Innovators

News and perspective from our
Research & Development teams

BAE SYSTEMS

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The pace of change in defence has never been faster

We can all see it in the conflicts shaping our world today, where mass drone warfare, contested electromagnetic environments and layered air defence have rewritten the rules.

The projects in this report show that our people not only see these shifts coming, but they're already building the technology to meet them.

We look at advances in autonomy and AI decision support, including a natural language controller that lets an operator command multiple drones by voice alone. You'll see how our synthetic environments, OdySSEy and MIMESIS, let us test, integrate and generate the high-quality data needed to train safe, assured autonomy before anything reaches the field. And you'll discover our progress in counter-drone systems, electronic warfare, undersea sensing and resilient navigation that works even when GPS is denied.

None of this matters without trust and resilience. The lessons from recent conflicts are clear: data, compute and secure communications are now as decisive as munitions and must be engineered in from the start, not bolted on later. That's why we're working with the UK Ministry of Defence and other partners on clear principles for autonomy, building guardrails into the software itself so meaningful human control sits at the heart of every critical decision.

Above all, this is about partnership. The challenges we face don't respect borders and neither can the response. Working alongside our customers and allies, sharing what we learn and building capability together, is what lets armed forces act with confidence when it counts. The stories in these pages reflect the talent, ambition and sense of mission of the people I'm fortunate to work alongside every day, and the partners around the world who share our determination to stay ahead.

I hope you enjoy the report. Please get in touch if you'd like to discuss anything on **ctocomms@baesystems.com**

"The lessons from recent conflicts are clear: data, compute and secure communications are now as decisive as munitions and resilience must be engineered in from the start, not bolted on later.

Julian Cracknell,
Chief Technology and Information Officer

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Transforming UK defence procurement for strategic advantage

The T-150 uncrewed air system – rapidly purchased by the MOD.

James Gavin,
Deputy Director Technology Transition – National Armaments Director Group

When I joined the Ministry of Defence (MOD) five years ago, I saw opportunities to reduce the natural stovepipes that had built up across the MOD between Front Line Commands, as well especially to improve the link between innovation and exploitation.

Creating the National Armaments Directorate and its model are helping make these changes possible at scale – bringing together different entities, aligning demand signals from Front Line Commands and moving towards outcome-based requirements.

A central part of this change is making investment decisions in the science, innovation and technology arena that focus on an intent to exploit. There is no shortage of good ideas, but what matters is whether there's intent to bring them into service, whether they link to a programme of record and whether the MOD, or partners, will field them if they succeed. We are now aligning demand signals from the centre, from Military Strategic Headquarters and Front Line Commands, so that we can direct investment with more clarity and confidence to achieve a better return on investment (ROI). The term 'ROI' is well known in industry but was missing in the MOD.

Standardisation and interoperability are at the core of MOD strategy. With decades of legacy systems, we must take a pragmatic approach, focusing on high-priority integrations to build a true system-of-systems architecture. Operators should not need multiple screens for command and control across domains, for instance. We're also recognising that industry is often ahead in digital integration solutions, so now is the time to scale capabilities that are already proven.

Speed is essential. The old multi-year acquisition model must be transformed. We need rapid down-selection, outcome-based requirements, lower bid costs and faster contracting. We see SMEs being able to respond to tenders in two weeks, but for large companies, this is more of a challenge given their internal mechanisms – changing tempo will be crucial for them, otherwise more agile competitors will win.

Sovereign technology and export potential are fundamental to what we buy from industry. New acquisition rules let us contract directly for UK-derived solutions, securing our supply chains and strategic freedom.

To be successful, primes like BAE Systems should not rely solely on MOD demand signals – they need to demonstrate that UK-sold products can also win in international markets. I want to see co-investment with industry in the capabilities we are prioritising, avoiding gold-plating and instead engaging early, investing collectively and placing strategic bets.

Shaping the force mix is also critical. I support the 40-40-20 structure: 20 percent high-end crewed, 40 percent attritable, 40 percent disposable. High-end assets remain vital, but scalable mass comes from a mix that includes helicopter-sized UAVs and thousands of one-way effectors. Autonomy will play a big part, especially in air systems. Uncrewed ground vehicles have further to go, with true off-road autonomy likely to be decades away. Until reliability improves, we'll focus on domains where autonomy delivers the most operational benefit.

All these changes demand a cultural shift. We must set clear policies, hold teams accountable and reward behaviours which demonstrate change even if outcomes are not perfect straight away. That is how we will ensure our armed forces maintain their decisive edge.

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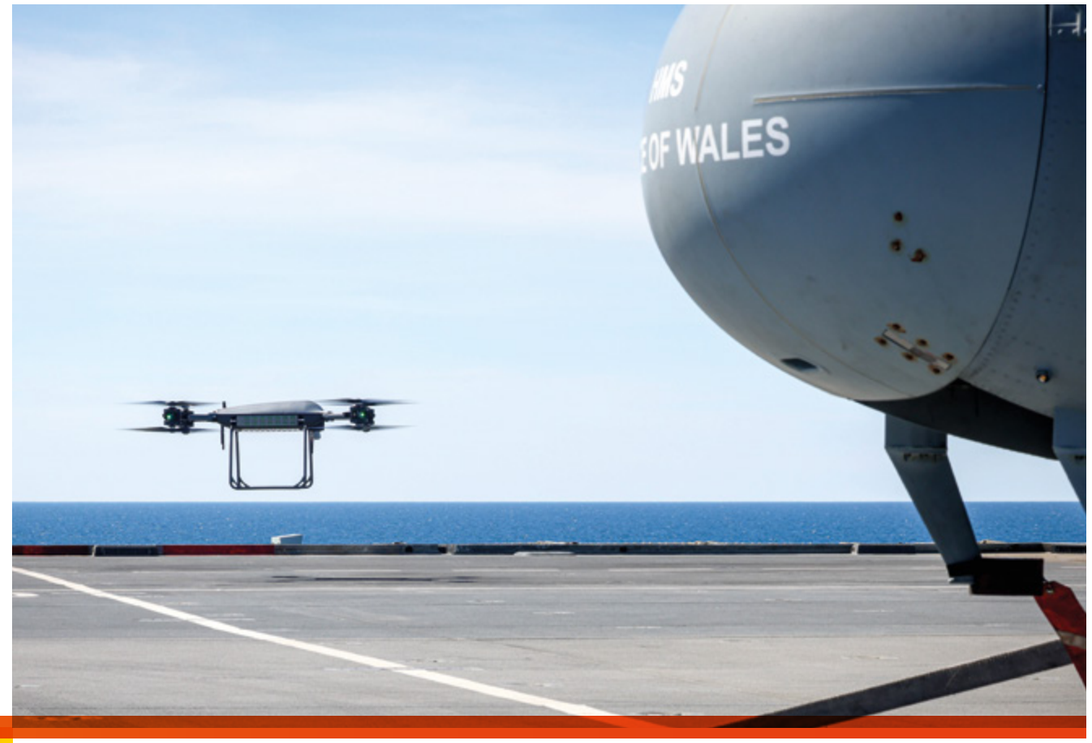
Technology to protect today



"We're moving away from monolithic software releases towards smaller, more frequent updates, letting customers evaluate capability long before it reaches the front line.

Rob Merryweather,
Group Technology Director

The pace of conflict has changed what 'fast' means in defence. Equipment fielded in the morning may be subject to targeted counter measures by the end of the day.

The lesson is blunt: the side that adapts quickest holds the advantage. That's why the stories in this section are about capability our customers can put to work now or in the very near future.

Information advantage runs through it all. Azalea™ fingerprints and tracks platforms by their radio frequency signature from low Earth orbit, processing intelligence onboard and pushing it straight to users in theatre. EM-CAT fuses radar, electromagnetic, electro-optical and acoustic feeds into a single counter-drone picture, cutting the decision cycle from minutes to seconds. INTeACT turns sensor overload into rapid decisions for naval command teams who literally have seconds to react.

These products are built to reduce operator burden, so people focus on judgement rather than mechanics.

What makes this practical is how we build and deliver them. We're moving away from monolithic software releases towards smaller, more frequent updates, letting customers evaluate capability long before it reaches the front line. Open architectures and international standards, from NATO's SAPIENT protocol to published software development kits, mean third parties and SMEs can plug in their best ideas. And through Launchpad, mature defence technology like Rho-C is spun rapidly into products serving entirely new markets.

That same urgency shapes our work below the surface. Our AI navigation tool draws on years of historical automatic identification system (AIS) data to give submarine crews context that helps them act with confidence, while dynamic nomograms keep AI outputs transparent and trusted. Oxford Dynamics brings agentic AI into mission orchestration, always with a human in a position of context appropriate oversight. Different domains, one principle: get reliable, integrated capability into users' hands while it still makes the difference. This is technology to protect today.

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AI drone controller adding advanced swarming capability

After successful testing on individual drones last year, we're now working to add swarming capability to our AI drone controller currently in development, along with support for more dynamic operations.

Drones are able to autonomously choose the most efficient search pattern between themselves, dynamically re-planning if a drone is lost.

New swarming capability would allow a single human operator to set mission intent with natural language – "search the area for potential threats" for example – with the swarm then working together to perform the mission, review the plan if the situation changes, then collectively report back.

Instead of individual uncrewed assets needing to communicate continuously with a central controller, our new architecture will embed an AI agent on each platform, allowing the group to form a self-organising and self-healing swarm. The system has strict guardrails, meaning that it needs direct human approval for any actions additional to its permission levels – humans would always have meaningful and context-appropriate input into any decisions.

"I haven't seen anyone adopting such a decentralised approach using AI agents on each drone along with a higher-level strategical agent for orchestration, all of which are separated from safety critical functions such as collision avoidance," explains Bashar, the project lead. "We think this is vital, as we don't believe that drones referring to a central brain for every decision is resilient enough for the modern battlespace. This approach also reduces the need to emit radio frequency (RF) signals that could reveal drones to the enemy."

To ensure the swarm works collaboratively rather than competitively, the orchestration layer will coordinate the actions of the individual AI agents. The system still needs human permission for actions outside of its scope, but this means it's much more able to cope with dynamic situations. This orchestration layer operates above the AI agents on each drone, distributing mission constraints and objectives to optimise the group's collective behaviour. This prevents individual drone agents from 'selfishly' optimising for their own success, instead ensuring they operate like a collaborative team driven by a common objective.

Having individual AI agents and extra compute power on each drone gives other benefits, too. If a mission changes, a drone will be able to rapidly and autonomously re-plan within the scope of permissions set by the human operator, sharing information with its teammates so the swarm can continue operating. For example, if a drone in a surveillance swarm is lost, the remaining group is designed to 'self-heal', quickly adjusting its search pattern to maintain effective coverage.

Bashar's team has also ensured the system can continually be developed in light of rapid changes in the world of AI and drones: "New, more powerful AI models and hardware are constantly being developed – innovations can become dated in a matter of weeks. Our system has been developed in a modular way so that new AI models can be implemented on new hardware rapidly, giving our customers access to the latest technology. To do this, we have developed a comprehensive evaluation approach to validate performance of new AI models on given hardware, so we can keep evolving capability."

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Charting a clearer course with AI-powered navigation

"Our AI navigation tool is great at spotting outliers – vessels that don't follow normal patterns – providing valuable intelligence for unexpected situations."

Submarines face unique navigational challenges. To maintain stealth, they use passive sensors to detect their environment, but this makes it hard to know their exact position or identify nearby vessels with complete confidence.

BAE Systems has developed a tool that uses historical maritime data to improve situational awareness and support navigation decisions.

The AI tool is trained on years of automatic identification system (AIS) data – information about vessel identity and location – which allows us to make a prediction of real-time maritime activity based on that data. It allows operators to compare a passive sonar reading to what our tool would expect to see in that location and at that time.

This helps users spot the difference between busy shipping lanes and crowded fishing areas. The system can also flag unusual vessel behaviour or outliers, giving extra clues that may point to unexpected activity or threats.

How our historical AIS navigation tool delivers contextual insight

There have been some historic incidents that bring to life why this tool could be so helpful. In one case, a submarine caught the nets of a fishing vessel after mistaking it for a merchant ship. Our tool could have helped show that fishing vessels were common in the area, helping the crew avoid the incident. In another case, a ferry came much closer to a submarine than expected, as the ferry had moved outside of its expected route.

Looking at that location with our AIS tool revealed that the ferry often changed its route in this area, which again would have been useful information for the navigator.

By giving crews extra context, this tool could make it easier to narrow down an actual position and identify contacts with more confidence. Navigators would get data-backed insights to inform navigation, which could then help make decisions faster and with greater confidence.

The submarine navigation challenge

Because staying hidden is essential, submarines avoid using active sensors that could reveal their position. Crews rely on passive sonar, which gives them a bearing to other objects but not their exact distance or clear identification. Operators track how these bearings change as the submarine moves, creating patterns that help them estimate what's nearby and how far away it is. This process is complex and relies heavily on skill, so it can take time to make informed decisions. That's why our historical AIS navigation tool could be so valuable.

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INTeACT: securing the data advantage in modern naval warfare

In an era of hypersonic missiles and swarm drone attacks, the speed of decision-making determines survival. Naval command teams must process vast quantities of data to defend their vessels and the wider task group.

To meet this challenge, we are delivering INTeACT, a next-generation combat management system (CMS), designed to turn information overload into decision superiority.

INTeACT serves as the central nervous system of a warship. It fuses data from onboard sensors, such as radar and sonar, with external feeds from supporting aircraft and other vessels. This integration creates a single, comprehensive tactical picture for situational awareness. The system detects threats and supports the allocation of appropriate countermeasures.

Elevating the operator

The primary goal of INTeACT is to reduce the cognitive burden on the operator. By automating the correlation of sensor data, the system identifies whether multiple signals represent the same real-world object. It enables filtering out of 'safe'. contacts, such as civilian aircraft broadcasting standard identification data, allowing the command team to focus on genuine threats.

"The intent is to take what is a manual, labour-intensive process and elevate it from 'human-in-the-loop' to 'human-on-the-loop'," says Richard, the INTeACT product technical authority. "We want to remove the hay so the operator can simply pick up the needle."

This capability is powered by the deployment of machine learning functions. The first iteration of this technology learns the typical movement patterns of civilian air traffic, then cross-references live sensor data against these patterns to flag any anomalies for immediate human investigation.

A new model of delivery

The development of INTeACT represents a fundamental shift in how defence capability is delivered to the Royal Navy. We are moving away from traditional all-encompassing software releases, allowing smaller, more frequent updates to capability. This approach allows the Royal Navy to start evaluating capabilities well before they reach the front line. By providing a continuously updated CMS environment throughout the contract, feedback from naval operators shapes the software.

"We are changing the way we do business to be more agile," Richard explains. "We sit at the centre of the development to speed things up, but we also ensure that the CMS remains a critical capability that will not fail when it matters most."

Open architecture for a hybrid force

Future naval operations will rely on a hybrid force of crewed vessels and uncrewed autonomous systems. INTeACT is architected to support this integration.

"We have been deliberate about creating a loosely coupled architecture rather than a monolithic one," says Richard. "It is easier to change a component and be confident that the rest of the system can handle it through robust application programming interfaces and modules."

This modularity ensures that as new sensors or effectors come online, they can be integrated into the CMS without requiring a wider system rewrite. It empowers the Royal Navy to exploit new information sources and coordinate responses across a task group, ensuring that every asset has a holistic picture of the commander's intent.

Defining open standards

True interoperability requires transparency. We use international open standards and provide a software development kit (SDK) for others to use. This approach allows third-party suppliers and SMEs to develop applications that plug directly into INTeACT. It is intended to foster a diverse ecosystem of innovation where the best available technology can be rapidly integrated into the combat system, regardless of who developed it.

Identifying threats quickly in congested waters is essential.

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Tracking radio fingerprints from space

"Once the SDR identifies a specific target signature, the cluster can cross-cue its companion SAR satellite, allowing it to capture high-resolution imagery of the fingerprinted asset, regardless of weather conditions or cloud cover. By tracking these unique signatures over time, allied forces can monitor adversary movements and uncover hidden threats with absolute precision."

Our Azalea™ satellite cluster can fingerprint a specific vehicle, ship or aircraft from its unique radio frequency (RF) signature, then track its movement over time from space.

Launched last year, our Azalea satellites are a constellation of highly capable RF and synthetic aperture radar (SAR) sensors. At the core of this system is our modern software defined radio (SDR), which provides analytical power directly from low Earth orbit.

Radiation-hardened resilience for low Earth orbit

Space presents a hostile operating environment that quickly degrades commercial electronics. To ensure mission-critical reliability, we engineered the Azalea SDR with advanced radiation-hardened circuitry. This protects the Field Programmable Gate Array from radiation events that could otherwise force a satellite into safe mode and disrupt intelligence gathering.

"Our SDR is the sweet spot for low Earth orbit," explains Tony, the lead on the Azalea payload. "Other radios use standard commercial components that are prone to errors in radiation. We designed our system specifically to manage those problems, providing a highly reliable capability for government and defence customers."

Operating in low Earth orbit also provides distinct tactical advantages. It is significantly harder for adversaries to disrupt than geostationary orbit, ensuring that the critical data pipeline remains secure during high-intensity conflicts.

Onboard processing and rapid intelligence

Traditional satellites transmit massive volumes of raw data back to ground stations for analysis. Instead, the Azalea SDR processes RF signals onboard after ingesting data from multiple antennas across wide bandwidths simultaneously. This allows it to filter out noise and extract actionable intelligence, then transmits this directly to users in theatre, helping inform rapid decision-making.

"The software-defined architecture gives us enormous flexibility," Tony notes. "We can programme it dynamically to experiment with secure communications waveforms or deploy entirely new processing algorithms. It turns the satellite cluster into a highly adaptable platform that can evolve with mission requirements."

Global RF mapping and platform fingerprinting

Beyond rapid processing, we are now using Azalea to build a comprehensive global map of RF signals over time. Our SDR detects and analyses emissions across the electromagnetic spectrum to create a unique fingerprint for individual platforms, such as naval vessels, aircraft or combat vehicles.

Building the satellites in our UK-based cleanroom.

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Azalea™

Delivering UK sovereign space-based intelligence surveillance and reconnaissance.

The Azalea™ satellite cluster monitors Earth from space by collecting radio frequency (RF) and synthetic aperture radar (SAR) data, analysing it onboard using the Azalea™ Enhanced Software Defined Radio and delivering insights to users across land, sea and air.

BAE Systems' RF satellites

RF and SAR data

Ground station

ICEYE's SAR satellite

1 Satellites deliver very wide area surveillance.

2 Satellites detect and analyse radio signals in area.

3 SAR satellite investigates in more detail.

4 RF and SAR data processed and analysed in space, delivering insight straight to decision makers.

5

Decision-makers receive insights.

6

These insights help decision-makers unveil and respond to threats such as troop movements or dark vessel activity.

7

They can also be used for a variety of defence or civil applications, including the protection of national infrastructure.

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Defence innovation powering oil and gas technology

What is BAE Systems Launchpad?

At BAE Systems, innovation has always been at the heart of what we do. Launchpad builds on this legacy by turning great technologies into new ventures. Launchpad helps create and grow start-ups that develop our advanced technology for use outside of defence. It also accelerates early-stage, potentially transformative defence research, giving it the support needed to make a real-world impact.

We're committed to supporting bold ideas and Launchpad provides the space, guidance and resources to help promising technologies grow into successful, independent businesses.

Rho-C is the first venture to emerge from BAE Systems Launchpad – our incubator. With Launchpad, we are aiming to invest in external start-ups and scale our own innovations rapidly, transforming them into independent business and empowering them to serve entirely new markets.

So, what makes Rho-C's technology so transformative? The breakthrough lies in the ability to transmit both power and data through solid structures – a capability that started as an idea for submarines. By removing the need to drill holes for cables, Rho-C enables safer, more efficient and lower-cost infrastructure installations, opening new potential for industries like oil and gas.

Rob Malkin, Chief Technology Officer at Rho-C, puts it succinctly: "Launchpad has provided us with a highly effective, mature technology that we can quickly turn into a product. We are currently working on our first operational unit, a milestone that would not have been possible this quickly without BAE Systems' support. We have received significant interest from prospective customers and anticipate an exciting first year of operations."

Rob highlights why this could be so useful for oil and gas: "Currently, most subsea networks operate with very limited data points, which means relying on models and risk-based inspections. Our technology can change that by enabling real-time monitoring across multiple data points, providing detailed insights into conditions like temperature and pressure at various locations. It's safer, faster, more cost-effective and can deliver much greater operational insight."

Rho-C is exactly the kind of high-potential business this model was designed to support. As Dave Ewing, head of Launchpad at BAE Systems, says: "We want to turn promising defence technology into independent start-ups, spinning out technology that has market value beyond defence into dedicated businesses serving many customers."

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Training AI to see with sound

"The vision is to see this running live on submarines, helping operators manage data overload by taking away non-critical events so they can focus on what's really important."

The underwater battlespace is becoming increasingly congested and contested. For sonar operators, this presents a significant challenge.

Sifting through a complex acoustic environment to identify genuine threats demands immense concentration and carries a heavy cognitive burden.

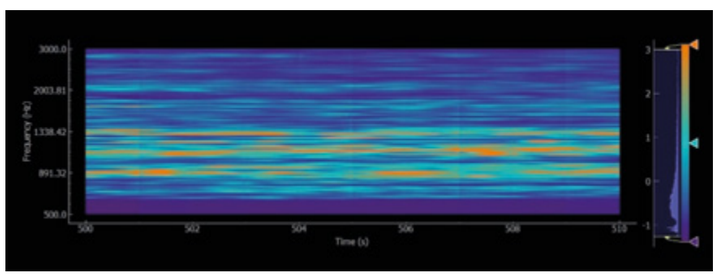
To address this, we are developing an AI tool designed to automate the classification of common vessels, allowing operators to focus their attention where it is needed most.

The first challenge was acquiring sufficient high-quality, labelled data to train a reliable AI model. Underwater acoustic data is often highly classified and difficult to obtain. Our innovative approach involved collecting our own data using hydrophones and cross-referencing it with commercially licensed marine automatic identification system (AIS) data. This allowed us to correlate specific sounds with known vessel types, creating a robust dataset to train our AI.

By training the model on the acoustic signatures of civilian and non-covert vessels, we developed a system that effectively filters out background noise. It removes much of the 'hay', enabling operators to more easily find the needle.

From raw data to mission-critical insight

The development process began over five years ago with a simple goal: to understand AI's potential application in the submarine environment. The most time-consuming phase was data processing. This involved synchronising datasets from different sources, manually verifying acoustic signatures against AIS logs and building a high-confidence training library. Early algorithm development focused on a basic but critical question: is a ship present or not? By prioritising high accuracy on a simple output, we built a solid foundation.



The AI system sifts out noise to help operators spot anomalies.

This approach has yielded impressive results. We were able to test the unclassified algorithm against classified sonar recordings, where it achieved over 85% accuracy in ship detection without any retraining. This suggests that the model has the capacity to generalise to previously unseen domains, and that insights derived from unclassified data can be directly transferred to new operational environments.

The system has received positive feedback during trials.

Ex-submariners found the tool highly effective, noting its potential to significantly speed up the classification process and reduce workload.

A new capability for the future fleet

The project is led by innovator Olivia, who sees its immense potential: "We always knew that any AI tool would need to be tested on classified data to prove its worth," she explains. "Seeing it perform so well in a completely new domain was a huge milestone. The vision is to see this running live on submarines, helping operators manage data overload by taking away non-critical events so they can focus on what's really important."

The next phase involves real-time testing on deployed platforms, such as autonomous gliders, to prove the system can ingest and process live data. The ultimate aim is to integrate this capability into the combat systems of submarines and uncrewed underwater vehicles (UUVs).

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Finding the needle in the haystack

The AI system sifts out noise to help operators spot anomalies.

The sea is an increasingly busy environment, so our AI model is trained to sift out the noise from expected civilian traffic in order to help highlight potential threats.

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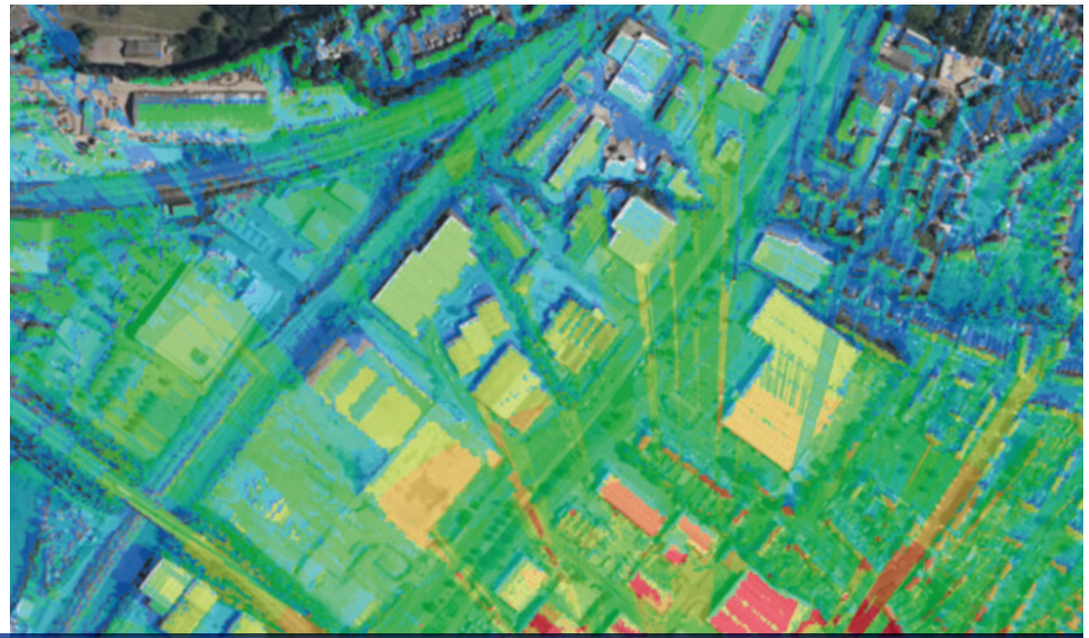
EM-CAT: a nerve centre for counter-drone operations

EM-CAT can graphically show you the electromagnetic signals present in the area, as well as any blind spots.



"EM-CAT centralises all the data, so operators can quickly understand what's happening and deploy responses faster than ever."

In today's evolving battlespace, countering drone threats is more critical than ever. Adversaries now rely on drones for surveillance, attacks and disruption, making effective drone defence a top priority.

To empower commanders with a clear tactical advantage, BAE Systems has developed the electro-magnetic co-ordinated activities tool (EM-CAT), a cutting-edge command and control (C2) interface, originally designed to master the EM spectrum but now expanded to unify and enhance counter-drone operations.

EM-CAT acts as the central brain of a counter-drone system, fusing data from a diverse range of sensors, including radars, electromagnetic sensors, electro-optical systems, and acoustic detectors. By integrating these inputs, EM-CAT provides a real-time, comprehensive picture of the airspace, helping operators detect, track, and neutralise drone threats with precision. Chris, one of our technical leads, explains: "Drones are a fast-moving challenge, so a connected system gives you faster access to the critical data. EM-CAT centralises all the data, so operators can quickly understand what's happening and deploy responses faster than ever."

While its counter-drone capabilities are the focus, EM-CAT retains its powerful electronic warfare (EW) functionalities, enabling operators to manage the electromagnetic spectrum and deploy non kinetic measures against drones.

The system's advanced track fusion engine ensures that drone threats detected by multiple sensors are consolidated into a single, clear target on the operator's display. This eliminates duplicate or conflicting information, improving situational awareness and accelerating decision-making. In addition, EM-CAT features sophisticated propagation modelling, showing operators where to deploy EW measures or other counter-drone electronic effectors for maximum impact. "It helps us see exactly where our systems can have an effect, minimising blind spots created by terrain or structures," Chris notes.

We designed EM-CAT to be modular and agnostic, so it can work with a customer's existing sensor and electronic effector network. It's capable of integrating with any sensor or electronic effector that uses open standards like NATO's SAPIENT counter-UAS protocol. EM-CAT uses a rules-based response engine, helping reduce cognitive burden on operators by providing alerts and pre-approved response recommendations to operators when threats are detected – this can reduce the decision-making cycle from minutes to seconds.

Chris added: "We can also integrate EM-CAT into synthetic training environments, so operators can train and develop tactics for almost any situation."

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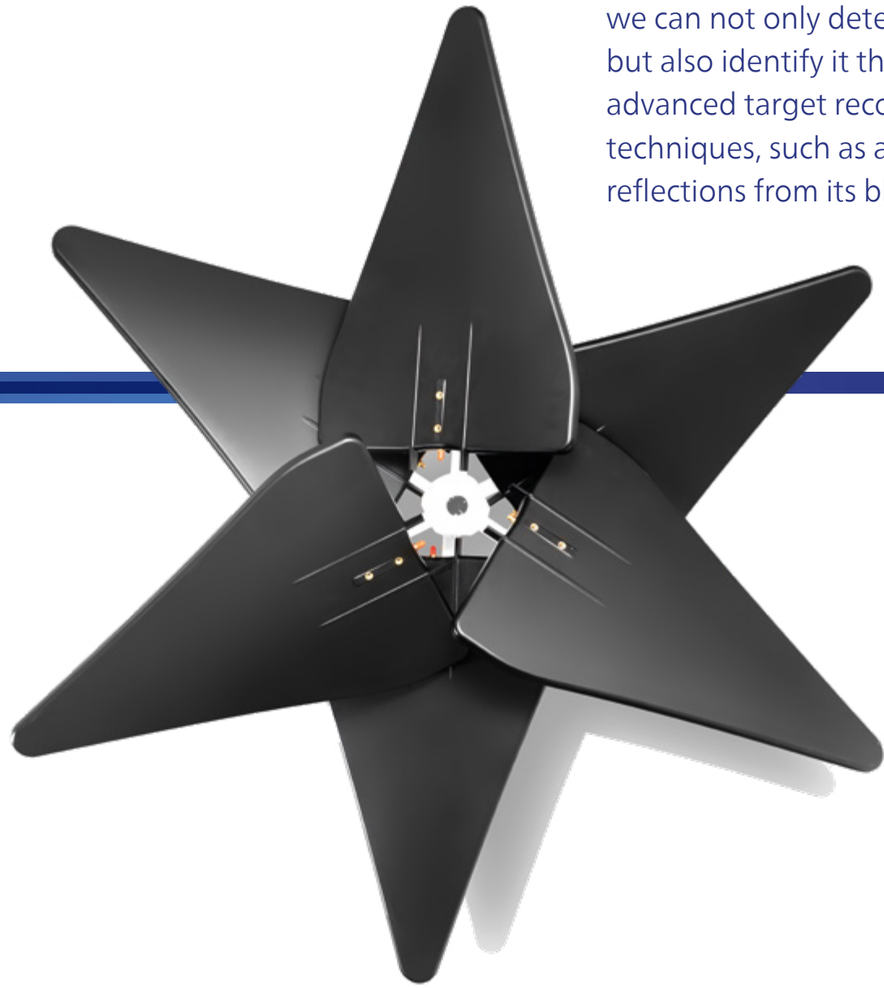
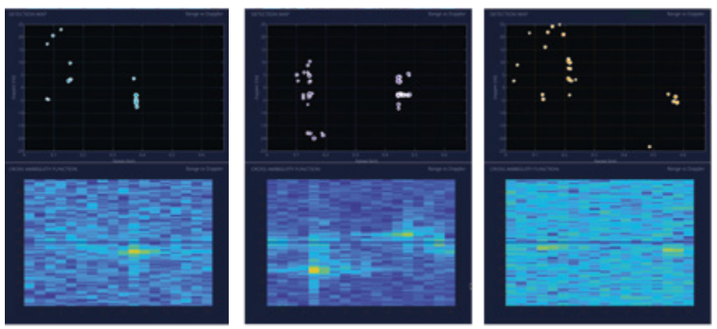
Invisible advantage: the power of passive radar

"We are looking at a future where we can not only detect a drone but also identify it through other advanced target recognition techniques, such as analysing the reflections from its blades."



Passive radar antenna picks up reflected signals from existing emitters. This raw output is turned into location information for detected objects.



In the modern battlespace, being detected often means immediate attack. Conventional radar systems, which emit powerful microwave signals to detect threats, can be easily located and neutralised if they're not protected.

To address this problem, we have developed an advanced passive radar system that provides a covert and cost-effective solution for both military operations and the protection of critical national infrastructure.

Instead of broadcasting its own signals, passive radar uses existing, ubiquitous radio frequency (RF) waves – such as digital television and cellular transmissions – to detect and track objects. By analysing how these ambient signals are reflected, the system can identify everything from small commercial drones to large aircraft, all without emitting a detectable signature.

"The core innovation is building a highly capable system using commercial off-the-shelf equipment," explains Chris, the project lead. "This makes it affordable, modular and easy to deploy. You can place it anywhere without needing frequency clearance (in the UK you would usually need a licence from Ofcom), and because it's silent, an adversary has no idea it's there."

The system offers a three-dimensional track of a target, providing range, speed and elevation data. This is a significant advantage over other small passive systems that only offer two-dimensional information and is crucial for an effective counter-response. This data can also be fused with other intelligence sources within command and control systems like EM-CAT (see page 26), providing operators with a clear, unambiguous picture of the battlespace.

This capability is not just for the front line. The demand for covert surveillance is growing for the protection of airports, power stations and other critical infrastructure. "The requirement has grown ten-fold," says Chris: "In operation, our passive radar would provide covert sensing capability at a fraction of the cost of equivalent active systems."

The technology is being integrated with other BAE Systems capabilities, including advanced electronic attack systems from Kirintec. This allows for a layered defence, where a threat detected by the passive radar can be neutralised by jamming or spoofing its guidance system – a highly effective and low-cost response compared to kinetic interceptors.

"We are looking at a future where we can not only detect a drone but also identify it through other advanced target recognition techniques, such as analysing the reflections from its blades," adds Chris. "This gives commanders the mission-critical information they need to decide which target to engage first and with what effector. It's about saving lives and maintaining a strategic advantage."

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BAE Systems invests in Oxford Dynamics to accelerate AI-driven decision intelligence

In modern defence and security operations, the ability to make rapid, informed decisions provides a critical advantage.

As part of our ongoing drive to identify and harness innovative technologies for rapid deployment, last year we made a strategic investment in Oxford Dynamics, a small but growing company specialising in AI and robotics.

We are now collaborating with Oxford Dynamics on a number of projects, combining our defence and security knowledge with the company's AI products. These focus on how we can generate actionable intelligence from vast amounts of data, whether that's in military operations, domestic security or platform management and maintenance.

Oxford Dynamics' key product, AVIS, is an agentic AI framework designed for sophisticated decision support. "A key application for AVIS is in mission orchestration and decision advantage – AVIS can process and fuse data from multiple sensors and intelligence feeds from across the battlespace to classify a threat, then analyse factors like effector availability and rules of engagement to recommend the optimal response," explains Andy, our lead for the Oxford Dynamics relationship. "AVIS massively enhances an operator's ability to make the right decision faster than an adversary. The system is designed to provide explainable and traceable outputs, ensuring a human remains firmly in control."

This decision advantage extends to broader security and intelligence missions. For instance, AVIS can be applied to analyse vast quantities of air traffic control data or feeds from border surveillance sensors. By orchestrating multiple AI agents to perpetually monitor these data streams, the system can identify anomalous patterns that might indicate illicit activity or an emerging threat. It can then generate actionable intelligence and alert the relevant authorities, transforming a reactive security posture into a proactive one. This capability is also being explored for strategic applications, such as monitoring subsea infrastructure by fusing data to detect potential vulnerabilities and threats in the North Atlantic.

Oxford Dynamics has already proven its capability by supporting the UK's Strategic Defence Review, where AVIS was used to sift through and summarise tens of thousands of documents from over 1,700 contributors. The company is also working on the British Army's Asgard project, which is developing a new command and control concept to support faster precision strike operations.

"Oxford Dynamics is finding a market pull in the application of agentic AI and the orchestration of those agents to make the decision-making process more effective," Andy adds. "Our role is to help them bring that capability to the customers who need it most."

Through this strategic collaboration, we are ensuring that innovative, UK sovereign technology can be rapidly developed and deployed to maintain a decisive edge in security and defence.

"A key application for AVIS is in mission orchestration and decision advantage – AVIS can process and fuse data from multiple sensors and intelligence feeds from across the battlespace to classify a threat, then analyse factors like effector availability and rules of engagement to recommend the optimal response."

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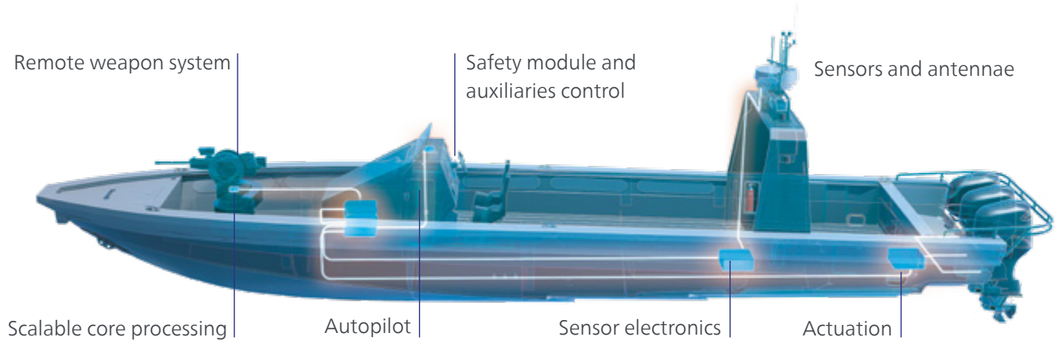
Nautomate® enables full autonomy for third-party vessels



Picture this: an autonomous vessel cutting through the waves, locking onto its target with precision and executing its mission with demonstrably high performance.

That's exactly what our Nautomate autonomous control system accomplished during a live trial. Integrated onto a third-party vessel, it performed complex patrol and engagement tasks, including human-approved remote firing of a .50 calibre machine gun. The result? Higher accuracy than achieved with a human operator and a glimpse into the future of autonomous maritime operations.

We installed our Nautomate system onto a P38 – a 14-metre, 60-knot fast intercept craft built by the Omani company Der'a. This vessel was never designed with autonomy in mind, showing that Nautomate's core can be retrofitted to a wide range of existing platforms.

"A key objective was to prove our autonomy is vessel-agnostic and can be rapidly deployed," explains Mike, the project lead. "We needed to bring all the equipment separately to another country, assemble and integrate it in a number of days, then travel to a firing range several hours' travel from shore. To bring all those elements together and successfully demonstrate the live firing – on two consecutive days – was a real achievement."

The demonstration included two mission scenarios. First, the Nautomate-controlled vessel conducted an area patrol, autonomously identifying and pursuing a simulated threat vessel.

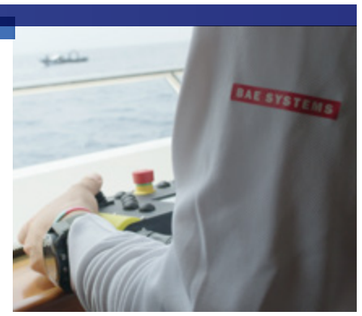
The second scenario demonstrated the integration of a Seahawk remote weapon station from UK-based company MSI. After receiving operator approval, Nautomate engaged the target at a range of approximately one kilometre.

"Once the coxswain identifies the target as a threat and grants permission, authority is handed to the weapon station to fire at will – on only that agreed target," says Mike. "The system demonstrated exceptional accuracy. For comparison, we had a highly trained former Royal Marine operate the weapon station manually as a comparison. The autonomous system was able to hit the target from around one km away, while the human operator had to get within around 500m before making direct hits. Nautomate also used significantly less ammunition to hit the target, all while operating at speed in challenging sea conditions."

A significant advantage of autonomy is that it can continue operating at high performance for hours at a time in environments that would be uncomfortable for a human. In extreme heat, for instance, a human may struggle to maintain concentration on monotonous tasks. Automating those tasks means the human operator can focus on decision-making.

This successful trial represents a critical step forward in deployable autonomy. It not only proves we can retrofit advanced autonomous control, but also deliver precise, mission-critical capability. The core software used in Nautomate is the same as that used in other BAE Systems autonomous platforms including the Herne underwater vehicle, highlighting a common, trusted architecture for multi-domain operations.

"This successful trial represents a critical step forward in deployable autonomy. It not only proves we can retrofit advanced autonomous control, but also deliver precise, mission-critical capability."



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Turning the seabed into a sensor: the future of critical infrastructure protection

"We are looking to use those undersea cables themselves to do the sensing."

The protection of critical undersea infrastructure (CUI) has moved rapidly up the strategic agenda. With greater dependence on seabed cables for energy and communications, the vulnerability of these assets has become a significant concern.

We are developing a new approach to turn the infrastructure itself into a surveillance asset, using existing fibre-optic cables to create a persistent, wide-area sensor network.

To do this we are using an existing technology, off-the-shelf distributed acoustic sensing (DAS) modules, but tailoring them for undersea use. By analysing light pulses sent through standard fibre-optic cables, it's possible to detect minute vibrations caused by acoustic pressure.

This turns a cable running for hundreds of kilometres along the ocean floor into a continuous array of microphones, capable of detecting everything from environmental shifts to the movement of vessels and even marine life.

From vulnerability to vigilance

The project began by exploring how to monitor power cables to provide early warning of faults and seismic activity, as well as accidental damage from maritime traffic. However, the application has evolved significantly.

"By turning the cables into sensors, it's possible to detect nearby maritime activities that could cause damage, so that operators are able to take action before it happens – perhaps contacting those vessels to warn them. We are also engaging with cable companies and operators to discuss how, as a community, this can be done consistently across undersea infrastructure," explains Jason, the project lead.

For an island nation like the UK, we are dependent upon a dense network of power and data cables, which provide much of our internet connectivity and electricity. Any technology that helps protect this infrastructure could offer substantial cost savings, from reducing repair bills to avoiding the economic impact from outages. It could also support broader government needs, such as detecting illegal fishing in protected zones or smuggling.

The data challenge

While the sensing technology we're tailoring for undersea use is already used in land-based applications, deploying it in the subsea environment presents a major data management challenge. A single DAS unit can generate up to a petabyte of data per day, which is the equivalent of streaming 57 continuous years of high definition video.

"The sheer amount of processing required to analyse all of this data is immense," Jason notes. "We are building the systems to store, access and retrieve the data over time. Alongside this, we are developing tools to autonomously detect signals of interest as they appear and alert the operator."

We are using our experience in machine learning to automate this analysis, developing algorithms to classify specific acoustic signatures and distinguish between things like whales, drifting containers, fishing trawlers or vessels of interest.

Visualising the underwater battlespace

To make this data usable for command teams, we've integrated the output with our wider intelligence system. This fuses the DAS data with other inputs such as radar, ship identification beacons (AIS) and satellite feeds, providing a comprehensive picture of the maritime environment.

"Intelligence from DAS can sit alongside other sensors to provide a richer picture. With further development, you could begin to fingerprint specific vessels from their acoustic signature," says Jason.

Future deployment and integration

The project is currently preparing for a long-term data gathering trial. DAS sensors will be deployed on a commercial cable for three months to capture data. This real-world data will be used to further train and refine the classification algorithms, moving the capability closer to operational readiness.

This work forms a key pillar of our broader subsea intelligence campaign. By integrating persistent cable monitoring with other surveillance assets, defence forces will be able to build a resilient, multi-layered picture of the underwater domain, helping ensure that critical infrastructure remains secure in an increasingly contested environment.

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Turning cables into sensor networks

Fibre-optic cables will actually be able to detect movement near them, letting operators know to take action to protect them if necessary.

We are using tiny acoustic sensors along the length of the fibre-optic cable to detect specific types of movement in the area that represent potential threats. This could then be monitored in real-time, in order to take action if needed.

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Visualising certainty: dynamic nomograms for submarine decision-making

"It's exciting to work on something new that could really make an impact. Knowing it could one day help submariners is really motivating."

Dominick, project lead

Navigating underwater is a highly skilled job.

Submarine operations demand fast, confident decisions where every second matters. To support crews in doing this, we are testing dynamic nomograms – modern, digital versions of a classic visual tool – to reduce cognitive burden for sonar operators.

Reviving a classic tool

Nomograms are graphical calculators that solve equations visually. First created by Maurice d'Ocagne in 1884, they help users find unknown variables – in medicine, for example, a nomogram could allow a clinician to quickly determine a recommended drug dosage by aligning a patient's weight with the drug's concentration. Although modern computers have largely replaced them, nomograms are still used in fields like medicine because they show the relationships between variables, not just a final answer.

We're now applying this concept to the underwater battlespace. Dynamic nomograms offer sonar operators instant visual validation of acoustic data, providing a "sanity check" for AI outputs. This ensures that as technology advances, decisions remain transparent and trustworthy.

Reducing cognitive burden

Sonar operators use target motion analysis (TMA) to classify contacts and determine their range, speed and course. This process relies on complex calculations, often performed mentally or using physical references, adding to the operator's workload.

The dynamic nomogram tool addresses this by automatically generating diagrams on-screen. It processes key acoustic data points, such as:

- TPK (turns per knot): propeller speed relative to movement
- Shaft RPM (revs per minute): noise patterns from a vessel's propeller
- Speed (knots): estimated target velocity.

By visualising these variables, operators can verify AI classifications. If the data points deviate significantly, it becomes immediately obvious on the display. This shifts the focus from mental arithmetic to verification, speeding up interpretation and reducing errors under pressure.

Increasing trust in AI

AI systems process data faster than humans but often operate as 'black boxes', delivering results without showing the reasoning behind them. Dynamic nomograms address this by visualising uncertainty and error ranges, providing clarity and transparency.

For example, rather than displaying a precise but potentially inaccurate figure like '5,000 yards', a nomogram shows the full range of probabilities. This 'white box' approach supports human judgement, ensuring operators trust the AI while retaining control over decisions.

From concept to command

Dominick's project has rapidly progressed from concept to user trials. Ex-submariners testing the system report faster and clearer data interpretation compared to traditional methods. The screen interface dynamically updates in real-time, significantly easing their workload.

Combining 19th-century visualisation with 21st-century AI, dynamic nomograms are set to enhance situational awareness, helping submarine crews make faster, more confident decisions in increasingly complex underwater environments.

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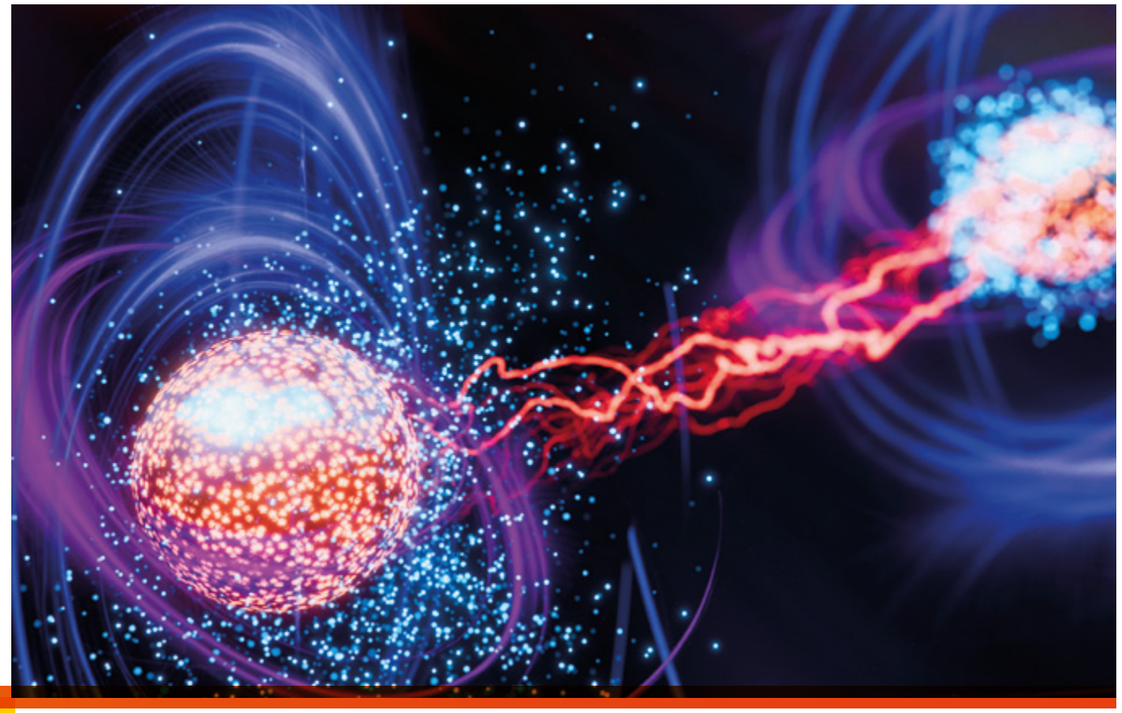
Pioneering future innovation



"We collaborate closely with universities, specialist start-ups and allied partners, and we prove concepts rapidly through trials and synthetic experimentation before physical deployment.

Ruth Nichols,
Head of Innovation

These stories look beyond today's threats to the technologies that will define defence in the years ahead. They share a common thread: each tackles a problem that's hard now and will only grow harder, from navigating without GPS to operating autonomously across a contested electromagnetic spectrum.

We can't wait for these challenges to mature before we act. The advantage goes to those who experiment early and learn fastest.

Trusted autonomy runs through much of this work. We're developing an AI mission controller with decentralised swarming, where each platform carries its own intelligence and the group self-organises and self-heals if a drone is lost or comms is jammed. Bio-inspired swarming behaviours, tested in our OdySSEy synthetic environment, show how a single commander could direct large formations. And our adversarial learning tool wargames electronic warfare, helping uncrewed platforms decide when to act and when to stay silent in contested airspace.

Resilient sensing and navigation matter just as much. With Mystique, we're working with UK Research and Innovation and the University of Birmingham on a compact hot-atom clock for assured timing when GPS is denied. Our passive radar detects threats without emitting a signature, while we're turning undersea fibre-optic cables into surveillance networks that detect threats to critical infrastructure. Below the surface, AI sonar classification and navigation support helps submariners when they're taking critical decisions in congested waters.

None of this happens in isolation. We collaborate closely with universities, specialist start-ups and allied partners, and we prove concepts rapidly through trials and synthetic experimentation before physical deployment. That's how we turn bold ideas into mission-ready capability. With our pioneering spirit, we're not just anticipating the future of defence. We're building the technologies that will shape it.

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Our uncrewed ground vehicle achieves high-speed autonomous milestone

"Achieving high-speed, cross-country performance was a significant milestone for the programme."

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The modern battlespace requires uncrewed ground vehicles (UGVs) that can operate with speed, agility and a high degree of autonomy alongside crewed vehicles.

To meet this need, our Australian business has developed ATLAS, a UGV engineered from the ground up for autonomous missions. In a significant advancement, ATLAS has successfully demonstrated high-speed, off-road autonomous navigation, proving its capability to keep pace with main battle tanks and other armoured assets in complex terrain.

During an intensive testing period in Australia, ATLAS achieved speeds of up to 50km/h under remote control across undulating, cross-country terrain. Critically, it also demonstrated point-to-point autonomy, where it navigated a designated route while autonomously detecting and manoeuvring around obstacles. This level of performance shows its potential for a range of mission-critical tasks without direct human control.

"Achieving high-speed, cross-country performance was a significant milestone for the programme," notes Paul, the project lead. "It demonstrated that the software and hardware are mature enough to handle complex environments. This proves ATLAS can operate alongside crewed formations, providing everything from logistical support to armed overwatch."

The ATLAS platform is designed with modularity and adaptability at its core. It can be fitted with various mission modules, including an advanced turret system that allows for the integration of multiple cannon calibres. The vehicle's low profile, which allows it to be transported covertly in a standard 20ft shipping container, provides a considerable advantage for rapid deployment.

Further innovations include the vehicle's ability to 'crab-crawl', moving sideways while the main platform faces forward. This is particularly effective in urban environments for engaging targets from unexpected angles and quickly returning to cover. The design also incorporates passive sensor fusion, combining data from day/night cameras, acoustic gunshot detectors and, in future, multi-spectral sensors. This allows the system to detect, track and classify targets with minimal emissions, reducing its signature and increasing survivability.

With its recent successful demonstrations and planned deployment with customers for further integration trials, ATLAS is intended to provide a decisive capability for modern ground forces.

Autonomous drone landings in severe sea conditions

"By automating mission-critical re-supply tasks to use more affordable platforms, our customers can free up larger air vehicles for other roles and missions."

James, senior technologist

Delivering critical supplies across a naval task group presents significant operational challenges. When weather conditions are poor, helicopters often cannot fly and ship transfers can become dangerous.

Drones offer a promising alternative, however as pilots will tell you, landing a heavy drone on a moving ship deck in heavy seas requires exceptional skill. To solve this problem, BAE Systems is developing an advanced artificial intelligence system that can land drones autonomously, even in severe weather conditions.

"At a time when navies are trying to reduce the number of crew needed to operate a ship, this technology is ideal. In a logistics re-supply mission, you may only have one expert drone pilot available, so with our system they could oversee a greater number of drones," James, senior technologist, notes.

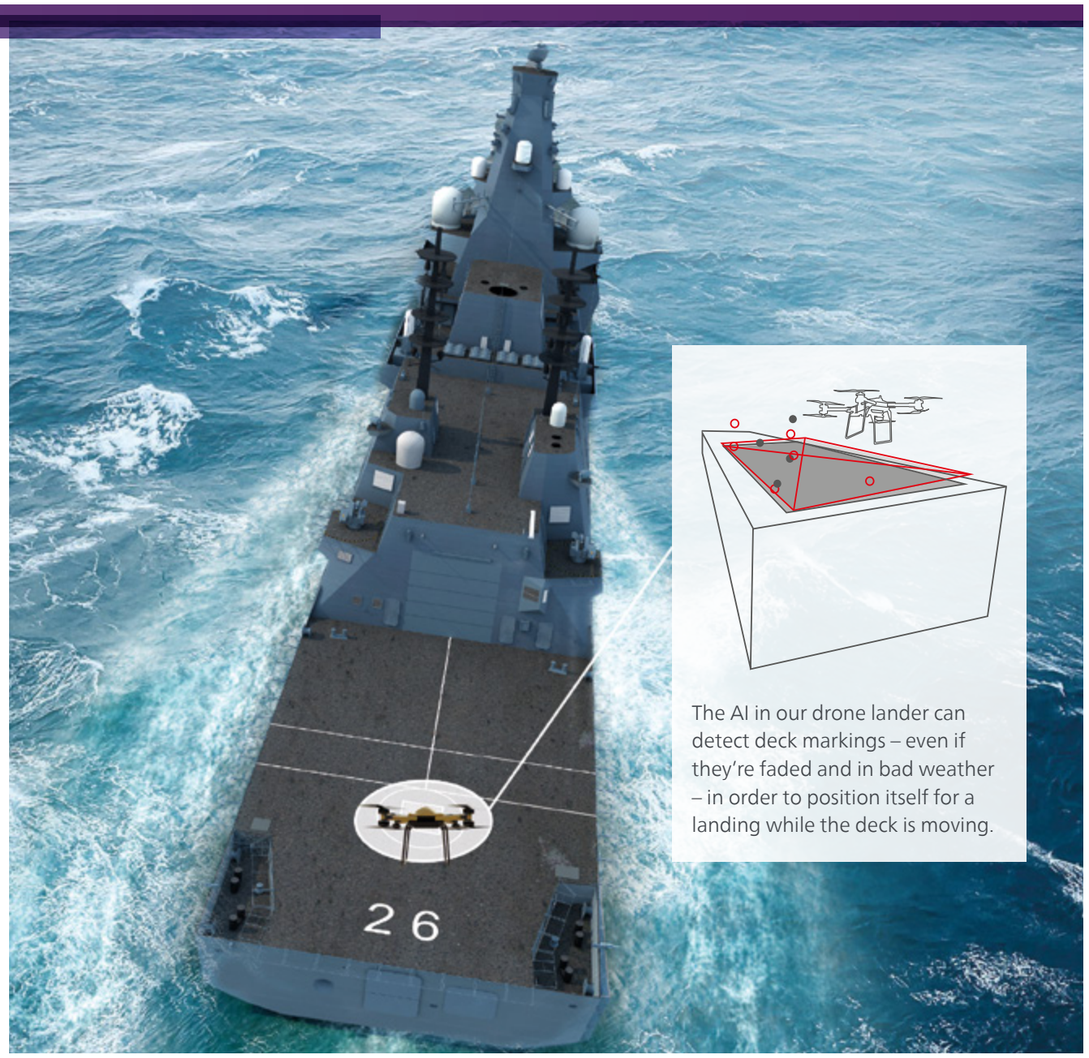
Our system combines a physics-based environment that can move and rotate in every direction, so it can simulate the deck in heavy seas and the movement of the drone. We then used that to train a prediction algorithm to estimate where the deck will be when the drone gets to it. "Synthetic testing has been really positive, so we're planning physical trials as our next step," James added.

Show me the data

Training an AI model to handle unpredictable weather requires vast amounts of data, which we'd never practically be able to get from real-world flying. We used our advanced synthetic environments to generate over half a million images, which we then used to train the system to learn how to recognise a deck even in heavy sun glare or if there are faded markings or bad weather.

Preparing for live sea trials

The project has already achieved successful demonstrations in the synthetic environment. In the next phase we will test the system on a static physical deck before progressing to a moving platform. Ultimately, we plan to conduct live sea trials to validate the synthetic models in real-world conditions.



The AI in our drone lander can detect deck markings – even if they're faded and in bad weather – in order to position itself for a landing while the deck is moving.

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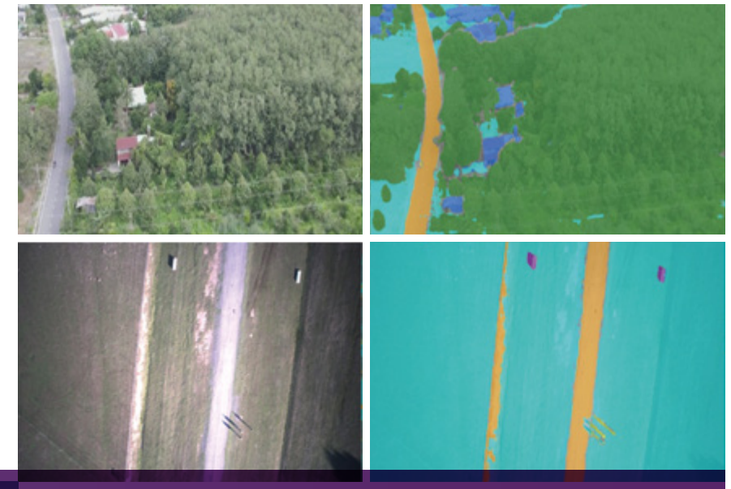
Uncrewed air vehicles provide real-time data for UGV route planning

Trained AI model converts visual feed into actionable data for the autonomous vehicle.



"For a UGV on a covert mission in a warzone, knowing that a building has just been destroyed is mission-critical information. This system provides that live update, allowing the UGV to adapt its route and achieve its objective."

Uncrewed ground vehicles (UGVs) offer a critical capability for logistics, reconnaissance and force protection. However, if they rely on platform mounted cameras or radar, then their ability to plan ahead can be limited.

One option is to use historic data, but this can become quickly outdated in warzones or coastal environments. To help solve this problem, we are developing a system that allows uncrewed aerial vehicles (UAVs) to provide real-time terrain and threat data directly to UGVs, allowing them to plan ahead accordingly.

The limitations of static intelligence

In a contested battlespace, a building that provided cover could be destroyed, or a clear route could become impassable – meaning the terrain can change in an instant. Similarly, complex natural environments can change quickly, such as the rapid jungle growth found in northern Australia, which can render maps obsolete in weeks. A UGV relying on outdated intelligence could be exposed to threats or fail its mission entirely. The system we're developing solves that problem by using UAVs to feed live intelligence into the UGV's mission planning software.

"A fundamental challenge is understanding what is happening in the 1km – 5km range," explains Nelson, chief engineer: "We need a way to augment a vehicle's situational awareness with real-time data from a UAV, whether that's changes in terrain or the presence of enemy forces, and fuse that into its operational picture."

Fusing multi-source data for adaptive planning

The system works by having a forward-deployed UAV capture imagery of the UGV's intended path. An advanced AI model then segments and classifies the imagery, identifying features like roads, vegetation, buildings and potential obstacles. This data is fed into a fusion engine that builds an evolving, near real-time map of the world. The process accounts for and corrects sensor inaccuracies, providing the UGV with a high-fidelity understanding of its surroundings.

The system uses multiple AI models, each tailored for different types of analysis. AI models trained on satellite data, for example, performed poorly on the lower-altitude imagery captured by a UAV.

"This work is critical for the future use of UGVs," Nelson notes. "Given how fast environments can change, you can't rely on satellite data or even recent drone footage. For a UGV on a covert mission in a warzone, knowing that a building has just been destroyed is mission-critical information. This system provides that live update, allowing the UGV to adapt its route and achieve its objective."

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Autonomous mission intelligence

With aerial drones scanning the path ahead, uncrewed ground vehicles can dynamically re-plan if terrain or enemy positions change, choosing a path to avoid detection or impassable obstacles.

Using intelligence from the aerial drone, we can see that the blue route gives the highest chance of achieving mission objectives, without encountering enemy vehicles en route.

After the aerial drone detects enemy vehicles, our uncrewed ground vehicle knows that the two red routes would lead to an encounter, so are not used.

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Commanding uncrewed air systems from a Typhoon cockpit

Modern warfare demands a scalable force mix of assets. We recently demonstrated a new capability that allows a single human operator to control a team of uncrewed air systems directly from a Typhoon cockpit.

This synthetic demonstration – developed as a team with QinetiQ – proved how pilots can direct intelligence, surveillance and reconnaissance (ISR) and strike missions using a highly simplified interface and uncrewed air systems (UAS) with autonomous capability.

Streamlining crewed / uncrewed teaming

Traditionally, coordinating large-scale operations in the battlespace is mentally demanding and relies on complex communication systems. Not only have we now used standard messaging protocols (Link 16 and STANAG-4586) to simplify comms, but the autonomous UAS behaviours mean a pilot doesn't have to control their every movement.

"We developed a new format for the Typhoon cockpit interface that allows easier control of uncrewed air systems," explains Leyton, an engineer on the project. "We focused on the chain of tasking the Typhoon to command and control a team of assets." While Typhoon operators can already control other assets from the cockpit, linking new autonomous behaviours to a simplified interface means this approach significantly reduces cognitive burden – particularly important for controlling a varied team of UAS for complex missions.

Executing advanced ISR and strike missions

During the synthetic trial mission, the Typhoon operated at a safe range to avoid enemy air defences while acting as the primary command and control node for the UAS team that included the QinetiQ Banshee and a Malloy T-150. The aircraft deployed an initial ISR team to locate a designated target, which once identified was transmitted as a target back to the cockpit via Link 16. The pilot then used the new interface to authorise a secondary UAS strike wave, which successfully neutralised the target using a combination of electronic attack and kinetic capabilities.

Assured autonomy using double-goalkeepers

A critical component of autonomous teaming is absolute trust. Operators must know that uncrewed assets will never overstep their operational boundaries. To provide this, the system uses a robust double-goalkeeper architecture, with two separate rules and constraints engines to ensure all assets strictly comply with the mission parameters.

A strategic collaboration for scalable mass

This self-funded initiative represents a powerful collaboration between BAE Systems and QinetiQ. The project used QinetiQ's AXIOM technology to act as an autonomous brain for the smaller uncrewed assets, with our contribution focusing on the synthetic environment and advanced cockpit technology to enable seamless crewed-uncrewed teaming.

While we successfully proved this capability in a synthetic environment, our next goal is to transition these concepts into live flight demonstrations. By simplifying the human-machine interface and guaranteeing strict mission compliance, we aim to provide commanders with the ability to deploy scalable mass without needing large human teams to control them.

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AI wargaming tool gives drones a strategic edge

"This adversarial learning approach has its origins in our cyber-defence research, where we modelled how autonomous agents would compete against one another."

Navigating an uncrewed aerial system through sophisticated enemy air defences is a complex tactical challenge.

While electronic warfare (EW) systems can help a drone to mask its signature or deceive enemy radar, these systems consume significant power. Deploying them unnecessarily could jeopardise a mission by depleting the battery before the objective is reached. To help address this, we have developed an artificial intelligence tool that wargames the use of EW to give uncrewed platforms a decisive advantage.

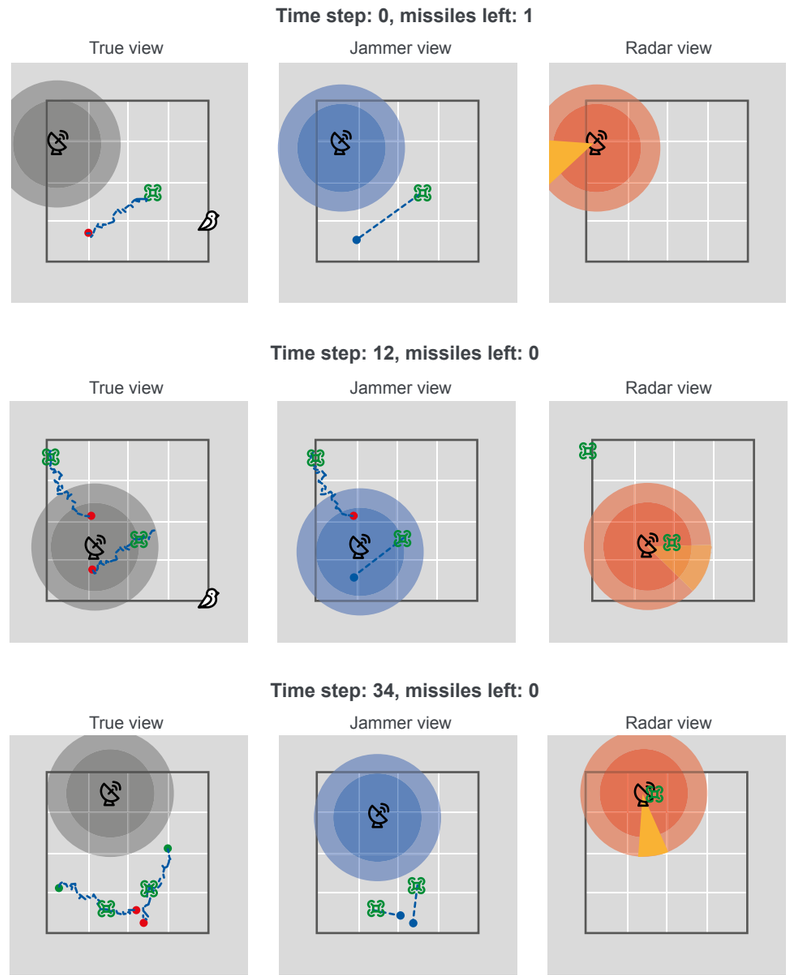
The system essentially plays a highly complex game against enemy defences. It analyses the operational environment, including the locations and types of enemy radar systems, then determines when and how to deploy EW systems to protect the aircraft as it flies to its target. By conserving power and only using its EW capabilities when essential to the mission, the drone increases its endurance and probability of mission success.

This adversarial learning approach has its origins in our cyber-defence research, where we modelled how autonomous agents would compete against one another. "To use this technique effectively, you need a deep understanding of the specific problem space," explains Greg, a lead engineer on the project. "How the data is related and how you classify it is a unique strength we bring. It's like a sophisticated game of rock-paper-scissors, where the AI constantly evaluates policies to find the dominant strategy."

The technology has dual-use applications. Offensively, it can guide a single drone or a swarm through contested airspace, with specific drones potentially using their EW capability to protect others. Defensively, we can reverse the logic to analyse our own integrated air defence systems.

The tool helps us identify potential vulnerabilities and determine the optimal placement of anti-air sensors and countermeasures to make it harder for hostile drones to penetrate. By wargaming these EW scenarios, we help our customers prepare for the evolving complexities of the electromagnetic spectrum.

This diagram shows a selection of steps within a wargame scenario, highlighting various decision points where the drone can maximise its chance of success.



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Mastering mass: bio-inspired drone swarms

Drone swarms – using a large number of cost-effective drones to overwhelm adversary defences – are not a new concept.

However, given most drones today are not truly autonomous, managing hundreds of platforms would usually need hundreds of people to control them. We are addressing this challenge by developing autonomous drone swarming behaviours and extensively testing them in synthetic environments. By using algorithms inspired by the natural world, we have shown how a single commander could control large drone formations with minimal human intervention.

Emulating nature for operational resilience

Nature offers proven solutions for swarming behaviour. Murmurations of starlings and swarms of bees use relative proximity sensing to navigate without a dedicated leader. An example of this behaviour is captured in the Boids Artificial Life algorithm developed by Craig Reynolds in 1986, where each bird or bee only observes nearby neighbours and adjusts its flight accordingly.

"Applied to uncrewed air systems, the Boids algorithm helps individual drones maintain formation, avoid collisions and exhibit emergent behaviour such as moving collectively in a given direction through distributed coordination," explained Falan, the project lead. "This also provides essential resilience. If electronic warfare disrupts communications, the swarm can continue its mission autonomously."

Validating tactics in a synthetic environment

Testing these complex behaviours requires a safe, scalable and accurate testing ground. We used elements of our OdySSEy synthetic training system to simulate a swarm of 60 platforms. Each drone in the simulation contained the real drone software, including flight and mission control systems, along with realistic physics behaviours. Operators were able to issue high-level commands to the swarm, such as converging on a target or splitting-up to avoid detection, then monitor as it navigated autonomously.

"Putting this into a synthetic environment allowed us to test novel swarming behaviours quickly and safely," Falan explains. "We were able to set intent and let the swarm execute the action with the operator only needing to step in when authorisation was required."

Collaborating with smaller AI companies

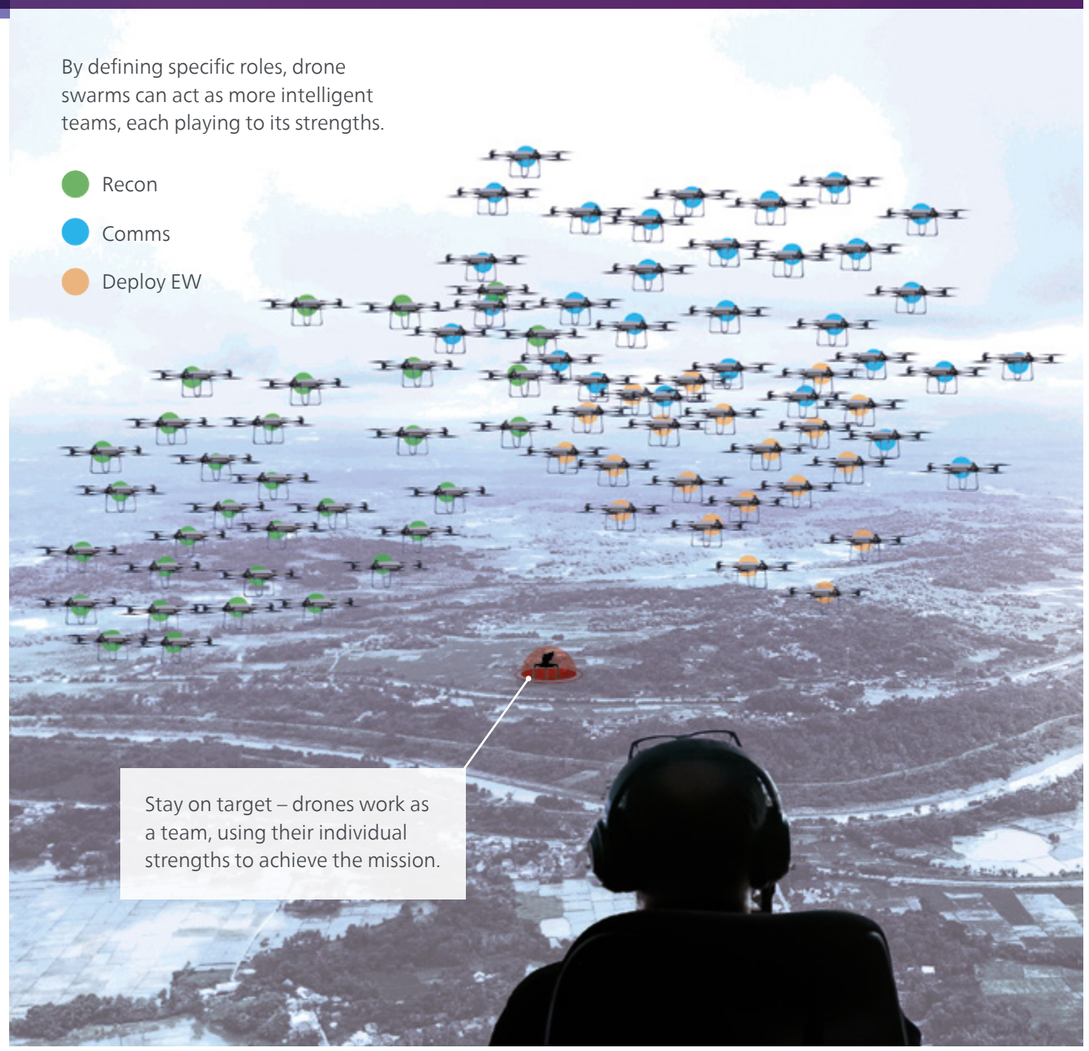
We also worked with an expert SME, Stanhope AI, to develop software that allowed drones to collectively learn from their environment and explore ways to reach their goal. They used something called the 'free energy principle', where drones can constantly predict what they expect to sense, then looking for ways to minimise the difference with what they actually sense. This causes them to become naturally curious without any human intervention.

From swarming to teaming

While swarms provide highly scalable mass, we have broadened our operational focus in this project to include intelligent teaming. A swarm typically relies on a large number of identical platforms acting collectively to perform the same task, whereas teaming introduces a far more hierarchical structure where a smaller number of drones perform very specialised roles. For example, some platforms in a team might carry surveillance sensors, others specialist payloads and some act as communication relays.

Broadening our focus should help offer both combat mass and targeted precision capabilities to meet a wider range of military applications. Continuing to use synthetic environments as our testing ground means we can more rapidly develop these products, then switch to physical deployments when appropriate.

By defining specific roles, drone swarms can act as more intelligent teams, each playing to its strengths.



Stay on target – drones work as a team, using their individual strengths to achieve the mission.

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Mystique: a hot-atom clock for GNSS-denied navigation

Navigating accurately without access to global navigation satellite systems (GNSS) is a significant operational challenge.

To address this, we are supporting the development of a revolutionary 'hot-atom' optical clock, which could help solve this problem and make radars more accurate. Importantly, this clock doesn't require atoms to be super-cooled like many other atomic clocks, so could be used much more easily with low size, weight and power (SWaP). This is part of the Mystique project, working with UK Research & Innovation and the University of Birmingham on a new generation of precise and resilient position, navigation and timing (PNT) solutions.

At BAE Systems, we are providing crucial military use-case knowledge and environmental constraints, such as size, weight and power limits and ruggedness requirements. This collaboration, supported by the start-up accelerator STL Technologies, is helping to translate advanced science into a viable, mission-ready product.

"The benefit of this optical clock is that it can use hot atoms, which allows you to make a much smaller clock," explains Iestyn, our project lead. "For its size, the Mystique clock will be more stable and accurate than other technologies, all packaged within a 100mm cube."

The project has recently achieved a major milestone by successfully demonstrating the atomic clock and a new stabilised laser system. The laser allows the atoms to maintain a precise frequency by using continuous feedback on their state, ensuring the clock remains robust even on a dynamic platform. This continuous feedback loop is what makes the hot-atom approach viable.

"We're now ready to put this hot-atom clock into a radar system, making it far more transportable and improving the signal quality," Iestyn adds. "Our next objective is to conduct a radar trial with the clock by the end of the year, integrating it into a ground-based radar system we previously supported at the University of Birmingham."

By making this technology smaller, more robust and power-efficient, Mystique paves the way for its integration into a wide range of platforms, from uncrewed systems to advanced radar arrays, ensuring armed forces can operate effectively in any environment.

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Fusing undersea data for strategic advantage

"We are building a data processing stack that uses AI and machine learning to sift through mountains of undersea information and identify anomalies."

Connecting a network of new and existing sensors could help us track almost any object in the sea.

The North Atlantic is a vast and increasingly complex maritime environment. Maintaining persistent situational awareness requires more than conventional assets like frigates and submarines.

To address this, we're creating a resilient undersea sensing network that combines data from disparate sources to provide mission-critical intelligence.

This network's core function is to establish a digital architecture that connects a wide array of sensors, both military and commercial, to decision-makers. This would include seabed sensors, autonomous platforms and data from survey companies or the oil and gas industry, as well as those on crewed naval platforms. Our expertise lies not just in deploying advanced sensors, like those already in operation on Type 45 Destroyers and submarines, but in creating the digital glue that connects them into a coherent and resilient network. The networked system is designed to process immense volumes of data, filter out noise and deliver actionable insights to operators, whether they are on a ship or at a command centre.

We have already demonstrated a physical system, connecting a variety of commercial and military sensors underwater to show they could all share data, which was then fused into a single picture and able to detect movement in the area. "The challenge isn't just collecting data, it's about making sense of it in real-time," explains Tim, our campaign lead for subsea intelligence. "We are building a data processing stack that uses AI and machine learning to sift through mountains of undersea information and identify anomalies. This moves us from slow-time analysis to providing near real-time alerts."

These real-time alerts provide a tripwire function for persistent, wide-area intelligence. Since deployments can collect data over months, they are able to establish 'patterns of life' suggesting what data to ignore – large sea creatures or known commercial traffic for example – and what anomalies to flag for investigation.

"This project should also have benefits for our Nautomate-powered autonomous maritime surface and subsea craft. As well as the network supporting command and control, being able to share and fuse data would give you a deployed sensor network that you can move around without needing people to drive them," says Tim. "We are providing that link from the remote sensor back to the operator, ensuring the data is collected and delivered in a resilient way."

The insights generated by this project can be tailored for a range of customers and classification levels. A cable company might receive alerts about potential anchor dragging, while the Royal Navy could receive high-confidence alerts about unusual vessel activity. With sensor inputs from a range of sources available and analysed in real-time, commanders would have clearer situational awareness to make rapid and accurate decisions.

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Efficiency through innovation

"By innovating in how we design, manufacture and maintain our products, we deliver greater value for money and stronger mission impact. That's why we treat innovation as central to efficiency.

Pav Bhogal,
Performance and Business Manager

In defence, efficiency is a strategic capability in its own right. With budgets under pressure and demand rising, every pound has to deliver more capability, faster.

The projects in this section show how the right technology helps us – and our customers – raise productivity, sharpen quality and get capability into service sooner.

It starts with how we design and build with automation in mind. In our submarine programmes, new robotics now weld pipes in tight spaces our engineers couldn't easily reach, while ultrasonic scanning checks weld integrity in real time rather than over several days. Laser scanning compares the build directly against the digital design, cutting inspection time by around 80 per cent. These methods improve safety, free up skilled people and lift throughput without compromising precision.

Digitisation runs through the rest of the story. Our blockchain-enabled supply chain gives real-time visibility across suppliers and a secure, traceable digital thread from raw material to delivery, strengthening a resilient industrial base. In the synthetic domain, MIMESIS and OdySSEy let us train crews, rehearse missions, verify AI and iterate designs before anything is built, reducing cost and risk. Meanwhile, our TIDE programme targets up to a 40 per cent reduction in fuel use, potentially saving around £25m over a warship's life while extending endurance and reducing noise.

Together, these projects prove a simple point. Efficiency and capability aren't competing priorities, they reinforce one another. By innovating in how we design, manufacture and sustain, we deliver greater value for money and stronger mission impact.

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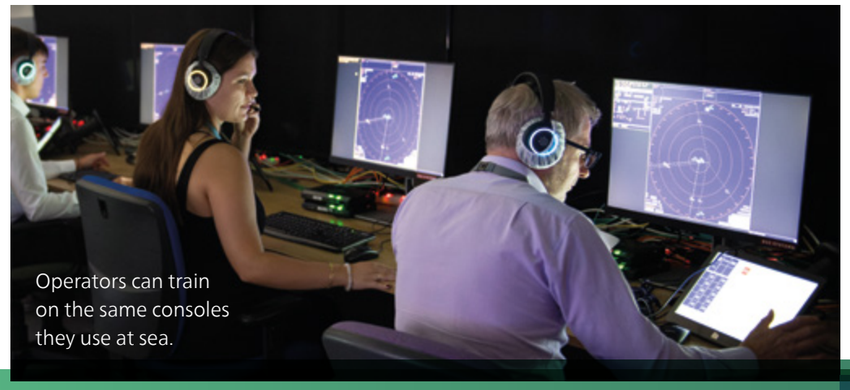
MIMESIS: transforming naval training and capability



Operators can train on the same consoles they use at sea.

Modern naval warfare demands a training environment that mirrors the complexity of the real world. As threats evolve and technology advances, we need to close the gap between traditional simulation and operational reality.

MIMESIS is a next-generation synthetic environment designed for training, mission rehearsal and even generating data for training AI models.

MIMESIS represents a significant evolution in naval simulation. Built on a heritage that has seen every Royal Navy warfare officer trained on BAE Systems simulators since 2006, the new system pivots towards a modular, open-architecture future. More than a training tool, it's now an open ecosystem for validating new technologies and tactics.

A modular architecture for rapid evolution

"The core strength of MIMESIS lies in its plug-and-play architecture. Unlike legacy systems that are often rigid and difficult to update, MIMESIS uses open standards to function as a set of interoperable building blocks. This means customers can integrate new capabilities, such as autonomous systems or novel sensors, without re-architecting the entire environment," said Becky, the project lead. This flexibility was demonstrated effectively when we integrated simulations of third party aircraft and uncrewed air vehicles (UAVs) into a multi-domain scenario. These seamlessly became part of MIMESIS, with the UAV being detected by the simulated BAE Systems sensors, which then passed data through to the operational command software, proving our ability to integrate assets across domains.

High-fidelity representation

MIMESIS delivers a comprehensive synthetic environment. It models complex variables including weather, terrain, seabed topography and underwater acoustics. Within this world, it generates computer-controlled forces representing friendly platforms, enemy threats and the pattern of civilian traffic.

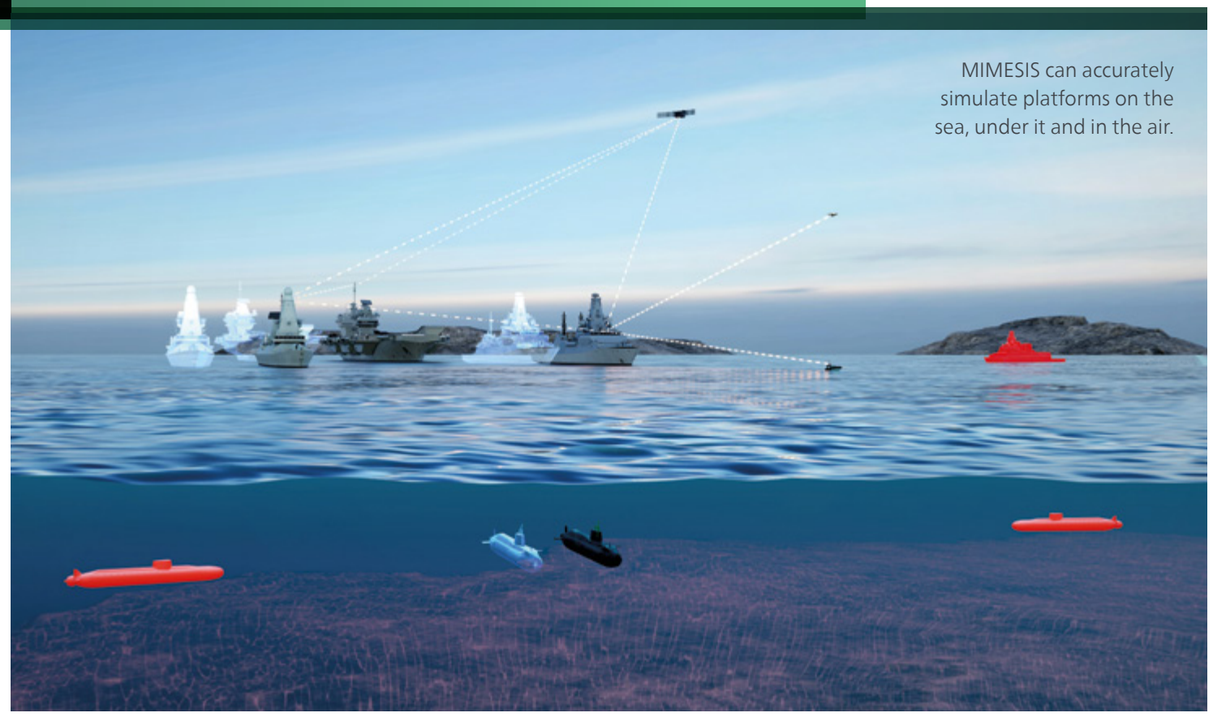
"In MIMESIS, we represent Royal Navy platforms to a very high level, modelling individual sensors and effectors to drive operational command system software," Becky explains. "Operators using MIMESIS interact with the simulated world in the same way as they would at sea – even using the same physical interface terminals. It creates a unique 'train as you would fight' capability."

AI integration and data analytics

Beyond human training, MIMESIS serves as a critical sandbox for AI. As defence forces look to deploy autonomous systems, these AI models require rigorous validation before operational use. MIMESIS provides a proven, scalable environment to generate the vast datasets needed to train and test these algorithms.

The system also leverages data to enhance human performance. By prototyping dynamic dashboards in collaboration with partners such as VRAI, MIMESIS captures performance data from training exercises. This moves assessment away from subjective feedback to objective, data-driven analysis.

Looking forward, the project is exploring role-player automation using AI. This aims to reduce the logistical burden of training by replacing human role-players with automated, voice-enabled AI agents, streamlining the delivery of complex training scenarios.



MIMESIS can accurately simulate platforms on the sea, under it and in the air.

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Project OdySSEy: simulating the all-domain battlespace

"Project OdySSEy is massively powerful, spanning domains and layers of realism."

Users can see a 3D map of the battlespace.

We've now integrated our tried-and-tested naval environment MIMESIS into Project OdySSEy, bringing in both surface and subsea assets from our maritime sector.

This means highly realistic physics and ship models are now available alongside our existing land and air capabilities. We also helped the British Army use Project OdySSEy for a wargaming exercise, in which our highly realistic environment allowed participants to play their roles in much the same way they would in the real world, while recording every detail of the mission to support objective feedback. To make Project OdySSEy truly all-domain, we've also integrated the space domain, so users can operate a truly multi-domain environment.

Securing the information advantage

Project OdySSEy delivers a 'full-stack' synthetic representation of the battlespace, meaning it accurately models the physics, sensors and weapons of individual military platforms. This helps commanders to test tactics at a high level of realism, without being observed by potential adversaries.

Beyond mission rehearsal, this environment could also help solve a critical modern challenge – generating enough high-quality data to train military AI models. Obtaining data from actual battlefields to train AI models is exceptionally difficult, so we are starting to investigate using Project OdySSEy to artificially generate the vast amounts of realistic data needed.

Simulating the full battlespace, with AI-enabled enemies and non-combatants.

Maritime and multi-domain integration

Over the past year, we successfully integrated proven naval environments and assets from our Maritime sector, covering both surface and subsea operations. This addition brings highly accurate physics modelling and detailed ship representations into Project OdySSEy, enhancing realism alongside our land, air and space domains. These maritime capabilities ensure users can train, experiment and develop tactics within a genuinely all-domain synthetic battlespace.

Rapid design iteration

Given the rapid pace of technological change, defence organisations need to evaluate new equipment before committing to expensive physical production. Project OdySSEy also allows teams to iterate designs very quickly in a virtual space.

Engineers and military leaders can use Project OdySSEy to test platforms before they are built physically to experiment with their operational impact. This helps deliver highly effective mission-critical solutions before physical manufacturing begins.

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Turning the TIDE: advancing naval efficiency

"TIDE is not just an academic exercise; it's about delivering tangible performance and efficiency gains – the 40% fuel reduction we're targeting could save around £25m over the lifetime of a naval ship."

After predicting efficiencies in a virtual environment, these were tested in a physical tank.

We're researching major potential advances in ship efficiency, targeting up to a 40% reduction in fuel use to achieve the same output.

By pioneering new hull and rudder designs, investigating air lubrication systems and introducing advanced energy management, the programme seeks to help vessels to travel further, operate more quietly and cut fuel use – delivering operational benefits without compromising capability.

To do this, we're working with the University of Strathclyde and the University of Southampton on the TIDE programme. This is focused on turning lab-based technologies into proven, real-world benefits for twenty-first-century warships.

The project is exploring three key areas:

Hull and propeller design

Led by Professor Osman Turan at the University of Strathclyde, this research stream is focused on a novel rudder design for single-shaft vessels. "Our work on a single-axis twin-rudder system, combined with an optimised hull-form, has demonstrated an efficiency increase of up to 35% and a speed increase of 23-24%," states Professor Turan. "This design could also significantly improve warship manoeuvring and reduce underwater radiated noise." The design also reduces load on the propeller, helping to improve durability and performance in challenging sea conditions.

Air lubrication systems

Research at the University of Southampton, led by Professor Stephen Turnock, is investigating the use of air lubrication to reduce frictional drag. "The concept involves pushing the ship through a bubbly layer of fluid rather than solid water, which can account for 50-60% of a ship's drag," explains Professor Turnock. While commercial systems exist for flat-bottomed vessels, this is pioneering work for military hull forms. "Our fundamental investigation proved that a system emitting bubbles along the keel line offers significant resistance savings. We are now moving to the next phase of testing."

Onboard energy management

The third component of TIDE focuses on optimising energy use across the entire platform. This includes evaluating energy storage systems like batteries and flywheels, as well as energy recovery from heat and exhaust. We're exploring an intelligent management tool to help triage power distribution, ensuring mission-critical systems, such as future high-powered lasers, have the energy they need without compromising other functions. This work has already shown a potential 15% saving.

Cathy, the project lead at BAE Systems, highlights the project's practical focus:

"What's unique about this programme is that our university partners have worked directly on a representative warship design and operational profile, so this is directly applicable to Royal Navy ships. TIDE is not just an academic exercise; it's about delivering tangible performance and efficiency gains – the 40% fuel reduction we're targeting could save around £25m over the lifetime of a naval ship."

By combining these innovations, TIDE has the potential to deliver a step-change in naval capability, offering extended endurance, reduced operational costs and even greater manoeuvrability.

The study looked at hull forms and new types of propeller system.

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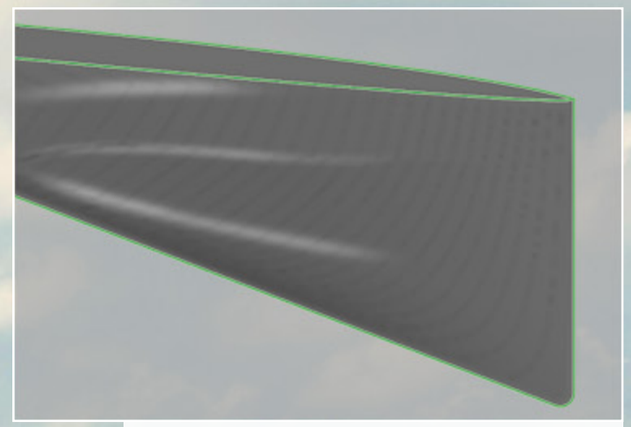
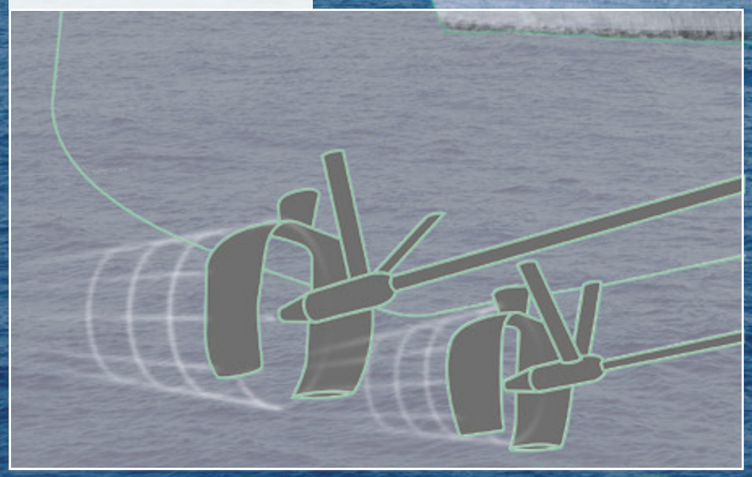
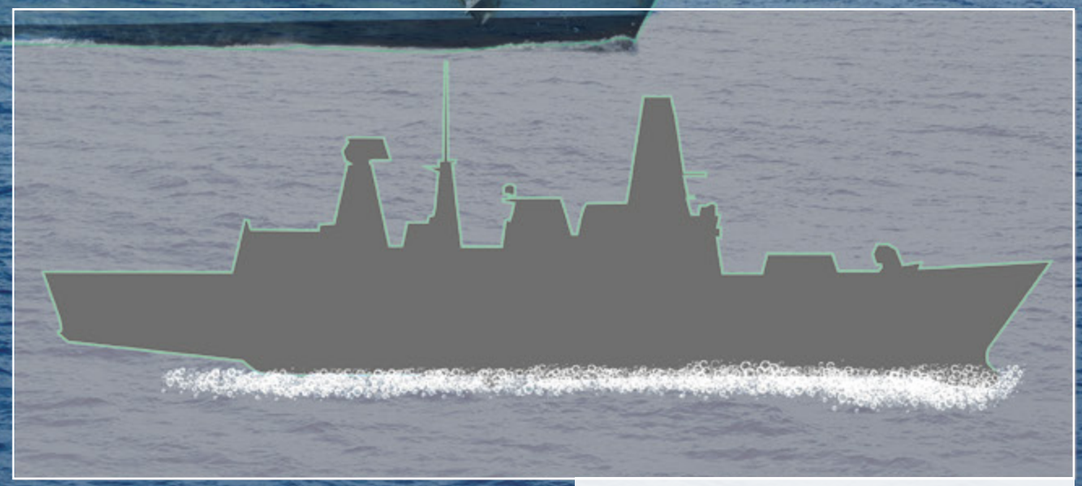
Increasing range and speed of naval vessels



Changes to hull formation and bulkhead placement could increase stability, reduce friction and reduce weight – all saving energy to potentially increase range and speed.

Single-axis twin-rudder system saves energy, as well as reducing strain on engine components.





Air bubbles released along the keel create a low friction surface for the hull, allowing it to pass through the water more easily.

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Securing the defence supply chain with blockchain technology

Supply chains need to respond quickly to changing demands. In future they may be called on to rapidly scale production of products such as drones.

To help provide better connectivity and responsiveness, we're digitising our supply chain with the help of blockchain technology. This connects SME suppliers directly into a smart manufacturing framework.

Enhancing real-time manufacturing capabilities

Sharing data securely across suppliers usually creates significant security challenges. However, by deploying a 'distributed ledger' – a secure feature of blockchain – alongside an on-premise cloud infrastructure, we've enabled real-time data exchange between our manufacturing facilities and external suppliers, which meets our strict security requirements.

"We are creating the first connected supply chain system that integrates directly with our on-premise environment," explains Ismail, the project lead. "This gives us real-time visibility into what our suppliers are doing. We can monitor the manufacturing lifecycle, track the quality of specialist raw materials and help avoid downstream quality issues."

For the suppliers, this connectivity allows them to coordinate engineering processes more closely with BAE Systems. Facilities can dynamically adjust their workflows based on the real-time status of inbound parts. This allows teams to dynamically re-plan manufacturing processes to help meet mission-critical timelines.

Driving the Future Combat Air System

This digital transformation plays a vital role in the Future Combat Air System (FCAS) programme. Building a next-generation combat air platform requires state-of-the-art manufacturing processes, which will need to be integrated across an international supply base. We're currently piloting this blockchain technology to learn how to manage manufacturing processes at higher security classifications.

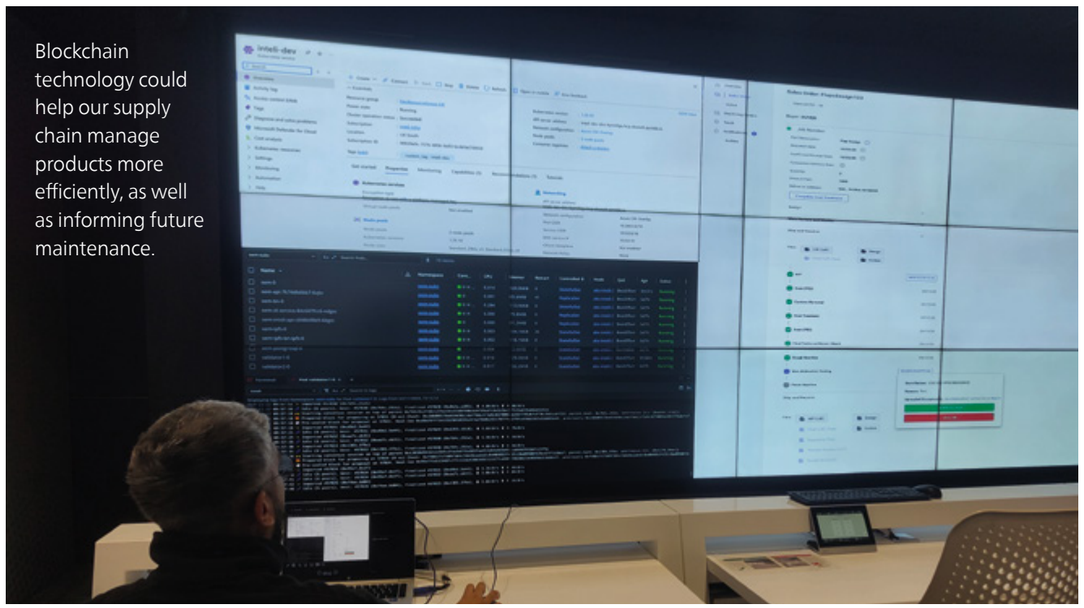
Traceable and secure

Blockchain technology provides an immutable record of every transaction and component movement. This delivers full data provenance, allowing us to track parts throughout their entire lifecycle.

"Traceability is a primary use case for this technology," Ismail notes. "We can coordinate data on raw materials, manage supplier credentials and maintain a digital thread of manufacturing data right through to delivery. If any issues occur later in the product lifecycle, this record helps us track back every component and material used in its production."

This tracking capability extends beyond the factory floor. The data remains with the products throughout their operational life, supporting ongoing maintenance, health monitoring and end-of-life disposal. By mandating secure data integration, we help ensure a trusted, resilient and highly efficient industrial base.

"We can coordinate data on raw materials, manage supplier credentials and maintain a digital thread of manufacturing data right through to delivery."



Blockchain technology could help our supply chain manage products more efficiently, as well as informing future maintenance.

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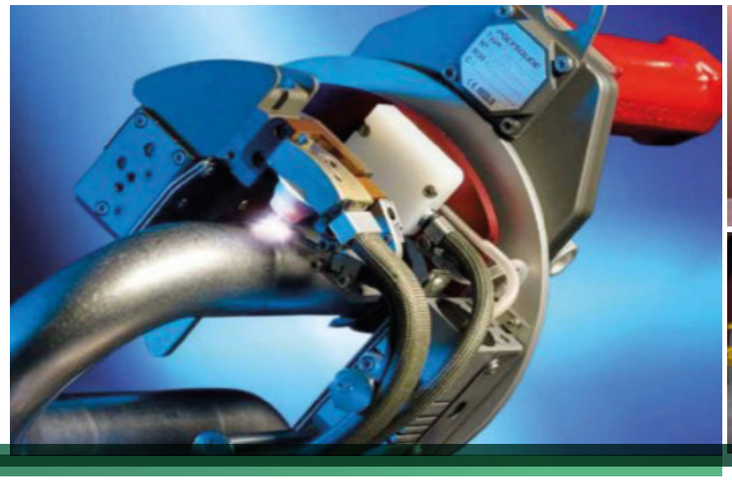
Robot welding and faster quality control for submarines

New welding robots can seal even tighter pipe bends, which are common in submarines.



Optical scan quickly compares actual build to the design, saving time.

Building a submarine is a huge manufacturing challenge, given the confined space you need to work in and incredible precision required to deliver such a unique and complex platform.

Our manufacturing team is developing world-leading technology for this challenge, with groundbreaking robotics, science and innovation to unlock next-generation quality and efficiency. Here are just three examples of this work.

Pipe welding technology takes a tight corner

How do you weld tightly bending pipes in a confined space and then assure quality of the weld? Usually, the answer is with specialist training, a fair amount of discomfort and a lot of time, but we're improving welding equipment and introducing weld scanning technologies that remove the need for x-rays to make major improvements.

Vince, leading on innovation in our submarines business explained why this is so important: "Submarines contain hundreds of kilometres of plate, pipe and cable packed tightly into compartments onboard. Pipes especially need to be installed to tight tolerances, many require complex welding operations and all need comprehensive quality checks once welded.

"There are many places where standard pipe welding equipment can't be used because there's not enough room or the pipe bends are too tight. Given that our submarine environment is so unique, there's no incentive for commercial manufacturers to make their equipment do this. However, over the last 18 months we have been working with the Manufacturing Technology Centre in Coventry to look at a method of modifying the welding equipment. Trials have been successful and we now have a new clamp that allows a 50% improvement in access to critical welds."

Sound investment: ultrasonic inspection

Many of the welds on a submarine need to be quality assured to a very high degree. Traditionally, we've used radiography to inspect the welds, but this meant our workforce had to leave the area with an exclusion zone around where it was being used. While radiography is usually completed during a nightshift, it still means that other work can't take place in that area for the shift. Additionally, there is an inevitable wait for the x-ray result before work can proceed.

To solve this problem and make inspections quicker and less disruptive, we have developed a new approach using sound waves to inspect copper nickel and stainless steel pipes, which means there's no need for people to leave the area.

Vince set out why this work was such a challenge: "Our product, material and acceptance standards are unique to the submarines we build. One of the challenges we faced was to design and prove a system that was sufficiently small to work within confines of our installed systems as we build the boat. Being able to get an immediate result, without clearing the area or waiting days, makes a huge difference in work planning and efficiency."

New laser-precision scanning saves time

During a submarine build, our engineers carry out frequent surveys to ensure every new item is located in exactly the right place – from brackets for tables to the location of bulkheads.

Previously, this meant a team taking printed engineering drawings with them through the boat and manually measuring each compartment. This was time-consuming and difficult, given the curved surface of the submarine and the small size of some compartments.

Chris, operations lead, and his team, have now revolutionised our approach: "Our engineers now place a laser scanning device in each compartment to generate point-cloud data. This is then compared against the 3D design in our CAD system, which shows clearly where components need to be placed and whether there are any discrepancies.

"It means our engineers no longer have to decipher multiple 2D drawings and manually measure each feature of a compartment, and that all of the relevant design files are checked simultaneously. The new process takes just 20% of the time we used to spend doing this."

Given we're now checking the original design files directly, we can also remove an entire step of generating design files to support the engineer's manual measurements.

Chris added: "Our engineers love this process. They just need to set up the tripod for the laser scanner, set it to go and leave the room briefly while it scans. As soon as it's finished, it highlights any discrepancies immediately. One of the amazing things to see is just how accurate our builds are – it's very rare to find a fault, which is incredible when building structures this large."

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