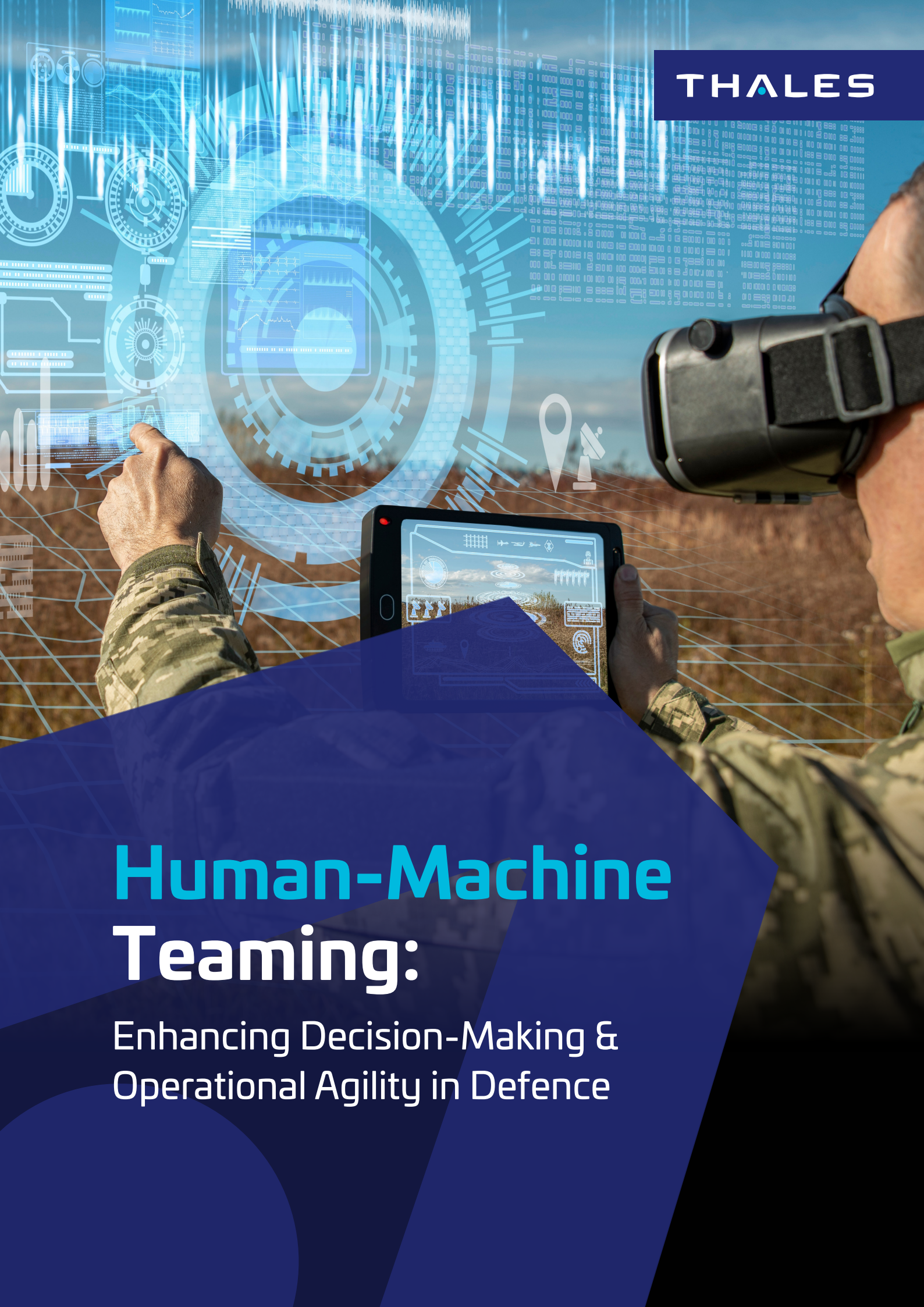


THALES

Human-Machine Teaming:

Enhancing Decision-Making & Operational Agility in Defence

Executive Summary:

As artificial intelligence (AI) and autonomous systems become embedded across modern defence systems, the way decisions are made and missions are executed is undergoing a profound shift. Human-Machine Teaming (HMT) offers a structured and ethical approach to integrating AI into operations, preserving human judgement while unlocking the advantages of intelligent systems. This white paper examines the critical elements of HMT, the challenges of implementation, and how these developments align with the UK's strategic defence ambitions. It begins to set out a roadmap for operationalising HMT across defence and national infrastructure to enhance mission agility, resilience, and decision advantage.

Introduction

Warfare is becoming increasingly complex, multi-domain, and data-driven. Defence organisations are seeking ways to outpace adversaries, reduce human cognitive burden, and improve situational awareness. AI and autonomy are central to this ambition, but their integration must be carefully managed to maintain operational control and uphold legal and ethical standards.

Human-Machine Teaming is the concept of blending the best attributes of human cognition – such as ethical reasoning, creativity, and contextual understanding – with the processing power, consistency, and speed of machines. It ensures that AI supports human operators rather than replacing them, and that humans retain meaningful oversight of decisions made in high-stakes environments.

This paper explores how HMT is already being developed and trialled in defence, what barriers remain, and how the UK defence sector can lead globally in responsible AI adoption.

The Core Components of Human-Machine Teaming

Defining HMT in a Defence Context

At its core, HMT is about integrating machine intelligence into the decision-making chain in a way that enhances rather than undermines human authority. It's about designing human centric systems that acknowledge the capabilities and limitations of both human and tech, and get the balance right.

HMT involves several models of interaction:

Human-in-the-Loop (HITL)

Human-in-the-Loop (HITL): Humans retain full control over key decisions, with AI offering recommendations or processing support. Common in targeting and surveillance systems.

Human-on-the-Loop (HOTL)

AI executes certain tasks independently, while humans monitor and retain the ability to intervene. Suitable for time-critical or high-tempo missions.

Human-out-of-the-Loop (HOOTL)

AI operates autonomously without real-time human supervision, usually in tightly bounded, pre-approved scenarios.

Each model requires careful design to ensure the right balance between human judgement and machine autonomy. Trust, transparency, and usability are essential for adoption and effectiveness.

Designing for Human-Machine Collaboration

A sociotechnical system refers to any system that is made up of both "social" and "technical" elements. According to sociotechnical systems theory, these two aspects must be considered together because arrangements that are optimal for one may not be optimal for the other.

User-Centred Design offers one approach to designing sociotechnical systems as it provides a way to help improve the ethical design of systems. This is because it strives to understand the intended user of the system, the tasks to be completed, interactions occurring within the system and the underlying information processing that contributes to decision-making. Adopting such an approach enables us to understand 'where', 'when', 'how' and 'why' to use AI, automated and autonomous systems.

The Role of AI in Decision-Making

AI is particularly effective at managing and interpreting large volumes of data – such as sensor feeds, satellite imagery and open-source intelligence. These tools can aid an operator's situational awareness and accelerate decision-making by surfacing relevant information, generating predictive insights, and even suggesting likely outcomes.

However, such power introduces new risks. Black-box AI systems that cannot explain their reasoning undermine trust, while data bias or poor training can result in flawed decisions. In addition, there is a risk that we look to AI to solve all problems when in fact alternative mitigation strategies may be more appropriate. Understanding the desirability, viability and feasibility of AI approaches within alternative defence contexts is therefore important.

To be effective in mission-critical settings, AI systems must be:

Explainable: Clearly communicate how a recommendation was derived.

Reliable: Perform consistently under varying operational conditions

Aligned: Reflect the commander's intent and broader mission objectives.

Key Challenges and Considerations

Enhancing Human Capability

To help inform the design and development of future concepts, products and/or technologies, it is essential that the strengths and limitations of the 'Human' element of HMT are considered.

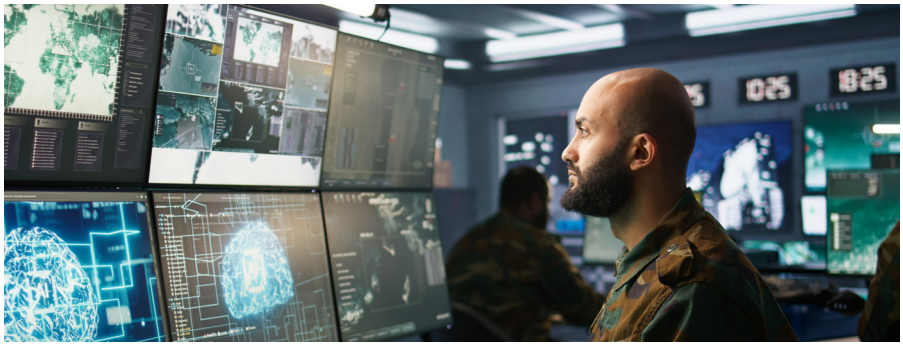
Whilst humans are fallible, their ability to dynamically assess and interpret information to make decisions cannot be fully matched by a machine counterpart. The technological advancements offered by AI and increasing use of autonomous capabilities can drive operational competitive advantage through superior data processing and assimilation that far outweighs the human counterpart, to fully exploit available sensor data. Appropriate implementation and utilisation of these technologies can increase the accuracy, efficiency and effectiveness of human decision-making cycles, whilst reducing the cognitive burden.

However, the design of these future systems must be user-centric if we want these joint performance benefits to be realised. Systems designed without the user in mind risk solving domain problems, such as the rapid processing of complex and prolific data sources whilst failing to support the decisions and cognitive demands of the operator.

The balance between 'human' and 'machine' is a difficult one to maintain in this context – the introduction of autonomous systems and AI may increase the risk of complacency, over-reliance and skill fade, whilst a lack of trust can lead to underuse or misuse, negating the benefits of introducing it in the first place.

Cognitive Workload

Defence operations can be uncertain and ambiguous. In some instances, this can limit the ability of operators to access, understand and cope with all the information that is available to them. Systems that incorporate AI and differing levels of autonomy should therefore seek to reduce complexity, not add to it. The most effective HMT systems support intuitive decision-making under pressure. They also preserve an operator's moral agency by enabling them to exercise their responsibility and use their own judgement when determining a course of action.



Ethical and Legal Implications

The integration of AI and autonomous systems into defence capability must align to our legal obligations and moral responsibilities. This requires us to design systems in a manner that upholds International Humanitarian Law (IHL), ensure accountability, and preserve human dignity.

Central to this is the principle of Meaningful Human Control (MHC) – ensuring humans remain responsible for decisions, up to and including decisions to use lethal force. This requires transparent AI design, robust validation processes, and clear chains of command.

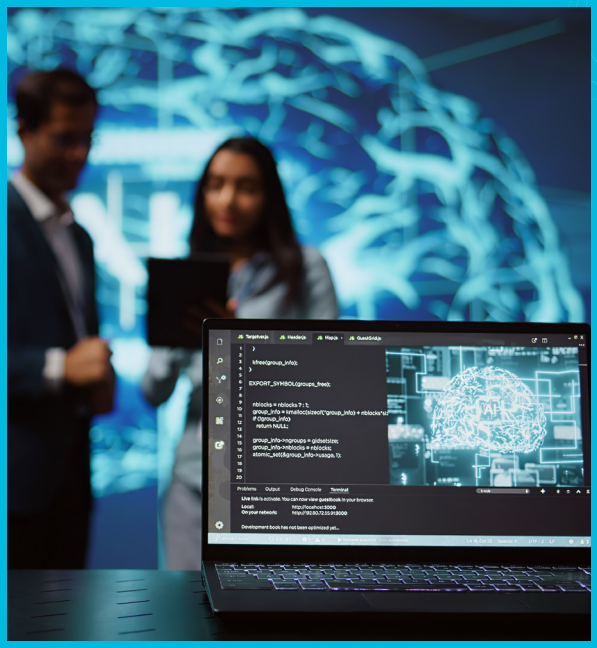
The underlying concept of MHC is to maintain safety and precision, responsibility and accountability, morality and dignity, democratic engagement and consent, institutional stability. These objectives provide clear goals to achieve and ensure MHC is at the heart of system design.

The UK Ministry of Defence's Joint Service Publication 936 (JSP 936) sets out guiding principles for the use of autonomy and AI in defence systems – including the importance of human oversight, transparency, and accountability – all of which should underpin HMT applications.

Addressing bias in training data, preventing adversarial manipulation, and safeguarding against unintended escalation are also critical ethical considerations.

Operational Integration

Despite the promise of HMT, there remain barriers to seamless integration across defence systems:



- **Data interoperability:** Defence systems must share and interpret information across platforms, but the lack of a unified architecture hinders multi-domain operations and leaves UK Defence exposed to adversarial threats.
- **Legacy systems:** Integrating AI into existing infrastructure is complex, often limiting the use of 'the best' technologies. Enterprise constraints hinder direct implementation, but 'sandbox' environments offer a way to test and de-risk solutions alongside ongoing operations.
- **Human factors:** Operators must be trained not only to use AI tools, but to understand their limitations and properly interpret their outputs. Human-AI interactions need to be monitored and adjusted based on context-specific needs. This requires both knowledge of the operational design domain but also the design of intuitive and useable interfaces, which can then be validated during user trials. This may be achieved through adoption of a user-focused approach to help develop solutions that address 'real world challenges'.

Overcoming these barriers is essential to creating and exploiting synergy between domains to deliver information advantage.

Trust

Trust is foundational to an effective HMT. Operators are more likely to use intelligent functionality if they feel in control over actions and consequences.

Building trust involves:

- Designing interfaces that clearly communicate system status and rationale.
- Conducting joint human-machine training exercises – allowing trust, learning and feedback to be developed on the combination of operators and advanced, autonomous or AI-enabled capabilities.
- Demonstrating system performance through realistic trials and operations.

Strategic Implications for Defence Policy and Industry

UK MoD and Strategic Defence Review Alignment

HMT directly supports the UK Ministry of Defence's vision for a modernised, digitally enabled force. The UK Strategic Defence Review has placed strong emphasis on AI, data exploitation, and multi-domain integration.

By embedding ethical and human-centred design into AI development, the UK can lead in responsible autonomy while strengthening operational readiness. HMT is also a critical enabler of multi-domain architectures, which require fast, decentralised decision-making across air, land, sea, space, and cyber domains.

Future Roadmap: Investing in HMT Capabilities

To mature HMT into operational capability, sustained investment is needed in:

- AI research and development focused on mission-specific autonomy, predictive analytics, and adaptive learning.
- Human factors research to understand how operators interact with AI tools.
- Testing and evaluation frameworks that simulate real-world conditions and build confidence in HMT systems.

The UK has an opportunity to shape international standards and doctrines on HMT, working with allies to promote interoperability and shared ethical commitments.

To support this effort, Thales UK is working to:

- Develop common frameworks for integration to support test and evaluation activities.
- Involve end user communities in the research and development lifecycle of solutions.
- Deliver evidence-based recommendations for the design of future systems through human sciences experimentation.

Conclusion and Recommendations

Human-machine teaming is not a future ambition – it is a present necessity. As the pace and complexity of operations increase, defence forces must adopt technologies that support faster, more informed decision-making while preserving the moral and legal accountability of human command.

To advance HMT adoption, this paper recommends:

- Prioritising human-centred AI design to enhance mission reliability and operator trust.
- Embedding ethics and explainability into AI procurement and development.
- Investing in skills and training to prepare the defence workforce for AI-integrated roles.
- Fostering collaboration with SMEs and academia to accelerate innovation and adoption.

Next Steps

Thales UK invites stakeholders across government, defence, and industry to engage with the insights in this paper. We are committed to supporting ethical, effective, and human-aligned AI systems that deliver tangible value in operational environments.

To explore collaborative opportunities or access detailed research insights, please contact the Thales UK Research & Technology team.

See us at DSEI

Thales isn't just theoretically looking at how HMT can improve operational agility and decision making in defence - we are already utilising it in our systems and solutions - to provide operational advantage where it is needed the most.

Visit our team at DSEI to see AI in defence, in action.

DSEI UK
9-12 Sept 2025
Excel - London