



Ministry
of Defence

Science and Technology Strategy 2020


MOD Science and Technology Strategy 2020

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Foreword



These are uncertain and turbulent times.

The world of today is hugely changed from just five years ago, and the pace of change continues to accelerate. New sciences are emerging, new technologies are being developed and adopted faster than ever and new analysis techniques are generating swifter understanding from increasing volumes of data. Science and technology (S&T) are themselves theatres of strategic competition, with new competitors challenging the established order. Amid this uncertainty, it is my responsibility to ensure the UK Armed Forces are supported by the right S&T to meet future challenges – to retain our strategic edge, to seize opportunities and to tackle threats – while also supporting UK prosperity. This strategy sets out how the Ministry of Defence will do that.

My guiding principle is a clear focus on the future. While there are many urgent technological and scientific problems we need to address, by lifting our eyes to the long term we can actively shape the future and move ahead of our adversaries. **Defence S&T endeavour must lay the foundations for the generation after next of military capability.**

We cannot succeed alone. Deliberate collaboration is critical to our success. We will

continue to work across government to achieve better S&T impact and strengthen our S&T capabilities, advancing the Prime Minister's ambition for the UK to secure its status as a Global Science Power. We will work with international partners in a targeted and structured way to deliver strong mutual benefit. And we will work closely with UK industry and academia, recognising the crucial role that they play in innovating, delivering and exploiting S&T.

So while these are uncertain and turbulent times, **by excelling in S&T we can secure our future strategic advantage.** We must set our sights on the long term, building towards the future capabilities we need. We must take risks, nurture scientific and technological literacy, and extract every drop of value from our data. The S&T community cannot do this alone, and through this strategy I will guide scientific and technological effort across Defence. Together we will secure our future strategic advantage.

Professor Dame Angela McLean
*Chief Scientific Adviser to the
Ministry of Defence*
19th October 2020

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Executive summary

We are living in a time of **unprecedented change**. Science and technology (S&T) are developing and proliferating faster than ever before and have become **new theatres of international competition**. New adversaries have emerged, alongside traditional threats, who actively undermine our democracy and society, supported by substantial and rapidly modernising militaries. Terrorist groups and non-state actors can access technologies and weapons far more sophisticated than before. The natural environment is challenging us with a global pandemic and we have reached the **tipping point** where decisive action on climate change is required.

In Defence, we have **collectively recognised** that we **must change how we invest in and develop capability** to avoid falling behind our adversaries. Through S&T we can **seize opportunities** and **pre-empt future threats**. We must act differently in order to meet these challenges and pursue a highly technological and innovative future to realise our ambition of becoming an **integrated high-tech armed force**.

We must **radically enhance** the way we understand the current and future technological landscape to achieve this future. We must fuse this insight, together with policy

implications, to ensure we identify and **integrate emerging technologies** into **generation-after-next capabilities** for our armed forces and deliver the capability outcomes we need. We will focus our efforts on Defence's most significant and enduring capability challenges, where emerging technologies can give the UK a **decisive edge in the future**. We will balance this with a technology push, to **nurture specific promising technologies**.

To achieve our potential, to overmatch and outwit our adversaries, **all of MOD must work towards this shared goal**. Every part of our organisation must be comfortable and literate in S&T, and we must attract, develop and maintain the right skills and approaches to do so. We must **invest in our people** so that they are confident in new technologies, so that we can use new capabilities to best effect. MOD's Chief Scientific Adviser (CSA) will ensure that S&T are an **intrinsic part** of all MOD's strategy and policy making. CSA will **monitor and evaluate** the department's progress against this strategy, **highlight opportunities**, and **provide the S&T direction** for MOD to thrive in this **highly technological future**.

1. The geopolitical context

We are in an age of unprecedented rate and breadth of technological change

The world of S&T today is very different to that of even five years ago. New areas of study are emerging at the intersection of established domains; new technologies and applications of technology are developing and being adopted faster than ever before; new data collection, curation and analysis techniques are producing greater volumes of data and access to information faster, with more nuanced understanding and more sophisticated insights. Finally, new players are emerging, so S&T innovation is no longer concentrated in large companies and just a few countries.

Our adversaries are changing – who they are and how they fight

During the Cold War, western militaries relied on technological superiority, allowing postures and operational concepts to offset and largely compensate for the Soviet Union's advantages in numbers.

After the Cold War ended, the same military-technological advantage provided western militaries a decisive advantage against extremist organisations for over two decades.

Extremist organisations remain a concern, but the threat picture now also includes two great powers with substantially greater capabilities. A resurgent Russia and a rising, increasingly powerful China are taking aggressive actions

that threaten regional security and stability and challenge the existing rules-based international order.

Whilst Russia continues to remain the UK's and NATO's principal strategic challenge, it is arguably China which poses the greater long-term challenge. China's economy has seen substantial growth, facilitating an increase in annual defence spending by at least 620% in real terms between 1995 and 2015. Whilst China is primarily concerned with regional dominance, its grand strategy and underlying national plans indicate aspirations for global power, delivered through an effective and efficient civil-military fusion and focussed on a number of critical areas including manufacture, dominance of supply chains, and by becoming first adopters in many disruptive technology areas. China aims to modernise its military by 2035 and evolve into a world class military force with global combat capabilities by 2049¹.

Advances in S&T have enabled new and more effective ways for hostile states to threaten and disrupt the UK, through undermining our democracy, government institutions and functions, disrupting global organisations and bodies, targeting critical national infrastructure, and undertaking espionage and violence against UK citizens and foreign nationals in UK territory.

¹ President Xi Jinping speech, 19th Chinese Communist Party Congress, Oct 2017

State actors such as China and Russia have shown an increased willingness and intent to exploit S&T to shape the world to their own advantage, including by engaging in constant competition against other states below the threshold of armed conflict.

The UK's advocacy for our principles and values – for example on the benefits of a free, open, peaceful and secure cyberspace – must continue, but will not be enough to deter these efforts from our adversaries. We can now expect to be under continuous sub-threshold attack.

The S&T innovation landscape has also changed

Historically, innovation in many sectors was the preserve of large, well-established companies, often with close ties to the states in which they resided. Today, immense multinational corporations absorb and assimilate innovations produced by multiple small enterprises, accruing science, technology and data capabilities that rival some states. Large technology companies are becoming geopolitical powers in their own right, with access to every aspect of citizens' lives and

effective control over the dissemination of political information and even voter turnout. It is clear that S&T are not just means of solving problems, they are themselves interdependent and contested domains, with the benefits of technological advances accruing unevenly across the globe.

The natural environment provides unprecedented challenge

The effects of climate change continue to be felt, with increasingly extreme weather being experienced across the globe, albeit unequally distributed. These effects are likely to become more severe. As throughout history, the uneven distribution of natural resources will impact geopolitics, potentially exacerbating existing instability which could lead to mass migration. As the Arctic region becomes more accessible it will assume greater geostrategic significance, with competition for fishing, accessibility of natural resources and new shipping routes likely to lead to an increased military presence.

The full impact and implications of Covid-19 have yet to be felt. We have seen science guide the response of governments across



The S&T landscape has changed



S&T is a strategic theatre of competition

the world, from behavioural science to immunology and medicine, but in doing so, science has come under greater scrutiny and increasing pressure to explain itself. The public appetite for accurate information about S&T has increased, but so has the risk of disinformation and hoaxes. One likely enduring implication is that the public will expect government to use science, technology and data to deliver more efficient and effective public services and drive our nation's prosperity and security.

We must shift from seeing S&T as a way of solving problems to a strategic theatre of competition

Given the impact that technology will have on national status and fortune, and on modern warfare, it is vital that we in Defence seize the opportunities to gain advantage and protect those technologies that will provide us with a decisive edge. To help MOD stay ahead in this new competition we will adopt a challenge-led approach, which will focus, prioritise and cohere our preparation for the future. It is not enough just to develop world-class S&T and apply it to Defence problems, we need to go further, actively using our S&T system as part of a broader UK approach focused on delivering national advantage through S&T. We must understand the new rules of engagement and take decisive action to

secure our future. We must:

- **understand the future** – combining our knowledge of the future operating environment, the opportunities that S&T provide and the changing nature of the threat;
- **make the right decisions** – providing guidance and direction to Defence to find technological superiority while protecting our critical technologies and information; and
- **seize the opportunities** – grasp the opportunities that S&T provide to secure the future that we want.

S&T is a critical component of force development

For future advantage, we will need to use our understanding of technological opportunities, new and evolving threats, and changes to the warfighting environment to take the right decisions across our entire Force Development process. We will ensure that S&T opportunities inform concept, capability and warfighting development. It will take a whole-of-Defence effort to react appropriately, making the right decisions, seize the right opportunities, and inform the best political and strategic decision making.

Russian sub-threshold activities in Ukraine

Seeking to weaken Ukraine's political independence, Russia has conducted and continues to conduct a range of covert activity to achieve its strategic goals.² In March 2014, Russia illegally annexed Crimea and in April 2014 pro-Russian groups attempted to take control of Donetsk and Luhansk. Later that year, NATO confirmed Russian equipment and personnel were crossing the border into Ukraine. As part of its obfuscation campaign, the Russian state has continued to deny this and put out numerous counter narratives – most notably, following the shooting down of civilian flight MH17.

During the annexation of Crimea, a range of covert actors were used to obscure Russian involvement, including 'little green men' – the Russian soldiers who appeared in Crimea in unmarked uniforms. Similarly, groups of armed men in unmarked clothing seized government buildings in Donetsk and Luhansk. As well as sending personnel, Russia supplied pro-Russian separatists with weapons. The foreign secretary at the time, William Hague, described the separatists as "led by people who by their training, equipment and behaviour give every appearance of sometimes being Russian special forces".

Since then, Russia has orchestrated covert activity against Ukraine. The National Cyber Security Centre (NCSC) assesses that Russian military intelligence, GRU, was almost certainly responsible for multiple disruptive cyber-attacks on Ukraine in 2017. In June 2017, the

'NotPetya' destructive cyber-attack hit Ukrainian financial, energy and government sectors. In October 2017, BadRabbit ransomware encrypted Ukrainian hard drives and rendered IT inoperable, causing disruption to the Kyiv metro, Odessa airport and two Russian media outlets. Information operations against Ukraine have been conducted by Kremlin-linked actors such as the Internet Research Agency. These operations primarily target ethnic and linguistically Russian populations, particularly in the south and east of Ukraine, with the intent to destabilise Ukraine and stymie its westward trajectory. Russia also leverages other levers of influence over Ukraine, including political influence, cultivation of criminal networks and assassinations.

² Greenberg, A. (2019) *Sandworm, A New Era of Cyberwar and the Hunt for the Kremlin's Most Dangerous Hackers*. Doubleday Books. ISBN:0385544405; ISBN13: 9780385544405 and *Defence Intelligence*.

2. Understanding the future

We will search the breadth of S&T, judge its likely impact, and guide smart responses

A new way of delivering Scientific Intelligence

this rapidly changing geopolitical and technological landscape demands a new way of operating in government and MOD. Defence already conducts a large amount of horizon scanning, technology watching and threat assessment to prepare us for the future. However, if we wish to compete in the global technology race, we must make a step change in our efforts to understand the future, and then act decisively to take advantage of this knowledge. Working collaboratively across Defence, combining different skills and approaches, we must be more efficient and effective in searching the immense breadth of new S&T, judging which new developments will evolve and combine to have useful Defence and Security applications and guiding

smart Defence responses. We need to use new technologies to draw meaning and inference from the wealth of external data, exploit novel approaches to human networks to gather personal insights from a wider range of experts, and better fuse all of that with our existing internal analysis to promote sound, joined-up decisions.

We will look to revitalise our Futures programme and combine it with our strategic analysis capabilities to identify and incubate our understanding of the impact of emerging technologies and novel threats for Defence. This will be coupled with an understanding of the changing nature of threats and knowledge of the impact of new technological developments on the future operating environment. This will provide Defence with a single, comprehensive, source of advice and

We will revitalise our Futures programme



We will be on the front foot when new technologies mature

direction on the promising technologies we should prioritise, how they could be used and combined in future capabilities, the issues and challenges they could precipitate and the S&T investments and policies we will need to adopt to develop them. This will also allow us to protect and prioritise the S&T research that is likely to be most useful to military capability. Through this approach Defence will also contribute towards the wider government Strategic Advantage through S&T agenda, industry and prosperity policies and strategies, and identify and shape the technologies of future benefit to UK citizens.

Feeding this into Defence's understanding of the future

This insight will inform Defence decisions about how we develop our future force structure³, working collaboratively across Defence to bring together the analysis of future threat and the future operating environment. This approach will cohere activities through Defence Concepts, Defence Intelligence, Capability Planning and S&T to provide a unified evidential basis for Defence to plan its future. We will develop our future forecasts into technology-driven conceptual opportunities for the Department. Defence has recognised that strengthening force development is critical for Defence to change

and has adopted an enterprise approach. It is vital that these conceptual opportunities are understood and evaluated as part of this development to give us the best chance of seizing the decisive edge S&T can provide. To be successful, innovative S&T must not be conducted in isolation from Defence's capability challenges. CSA will therefore use these forecasts to shape Research and Development (R&D) priorities for Defence. This will allow us to investigate scientific disciplines and technologies for which we have not yet identified a Defence requirement, so we can be on the front foot when the technologies mature.

³ Force structure – the way in which our armed forces and their equipment are organised into a clear set of 'capabilities'. The force structure that we plan for the future – 10 years from each Strategic Defence and Security Review / Integrated Review and reviewed every 5 years – is known as the 'Future Force'. *How Defence works*, v4.2, Dec 2015

3. Making the right decisions

It is not enough to just understand the future, it is essential that we *make the right decisions* in response

We must respond appropriately to technology-driven issues and prioritise the right investment in R&D while ensuring, across the Department, rigorous scientific thought is applied to all our wider policy and programmatic choices. This coherent departmental approach will provide a strong evidence base for key strategic decisions.

Defence will achieve this through:

- prioritising R&D according to the **capability outcomes** we wish to achieve;
- re-focusing CSA's S&T budget to ensure that Defence has decisive military advantage in the **generation-after-next** of capabilities, boldly accepting that potential rewards outweigh the risks;
- balancing capability needs with appropriate S&T push to ensure we provide the right opportunities to develop future decisive military edge;
- identifying and understanding the future capability challenges that R&D must address and the outcome required to initially realise the ambitions of the Integrated Operating Concept 2025 and then beyond to our Future Force;
- proactively addressing the technology-related policy decisions – including legal and ethical dimensions – needed before we can bring new capabilities into service;
- shaping the broader decision-making culture in Defence, supporting scientific literacy through relentless promotion of evidence-based decision making and

- application of the scientific method; and
- aligning to the new MOD data strategy, including by curating S&T data effectively so that Defence gains maximum benefit from our highly valuable datasets.

Achieving a highly technological and innovative future

We must act differently in order to be able to pursue a highly technological and innovative future. If we continue to invest and develop capability in the way we do now, we will fall behind our competitors and adversaries.

An important aspect of MOD's approach is to clearly distinguish between S&T and R&D. S&T generates the enabling technology and system building blocks required for R&D. R&D then integrates and matures these building blocks to operational capability. In Defence, CSA provides leadership in S&T and the Deputy Chief of Defence Staff Military Capability drives R&D, with CSA providing coherence, direction and ensuring it is undertaken in a legal, ethical and rigorous manner.

We will have a streamlined strategic approach to R&D to ensure we can continue to deliver valuable incremental innovation, but create space to pursue truly new, disruptive capabilities. Concurrently, we will accelerate the adoption of existing technologies at scale, pull through emerging technologies and

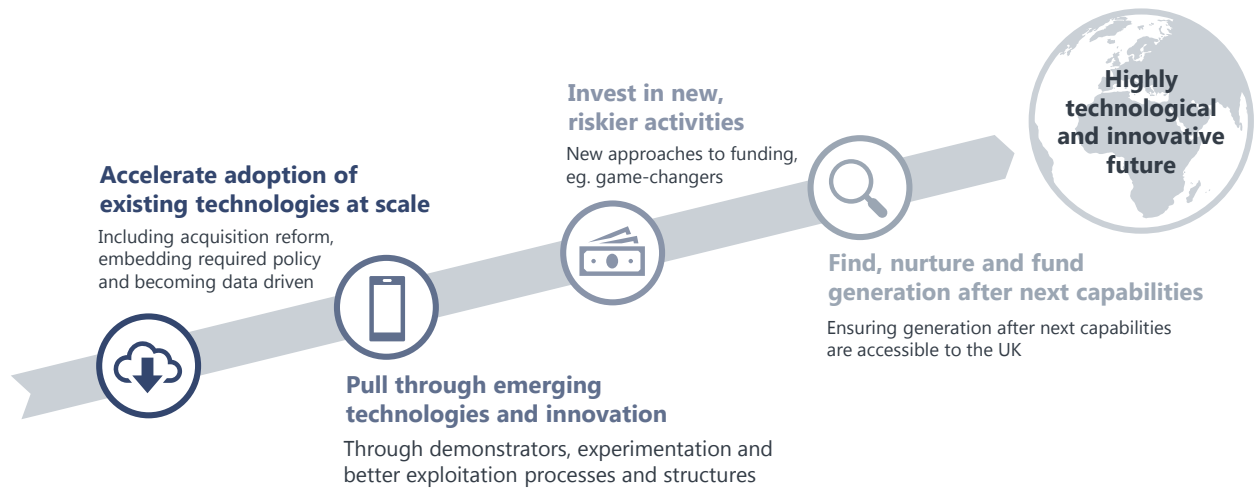


Figure 1 - Defence's streamlined approach to science, technology and innovation to ensure we continue delivering valuable incremental innovation while pursuing truly new, game changing capabilities.

innovation, being bolder and taking more risk, and find, nurture and fund research to allow us to develop generation-after-next capabilities.

This approach will transform Defence into an agile, technologically advanced organisation able to understand, develop and exploit technology and new ideas faster than ever, and ultimately deliver an integrated high-tech armed force. This will build on rather than replace our underpinning research programme. To do this, we must focus our efforts on the right technologies and scientific disciplines. To find them, we will have both a **top-down** and **bottom-up** approach.

We have identified our most significant enduring capability challenges, where emerging technologies can give the UK a decisive edge in the future. These challenges provide a framework for a coherent R&D effort. A capability challenge pull (from the top) will set challenges and then allow innovators to find solutions, including those we would not have thought of. This avoids us presupposing all the potential solutions that might be relevant. But we will also bet on certain technologies – a complementary technology push (from the bottom) will find, nurture and encourage the most promising innovations. We intend to emphasise the pull over the push – allowing space for innovators

to find novel solutions to the problems Defence sets out. CSA will guide Defence to the right balance.

One of the consequences of focussing on research to underpin the generation-after-next of capabilities and taking a less iterative approach, is that some truly disruptive research may well fail to deliver what we need. We will introduce agility into our thinking and processes so that we can change our approach without losing sight of our outcomes and manage risk effectively.

A challenge led approach will allow space for innovative solutions

The Integrated Operating Concept 2025 (IOpC25)⁴ sets out how Defence needs to operate context of persistent competition. It explains how we wish to routinely operate through the Protect, Engage and Constrain pillars, and undertake War Fighting if required, from tactical, through operational to the strategic level.

We have identified Defence's most significant enduring capability challenges, where emerging technologies can give the UK a decisive edge in the future, in the context of IOpC25 and looking beyond to future operating environments and the Future Force

⁴ Integrated Operating Concept 2025, September 2020. UK MOD <https://www.gov.uk/government/publications/the-integrated-operating-concept-2025>.



Concept. The five capability challenges are:

1. **Pervasive, full spectrum, multi domain Intelligence, Surveillance and Reconnaissance (ISR)** – respond to threats and opportunities of emerging technologies affecting our ability to conduct ISR in all domains and environments through affordable resilient solutions.
2. **Multi-domain Command & Control, Communications and Computers (C4)** – develop the capability for multi-domain integration and ability to coordinate effects globally enabling us to execute joint operations against adversaries with well-integrated and resilient capabilities.
3. **Secure and sustain advantage in the sub-threshold** – improve the UK's ability to compete against adversaries below the threshold of conventional conflict and address our vulnerabilities, especially in the Information Environment.
4. **Asymmetric hard power** – develop highly-capable systems to target adversaries in

new ways across all domains; develop novel means of delivery of hard power and effective protection against highly capable adversaries.

5. **Freedom of Access and Manoeuvre (FOAM)** – generate affordable, survivable capability responsive to rapidly evolving threats operated within a denied electromagnetic environment and be interoperable with our allies and partners.

These challenges are aligned to threats that we know will intensify and evolve in the future, and where emerging S&T presents opportunities to deliver decisive military effect and operational advantage. They are intrinsically volatile and therefore will persist, as our adversaries seek to find advantage against our solutions. These challenges draw on, contribute to and support the IOpC25 intent. They have been recognised as the key drivers for both S&T and R&D within the Department. They do not cover the totality of Defence capability requirements. The Department will continue to have an enduring requirement to maintain investment in S&T capabilities and programmes beyond these



Freedom of access is an enduring capability challenge



We will invest in potentially disruptive S&T, even where exploitation routes are unclear

five areas, for example national security, resilience and emergency response capabilities and the human element of Defence, as well as maintaining S&T operational policy to ensure these capabilities are fit for purpose. Enablers, such as logistics and medical, are a critical requirement to ensure that capabilities are viable in a military context and will be considered within each of the five challenge areas.

A technology push will nurture specific, promising technologies

While a capability outcome approach will address the challenges that we are aware of, it is essential that we continue to invest in cross-cutting S&T that offers disruptive potential, but where we have not yet identified exploitation routes. Our 2019 Defence Technology Framework (DTF)⁵ sets out at a high level the priority technology families that we must adopt to secure our technological advantage. We will continue to refine the DTF as we clarify our capability outcomes and find potential technological solutions. Moreover, we will take risk in backing our judgement on the right technologies to develop more and better opportunities for capabilities in the future.

We must always look at a range of potential solutions at the conceptual level before committing to a single solution, as technology alone will not solve all of our capability challenges. We must understand the

implications across all the Defence Lines of Development⁶ at the earliest stage of R&D to ensure we avoid developing technological solutions that are never fieldable. For example, should a possible capability concept never be fieldable for logistical reasons, we must swiftly identify this and either change course or devise appropriate changes in policy and doctrine to ensure that a fieldable capability can be developed.

Our focus on *generation-after-next* will equip us for the future

The **next generation** of military capabilities will spawn from technologies that have already emerged. Technologies vital for the **generation-after-next** of capabilities are those beginning to emerge now and in the near future. In some areas, particularly digital, they are evolving at a rapid pace. With our ability to understand our future context and therefore back those promising technologies, we will ensure we are ready and prepared to integrate them into our future capabilities. This doesn't mean that we will simply conduct more research. What we will do is ensure that Defence is prepared as best as possible for the future as part of a whole-Defence approach. For example, Defence foresight and S&T research focussed on generation-after-next capabilities over many years led to the world-leading Dual Mode Seeker Brimstone missile, which has been used decisively on our operational deployments in Afghanistan and the Middle East

⁵ The Defence Technology Framework, 2019. UK MOD

⁶ The Defence Lines of Development are: Training, Equipment, Personnel, Information, Concepts & Doctrine, Organisation, Infrastructure and Logistics considered in conjunction with Interoperability and Security.

The Dual Mode Seeker Brimstone

The Brimstone missile began life as a 'fire and forget' guided weapon for use against the massed Soviet tanks of the Cold war era. Defence research from the early 1990s and UK operational experience in Kosovo, Afghanistan and Iraq revealed a military capability gap for the suppression of small insurgent teams and moving vehicles, especially where collateral damage was a concern.

Defence S&T capabilities were at the heart of efforts to increase its precision and overall effectiveness. Research from the late 1990s delivered significant improvements to the original guidance systems and was introduced to the capability as the Dual Mode Seeker Brimstone (DMSB) through a collaborative partnership led by MBDA. Defence research and modelling were then critical to the development of Brimstone 2, which features Semi-Active Laser guidance capability for

unrivalled precision, and was selected for MOD's SPEAR 2 capability in 2011. The S&T used to develop DMSB and Brimstone 2 is being exploited to develop SPEAR 3 for future use with the UK's F35-B and Typhoon.

DMSB alone cost only £20M; a fraction of the cost of developing a new weapon (~£850M). 700 UK jobs were also safeguarded. 501 DMSB missiles were fired between 2008 and 2016 on operations against the Taliban and Da'esh. The United States military were frequently reliant upon the UK for its capability, and it remains the world's preeminent precision-attack missile solution for counter-insurgency operations. With the re-emergence of the Russian conventional threat to NATO, the S&T innovations at the heart of Brimstone means it is once more at the core of UK capabilities to counter enemy surface-based systems.



Our future capabilities will be greener than ever before

Overarching all of this is a need for our future capabilities to operate effectively in our future global environment, particularly in the context of climate change, and support the government's systems approach to achieving net zero carbon emissions by 2050. We will ensure Defence plays its part, mirroring the 'clean growth' agenda at the heart of the UK's Industrial Strategy with a 'clean capability' agenda at the heart of Defence's climate change strategy.

Anticipatory policy making is essential for successful adoption of new capabilities

The challenges of operating within a highly technological world and adopting S&T go significantly beyond research breakthrough. To integrate technology for military benefit and position Defence to best effect it is important to understand and address numerous policy considerations, including moral, ethical, legal, industrial and international. We must ensure S&T policy is integrated properly within Defence and wider government policy and strategy processes. To avoid ceding strategic advantage by failing to integrate and use new capabilities, we must resolve technology policy challenges and shape continually evolving societal norms.

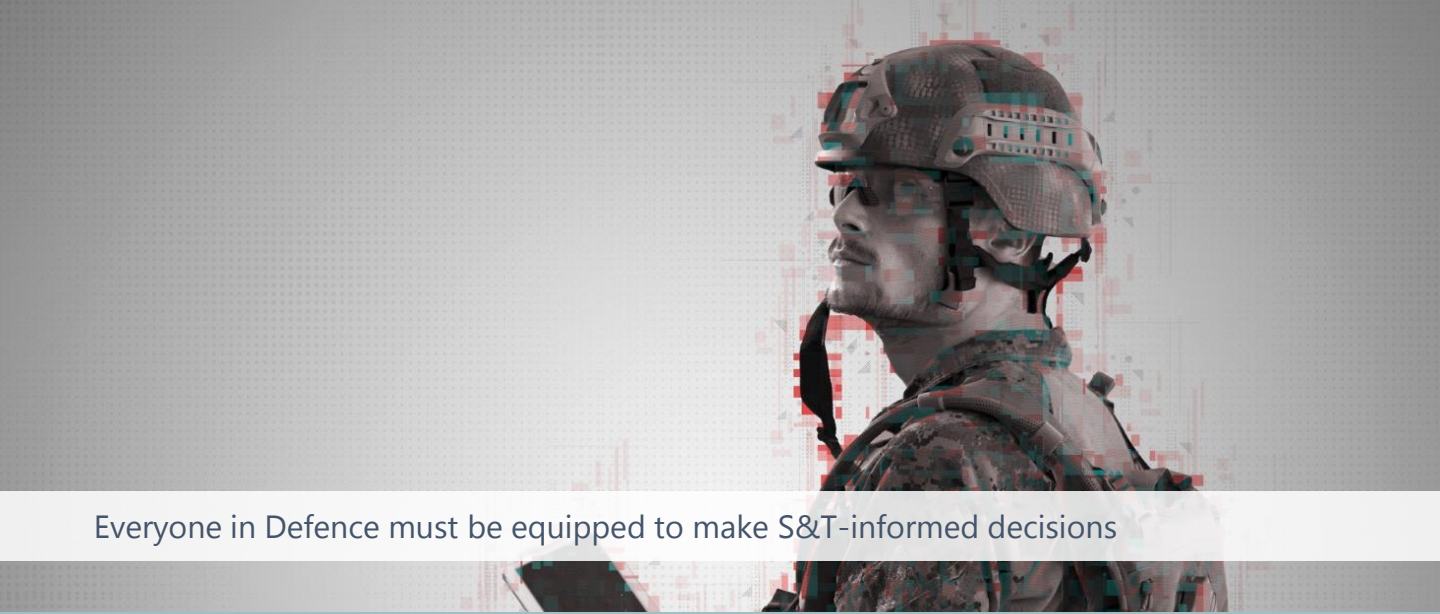
We must establish a much more effective and more clearly defined relationship between science and policy expertise – and between scientific advice and science, technology and data policy-making roles – at every level. Close collaboration between policy and science professionals will give Defence a strong platform for its own technology push, but also ensure that we can make a valuable

contribution more widely, for example as part of government's 'Global Science Power' agenda.

As part of the development of our S&T policy function, we have established a Defence Artificial Intelligence and Autonomy Unit to address some of these policy issues and will publish a Defence Artificial Intelligence & Autonomy Strategy to help the department adopt these technologies at pace. Now we must prepare for the next emerging disruptive technology and ensure that Defence is on the front foot to respond.

We will work closely with our allies and partners who share our ethical, legal and moral standards to promote understanding – an important contribution to establishing the UK as a Global Science Power. We will aim to resolve policy issues before the point of technology maturation. The S&T policy function will:

- work collaboratively across Defence to identify critical emerging technologies;
- develop forward-thinking technology policies to support Defence posture or policy, to mitigate the chance of unforeseen issues and development causing disruption to Defence and ensure that the Department and wider industrial base are pre-positioned to exploit technological applications as they emerge at pace;
- work with colleagues across Defence and wider government to ensure our scientific and technological strengths are properly protected, and to shape regulations, standards and norms of behaviour; and
- work with our international partners to understand the related implications of technologies, for example interoperability, deterrence, arms control and inadvertent escalation.



Everyone in Defence must be equipped to make S&T-informed decisions

Overall, our S&T policy function will reinforce S&T's place at the heart of major policy and strategy decisions. Together we will look beyond the bounds of current policy and inform future policy development so that we are ready to receive and effectively operate novel and disruptive capabilities as soon as possible.

Embracing a highly technological future is a whole-of-Defence effort


Making the right decisions about S&T has never been more important. This is much more than making the right decisions for investment. To be successful, everyone in Defence must be equipped to make sound S&T-informed decisions, weaving S&T into every aspect of Defence business. We will ensure our people acquire the skills and awareness they need to have informed S&T conversations, and value the evidence that S&T can provide in decision making. More than just sharing understanding of what S&T can provide and raising awareness of emerging technologies, we will help everyone understand the role that science, technology and analysis can play in strategy and policy development. This does not mean turning everyone into a scientific expert, but enabling our people to make better choices, to understand in broad terms the implications and applications of S&T, and the importance of the scientific method in evidence-based

decision making. This will require education, training and continuous development to ensure that we are best placed to exploit the rapid development of new capabilities.

CSA is Head of the Science Profession in MOD and oversees an active professional development programme. An important element of this is further improving the blending of technical excellence and scientific literacy with key policy and strategy skills to avoid science being distinct from core departmental functions.

Decision makers will be directly supported through our embedded Scientific Adviser network. These advisers play an important role in the operations of the Department and are a trusted source of independent advice and constructive challenge. They also provide access to our expertise in the Defence Science and Technology Laboratory (Dstl) as well as world-leading experts from industry, academia and internationally. They translate the science community's deep expertise into terms the user understands and translate the users' contexts and needs into terms the specialist science community understand.

We will support learning and development for non-scientists in the scientific method and S&T developments and implications, including an enhanced S&T presence at the Defence Academy. We will develop Communities of Practice for our scientific specialists to



network effectively with others from across MOD, government, industry and academia, fostering increased awareness of career paths and attracting and nurturing the best talent. We will encourage and support our scientific specialists to develop generalist skills so they can move into influential roles across government where their expertise can bring wider benefit.

Innovation requires diversity

Innovation will thrive if there is a rich mix of skills, experience, thought and approach in our people. We are working across Defence to develop and implement an ambitious diversity and inclusion (D&I) strategy. Many people are already involved in brilliant and important D&I activities in many different settings. One of the ambitions for the strategy is to understand and cohere all this activity so that we can be confident it is having a meaningful impact on our shared aims and objectives.

S&T can make a particular contribution, and we will increase our own skills and knowledge of 'D&I science' so that we can provide D&I scientific advice – helping Defence to choose evidence-based interventions that will work in

our varied contexts to solve the critical problems that impact most on our diversity.

We will define and implement interventions to address critical problems in an impactful way – be that within the Defence S&T specialist community, within MOD, influencing across government or joining forces with external organisations to have the impact we seek.

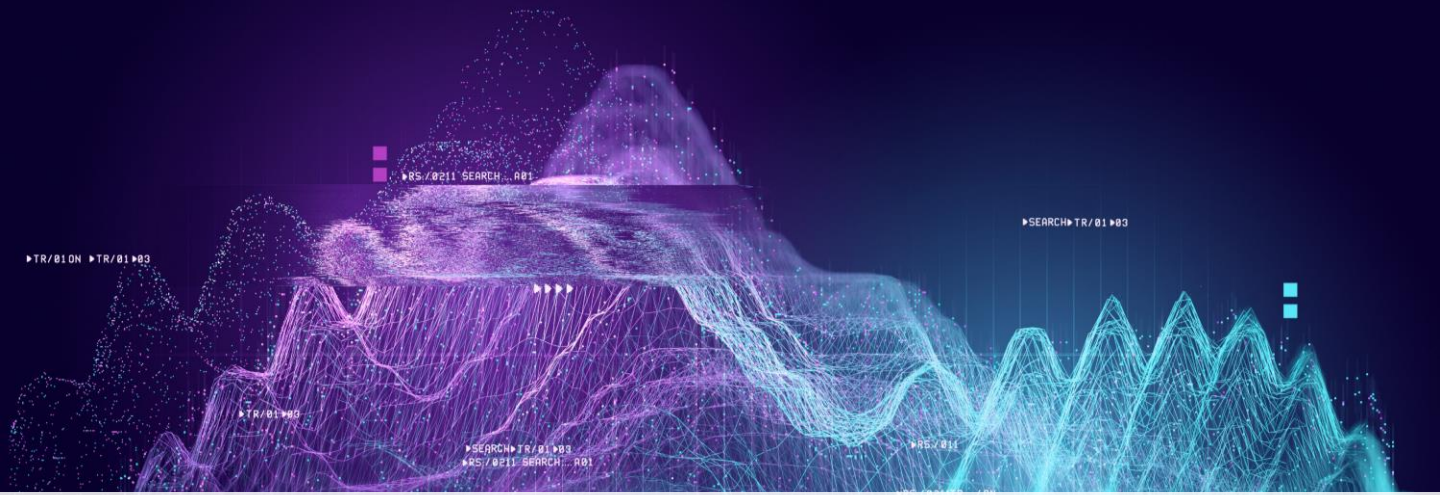
We will design a suite of monitoring tools so we can understand and monitor our progress effectively and adjust our approach in the light of new ambition or lessons learned.

Data stimulates innovation

Good decision making requires good underpinning evidence, which is based upon data. Data therefore underpins all aspects of the delivery of government and Defence business. Access to and governance of the right data is integral to our ambition to achieve a highly technological and innovative future, particularly as software- rather than hardware-defined capabilities gain in strategic importance. If we are to achieve our goal of multi-domain integration and effective command and control across Defence, we



Innovation will thrive if there is a rich mix of skills, experience, thought and approach



Data is integral to our ambition to achieve a highly technological and innovative future

must be able to access data and translate it into actionable information. Competitive advantage will increasingly be gained from high quality, well-curated and interoperable data, seamlessly integrating our own data with data from outside Defence. We must therefore protect our data and develop appropriate digital technologies and infrastructure – the digital backbone that supports the collection, assurance, storage and processing of data as a strategic asset. To seize the advantages afforded by algorithmic development, including Artificial Intelligence, we need robust data sets that are fit for purpose. We must have reliable data, collected and appropriately shared, or our digital revolution will fail.

In MOD we have demonstrated our intent for data-driven modernisation by appointing our first Chief Data Officer and publishing the 2020 Data Management Strategy⁷. Data will be made available, safely and reliably, and it will be curated, standardised, assured, exploitable, secure and Digital by Design. It will be treated as an enduring sovereign asset that is managed in accordance with the highest standards. This will require new architectures, seamless multi-classification systems and modern data storage technologies.

Defence holds a wealth of scientific data collected through decades of research,

operations and experimentation. Our approach to S&T will support the Data Management Strategy by curating this data in line with leading practice. We will enable scientists working on sensitive projects to publish their research in a secure environment, so results are appropriately shared. We will encourage the publication of all results, including negative results. As we develop new technologies, access to data from across Defence and wider government, industry, academia and international partners, as well as our own datasets, will be required. Data stimulates innovation and so we will make our rich data sources available as widely as possible wherever we can, supporting the development of new capabilities for Defence.

⁷ [Defence Data Management Strategy 2020](#), UK MOD

4. Seizing the opportunities

CSA will guide Defence in harnessing S&T across every aspect of our business

The role of the Chief Scientific Adviser in Defence

Success against our adversaries in this technological age requires the whole of Defence to harness S&T in every aspect of our business. CSA will guide MOD and government partners in this endeavour as part of an enterprise approach⁸.

Working with other senior leaders in Defence, CSA will:

- **understand** the current and future Defence S&T landscape;
- **translate** S&T knowledge and advances into actionable strategic direction for UK Defence;
- **ensure** that our S&T choices complement, support and take advantage of whole-of-government S&T strategy and wider government initiatives;
- **ensure** the adoption of emerging technologies is supported by sensitive, coherent and timely policy;
- **challenge** the Department on how it is integrating new technologies within its capability planning;

- **directly** invest, at the very minimum, 1.2% of the Defence budget in S&T;
- **steer** and endorse direct investment in R&D by other parts of Defence, cohering it with CSA's S&T investment;
- **develop** policies for how the department conducts research and applies cutting edge science in a safe, ethical and rigorous way;
- **define** targets for the sustainment of critical S&T capabilities for Defence, National Security and resilience; and
- **champion** S&T literacy across Defence, supporting timely and effective decision making by all our people.

The research portfolio will balance multiple demands

The S&T research portfolio balances needs across Defence. It must:

- fund fundamental research to underpin the development of the generation-after-next of capabilities;
- fund development and feasibility studies to accelerate the adoption of the next generation of capabilities by pulling S&T through at pace;

⁸ The S&T Enterprise encompasses CSA, the MOD Head Office S&T function, Dstl, and our collaborators and suppliers.



We will rebalance our investment to address the five capability challenges

- sustain critical capabilities on behalf of UK Defence and Security;
- support MOD as a department of state;
- support broader government policies and initiatives; and
- support operations at home and abroad.

The S&T research portfolio is commissioned to address short, medium and long-term Defence and Security needs and is funded centrally by CSA, other Defence stakeholders, other government departments and international partners. Centralised commissioning is critical to ensure that essential capabilities are sustained on behalf of Defence and Security and that all S&T undertaken within Defence is strategy-driven rather than demand-led.

The S&T research portfolio sits within the context of a broad R&D ecosystem for Defence which has a complex network of stakeholders and delivery agents. Annex A provides an overview of this ecosystem laying out responsibilities for setting the requirements as well as funding sources and delivery mechanisms.

We will rebalance our S&T investment to

better address the five capability challenges outlined previously, transitioning smoothly to a new portfolio within five years. We will focus funding on S&T that addresses generation-after-next capabilities aligned to these challenges, with boundaries agreed collectively through the Defence Technology and Innovation Board (DTIB). This will not be to the complete exclusion of current and next-generation S&T. We will take carefully judged risk with our investment, failing fast and safely and learning effectively. We will build in greater agility, so that we can more easily adjust priorities within a five-year cycle. This does not mean that we will only conduct research in response to these capability challenges – we will continue to balance this future focus with the need to sustain critical S&T capabilities and provide the underpinning S&T in a number of additional critical areas. We will also fund our S&T push to ensure Defence is prepared for future unknowns.

The portfolio rebalance will require Defence to make some hard decisions on where to disinvest. We cannot deliver all of Defence’s perceived needs and must take risk against some S&T capabilities. We will have to grow some capabilities and repurpose or scale back





We will simplify how our stakeholders engage with S&T

others. To facilitate this, we will simplify how our stakeholders can engage with the S&T portfolio and use the five challenges to more clearly link research to future capability. Investment in the most mature technologies nearest to the users' hands is best made by the users. Defence Innovation has a raft of funding streams to support rapid adoption of the most promising and game changing technological advances. CSA will provide expert support and guidance to ensure users' investments are scientifically and technically sound and coherent with the portfolio as a whole. We will assist users to find the right funding streams and novel collaborations to achieve the best outcomes for Defence.

We will continue to provide critical S&T capabilities

CSA will continue to support niche S&T capabilities that are critical to UK Defence and Security, emergency preparedness and/or to meet government's legal obligations, including:

- chemical, biological, radiological;
- cyber;

- electromagnetic environment;
- energetics;
- forensic science (explosives, digital data);
- intelligence;
- military working animals;
- novel materials;
- novel weapons;
- protecting information techniques/measures;
- sensors and sensing;
- signature management (all domains);
- strategic systems;
- survivability/threat evaluation;
- system of systems integration (e.g. survivability, software, security); and
- the human element of capability.

To secure the future of these capabilities we must work with our colleagues across government, industry and academia to find viable long-term solutions that safeguard their resilience. Together we must:

- sustain a cohort of suitably qualified and expert persons (SQEP), who maintain their skills through conducting research, while ready to respond to operational demands⁹;

⁹ This will develop the next generation of scientific specialists – not necessarily possible through operational response work alone, or through those specialists providing technical advice to the delivery of the equipment programme.



We will work with partners to maintain critical capabilities

- investigate how to sustain and improve the resilience of critical capabilities through new arrangements and/or partnerships across government, with academia, industry and international partners;
- ensure our people are suitably equipped to deal with the rapidly changing landscape;
- examine novel ways to reduce the cost of sustaining critical capabilities¹⁰; and
- build in flexibility to respond to the demands of emerging technologies critical to Defence.

We will clarify departmental and wider government policies and requirements for the sustainment of critical capabilities and use this to refresh our S&T capability strategy to ensure that our operational S&T capabilities are ready and available when needed. This will allow us to have a clear policy and demand signal for MOD's S&T capability framework¹¹. We will work with other government departments and our partners in national security to develop a coherent and effective approach to maintaining these critical capabilities.

Defence S&T supports MOD operations and the MOD as a Department of State

Defence S&T plays a vital role supporting MOD as a Department of State, and military operations both at home and abroad. UK expertise in energetics continues to provide critical support for both the armed forces and security services and is in continual use. We continue to support other government departments by providing expert advice on home-made explosives, informing policy and decision making, as well as developing effective render safe tools and procedures for handling conventional legacy munitions and terrorist devices.

Chemical weapons expertise is in high demand and has seen a lot of use in recent years, most prominently the deployment of extensive chemical/biological expertise in response to the use of Novichok in Salisbury and Amesbury in 2018 and the use of chemical agents in Syria.

¹⁰ Ensuring that critical capabilities are available with sufficient expertise to operate them is a significant annual cost to S&T.

¹¹ The MOD S&T Capability Framework 2019



Sustained investment in chemical and biological capability has been critical in UK operations both at home and overseas

At home:

Since the end of the Cold War our Chemical and Biological expertise was sustained and developed through more than 3 decades of investment. During the response to the use of Novichok in Salisbury in 2018, Dstl's analytical chemistry capability identified the threat material, and Dstl experts informed the health and environmental advice that saved lives and protected the public. The Dstl Clinical Laboratory screened the blood of all responders during the operation. Dstl rapidly generated new capabilities to forensically analyse large contaminated items and safely store and dispose of contaminated material found in public places. Scientists were deployed alongside military and other services

to establish the extent of contamination and inform the safe release of sites, advising at strategic, operational and tactical levels. More than 300 staff from the Chemical and Biological capability area were involved.

Overseas:

Dstl's analysis and attribution capability analysed soil samples to confirm the use of the chemical weapon Sarin by the Syrian government on their own people in 2014. When Syria voluntarily agreed to turn over their chemical weapon stockpiles to the international community, Dstl's expertise was again used to develop capabilities to safely access barrels of agent, and to advise on safety and decontamination protocols.



S&T enables F-35 Lightning II into UK service

The F-35 Lightning II Programme declared Initial Operational Capability (IOC) at the end of 2018, with S&T integral to its development and delivery. This marks the beginning of the UK using advanced low-observable capabilities. Allied with the F-35's advanced sensors and systems, this provides a step-change in UK Combat Air Power and is the RAF's first 5th Generation fighter.

The CSA S&T programme invested circa £350M in combat air technologies in the late 1990s and early 2000s – a critical contribution to the UK to becoming the only Level 1 partner with the US, in the world's largest Defence procurement programme.





Getting capability into the hands of users is the ultimate goal

Successful exploitation of Science & Technology

Successful exploitation of S&T – placing new technology with enhanced capabilities into the hands of the users at the right time – is the ultimate goal of S&T activity. The F-35 Lightning II is a great example of this exploitation ecosystem in action. Across Defence we will work together to enhance and more effectively govern the exploitation ecosystem in order to:

- more effectively manage the S&T portfolio so that benefits, risks and opportunities are managed, monitored and evaluated;
- effectively situate the S&T portfolio so it is sufficiently agile to co-evolve with threats;
- better use our relationships with industry and academia in the delivery model to ensure S&T capability maintenance is incorporated into our portfolio design;
- improve our effectiveness at working across government and with industry, academia and international partners to deliver key government policy goals, for example, considering the prosperity benefits of exportability early in technology development;
- place S&T at the heart of acquisition reform, testing the traditional development cycle and embedding experimentation, early development and wider Defence Lines of Development assessments into foundation stages of R&D;
- support users and innovators to run their

experimentation in a scientifically rigorous way;

- more closely align with Front Line Command capability planning, as agreed through exploitation plans and business cases for project planning; and
- more effectively monitor and evaluate projects to spot and correct unproductive approaches.

Exploitation through experimentation

Experimentation is a vital component of capability development within Defence. For example, S&T experimentation in Space is helping MOD realise its ambitions in this new domain of international competition. Across Defence, we are transforming our approach to experimentation, drawing on expert S&T advice, guidance and coherence. Our S&T experimentation, on early prototypes and proofs of concept, will be rigorous, and we will store and curate our hypotheses and data effectively to ensure that others can benefit and we avoid costly repetition. We will share what we learn with other Defence experimenters and advise on improvements to experimental design and the propagation of results.

We will focus our S&T experimentation on immature concepts and technologies (with correspondingly low Technology Readiness Levels (TRLs)) to assess the feasibility of



We will support UK prosperity through our network of suppliers and partners

exploitation of generation-after-next research. This prototype or conceptual experimentation will demonstrate the opportunities S&T provides and also give us valuable assessment points to change course.

The majority of the extensive experimentation programme within Defence is funded through the Front Line Commands and innovation stakeholders as part of our R&D pipelines, accelerating the adoption of the next-generation of capabilities. Our research will feed the front end of those pipelines, ensuring that there is a supply of technologies and capabilities for experimentation for the future. We will factor in technology and capability integration from the outset through adopting open standards, systems and approaches. Across Defence, we will work to have a seamless chain of custody, from the early S&T building blocks, all the way through to new capabilities in the hands of the users on the front line, avoiding the Valley of Death¹² in capability development.

Defence S&T investment will bring prosperity benefits

The UK is taking a strategic approach to how we develop, protect and secure technologies that are essential to national security and

prosperity. CSA will lead Defence's contribution, working closely with across government and with partners in academia and industry in the UK and overseas. This strategy has been developed alongside the Defence and Security Industrial Strategy (DSIS)¹³ and the UK R&D Roadmap¹⁴, and we will continue to cohere our efforts, recognising the crucial role that industry and academia play in innovating, delivering and exploiting S&T, and the spill-over benefits of Defence spending into the UK economy.

Our intention is to be an understanding first customer, an early adopter of innovation and prepared to take some risk – taking relatively immature technologies and experimenting with them within Defence systems. We will send clear messages to innovators and potential collaborators about the applications we have identified which we believe may benefit from innovative technologies, while also welcoming and encouraging novel ideas and opportunities that Defence may not yet have considered.

The National Quantum Technologies Programme provides a good model for Defence collaboration on emerging technologies and how we can position ourselves as early adopters.

¹² In technology, the Valley of Death is a metaphor often used to describe the gap between academic innovations and commercial application. The technologies are not yet proven, so risks are high, but significant investment is required if these nascent technologies are going to develop into full capabilities. The Valley of Death is wide, deep and risky to cross. Sponsorship by government and/or private investment is often required for a successful passage.

¹³ In development at the time of writing.

¹⁴ <https://www.gov.uk/government/publications/uk-research-and-development-roadmap/uk-research-and-development-roadmap>

Enabling space through S&T

Space, recently recognised as a Military Operating Domain, is an area of huge technological growth. Across government, the military and commercial sectors, we are embracing the opportunities of the Small Satellite Revolution and responding to emerging threats from our adversaries.

Defence S&T investment has rapidly grown our Space capability, building a new generation of Space scientists and engineers in MOD, partnerships with leading academics and industry suppliers, and the infrastructure required to conduct space experimentation.

Dstl recently conducted the first tasking of a satellite by a UK Government-owned and

operated ground station for nearly 20 years, communicating with a satellite from Surrey Satellite Technology Ltd as it passed over UK skies. Their Coordinated Ionospheric Reconstruction Cubesat Experiment (CIRCE) mission, a collaboration between world-leading UK scientists and the US Naval Research Laboratory (NRL), will deliver unprecedented understanding of Space Weather. This will help us develop advanced Space capabilities and protect them from the harsh space environment. These activities, along with advanced S&T concepts for earth observation, space awareness and military communications, provide real choices for MOD as it seeks to build strength in Space.



MOD and the National Quantum Technologies Programme

MOD was one of the key stakeholders in setting up the National Quantum Technologies Programme (NQTP) in 2014. From the outset, we identified key applications for quantum technologies in Defence, those of sensing, imaging and timing, as well as subsequent near-term opportunities in communications and computing. The NQTP reaches across government, academia and industry to co-develop a national approach to quantum S&T. It accelerates the adoption of these technologies, ensures a sovereign capability for National Security and drives UK prosperity. Circa £1.1bn has been invested since 2014. The second phase of the programme is now underway, aiming to develop timing, sensing, imaging, communications and computing technologies that are fieldable by 2025. Defence has shared its own novel S&T with this initiative, while in turn drawing on the expertise within the programme. This has allowed us to assess future challenges, understand applications and routes to

exploitation, and ensure Defence is 'quantum ready'. Successful research includes:

- low size, weight and power atomic clocks, which offer alternatives to traditional satellite-enabled Global Navigation Satellite Systems (GNSS);
- gravity sensing to detect difficult targets at range;
- quantum magnetometers for maritime applications;
- quantum Light Detection and Ranging (LIDAR) for ultra-high resolution mapping;
- free-space quantum secure communication systems; and
- first generation enablers for quantum computing (including signal processing and cyber applications).

Through this activity we are building a world-class quantum S&T capability, in partnership with the UK's world leading hubs and other R&D groups. Our approach benefits UK prosperity and National Security as well as our key international research collaborations.





We cannot succeed alone – we will design in collaboration

Collaboration by design – domestic

Through collaboration, not only can we access niche S&T capabilities, but we can also build UK prosperity and influence and meet government objectives for levelling up across the UK. Matching our international by design approach to capability development, our S&T must be collaborative by design. We will understand where the UK has strength and depth in knowledge, experience, skills, technologies and capabilities that are relevant to Defence and Security to help us communicate our offer to our potential partners.

We will build on our excellent relationships with industry, academia and international partners, to reaffirm in a new S&T **collaboration and engagement strategy** the strategic basis and benefits of each relationship, optimising them to meet the desired outcomes. This will design-in collaboration, minimise conflicting priorities and merge S&T delivery. Our collaboration strategy will be built around the five capability challenges, as well as broader UK prosperity and influence agendas. Clearly setting out our priority challenges will help academia and industry, particularly small and medium size enterprises, to understand the scientific problems we want to address, and allow these professional innovators to innovate unconstrained by pre-judged solutions.

We will publish our departmental Areas of Research Interest (ARIs), coordinating with other government departments – for example with the national security community through NSTIx – to maximise incentives and opportunities for research partners. We recognise that a significant proportion of research is common to many problems, it is just the end application that is tailored for the user. This enables greater sharing of fundamental research. The ARIs will set out:

- our *challenge-led* priorities in the form of meaningful research questions;
- our areas of *technology push* where we are interested in key emerging technologies;
- our areas of focus where we are looking to develop new cadres of excellence in skills essential to sustaining our critical S&T capabilities; and
- the mechanisms through which organisations can effectively collaborate with us.

We will reissue the Defence Technology Framework, first published in 2019, to articulate potential routes to addressing the five capability challenges and highlighting priority technologies within each family. This will provide an updated demand signal of long-term priorities for future MOD investment through the R&D pipelines that address each challenge.

We will continue to work with the Research

and Technology Industry Group (RTIG) through the Defence Academic Pathway (DAP) working groups to ensure that demand signals are clear and useful for our collaborators and suppliers. As we implement the Defence and Security Industrial Strategy (DSIS), we will ensure S&T expertise guides our decisions about the right capabilities to nurture in industry and Defence to secure the future outcomes we want.

Our engagement with industry will be focussed on the future outcomes set out here. The five capability challenges provide a clear signal of intent to help guide endeavour in industry that aligns to Defence needs. We will avoid over-using military jargon and will not pre-judge solutions. This will improve Defence's access to the UK's world-leading scientific and engineering expertise.

Collaboration by design – international

As part of our strategic research, capability and industrial partnerships, Defence will maintain an extensive range of international S&T partnerships and strengthen our relationships to move beyond 'only' research collaboration. To deliver our international agenda, we will:

- develop an international approach, as part of wider Defence's international strategy for research, capability and industrial collaboration;
- align S&T priorities and objectives through the International Capability Steering Board for strategic partnerships, and with other government policy commitments; and
- identify new opportunities for joint work and true burden-sharing, focused on the five capability challenges for generation-after-next capabilities.

We will work with our allies and partners to influence standards and norms around the use of emerging technologies, including ethical frameworks, technology protection and interoperability challenges, contributing to the UK's positioning as a thought leader in this increasingly important domain. We will set out how we will use our bilateral and multilateral partnerships to deliver our own S&T goals, as well as enhancing our influence and shaping the technological world to our advantage. We will re-examine our risk profile in our research collaborations, demonstrate impact through rigorously monitoring and evaluating collaborative programmes and enhance our burden sharing with key partners. The Defence and Security Accelerator (DASA) Don't Blow It! campaign is a recent example of a joint UK/US call for innovation, illustrating our collaborative approach.

Our relationship with NATO remains particularly important, and we will work closely with our NATO allies to shape its modernisation and transformation. We will align to and support the Secretary General's 2019 Emerging and Disruptive Technologies Roadmap, not only by focussing on developing technologies that will drive battle-winning capabilities, but also by addressing barriers to development and exploitation, and ensuring we understand how new technologies will affect how we operate and fight in the future.

Don't blow it!

DASA launched Phase 1 of Don't Blow It! in September 2018. The aim of this industry call was to identify and develop novel solutions to enhance field-expedient chemical weapons elimination capabilities in non/semi-permissive and austere environments. In early 2019, the 32 proposals received were down-selected and seven contracts, spanning the three challenge areas of access, disable and destroy, were awarded. Proof of concept demonstrations for these technologies took place in late 2019.

Following on from the successful Phase 1 of Don't Blow it!, Phase 2 launched in October 2019 and attracted a range of interested parties, including some totally new to the competition. Of the 14 proposals submitted, three were selected for Phase 2 funding. Contracts were awarded on 1 June 2020 and will run for 12 months, with work taking place in the UK, US and Greece. Phase 2 will develop technologies currently at TRL 3 into full-scale prototypes at TRL 6, whose capabilities will then be tested and demonstrated in 2021.



5. Strategy implementation and monitoring our progress

We must check our progress, adjusting and accelerating where necessary

To drive a highly technological vehicle effectively, you need a sophisticated dashboard

Successful implementation of this S&T strategy is critically important to UK Defence. Starting with comprehensive Theories of Change¹⁵, we will develop a detailed strategy implementation plan, including how we will monitor and evaluate Defence's progress against:

- the five capability challenges;
- the benefits realised through our S&T investment portfolio;
- our sustainment of critical S&T capabilities;
- the impact of S&T on departmental policy and strategy; and
- our S&T collaboration and engagement strategy.

This ambitious and comprehensive monitoring and evaluation will provide metrics and insight that will allow Defence to adjust and accelerate as we progress, and/or evolve our intended impacts as more ambitious goals become achievable. CSA will provide expert interpretation of this comprehensive dashboard and pilot Defence to world leading S&T outcomes. We will actively encourage both internal and external challenge and assurance to our strategy implementation, drawing on a diverse range of thought and expertise throughout academia, industry and internationally.

¹⁵ Theories of Change: a method to describe the set of assumptions (or theories) that explain all the steps that lead to achieving a long-term goal, and the connections between program activities and outcomes that occur at each step of the way.



In the short term

- Publication of a Strategy Implementation Plan (SIP);
- the establishment of the five capability challenges established at the heart of departmental R&D priorities;
- a revitalised S&T Futures and technology incubation programme;
- clear policy positions on the critical S&T capabilities we need to sustain; and
- a designed approach to S&T collaboration and engagement.

Within a year

- A refreshed S&T portfolio design;
- close working across MOD and with other government departments on S&T intelligence and strategy;
- publish our S&T collaboration and engagement strategy;
- clear direction to academia and industry on our priority areas of focus; and
- governance in place to identify and intervene in non-coherent R&D activities.

Within two years

- Framework for Monitoring and Evaluation of S&T in MOD implemented;
- establishment of an anticipatory policy

framework;

- a clear focus on the generation-after-next capabilities within CSA's S&T investments;
- our S&T data is effectively curated and shared for Defence and Security benefits; and
- agreement of a sustainable basis for critical S&T capabilities for Defence and Security across government.

Longer term

- A challenge-led approach embedded in Defence Force Development;
- a seamless pipeline from fundamental research to capability in the hands of the user;
- S&T exploitation plans directly feeding into Front Line Commands' capability management strategies and plans;
- a permanent cultural shift in the departmental approach to – and literacy in – S&T; and
- an established cycle of production of the next set of capability challenges for Defence that are susceptible to disruption through S&T.

Annex A - The Defence R&D Ecosystem

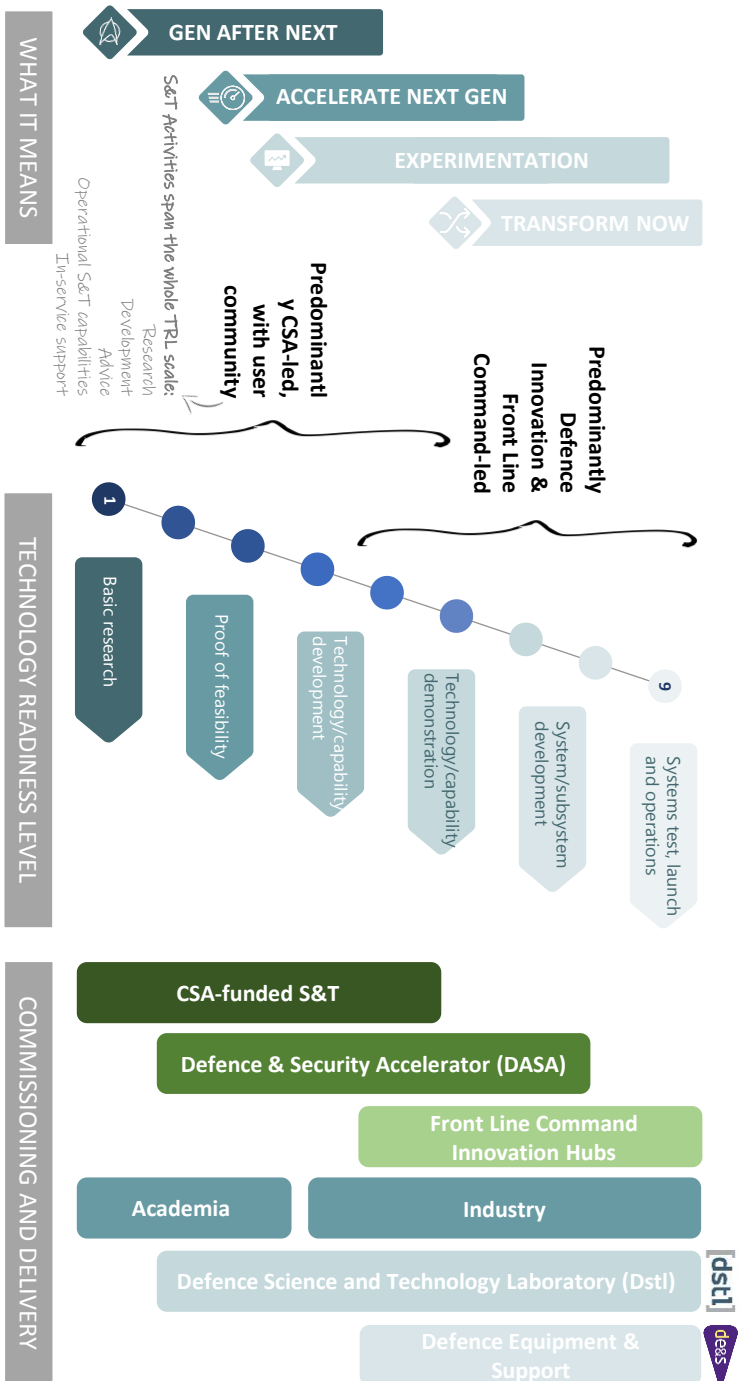


Figure 2 - A simplified schematic of the Defence R&D Ecosystem. S&T is used across all phases of R&D, performing different functions. There is a complex network of stakeholders feeding requirements in, and it is funded and delivered through different agents. The diagram indicates the agents' areas of main effort.

Annex B - The MOD S&T Strategy in the wider context

The MOD S&T strategy is part of a broader drive to secure the UK's future advantage, and for Defence and Security to address key strategic issues. Figure 3 shows a selection of the strategies and policies that have driven the development of this strategy, and gives an indication of the breadth of the collaboration that will be required to implement this strategy. This is by no means an exhaustive list. It illustrates how important it is to find coherence through collaboration in this complex ecosystem to deliver the outcomes that we need.



Figure 3 - A selection of the International, UK and Defence strategies and policies to which the MOD S&T Strategy relates. Strategies in grey bubbles are not yet published.

