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Progress and challenges in Defence R&D for operational Robotic and Autonomous Systems

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Ministry of Defence

The Defence Science and Technology Laboratory

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Part of the UK Ministry of Defence

We deliver high impact S&T for the UK's defence, security and prosperity

We only do what has to be done in Government – for reasons of security and international collaboration

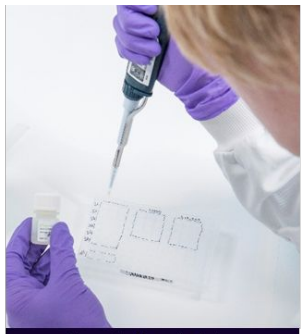
We underpin and maintain UK sovereign capability

Requirements & Evaluation

Analysis and decision support for policy development, decision-making and prioritisation

Research

Next generation technologies that will transform defence and give future capability



Specialist Advice & Services

Knowledge and facilities at readiness to meet priority needs

Operational Support

Rapid and deployed S&T to meet the urgency of operations

~4,500 staff across 4 sites

~£875m turnover

~£450m spend with industry

So, this 'AI' that everybody's talking about then….

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"Artificial Intelligence is the fastest growing deep technology in the world, with huge potential to rewrite the rules of entire industries, drive substantial economic growth and transform all areas of life."

UK National AI Strategy, 2021

NATIONAL SECURITY COMMISSION ON ARTIFICIAL INTELLIGENCE

"Defending against AI-capable adversaries without employing AI is an invitation to disaster. AI will compress decision time frames from minutes to seconds, expand the scale of attacks, and demand responses that will tax the limits of human cognition. […] Humans cannot be everywhere at once, but software can."

US National Security Commission on AI, final report to Congress

Benefits

01 Scale
Adds potentially vast new capacity to (human) resource constrained systems – physical & virtual

02 Tempo
Human machine teams can enable faster, better decision making. "Get inside" the adversary's OODA loop

03 Edge
"Edge AI" can improve capability in environments where communications are denied or degraded

04 Performance
AI can exceed human performance for some tasks, especially where speed or endurance are critical

05 Surprise
Can help overcome cognitive biases, deliver new insight and challenge human thinking

06 Dull, dirty & dangerous
Can free humans from performing repetitive or hazardous tasks

Challenges

01 Data
Many machine learning approaches require large amounts of labelled training data

02 Robustness
Deep learning methods do not generalise well & are susceptible to adversarial attack

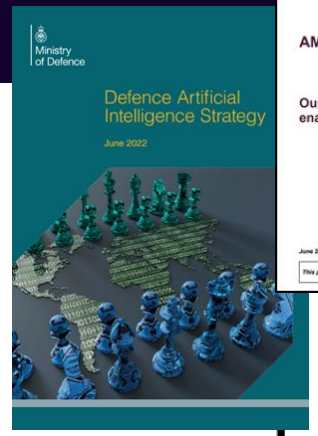
03 Bias
There is a need to develop AI systems that are fair and free from bias. Bias is often "baked" into our datasets

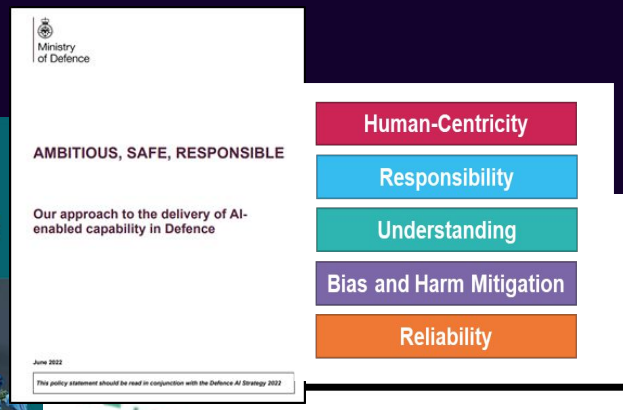
04 Democratisation
Highly capable AI techniques are widely available. There is a low barrier to entry for those who wish to misuse to cause harm.

05 Trust
AI-enabled systems must be safe, explainable, transparent and trustworthy

06 Ethics and public perception
Concern about military use of AI. Need to establish international norms and inform public debate

The UK Defence AI Strategy





Human-Centricity
Responsibility
Understanding
Bias and Harm Mitigation
Reliability

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Introducing the Defence AI Centre

DAIC DEFENCE AI CENTRE

Enabling MOD to harness the game-changing power of AI

Champion by acting as a visionary hub, accelerating the coherent understanding, development and use of AI capabilities across Defence

Enable by providing common AI services, good practice and a critical mass of expertise to support local adoption across Defence

Innovate by rapidly developing, delivering and scaling AI projects that generate breakthroughs in strategic advantage, in support of Defence priorities

DAIC | OFFICIAL

Continuous development & experimentation

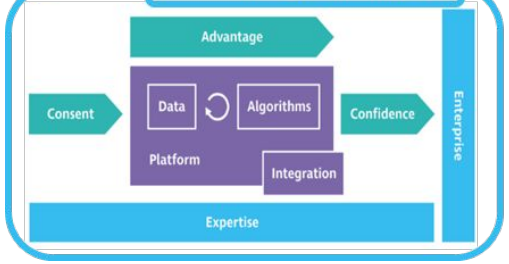
Agile software development e.g. MLOps

Close end-user engagement

"One-team" collaboration

dstl · Strategic Command · Strategic Command Defence Digital · de&s · kainos · FRAZER-NASH CONSULTANCY · faculty · BAE SYSTEMS · ACTiCA · TECHMODAL · cognizant · The Alan Turing Institute · UNIVERSITY OF EXETER · CATAPULT Digital

Putting in place the building blocks



Diverse, multi-disciplinary teams

MILITARY EXPERTS
- End-user engagement
- Capture requirements
- Provide context
- Label datasets
- Lead deployment

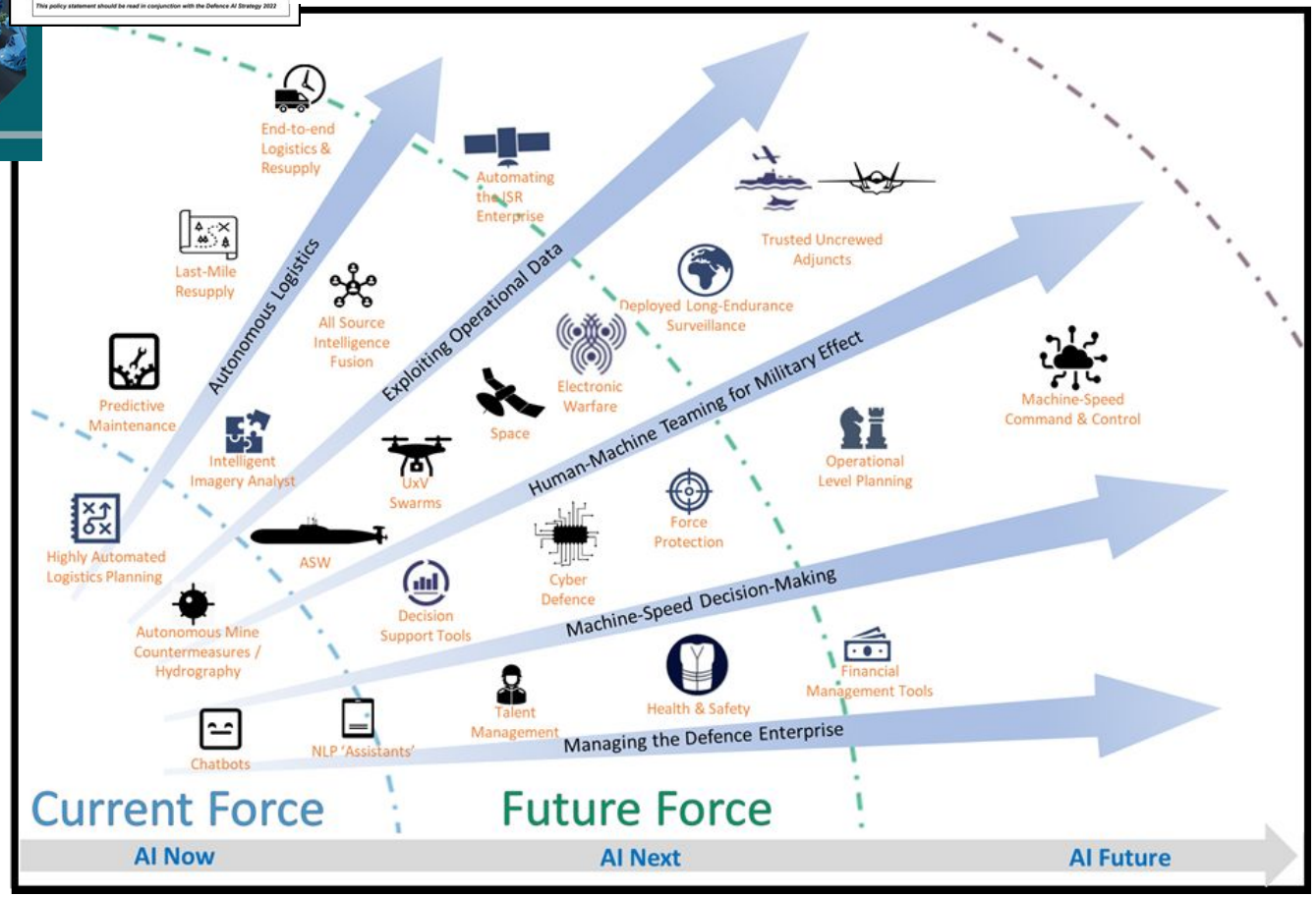
BUSINESS LEADERS
- Entrepreneurial skills
- Select problems
- Set goals
- Drive delivery
- Continuous improvement

DATA SCIENTISTS & AI/ML ENGINEERS
- Wrangle data
- Tune algorithms
- Generate models
- Processing pipelines
- Data visualisation

SOFTWARE DEVELOPERS & DATA ENGINEERS
- Design architecture
- Systems integration & scaling
- Performance optimisation
- Standards

USER EXPERIENCE
- User engagement
- Interface design
- Service design
- Human machine teaming

ACCREDITORS
- Security
- Safety
- V&V
- Best practice



Read some more – the Dstl Biscuit Books

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Strategic Command
Defence Digital

https://www.gov.uk/government/collections/dstl-biscuit-books

Putting the ‘brain’ in the physical system
A simplistic RAS systems model

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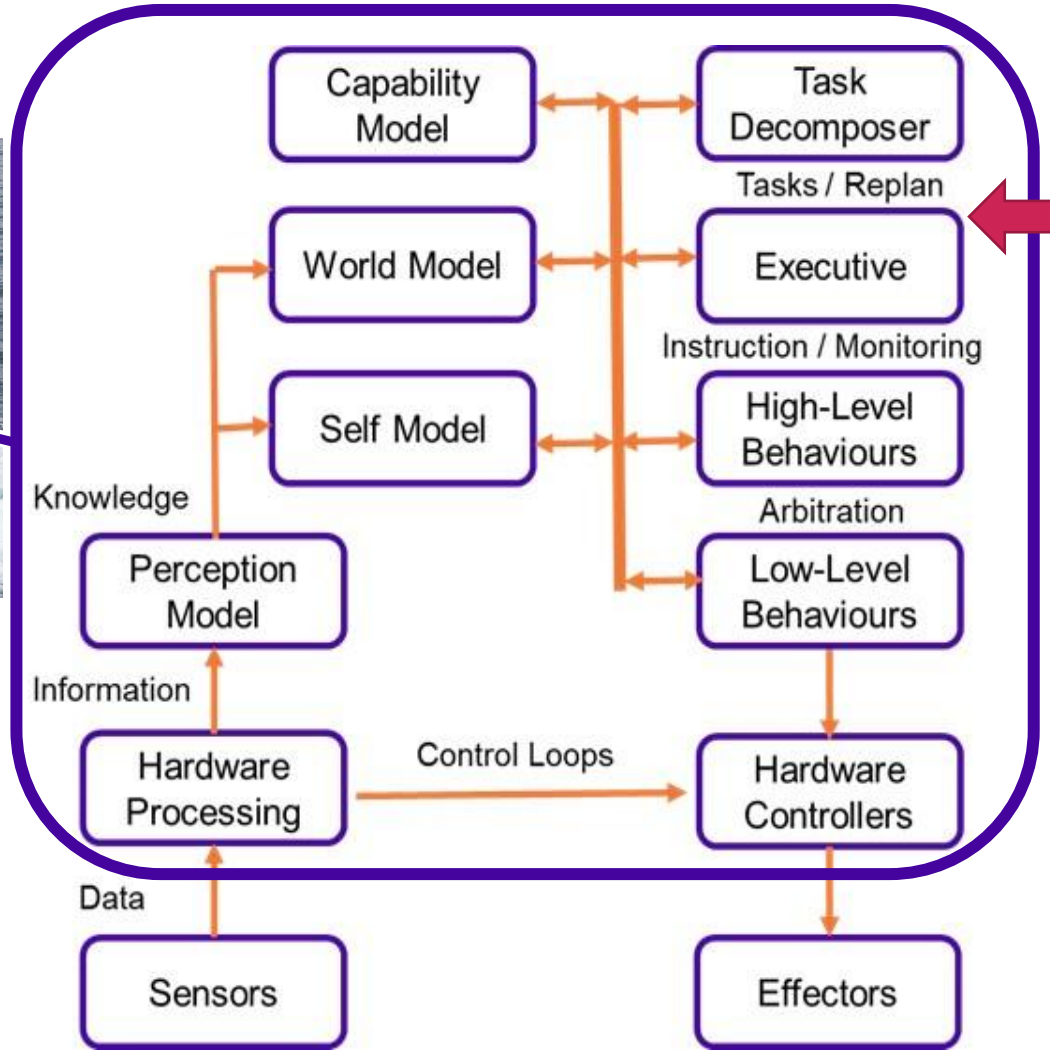
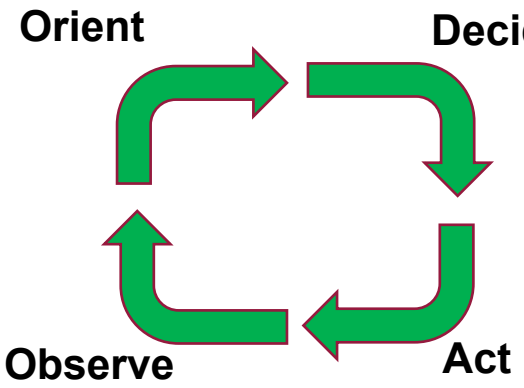


Mission/Task Behaviours

System/Sub-system Behaviours



- Understanding the context and functionality in situ is critical
- Understanding the ‘art of the possible’ requires the user firmly ‘in the loop’
- People are part of the system

Our R&D is creating world class game-changing opportunities for the UK Armed Forces

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Tackling the challenge of the '6 D's' through advanced Autonomy

Enabling those tasks that are 'Dull, Dirty, Dangerous, Distant, Demanding and Distributed'

- Reduce the human burden
- Improve operational tempo and agility
- Enhance combat mass
- Decrease risk and casualties
- Improve operational efficiency

Maritime Autonomous Systems R&D Pedigree Examples

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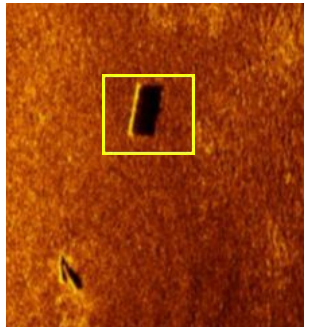
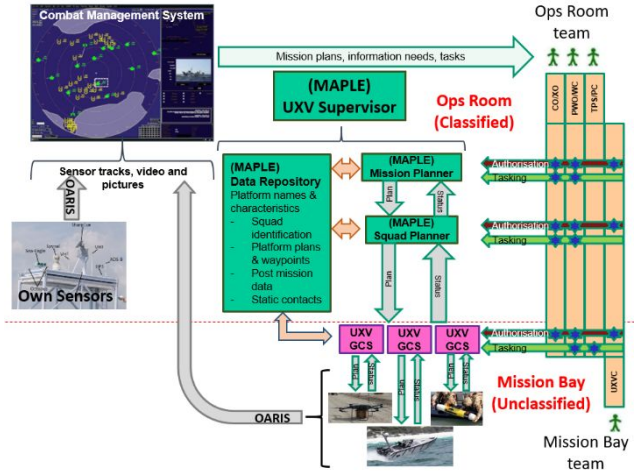
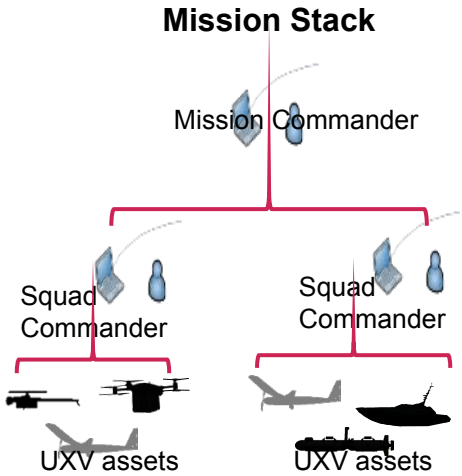
- Mine Hunting & Countermeasures (MCM)



- Maritime Autonomous Platform Exploitation (MAPLE)

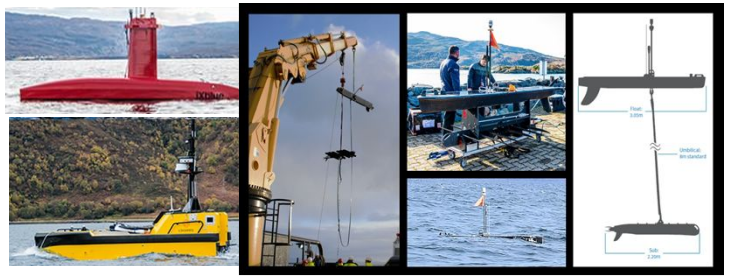




- Maritime Autonomous Systems Testbed (MAST-13)

Autonomous Mission

- Anti Submarine Warfare (ASW)



Transform to Deliver the Next Generation Key Autonomous Systems Challenges

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Minimum Viable Product
Will it do the job?

Minimum Viable Capability
Make it useful?

War Winning Capability
Make it threatening?

- Tools, processes and facilities for Verification & Validation, Test & Evaluation for medium-high levels of trusted autonomy
- Understanding and mitigating the threat from autonomous systems whilst protecting our own autonomy with new approaches, tools and capabilities
- Robust machine sense-making, perception and reasoning for all environments
- Safe and effective human-machine systems partnerships and teaming
- High levels of trusted autonomy for long-duration and evolving missions without assured communications
- Concepts of operation and regulatory approaches at pace for robust autonomy at scale in complex and contested environments

Remove the blockers / Build the enablers

EXPANDING OPERATIONAL UTILITY – ENSURING ROBUSTNESS AND RESILIANCE – REDUCING COST

Some next steps…..

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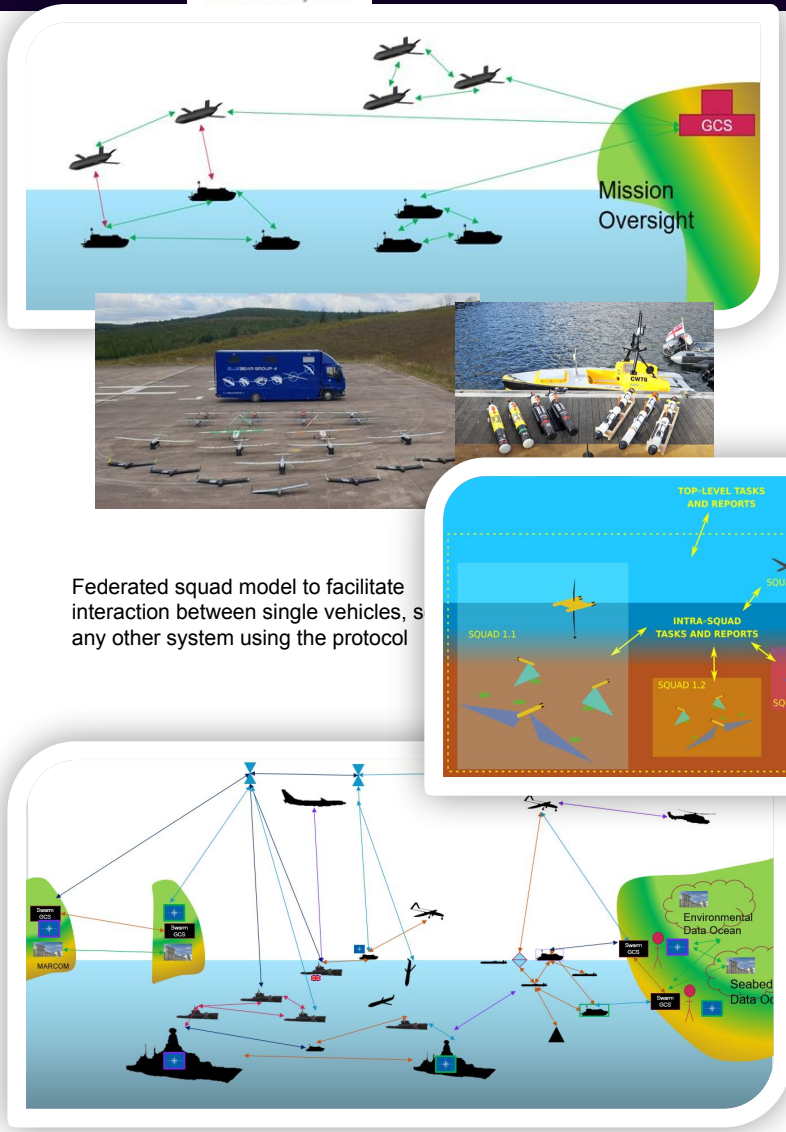
Mixed environment collaborative uncrewed systems for Maritime and Littoral operations;

- Address technical challenges to enable a mixed environment multi-system collaborative uncrewed systems
- Develop an open, common approach for heterogenous air and maritime assets
- Develop certifiable, common processes, messages and autonomy functionality and explore regulatory challenges

Collaborative Autonomy Tasking Layer (CATL)

- Define a common message set enabling collaborative autonomous operations between heterogeneous systems in communications-limited environments – formally define data model
- Establish shared mission information drivers and constraints and task handling approaches
- Define encodings for different transmission methods
- Address security aspects for federated operations

- **Allied Underwater Battlespace Mission Network (AUWB-MN)**
  - Define and demonstrate first physical instantiation through synthetic and live experimentation/trials, based on the NATO Federated Mission Network (FMN)
  - Identify technologies, standards, processes, security challenges and opportunities to enable realisation



Federated squad model to facilitate interaction between single vehicles, s any other system using the protocol

Next Gen Concepts - Examples

- Enhancing ASW through teamed Autonomous
  - C2 / Autonomy Approaches with Maritime Autonomous Systems
    - Hosted
    - Global
    - Agile
    - Partners

- Enabling FMAF - Enhancing Carrier Strike through Autonomous Aviation
  - UxS crewed-uncrewed teaming to enhance combat mass and maritime PROJECT capability, through adding affordable situational awareness, persistence and lethality

How do we know we're making progress? The 'Common Maturity Framework' (CMF) can help

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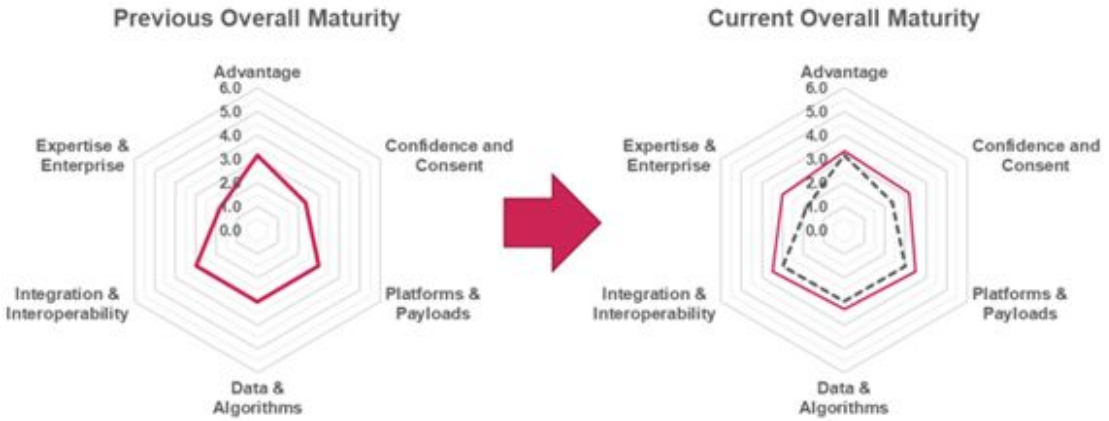
Concept R&D	Minimum Viable Product	Minimum Viable Capability	War Winning Capability
What can it do?	Will it do the job?	Make it useful?	Make it threatening?

Anchored in the Autonomy Building Blocks, the CMF is a structured discussion handrail to establish a collective understanding of maturity and the development priorities for key human and technology factors that must, at some point, be addressed to deliver an end capability vision involving Autonomous Systems

- **Do you know who your end information customer is? How is your product exploited?**
- **Are trials benign or representative? Path & timeframe known?**
- **Have you defined concept shortfalls? How will they change over time?**
- **Cannot tackle everything at once, but have you captured what you're not looking at? If not now when, who?**



Challenges for a Minimum Viable Product

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Advantage	Consent & Confidence	Platforms & Payloads	Data & Algorithms	Integration & Interoperability	Expertise & Enterprise
Concept Definition & Adaptability	Legal & Regulatory	Deployability	Data Requirements	Open Architecture & Standards	People & Training
Benefits	Policy & Risk Appetite	Power & Endurance	Availability & Access	Human-Autonomy Teaming & Control	Organisational Readiness & Governance
User Needs	Security	Navigation & Positioning	Autonomous Functions	Communication & Networks	Support & Infrastructure
Risk	Trust	Reach	Data Processing	Physical Integration	Cultural Acceptance
Cost	Resilience	Accuracy	Data Quality	Command & Tasking	Ethics
Scalability	Survivability	Reliability	IX & Decision Support	Allied Interoperability	Acquisition & TLCM

Enabling MOD to harness and adopt safe and effective autonomous systems at the speed of relevance

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Safe and responsible adoption of Autonomous Systems

Working with the best minds to support our Armed Forces

Enhancing UK prosperity through creating world class solutions

Creating new networks and partnerships to innovate at pace

"Now, how do I get the Red Button off this thing so I can go do operations?"

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End

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