness and facilitate human teams, in command of teams of machines, in order to deliver effective, efficient and ethical decision-making.

FIGHTING NAVY

"We must be able to fight in all domains, including cyber and EW, not just in physical domains"

JOINT INTEGRATION

RAS-AI systems, while optimised for the particular demands of the maritime environment, form part of a joint warfighting system. They must be readily integrated with Army, Air Force and enterprise level enablers as well as be interoperable with our coalition partners. This includes systems of control and approaches to data management.

EVERGREENING

The growing pace of regional military modernisation will challenge Navy's technological advantage. To maintain its competitive edge, Navy will pursue disruptive RAS-AI technologies that have the potential to be 'game changing'.

Any technological advantage over a pacing threat will, however, be temporary. Capability programs need to be sufficiently agile to allow hardware and software to be continually developed and upgraded. This process of 'Evergreening' means transitioning from a platform centric approach to a system-of-systems methodology. This in turn will depend upon building close, long-term teaming relationships with and between industry and academia to achieve the agility to adapt to emerging threats and technologies.

AUSTRALIAN NAVY

"Our ongoing quality will increasingly depend on our culture and above all, the generation and maintenance of a fighting spirit"

MADE FOR AUSTRALIA

RAS-AI systems must be designed for Australia's distinct strategic circumstances including our geography, maritime and strategic environment. Systems must be:

Robust: able to survive and perform in Australia's challenging maritime operating environment.

Reliable: trusted to perform tasks in an explicable way within acceptable boundaries.

Repeatable: offer high assurance of bounded behaviour to deliver dependable, repeatable outcomes.

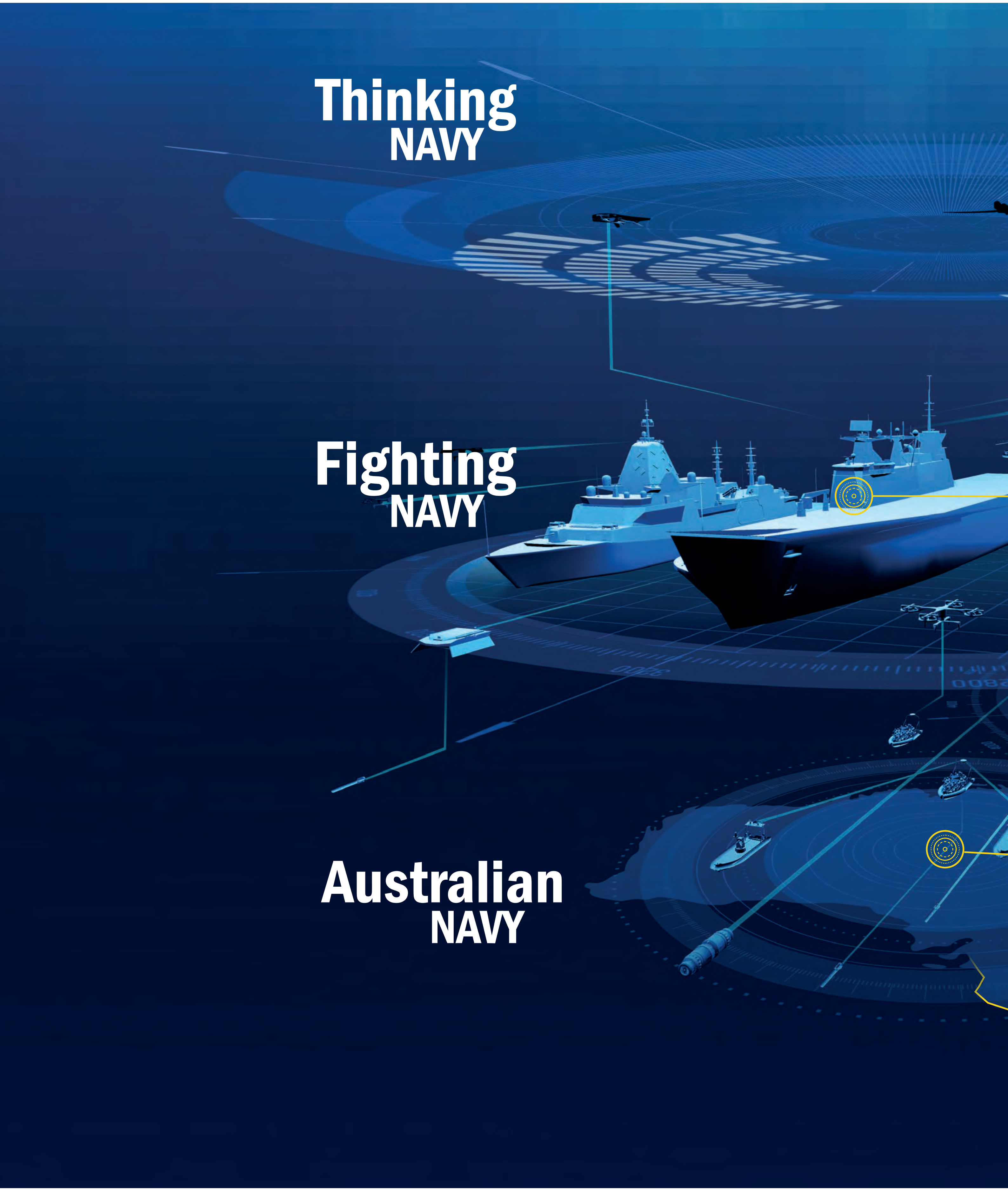
AUSTRALIAN SOVEREIGN CONTROL

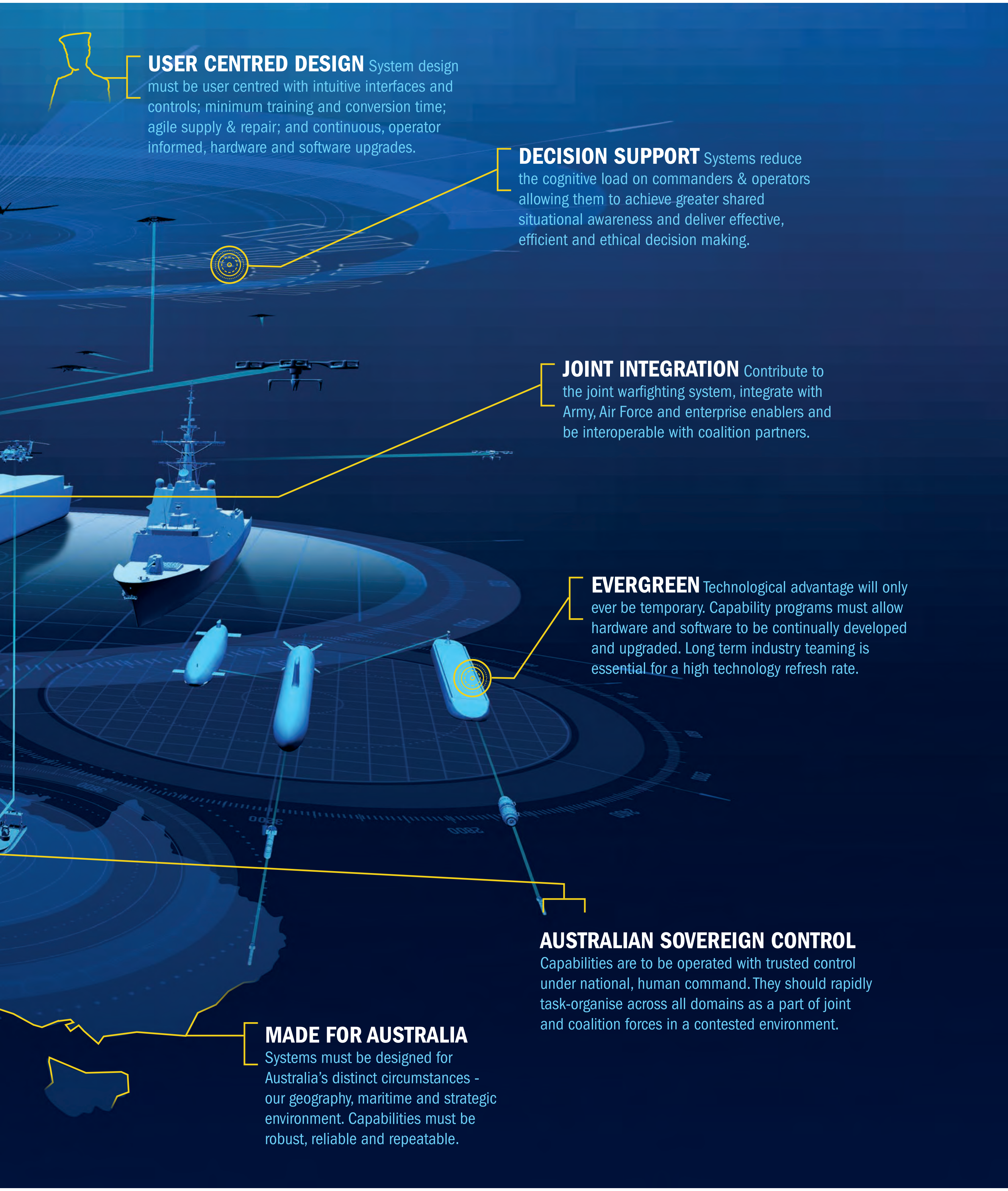
Navy's system of control for RAS-AI capabilities must reflect Australia's legal, ethical, and cultural values and embody Navy's operational approach. Systems must integrate with a unified means to support human command and trusted machine control of multiple robotic, autonomous, intelligent assets across a coalition force in a contested environment.

Navy may employ a variety of platforms and payloads but the data that fuels machine learning, and the algorithms that underpin its system of control, must be trusted, and reflect Navy's operational approach. RAS-AI capabilities must be able to 'plug and fight'.

PRINCIPLES

Navy's RAS-AI design principles define how new capabilities should be developed and employed to complement the maritime fighting system.





USER CENTRED DESIGN System design must be user centred with intuitive interfaces and controls; minimum training and conversion time; agile supply & repair; and continuous, operator informed, hardware and software upgrades.

DECISION SUPPORT Systems reduce the cognitive load on commanders & operators allowing them to achieve greater shared situational awareness and deliver effective, efficient and ethical decision making.

JOINT INTEGRATION Contribute to the joint warfighting system, integrate with Army, Air Force and enterprise enablers and be interoperable with coalition partners.

EVERGREEN Technological advantage will only ever be temporary. Capability programs must allow hardware and software to be continually developed and upgraded. Long term industry teaming is essential for a high technology refresh rate.

AUSTRALIAN SOVEREIGN CONTROL
Capabilities are to be operated with trusted control under national, human command. They should rapidly task-organise across all domains as a part of joint and coalition forces in a contested environment.

MADE FOR AUSTRALIA
Systems must be designed for Australia's distinct circumstances - our geography, maritime and strategic environment. Capabilities must be robust, reliable and repeatable.

FROM STARTING POINT TO VISION – RAS-AI LINES OF EFFORT

Navy's design principles represent a starting point for implementing the strategy and define the approach to be taken moving forward in the development of RAS-AI. The RAS-AI effects (4PC) provide the vision that Navy will be constantly moving toward over the next 20 years.

An analysis of the issues outlined in the technology context, and Australian context, identified a number of common challenges to realising Navy's RAS-AI vision. Navy will pursue four LOE, *People, Discover, Design, Deliver,* to address these common factors and provide a roadmap which connects the principles to the vision.

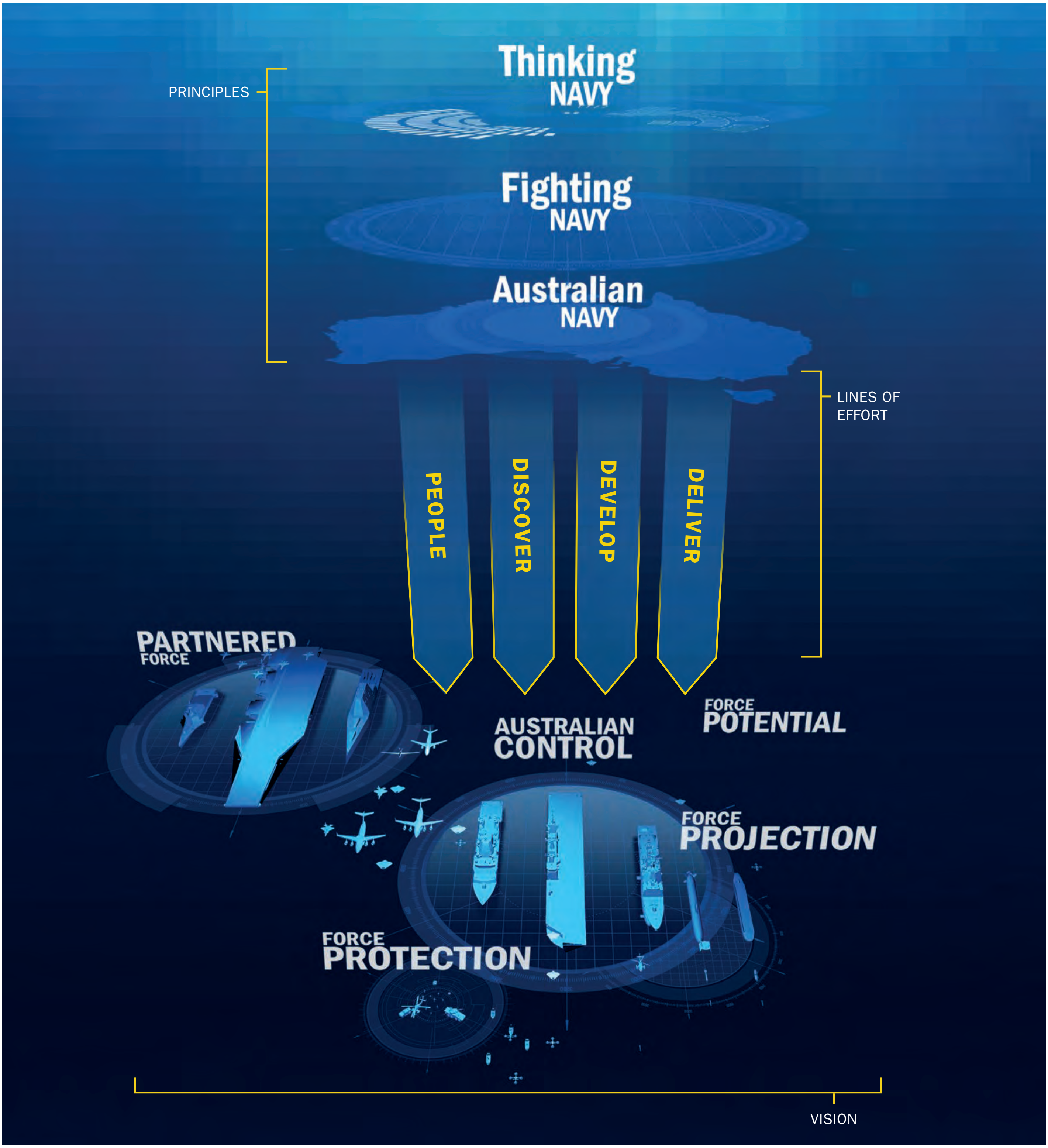


Figure 4 Navy's RAS-AI Roadmap

PEOPLE

Realising Navy's RAS-AI vision relies on its people. The ability to plan for, acquire, operate and maintain RAS-AI capabilities is contingent on growing a workforce who have a deep understanding of the Australian maritime operating environment and RAS-AI technologies. Many essential skills and competencies needed for RAS-AI employment do not currently exist in the Navy.

Identifying, developing, and sustaining the future workforce will require not only bringing new personnel to the Navy in highly sought-after disciplines but, accessing a range of skills outside of Navy. Ensuring Navy has suitably qualified and experienced personnel to develop and employ RAS-AI will require workforce transformation, training system adaptation and a framework for human machine teaming.

WORKFORCE TRANSFORMATION

Learning by doing: Leveraging expertise from industry and academia to deliver formal RAS-AI training and on the job upskilling has been, and will be increasingly, important in growing Navy's RAS-AI workforce. Navy will continue to build upon these relationships.

Specialise: In the near to middle term Navy will need to rapidly develop new specialist skills such as technicians, RAS operators, data analysts and T&E practitioners. These may require new categories or expanding/re-defining existing ones, the most prominent being:

- **Technician:** Keeping RAS platforms operational will require conventional maintenance skills and knowledge, however, as systems become increasingly software defined maintainers will need skills analogous to network administration. These will be required as a part of the 'toolbox' approach to support flexible mission planning through mission configuration and management of platforms.
- **Data specialists:** The volume, velocity and variety of data collected by RAS-AI systems will require specialists with skills in both maritime warfare and data analysis.
- **Operators:** Initially operators will require predominantly 'fly/drive' skills, however, as control systems become more advanced and integrated with combat management systems, operators will be responsible for directing and monitoring teams of machines. This will reflect a transition from controlling remote sensors and effectors to combining broad, area effects from distributed capabilities.
- **Test & Evaluation (T&E):** As machine learning systems become more sophisticated, they will require highly skilled T&E practitioners who can not only support introduction into service activities, but the ongoing development and assurance of learning systems.

Generalise: Navy's total workforce will need to incorporate foundational RAS-AI technology literacy. All commanders, operators and decision-makers will need to have a strong foundational understanding of autonomous systems. This is likely to include basic skills in machine learning, as well as an understanding of teaming and social decision-making. While a long-term investment, an introduction to RAS&AI should be introduced into ab initio training as soon as possible.

Integration with industry: The speed of development will not allow skills maintenance across the full suite of expertise and knowledge Navy requires to deliver the RAS-AI effects. Industry will be required to house, maintain and deliver RAS systems and will also increasingly play a role in analysis and decision support to deployed forces.

These elements of workforce transformation are not mutually exclusive. Although by 2040 Navy's total workforce will require foundation RAS and AI knowledge, it will still require specialists with deep knowledge and training as well as the ongoing delivery of specialist training and education by industry and academia.

For some categories, such as Combat Systems Operators, the change will be evolutionary. For other categories, the introduction of RAS-AI will be disruptive and require close collaboration between RAS-AI technologists, category managers and workforce planners.

TRAINING SYSTEMS

RAS-AI will have a significant impact on the training system, offering both challenges and opportunities.

Care must be taken such that operators do not become overly dependent, complacent, or uncritical in RAS-AI employment. Training scenarios must avoid complacency and develop users who 'trust but verify' i.e. have confidence in, but not become uncritically accepting of, autonomous systems.

Training will need to evolve to incorporate the development of human-machine teams. Data is the 'fuel' of machine learning. As Navy embraces human-machine teaming data will increasingly become the fuel of human learning as well. Navy will need to capture and manage data generated in training environments to refine machine learning and system improvement.

NORMALISE HUMAN-MACHINE TEAMING

The teaming of humans with intelligent machines offers avenues to build on the strength of each. Humans excel at reasoning, dealing with ambiguity, making ethical and moral decisions, and thinking creatively. Autonomous systems can rapidly synthesise and analyse large amounts of data and will operate with precision in complex, time constrained environments. They are also more expendable, can learn from experience, are unaffected by human emotions and offer solutions that humans have never conceived.

As more RAS capabilities are integrated into the maritime force, these systems will need to work seamlessly with existing crewed and additional RAS systems. Human-machine teaming must be normalised and developed through ab initio training and revisited periodically throughout career courses.

In a rapidly developing field such as RAS-AI it is essential that Navy has a cooperative approach to obtaining, supporting, and leading research with the Whole-of-Defence, industry and academia.

RESEARCH PARTNERSHIPS

Academia: Navy will leverage the *Defence Science Partnerships 2.0* program to establish long-term research partnerships with prominent research institutions. This program includes all thirty-seven public universities in Australia and provides a framework for implementing the higher value, longer term collaborative research agreements that will be required to address the underpinning knowledge base for developing RAS-AI. Warfare Innovation Navy (WIN) will undertake an annual review, with DST and other stakeholders, to communicate research needs and opportunities to partners.

DST: As Defence's science and technology agency, DST is a key research partner for Navy in the development of RAS-AI. Navy will collaborate with DST to answer key RAS-AI research questions with particular interest in *Science, Technology and Research Shots* (*STaRShots*) programs including:

- Remote Undersea Surveillance;
- Quantum Assurance;
- Agile Command and Control; and
- 'Battle Readiness' through the use of data analytics.

INDUSTRY

A great amount of cutting-edge research is being undertaken by industry – both in traditional defence, but also the non-defence sectors. Navy needs to access and learn from this body of knowledge to successfully develop RAS-AI.

Defence Industry: Navy will develop long-term, multi-party teaming arrangements with industry for deep research and development, such as the Combat Management Systems Enterprise (CMSE).

Non-Traditional Industry Sectors: Navy will also build new relationships with non-traditional industry sectors to foster Australian research. For instance, the natural resources sector has made great advances in undersea exploration and remote-control systems, while the financial technology sector (FINTECH) are developing best practise methods of testing & evaluating AI software.

The Defence Innovation Hub (*The Hub*): is a key mechanism for Navy to identify emerging concepts and technology from industry and academia and progress them towards operational capability. The Hub encourages industry to submit proposals to Navy offering innovative technologies and solutions while also allowing Navy to solicit novel solutions to known problem spaces. WIN sponsors RAS-AI and other projects proposed through The Hub by Australian industry and academia. Navy will continue this relationship to enable Australian capabilities to be discovered and progressed to a TRL that allows incorporation into Navy and Defence acquisition programs.

DEVSECOPS: describes a continuous delivery software development life cycle (SDLC) with a security focus (evolved from the traditional DevOps methodology). It is a combination of culture, practices, and tools. Navy RAS-AI development depends on creating an agile, collaborative development process to ensure applications remain relevant and secure, what the USN refers to as 'Compiling to Combat In 24 Hours' (C2C24). WIN will work with Joint Capabilities Group to provide a secure DEVSECOPs environment that protects intellectual property, where Navy, industry and academia can collaborate.

DEVELOP

Engagement, design and demonstration, three focus areas that support the development of RAS-AI capabilities that integrate with Navy's current and programmed force, are interoperable with allies while meeting Australian conditions. First, Navy will undertake a process of wide-ranging engagement with RAS-AI partners across Defence, Industry, and Coalition. Second, Navy will employ a concept led design approach to architectures, mission management and common control systems. Third, Navy will create opportunities to demonstrate emerging and mature RAS-AI capabilities to users thus enabling better informed development to rapidly introduce fit-for-purpose capabilities into service.

ENGAGEMENT

WIN sponsors a wide-ranging program of engagement while also acting as the maritime RAS-AI point of contact for Defence Groups & Services, Australian Government agencies, industry, academia, and coalition militaries.

WIN represents Navy on Five Eyes, QUADLAT, regional and bi-lateral autonomous warfare working groups and the NATO *Maritime Unmanned Systems Initiative* (which includes 18 member nations), where it advocates Navy's external requirements, standards, and initiatives. This allows Navy to contribute to partner nation experimentation, tactical development, doctrine, and concepts of operation & employment. WIN will also continue to grow the RAS-AI community of practise across Defence through roundtables, working groups and other fora.

Navy engages widely with the RAS-AI community including industry, Defence and coalition partners

DESIGN

Experimentation: WIN will facilitate a program of experimentation to inform force options development and program strategies.

- What RAS-AI capabilities are likely to enhance current projects and programs?
- How does such capability interact and integrate with the joint force?
- What are the counter RAS-AI effects that may be employed by, or against, Navy?

Navy has already demonstrated the effectiveness of a dedicated experimentation and evaluation organisation through the work of 822X Squadron on contemporary UAS and advanced payloads. Navy will need to replicate the success of this approach to support projects and programs in other domains to grow knowledge and experience; develop tactics, techniques and procedures (TTP); and to support the assessment and integration of RAS-AI capability options.

Maritime RAS-AI Concept: A RAS-AI concept will provide a coherent basis for developing RAS-AI capabilities, architectures, and integration. Navy will develop this concept with the support of DST, Capability Acquisition and Sustainment Group (CASG), industry and academia to ensure that it reflects trends and opportunities created by emerging technology and informs capability developers. The concept will nest within the *Defence RAS Concept 2040* as a part of Navy's Whole-of-Defence approach to the development of RAS-AI capability.

Architectures & Mission Management Systems: All RAS-AI capabilities need agile, dynamic, and distributed Command and Control (C2) arrangements. This requires a robust communication architecture with the capacity, security, and redundancy to assure C2 and the ability to manage redundancy as assets join and leave networks (through re-tasking or as a result of degradation or damage or tasking).

Navy is developing RAS-AI architectures as a part of the joint force that are harmonised with joint and coalition partner architectures. These are underpinned by the principles of modularity, open architectures, and prioritisation of C2 interoperability and data dissemination. WIN will continue to develop and evolve RAS-AI architectures and data frameworks (philosophies) to manage the distribution of data over a finite and sparse communications network. All Navy RAS-AI will need to form a part of this system-of-systems in order to 'plug and fight'.

Navy will increasingly employ human commanded/machine-controlled RAS-AI teams where each asset will be a sensor, a processor, and a communication node. RAS-AI systems will also support delivery, launch and recovery of other RAS. These teams will employ scalable many-to-many, distributed communication to harness the benefits of RAS.

Min-AI: Human-machine teams will initially utilise minimum AI (Min-AI[5]) to process data and operate at the edge of the RAS network (known as 'Edge Processing') to realise a smart, query-able, and decentralised RAS-AI effect. Min-AI agents will provide network management; mission planning; de-confliction; mission management; and data fusion and AI safety, amongst many other tools to support humans in command.

RAS-AI offers opportunities to field a diverse and rapidly evolving range of sensors, platforms, and payloads. The operational coordination required for such operations will challenge current approaches to technical interoperability between communication and information systems, and commensurate bandwidth management. Effective cybersecurity, cyber defence, and electronic counter measures (ECM) are critical.

Sovereign Common Control Systems (CCS): An Australian CCS will provide a unified approach to support mission command and trusted control of multiple robotic, autonomous, intelligent assets across a coalition force in a contested environment. It is not a bespoke Australian system and will be developed in concert, and completely interoperable, with our allies.

Navy will pursue a CCS to augment crewed and remote piloted platforms to allow the rapid task-organisation and re-organisation of multiple RAS-AI assets across air, land, sea, space, electromagnetic and cyber domains. This will employ a method of human command and machine control that is suited to Navy, ADF, allied and coalition forces. When mature, an Australian CCS will allow new UxVs to be introduced into use and integrated into the force in days, not years.

DEMONSTRATE

The Autonomous Warrior Series (AW): is Navy's flagship programme to demonstrate, evaluate and trial emerging RAS-AI capabilities at a variety of TRL. AW is not a trial nor test & evaluation activity but an opportunity to increase mutual understanding between industry and Defence in a realistic environment while fostering collaborative relationships. It also supports Fleet Command to increase familiarity with RAS capability.

Starting in 2021, AW will transition from a biennial series to four events conducted each year. Each event will have a specified operational focus and utilise different exercise locations to suit the nature of the activity and increase accessibility for industry. Navy will regularly communicate the forward plan of events, locations, and focus areas to industry.

AW will also sponsor targeted demonstrations and displays, industry briefs and operator/maintainer engagement with manufacturers and designers.

This process of co-design (bringing together uniformed end-users, industry, and those in between) will underpin a program of learning by doing, continuous improvement and development. Rapid introduction into service of RAS-AI systems identified through AW (and other means) will require close relationships between Navy and CASG elements from the design stage through delivery and sustainment. This relationship will support integration across platforms and maritime systems.

5 Min-AI is defined as "enough AI to improve current systems to be more discerning, effective and safe" and is a bounded, machine learning generated agent with a specific purpose. It is a form of narrow AI.

Industry, Coalition and Defence personnel participate in Autonomous Warrior 2018

DELIVER

To achieve the RAS-AI effects, Navy will develop trusted autonomous capabilities which verifiably and reliably act in accordance with our legal and ethical obligations. This requires a framework to develop and maintain trust and assurance; an agile approach to sustainment; and continual development and review.

Navy will continue to work with CASG as part of an enterprise approach to develop and deliver RAS-AI through evergreening and leveraging existing and emerging projects and products. This approach will be central to supporting integration across platforms and maritime systems.

TRUST

Navy already has experience in the operation of remote/robotic systems and machine learning enabled systems, however, RAS-AI represent a new and emerging field. Unlike non-autonomous systems, which can be evaluated by human agents for deviations from desired performance and behaviour of the system, *"Autonomous systems may have… limited or no communication; during those periods the system must reliably behave in known ways to the full range of stimuli that the system is designed for. Ensuring that the system will respond appropriately to all of the possible inputs will exceed the capability of conventional testing."*[6]

Challenges: Unsupervised machine learning algorithms are used to find structure in large data sets – essential to developing effective AI systems. Although the process will begin with a known dataset for initial training (e.g. a collection of aircraft labelled friendly and enemy by a human analyst) the AI system will eventually identify and select its own discriminators. Unsupervised learning poses challenges for trust in AI demanding validation, explicability, and assurance.

Test and Evaluation (T&E): T&E provides proof that risk is contained within acceptable boundaries. Navy's lead agency for T&E is the *Maritime Warfare Centre* which is responsible for the validation and assurance of operational effectiveness standards and suitability through T&E. Navy has already established a body of knowledge in T&E in support of projects delivering remote and robotic systems.

Machine learning represents a new frontier and presents a set of distinct challenges and opportunities which will require new approaches. To address the issues posed by emerging technologies, Navy is already contributing to an enterprise approach as Defence seeks to establish a sovereign T&E capability. Validating machine learning systems will require expanding existing skill bases within Navy and developing new ones, particularly in mathematical modelling and simulation.

Opportunities: Although existing T&E regimens will be challenged by AI, the field also offers significant opportunity for improved outcomes, especially in the validation of autonomous systems. Navy will pursue these opportunities including:

- For software intensive systems (like AI) testing can also be highly automated, and automatically documented offering potential gains in speed of deployment and greatly reduced likelihood of defects or faults.
- Many industries already employ advanced T&E regimens and techniques which Navy will seek to learn from.
- AI and autonomous systems can significantly support (or perform) complex data processing, decision-making and system control in support of T&E.
- Agile processes may allow a more continuous T&E regimen with every small increment of development or change including a 'test harness' to validate system-wide evaluation. This may include real-time T&E in a contested environment when deployed operators must overcome enemy efforts to undermine trust in a system by adjusting algorithms (reprogramming). This will require a rapid process of validation to provide assurance of the changes and re-establish trust in the system.
- AI enabled T&E can provide high assurance mathematical proofs and certificates of bounded behaviour.

Explicability & Assurance: The assurance of algorithms and machine learning code is an emerging field, and one that relies heavily on advanced scientific and mathematical knowledge bases. DST and Joint Capabilities Group have established partnerships, on behalf of Defence, with leading industry and academic centres of excellence, along with other expert bodies, to address the issue of algorithm assurance.

Navy will leverage and expand on these relationships to ensure algorithms conform to expectations; reveal the scenario space where an algorithm is guaranteed to be assurable; or fine-tune algorithms if not assurable. The assurance of learning algorithms is a continual process.

WIN will facilitate support to Navy projects to help develop, and provide ongoing assurance of AI systems. Navy will also pursue the emerging potential of using AI to enhance overall compliance with regulatory standards and protocols (such as COLREGS).

6 Office of Secretary of Defense: 2016 p29

Network Assurance: RAS-AI systems will rely on Navy's ongoing work to deliver unimpeded, secure, assured, and interoperable access to large amounts of data, bandwidth, and spectrum as well as absolute control of its information.

Legal and Ethics: Development of trusted autonomous systems is expected to increase accuracy, maintain compliance with Navy's legal and policy obligations as well as regulatory standards, and if utilised during armed conflict, minimise incidental harm to civilians.

Navy operates all weapons systems – now and into the future – in accordance with Australia's international and domestic legal obligations through a robust 'system of control' regulating the use of force. Australia's 'system of control' incrementally builds upon itself embedding controls into military processes and capability at all stages of a weapon system's design, development, training and usage. This ensures that all aspects of the military operate consistently in accordance with Australia's approach towards the use of force.[7] If a weapon system is incapable of being utilised in accordance with Australia's legal obligations, Navy will not deploy it.

RAS which are not weapon systems must also be capable of operating within the bounds of Australian domestic and international legal obligations. Navy will work closely with Defence Legal and other Government agencies to ensure compliance.

SUSTAIN

Evergreening: Requires a deliberate approach to capability life cycle management. Projects and programs will need to consider from the outset how they deliver an initial set of tools while setting out a long term plan to fund and conduct continual R&D, and deliver subsequent hardware and software upgrades.

Data: Data has become the currency of success on the battlefield and is the 'fuel' of AI systems which require access to appropriately labelled, classified, and stored data. Autonomous systems need large quantities of high-quality data to develop and train their learning AI systems while the warfighter requires data at the speed of relevance to gain and maintain decision superiority over adversaries. The centrality of data to combat effectiveness means that adversaries will perpetually seek to undermine, corrupt, deceive, and disrupt such decision-making systems making data security a necessity for all systems to evolve against threats.

Navy regards data as a strategic resource which directly contributes to operational capability and enterprise performance. Consequently, data needs to be managed as a warfighting enabler and core input to combat and enterprise AI capability. This accords with current best practices with allies and high performing organisations.

Responsibility for data acquisition, storage, labelling, and maintenance resides, in the first instance, with data owners. The management and protection of Navy's combat and enterprise data will require a dedicated business unit within Navy with an accountable uniformed Navy Chief Data Officer a critical factor to realising the opportunities associated with artificial intelligence.

This approach aligns to the enterprise hub and spoke model being developed by the Defence AI Centre. A Navy Data Office will be a spoke within the enterprise approach and will work to facilitate Navy specific outcomes.

Monitoring: Autonomous systems by their very nature have increased telemetry which will in turn increase the capacity for continuous monitoring of platforms. An array of sensors managed by AI will enable maintenance-as-needed, replacing the current pre-determined, mean-time based approaches. Current industrial applications of this approach to maintenance have demonstrated the potential for large cost savings (and in the operational context increased persistence and operational reach).

Realising opportunities for both operational and enterprise applications requires Navy to mine and utilise the data that it already generates. The next step is to create and utilise new data fields to be captured which in turn will reduce cost and enhance reliability, availability and maintenance.

REVIEW

To ensure that Navy's approach to RAS-AI remains valid will require an ongoing process of review and development. The RAS-AI campaign plan, which will support the implementation of this strategy, will set out milestones, key performance indicators and metrics along the four LOE against achievement of the RAS-AI effects over that period. It will also articulate R&D priorities and a forward work plan for AW which will be reviewed on an annual basis.

Emerging technology will be regularly reviewed as a part of the annual campaign plan cycle. Close cooperation with the intelligence community, DST and industry will be essential to this process of review.

7 See Australia's 2019 United Nations Group of Government Experts working paper: 'Australia's System of Control and applications for Autonomous Weapon Systems'

GLOSSARY

Automatic System A system that is pre-programmed to respond to stimuli in a rules-based, deterministic manner and achieve its function without further human input.

Autonomous System A system that determines how to perform the tasks necessary to achieve a defined goal. Autonomous systems respond to stimuli in a probabilistic manner but can be regulated by deterministic controls so that it can perform their tasks or functions without further human input.

Autonomy The ability of a machine, whether hardware or software, to perform a task without human input.[8]

Artificial Intelligence (AI) is a collection of interrelated technologies used to solve problems and perform tasks that, when humans do them, requires thinking.[9]

Algorithms are clear processes or sets of rules to be followed in calculations, data processing or other problem-solving operations.

Artificial Narrow Intelligence (ANI) is also referred to as weak AI or narrow AI, is the only type of artificial intelligence we have successfully realised to date. Narrow AI is goal-oriented, designed to perform singular tasks – i.e. facial recognition, speech recognition/voice assistants, driving a car, or searching the internet – and is highly intelligent at completing the specific task it is programmed to do.

Artificial General Intelligence (AGI) also referred to as strong AI or deep AI, is the concept of a machine with general intelligence that mimics human intelligence and/or behaviours, with the ability to learn and apply its intelligence to solve any problem. AGI can think, understand, and act in a way that is indistinguishable from that of a human in any given situation. This has not yet been achieved.

Artificial Super Intelligence (ASI) is the hypothetical AI that doesn't just mimic or understand human intelligence and behaviour; ASI is where machines become self-aware and surpass the capacity of human intelligence and ability. This has not yet been achieved.

COLREGS are the International Regulations for Preventing Collisions at Sea, published by the International Maritime Organization.

Combat Artificial Intelligence (Combat AI) refers to the use of AI to support mission-based outcomes aimed at improving Situational Awareness, Decision-making, and Operational Tempo. Combat AI solutions may integrate structured and unstructured data from combat and weapon systems, networks, and sensors. Combat AI solutions may interface with, or be a component of, hardware such as autonomous systems.

Command The authority that a military member lawfully exercises through rank or appointment to determine what is to be achieved by subordinate forces.[10]

Control The act of coordinating forces towards outcomes determined by Command. Control is undertaken by elements that integrate the actions of forces necessary to achieve Command intent.[11] Types of control:

- **Full Human Control** A human controls every aspect of the systems function, physically or through other means of remote control.
- **Human In The Loop** The system performs some functions independently but requires a human to perform functions that complete the systems task cycle.
- **Human On The Loop** The system performs all functions autonomously but a human may intervene to stop or modify the outcome before the task is complete.
- **Human Starts The Loop/Human Before the Loop** A human sets the operational parameters and initiates the systems operation; the machine requires no further human interaction to complete the task.

Enterprise Artificial Intelligence (Enterprise AI) refers to the use of AI to support insights, decision-making and analytics against business objectives or desired corporate outcomes, such as improving Force Generation and Sustainment. Enterprise AI (similar to business intelligence) can be used to gain insights into data (structured and unstructured) associated with operational efficiency and effectiveness. Enterprise AI has numerous use cases including natural language processing, self-learning models, voice recognition, predictive models, image and video analytics, deep learning, neural nets, or as an input to other hardware and software.

Level of Autonomy The degree to which an unmanned system is able to accomplish its mission without human intervention.

Machine Learning (ML) uses statistical techniques to give computer systems the ability to recognise patterns in data without explicit programming. This pattern recognition can be used as a basis for an AI implementation. Machine learning can be achieved through a range of methods that may not be specific to a task.

Minimum AI (Min-AI) a discrete bounded AI agent to perform specific task and functions more effectively and safer. Min-AI is a form of narrow AI.

8 Paul D Scharre. *The Opportunity and Challenge of Autonomous Systems*. NATO ACT publication 2017
9 Defence Enterprise Artificial Intelligence Strategy 2019
10 ADF Concept For Command and Control of the Future Force 2019
11 *ibidem*

Unmanned/Uninhabited system is a machine that does not require or usually support a human on-board. Such as Unmanned Aerial Vehicle (UAV), small Unmanned Surface Vessel (USV), or Unmanned Underwater Vehicle (UUV).

Uncrewed/Optionally Crewed system is a machine that does not require a human on-board, but can support human control from on-board. Such as an Unmanned Surface Vessel that has seats and a control station on-board for direct control.

Remote Control (RC) is a tethered system that is remotely controlled by a human. Without the human RC inputs the system has limited ability to operate independently.

Remote Operated Vehicle (ROV) is a vehicle that is remotely operated by a human. Often referring to an Unmanned Underwater Vehicle (UUV). Without the human inputs the system has limited ability to operate independently.

Software Agent (Bot) Refers to a non-physical system that is authorised to act on behalf of a human to conduct non-physical, or cyber, tasks. To differentiate between physical and non-physical robots, software agents are colloquially known as 'Bots'.

REFERENCES

Alkire, Brien, James G. Kallimani, Peter A. Wilson, and Louis R. Moore (2010). *Applications for Navy Unmanned Aircraft Systems*, Santa Monica: RAND Corporation.

Australian Army, (2018). *Robotic and Autonomous Systems Strategy*. Canberra: Defence Publishing.

Australian Group of Government Experts, (2019): 'Australia's System of Control and applications for Autonomous Weapon Systems' *Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems*. Geneva: United Nations. Agenda item 5.

Button, Robert W., John Kamp, Thomas B. Curtin, and James Dryden, *A Survey of Missions for Unmanned Undersea Vehicles*, Santa Monica, Calif.: RAND Corporation, MG-808-NAVY, 2009. As of June 22, 2020: https://www.rand.org/pubs/monographs/MG808.html

Commonwealth of Australia, (2018). *2018 Defence Industrial Capability Plan*. Canberra: Defence Publishing Service.

Commonwealth of Australia, (2018) *Defence Strategic Policy Statement* – Artificial Intelligence, (Sep 2018). Canberra: Department of Defence.

Commonwealth of Australia, (2020). *Defence Strategic Update*. Canberra: Defence Publishing Service.

Commonwealth of Australia, (2020). *Force Structure Plan*. Canberra: Defence Publishing Service.

Commonwealth of Australia, *Maritime Activities Environmental Management Plan*

Commonwealth of Australia, (2019). *Navy Industry Engagement Strategy*. Canberra: Defence Publishing Service.

Defence Science and Technology Group, (2020). *More, together: Defence Science and Technology Strategy 2030*. Canberra: Department of Defence.

Eckhause, Jeremy M., David T. Orletsky, Aaron C. Davenport, Mel Eisman, Raza Khan, Jonathan Theel, Marc Thibault, Dulani Woods, and Michelle D. Ziegler (2020). *Meeting U.S. Coast Guard Airpower Needs: Assessing the Options*. Santa Monica: Homeland Security Operational Analysis Center operated by the RAND Corporation.

Savitz, Scott, Irv Blickstein, Peter Buryk, Robert W. Button, Paul DeLuca, James Dryden, Jason Mastbaum, Jan Osburg, Phillip Padilla, Amy Potter, Carter C. Price, Lloyd Thrall, Susan K. Woodward, Roland J. Yardley, and John Yurchak, *U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs)*, (2013). Santa Monica: RAND Corporation.

Scharre, Paul D (2017). The Opportunity and Challenge of Autonomous Systems. NATO: ACT publication

U.S. Department of Navy (2004), *The Navy Unmanned Undersea Vehicle (UUV) Master Plan*, Washington, US DOD.

US Joint Chiefs of Staff (2016). *Joint Concept for Robotic and Autonomous Systems*. Washington, US DOD.

Vice-Chief of Defence Force Group, (2019). *ADF Concept For Command and Control of the Future Force*. Canberra: Department of Defence.

Vice-Chief of Defence Force Group, (November 2019). *Defence Artificial Intelligence Strategy*. Canberra: Department of Defence.

NAVY