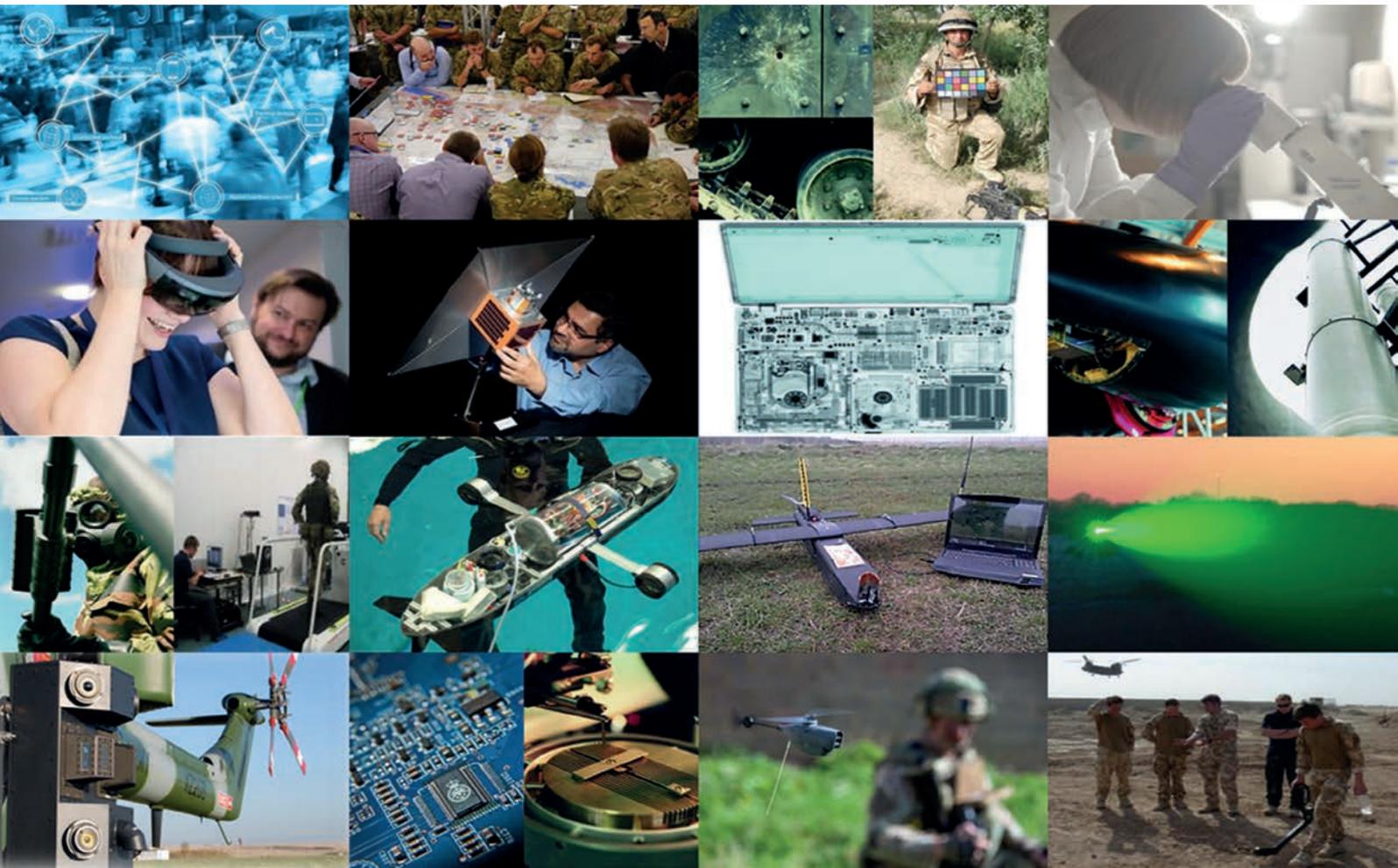




Ministry
of Defence

Science and Technology Strategy 2017



Foreword



Science and Technology (S&T) underpins the entirety of UK Defence. It shapes Government policy, sustains strategic national capabilities and is central to countering emerging threats. For our Armed Forces it creates and develops affordable and battle winning capabilities, both now and into the future, and supports them to develop new ways to operate in new environments using novel capabilities.

The importance of S&T to Defence has been visible in recent years during which it has been critical to the design and delivery of many Defence capabilities and systems. The survivability systems in the Foxhound armoured vehicle, the rapid confirmation that the nerve agent sarin was used in Syria and the development of the world-leading Brimstone ground-attack missile were only possible thanks to S&T.

In an increasingly connected world where we face new as well as traditional threats and which is increasingly defined by technological advances of a speed and scale previously not experienced, it is time for a renewed focus on S&T in Defence. My role in the Ministry of Defence is to drive S&T into the heart of its strategic thinking and everyday business. I will provide technical challenge to the Department and ensure that S&T offers innovative solutions that address Defence's key needs. I will ensure that the S&T I commission develops, and sustains, critical capabilities for the future whilst retaining the agility to react to urgent operational needs.

I recognise that to achieve this we must be ready to work across the Department, across government and with our international partners and, crucially, with the brightest and best in UK industry and academia to ensure that Defence benefits from innovative ideas, wherever they originate from.

This strategy sets out our vision and our approach to achieving it at a time when, now more than ever, S&T must be at the heart of the UK's Defence.

Hugh Durrant-Whyte, MOD Chief Scientific Adviser
October 2017

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Executive Summary

1. Science and Technology (S&T) is essential to the Defence and Security of the United Kingdom. Since 2010 the threats to the UK have increased in scale, diversity and complexity whilst the world is experiencing an unprecedented rate of technological development. In this context, the Ministry of Defence's (MOD) vision for S&T is that:

S&T plays a central role in Defence thinking and culture, directing and applying innovative research and thinking to meet the current and future strategic needs of Defence and Security.

2. To achieve this vision, firstly, S&T must be mainstreamed into MOD's strategic policy and decision making, referred to in this strategy as the '*upstream*' activities of Defence. Secondly, S&T has a critical role to play in the implementation of those policies and decisions, referred to in this strategy as the '*downstream*' activities of Defence.
3. For S&T to become an integral part of Defence's strategic decision making and to mainstream it into the culture of Defence, MOD's Chief Scientific Adviser will provide an independent technical challenge function to Defence. This function will drive the consideration of innovative concepts and disruptive technologies into strategic planning and inform MOD decision makers of emerging technologies which present threats or opportunities to Defence and Security. MOD's CSA will lead the mainstreaming of S&T into MOD's upstream activities.

4. To play its critical role in Defence's *downstream* activities, S&T will maintain its focus on the delivery of sustainable and cutting edge S&T for both the current and future capabilities of our Armed Forces. To achieve this, S&T will sustain critical S&T capabilities, support Defence to be an 'intelligent customer', support business-focused outcomes and support the pull-through of S&T into systems and Defence capabilities.



5. S&T plays another critical role linking MOD with the wider Defence and Security innovation ecosystem. This strategy recognises that innovation comprises two components: the generation of new ideas and the implementation of those ideas into MOD's operations and business processes. Defence is relatively good at generating new ideas. It is, however, less good at implementing them in MOD's operations and business processes. S&T cannot solve this alone, but it can play its role by, firstly, ensuring that every S&T project has a clear S&T offer for Defence and a clear customer focus and, secondly, by identifying solutions to overcome organisational road-blocks so that they are removed, one-by-one, across Defence.

6. MOD's core research portfolio, and the funding associated with it, is the primary mechanism to implement this strategy and to sustain S&T skills and capabilities. MOD agreed the design of its new core research portfolio in January 2017. The portfolio is aligned to Defence and Security's priorities, addresses its short and long-term needs, has an increased emphasis on strategic and high-risk, high-reward S&T, seeks to exploit the most promising emerging technologies and seeks to sustain critical S&T skills and capabilities. MOD's S&T community will adopt a collaborative approach to deliver the portfolio and to sustain S&T capabilities, including partnering with industry, academia, our allies and across government.
7. Success for this strategy will be achieved when Defence's senior decision makers routinely act on innovative S&T to shape policy and acquire novel battle winning Defence and Security capabilities in more agile, innovative, cost-effective and affordable ways.
8. This strategy provides more detail on each of the topics outlined above. Chapter 1 sets S&T in the Defence context. Chapter 2 explains the role of S&T in the Defence and Security innovation ecosystem. Chapter 3 places S&T in Defence's *upstream* activities and chapter 4 places S&T in its *downstream* activities. Chapter 5 explains Defence investment in S&T and, finally, chapter 6 explains how the MOD core research portfolio delivers this strategy and sustains S&T capabilities.

Chapter 1

S&T in Defence and Security

MOD's vision for S&T

9. S&T is central to the Defence and Security of the UK. It drives the effectiveness and efficiency of our national security, the capability of our Armed Forces and underpins our international relationships with Allies.¹ S&T is a critical force multiplier: whilst it makes key contributions to overseas operations, the nuclear deterrent and homeland security, it also enhances UK strategic understanding, develops disruptive and affordable winning edge technologies and identifies alternative solutions to address Defence's strategic challenges.
10. The Ministry of Defence (MOD) must embrace the opportunities offered by S&T so that the UK can maintain its technological and operational advantage² over adversaries. MOD's vision for S&T is that:

S&T plays a central role in Defence thinking and culture, directing and applying innovative research and thinking to meet the current and future strategic needs of Defence and Security.

11. This strategy considers the functions of Defence in two broad aspects. Firstly, there are the strategic policy and decision making activities of MOD, which this strategy refers to as its '*upstream*' activities. Secondly, there is the implementation of those strategic policies and decisions, which this strategy refers to as Defence's '*downstream*' activities.
12. Success in mainstreaming S&T will be demonstrated by decision makers across Defence actively seeking out S&T advice and evidence to shape their thinking and strategic choices. Downstream S&T success will be demonstrated when Defence is harnessing S&T outcomes and is confidently prepared to tackle and exploit future risks and opportunities with visible impact in strategic planning, force structures and affordable equipment plans which embrace battle winning technologies.

A model of S&T in Defence

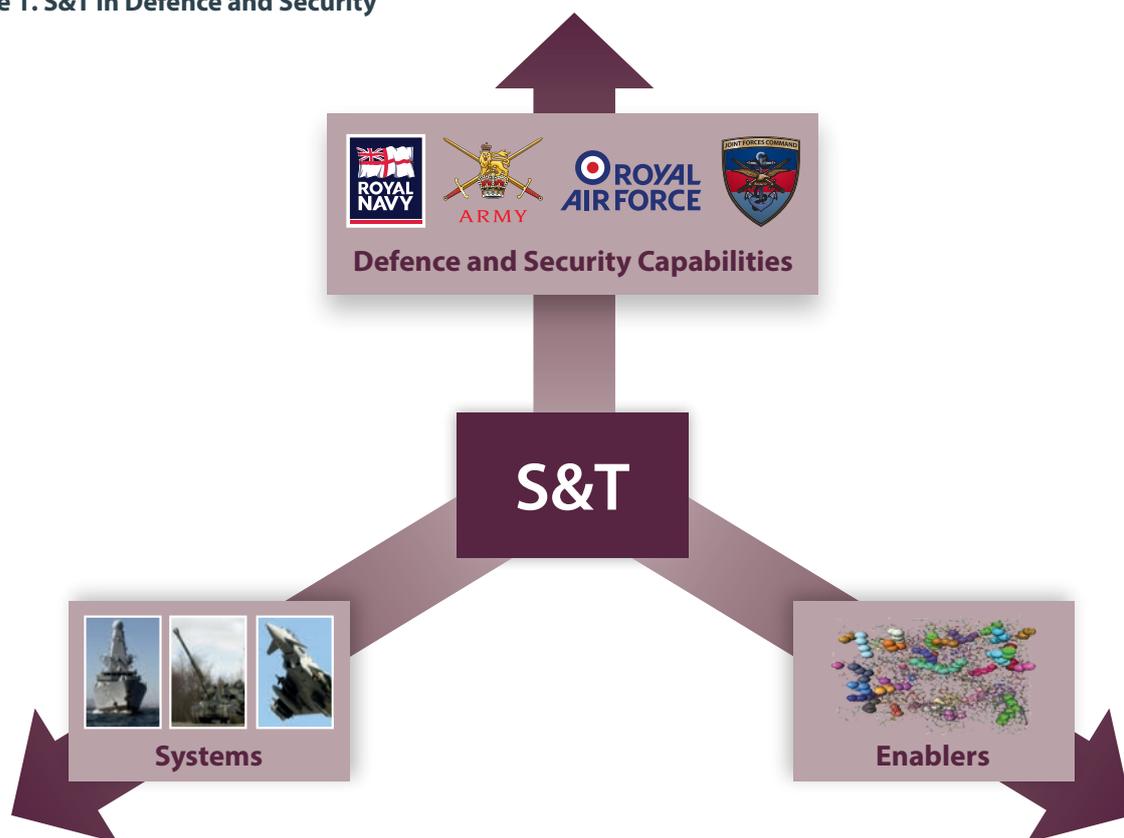
13. Figure 1 shows a simple model of S&T and its central role in Defence. In this model S&T is at the heart of Defence and contributes to each of its three key components.
 - **Enablers** are the fundamental and often sovereign S&T capabilities³ required by Defence to support freedom of action, for example energetics and chemical and biological capabilities. In the short term, these enablers are key to supporting urgent operational needs. In the longer term, they ensure the UK's future winning edge by harnessing new and emerging technologies, for example machine learning, synthetic biology, autonomy, cyber and quantum. These S&T enablers are also the cornerstones for critical national and international partnerships.
 - **Systems** are Defence's tangible tools, spanning platforms, weapons, communications, information and people. S&T plays a fundamental role in developing, delivering and sustaining Defence systems. It explores

¹ A Review of MOD's Science and Technology Capability, Sir Mark Walport, March 2015, page 3.

² Operational Advantage and Freedom of Action referred to throughout this strategy are defined in National Security Through Technology: Technology Equipment and Support for UK Defence and Security, February 2012.

³ MOD S&T capability comprises the people, knowledge, infrastructure (including validated models and data), licences to practice, and mature relationships across government, with external suppliers and international partners.

Figure 1. S&T in Defence and Security



what is or could be possible, what is affordable, how systems should be tested and evaluated, how new technology can be integrated into legacy systems and advises Defence on their operation and sustainability.

- **Defence and Security Capabilities** are the capabilities that Defence uses to achieve its strategic objectives, for example strategic understanding, nuclear deterrence, homeland resilience, overseas strike operations, the deterrence of adversaries, protection of our people and the management of Defence. S&T plays a critical role in delivering these capabilities: it explores, understands and develops viable technical options to meet strategic objectives, it understands adversaries,

threats and opportunities and it analyses the affordability, value for money, technical capability and resilience of Defence capabilities.

14. S&T has a central role in growing and sustaining Defence's enablers, systems and capabilities. It does this in both the upstream and downstream activities of Defence. Upstream, S&T provides Defence with an opportunity to experiment, develop understanding and evolve its approach to problem-solving and innovation to facilitate more informed strategic choices. Downstream, S&T delivers novel science and advanced technologies so that Defence can acquire winning, affordable and coherent Defence capabilities.

Chapter 2

The Defence and Security Innovation Landscape

The innovation context

15. There is a sense of urgency in Defence and Security S&T. The world is changing and evolving in ever larger and faster technical leaps and bounds. The commercial sector is the big investor and leader in many technical areas and many companies in the information age have research budgets much bigger than that of UK Defence and Security. Our adversaries, both new and old, are learning to close the technology gap more rapidly and with more agility than we had anticipated.
16. The threats faced by the UK have increased in scale, diversity and complexity since 2010. Strategic Defence and Security Review (SDSR) 2015 notes the particular challenges of terrorism, extremism and instability, resurgent state based threats, the impact of technology and technological developments and the erosion of



the rules-based international order. At the same time, developing the leading-edge Defence technologies that the UK aspires to, using conventional scientific and technical processes, is becoming prohibitively expensive in both time and resources.

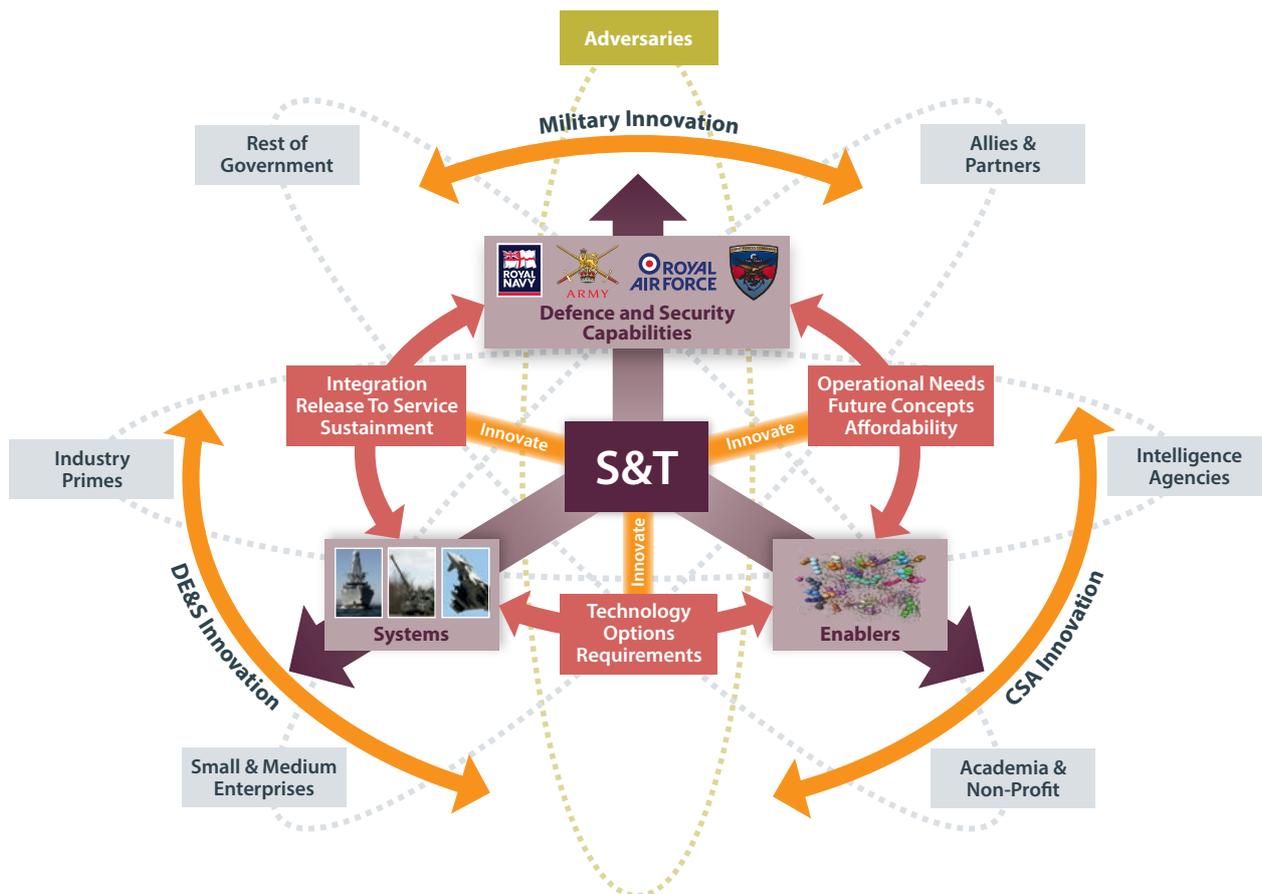
17. Innovation is a key tenet of SDSR 2015⁴ and is essential for the UK to maintain operational advantage into the future. This strategy recognises the plethora of innovation activities taking place across Defence, and more broadly across Government.

S&T in the innovation ecosystem

18. Figure 2 illustrates the broad and diverse Defence and Security innovation ecosystem within which Defence S&T sits. The UK's adversaries are, arguably, the most important part of that ecosystem as they act as drivers for innovation in Defence and Security. The UK's industrial base, both its prime contractors and small and medium enterprises, is critical to achieve Defence's drive for innovation. In addition, the UK's academic community is world-leading in many critical technologies including quantum, machine learning, materials and synthetic biology.
19. S&T will work harder to harness the wider innovation opportunities offered by academia, industry and those elements of the start-up community currently not well engaged with Defence and Security. Furthermore, Defence innovation is not taking place in isolation but is part of a wider government drive for innovation, and S&T must work across government to leverage capabilities that can address Defence and Security's needs.

⁴ National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom, paragraph 1.9 and Chapter 6B.

Figure 2. S&T in the Defence and Security Innovation Ecosystem



Components of innovation

- 20. This strategy recognises innovation as having two critical components: firstly, the generation of new and potentially transformational technologies, methods and processes; and secondly, the translation and implementation of those ideas.
- 21. The first component - the generation of new ideas - is relatively well catered for across Defence. S&T will engage with, complement and provide S&T skills to support the range of existing innovation activities that are generating and exploring new concepts and technologies for Defence.

- 22. The second component of innovation - the implementation of innovative ideas - is the translation and implementation of those concepts and technologies into MOD's operations and business processes. This component of innovation often relies upon bridging organisational boundaries, the most pertinent of which, in Defence, are the interfaces between S&T and policy, force development and equipment procurement.

23. This implementation of innovative concepts and technologies is much more challenging and, in Defence, examples of success are often the exception rather than the rule. When Defence lacks an operational imperative, the implementation of innovative ideas is inhibited by a conservative culture within Defence.
24. To meet its strategic challenges, Defence must focus on how to get innovative concepts and novel technologies translated and implemented into MOD's operations and business processes. This is a challenge for the whole of Defence which S&T cannot address alone. However S&T can play a role by engaging across Defence to support the removal of obstacles to the implementation of innovative ideas. For S&T, this will involve a two-step process:
- Firstly, every S&T project will require a clear case which articulates the benefits it offers Defence. This case will answer the Heilmeier catechism; and
 - Secondly, S&T will play a role in the identification and removal of obstacles and organisational road-blocks to innovation.
25. These questions aim to maintain S&T's focus on the benefits it aims to create for Defence and Security. They can be asked both of long-term fundamental research and near-term technology developments. In an agile and innovative organisation, the answers to these questions may well change over time but the business and customer focus remains.
- How is it done today, and what are the limits of current practice?
 - What's new in your approach and why do you think it will be successful?
 - Who cares? If you're successful, what difference will it make? What are the risks and the payoffs?
 - How much will it cost? How long will it take? What are the "exams" to check for success?
26. These questions aim to maintain S&T's focus on the benefits it aims to create for Defence and Security. They can be asked both of long-term fundamental research and near-term technology developments. In an agile and innovative organisation, the answers to these questions may well change over time but the business and customer focus remains.

S&T offer and Heilmeier catechism

25. Every S&T project will have a clear case articulating its offer to Defence. This S&T project offer will focus on how the project will address Defence and Security's challenges and simply answers the Heilmeier catechism, which asks the following questions:⁵
- What are you trying to do? Articulate your objectives using absolutely no jargon. What is the problem? Why is it so hard?



⁵ Heilmeier's catechism is a set of questions developed by George H Heilmeier that anyone proposing a research project or product development effort should be able to answer. It is important for the research project itself but also to communicate to others what is hoped to be accomplished.

Overcoming road-blocks to innovation

27. Defence needs to inculcate a culture of innovation and support the iterative removal of road-blocks to innovation which exist between different organisational functions. Much innovation in Defence stalls in areas around requirements capture, procurement and funding, fear of new concepts and understanding the impact of technology.
28. Although the removal of road-blocks is not generally a task for S&T, S&T is by its very nature innovative. S&T will operate across the Defence and Security innovation ecosystem to support Defence Innovation Champions, shape challenges for the Defence Innovation Fund, leverage the Defence & Security Accelerator⁶ to reach out to new suppliers and champion technologies for exploitation by Defence.
29. Through this engagement, S&T can play a key role in identifying solutions to overcome obstacles and organisational road-blocks to implement innovative ideas. As in most organisations, there is no fix-all solution to this problem. The only approach is to tackle road-blocks one-by-one, engaging key decision makers across Defence. By addressing these road-blocks one-by-one, Defence will gradually build a culture of problem solving and of innovation, prioritising its activities around a set of agreed projects for the benefit of Defence. It will create a “learning by doing” innovation culture.

⁶ www.gov.uk/government/organisations/defence-and-security-accelerator

Chapter 3

Upstream: Mainstreaming S&T Into Defence's Strategic Policy And Decision Making

Mainstreaming S&T

30. S&T must play a critical and central role in Defence's strategic policy and decision making, referred to in this strategy as its upstream activities. MOD's S&T community will take a series of steps to bring S&T into the mainstream of Defence's upstream activities. With a stronger focus on working with senior decision makers, S&T will play an active part in challenging the technical status quo and will offer tangible alternatives to address strategic challenges such as affordability and capability. Figure 3 illustrates S&T in Defence and Security's strategic context.



31. Supported by the S&T community, MOD's Chief Scientific Adviser (CSA) will guide MOD's strategic approach to S&T and shape the strategic and technical landscape for Defence and Security. To be successful, S&T must be cognisant of Defence's strategic capability priorities and challenges, articulated in SDSR 2015, and current Defence procurement strategies. S&T's downstream activities must be tailored to produce the evidence required to support this mainstreaming of S&T into Defence. This includes:

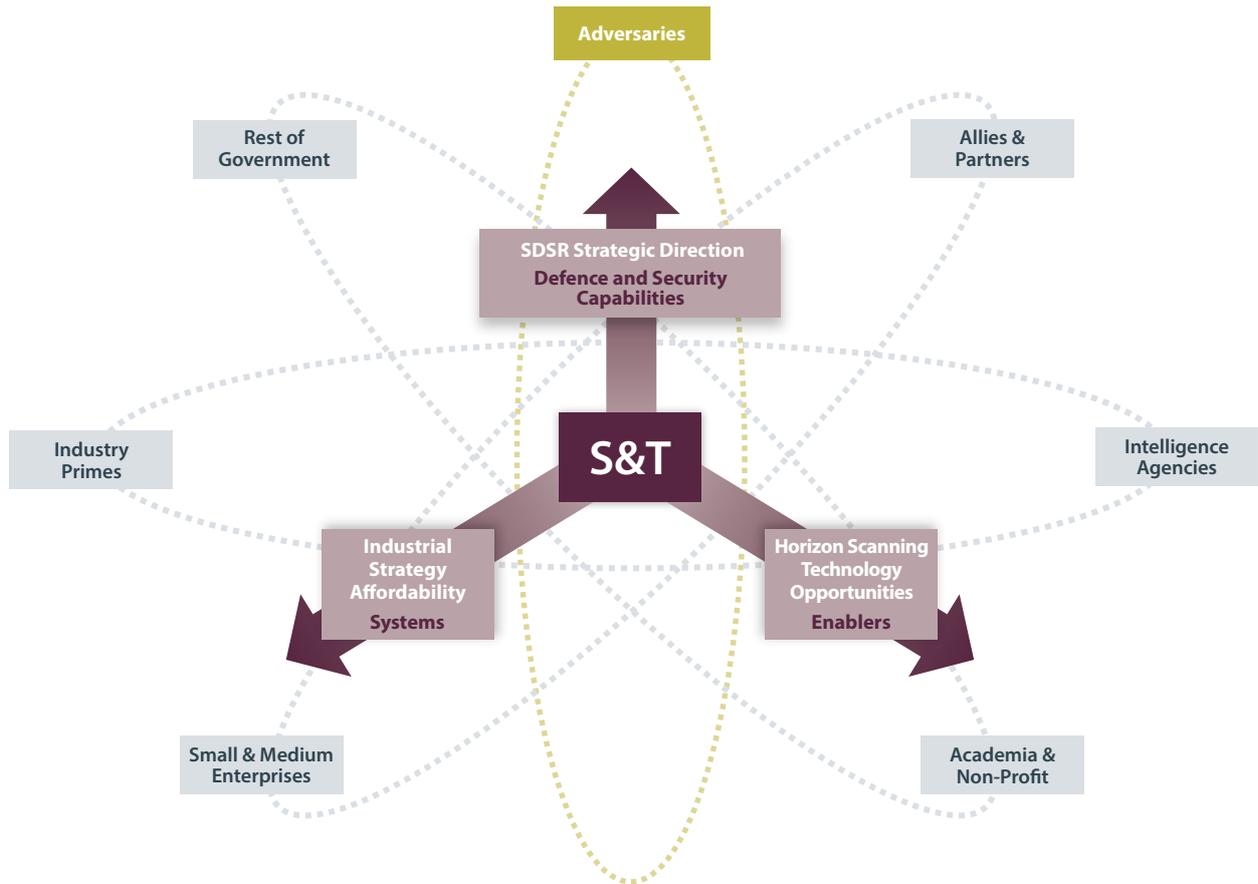
- Conducting continual horizon scanning to understand evolving technology threats and opportunities for consideration by senior decision makers;
- Providing scientific evidence, advice and coherent multi-disciplinary analysis to support Defence's strategic decision making; and
- Developing and demonstrating novel technical options to harness new technologies and approaches to build confidence in their potential and to address MOD's strategic challenges such as affordability and capability.

Mainstreaming activities

32. To mainstream S&T into Defence's strategic policy and decision making, MOD's CSA, supported by MOD's S&T community, will engage with senior colleagues across Defence to:

- a. **Lead an independent technical challenge function** by:
 - Driving into strategic planning the consideration of innovative and disruptive technologies that could provide a step-change in future capability, for example directed energy weapons, synthetic biology and advanced materials;
 - Engaging and informing senior decision makers on the emerging technologies which present threats or opportunities to their policies;
 - Enhancing the best understanding and use of S&T across Defence by challenging requirement definitions throughout the equipment acquisition approvals process;
 - Working with the Armed Forces, DE&S and others to identify the critical points of influence and impact for S&T before Defence capability programmes reach MOD's Investment Approvals Committee;

Figure 3. S&T in Defence and Security's Strategic Context



- Actively proposing and articulating new technical means of achieving Defence capabilities, for example through the use of autonomy and machine learning.
- b. Drive innovative thinking and the implementation of innovative ideas** by:
- Advocating the greater use of experimentation and demonstration to allow innovative concepts, technologies, methods and processes to be trialled and refined;
 - Working with academia and industry to develop innovative solutions in MOD priority areas, for example space, cyber and advanced materials. This will enable MOD to harness technological advances, sustain talent and support growth and productivity in the UK economy;⁷
 - Optimising collaboration with, and exploiting research and technological advances in, industry, business and the health and education sectors to help meet Defence and Security's priorities.

⁷ This activity is aligned with the emerging Government Industrial Strategy's focus on skills, talent and Small and Medium Enterprises.

c. **Better articulate the value of S&T to Defence** by:

- Demonstrating the benefits created by S&T across Defence, including in terms of affordability, capability and future workforce. S&T will undertake a series of pilot activities, addressing the priorities of MOD's Head Office and the Armed Forces, to make the case that new technologies and approaches can result in different, more affordable and more effective outcomes;
- Articulating each S&T project offer, which answers the Heilmeier catechism, to influence policy and investment priorities at senior committees and governance boards.

d. **Champion critical S&T and analytical skills** as MOD's Head of Profession for Science and Engineering and by working closely with MOD's Head of Analysis Group.

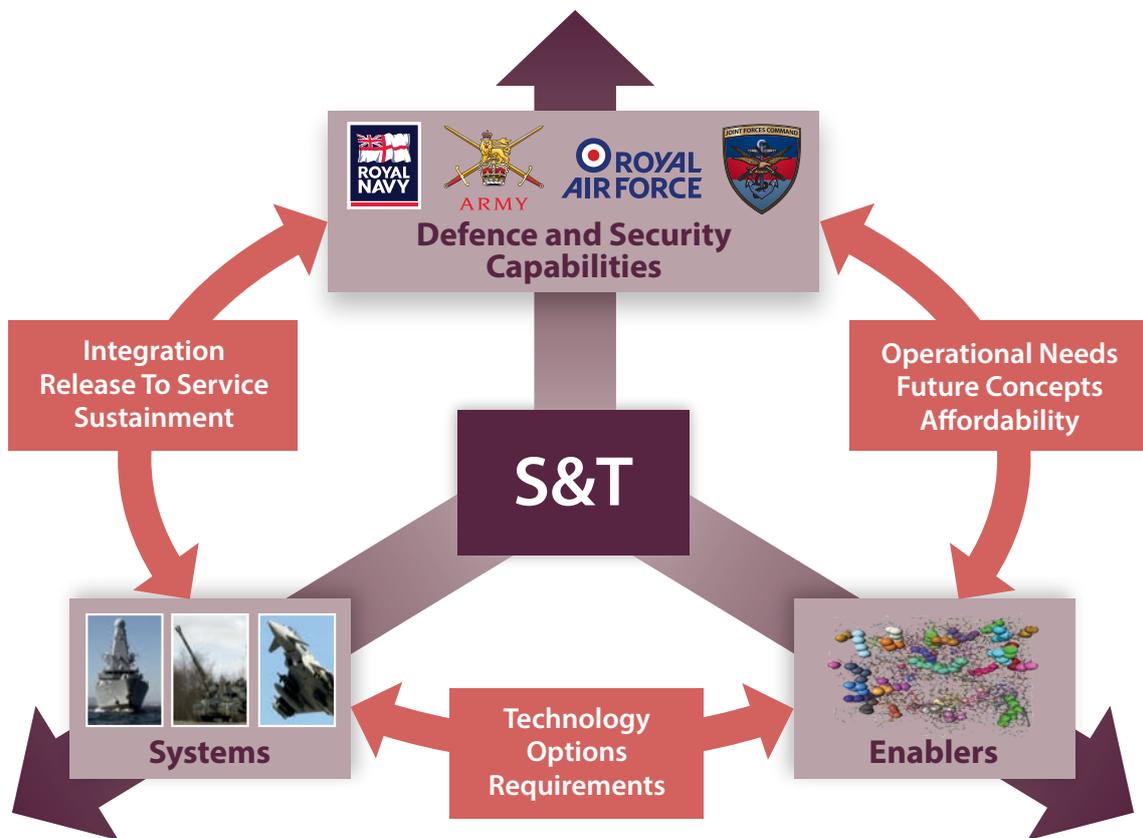
33. Collectively these activities will drive S&T into the mainstream of Defence's strategic policy and decision making.

Chapter 4

Downstream: Leading Edge S&T for Defence And Security Capabilities

- 34. As well as being central to MOD's upstream activities, S&T also has a critical role in the implementation of MOD's strategic policy and decisions, referred to in this strategy as Defence's *downstream* activities. S&T's downstream activities are strongly focused on the Armed Forces, MOD's Head Office, DE&S and wider government, although they do also focus more broadly on Defence and Security's strategic objectives.
- 35. As outlined in chapter 1, S&T underpins Defence's enablers, systems and capabilities. However, it is how S&T operates to implement, deliver and exercise the enablers, systems and capabilities that is most important to Defence, and the Armed Forces in particular. Figure 4 highlights how most of the operation of S&T lies at the *interface* between S&T enablers, systems and Defence capabilities.
- 36. Ultimately, the downstream role of S&T in Defence is to carry out S&T activities which link the enablers, systems and capabilities. For example, integrating the S&T community's knowledge of enablers to shape development of future concepts and establish appropriate system requirements. Similarly, how technical knowledge of systems allows Defence to integrate and utilise those systems to develop strategic capabilities.

Figure 4. Operations of Defence S&T



S&T's downstream activities

37. S&T's downstream activities within Defence include:

- a. **Sustaining critical S&T capabilities** to ensure that the UK can reliably and confidently deliver its strategic Defence and Security objectives and maintain operational advantage and freedom of action. The primary mechanism to sustain S&T capabilities is through the delivery of the S&T portfolio;
- b. **Conducting horizon scanning** to understand future technologies, their application and their impact on Defence and Security, including key technologies such as machine learning, quantum, advanced materials and autonomy. S&T will achieve this through collaboration with industry and academia and targeted technology development and demonstration;
- c. **Servicing and supporting urgent operational needs** that enable Defence to be credible, effective and dominant in conflicts. In particular this means providing tailored support to the Armed Forces, Defence Intelligence and Counter Terrorism activities;
- d. **Supporting evidence based decisions** by providing scientific evidence and analytical advice to shape policy and inform future operational capability need. In particular S&T will:
 - Support future conceptual force exploration, by challenging assumptions and conceptual thinking whilst recognising the rapidly evolving technical threat and socio-technological environment;
 - Provide critical advice on the affordability and value for money of options to deliver future Defence capabilities. S&T must play a key role in developing Defence's future concepts;

e. **Enabling Defence to be an intelligent customer** so that Defence's systems and capabilities can deliver the future strategic and operational needs of the Armed Forces. To accomplish this S&T will:

- Work with, and influence, a broad industry supply chain. S&T will develop concepts and technology options to address key capability risks and shortfalls and demonstrate their viability for inclusion in the funded Equipment Programme and Equipment Support Plan;
- Understand technical options, identify technical risk and articulate appropriate technical requirements. In particular, this means providing scientific expertise for current acquisitions made through DE&S;

f. **Supporting the pull-through of S&T** into Defence and Security capabilities. This support can include activities such as:

- The integration of sub-systems and the delivery of operational capabilities, through trials, release to service and common architectures;
- Specialist test and evaluation services to understand the efficacy of technical options;
- Scientific support for the sustainability of platforms and systems in response to a changing operational and threat context.

38. Collectively these activities will better link enablers, systems and capabilities so that Defence can more affordably and more innovatively implement its strategic policies and decisions.

Chapter 5

Defence Investment in S&T

39. S&T's downstream activities described in chapter 4 are delivered by technical expertise from across the S&T community. This includes MOD's primary in-house technical capabilities within Dstl, Defence's innovation units, embedded technical staff across MOD and the broad academic and industrial supply chain. These technical capabilities are sustained by funding from MOD's core research portfolio, the Armed Forces, DE&S and a range of non-Defence customers requiring specialist S&T advice and services.

MOD's core research portfolio

40. MOD's core research portfolio represents 1.2% of the Defence budget. MOD's CSA is custodian of the portfolio. Under the direction of the Research Technology and Innovation Board⁸ (RTIB), commissioning of the portfolio is the responsibility of MOD's directorate for Defence Science and Technology (DST).
41. MOD's core research portfolio is designed to:
- Drive the development of innovative future capabilities to support the Defence and Security agenda;
 - Generate S&T knowledge, skills and experience which enables Defence and Security, primarily DE&S, to be an intelligent customer; and
 - Sustain underpinning, critical sovereign S&T skills and capabilities for the long-term.
42. The RTIB determines the balance between these areas shaped by its understanding of Defence and Security risks, technology opportunities and S&T capability health, all the while balancing them against S&T funding constraints. Through MOD's core research portfolio and MOD's S&T



capability framework (Annex A), MOD will signal the areas of S&T where it will invest to develop bespoke technology solutions rather than buy technology solutions from the commercial market to address MOD's strategic needs.

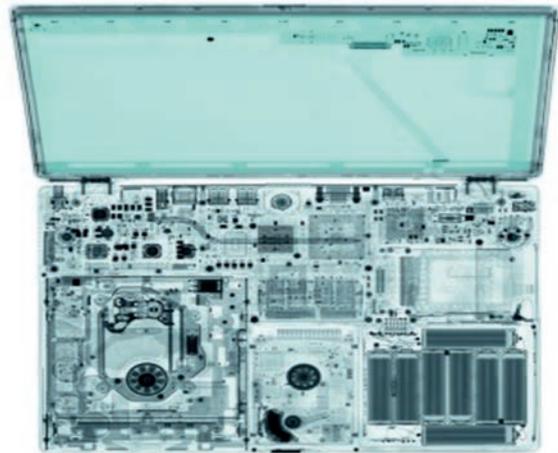
Delivery of Defence S&T

43. MOD's core research portfolio is delivered by, and through, Dstl. To ensure coherence and strategic S&T capability planning, DST also commissions S&T which is funded directly by DE&S, the Armed Forces, other Defence organisations and wider government to address those customers' nearer term and specific requirements.
44. The funding invested in MOD's core research portfolio accounts for approximately half of Dstl's income. Working in partnership, Dstl invests approximately 40% of its income in a broad supply chain spanning academia, small and medium enterprises, industry and international partners.

⁸ The Research Technology and Innovation Board is the Ministry of Defence's S&T governance board. It is chaired by the Minister for Defence Procurement.

S&T offer to Defence

45. This strategy requires each MOD core research project to articulate its S&T offer to Defence by answering the Heilmeier catechism.⁹ Private sector 'start-ups' describe the point at which a new product has sufficient features to satisfy early adopters as a 'minimum viable product', that is when a product is 'saleable' but may require further development. Each S&T project offer will clearly articulate the additional development required for the S&T to be adopted and transitioned into Defence and Security capabilities. This further development is likely to be funded through non-core investment.
46. MOD's CSA will articulate the S&T offer for the whole of the MOD core research portfolio to explain the benefits and strategic influence created by S&T and will argue for a progressively increasing S&T budget to match those of the UK's peers and adversaries.



⁹ The S&T offer to Defence will use the Heilmeier catechism, as detailed in paragraph 25.

Chapter 6

From Strategy to Implementation

47. This strategy will change MOD's approach to S&T, drive delivery of a new MOD core research portfolio and introduce new ways of working. MOD's core research portfolio has an increased emphasis on the delivery and implementation of innovative and transformational S&T supported by a S&T offer and Heilmeier catechism.¹⁰
48. Despite the importance of customer requirements, S&T research must not be entirely driven by them. It must, however, deliver game changing capabilities when called upon. The US Defence Advanced Research Projects Agency¹¹ has articulated the risks of focusing solely on military requirements: "*None of the most important weapons transforming warfare in the 20th century – the airplane, tank, radar, jet engine, helicopter, electronic computer, not even the atomic bomb – owed its initial development to a doctrinal requirement or request of the military.*"¹²

Strategic priorities for MOD's core research portfolio

49. Strategic direction for MOD's core research portfolio is set by the RTIB and balances the need for S&T to address the priorities for enablers, systems and Defence capabilities. For S&T to continue to contribute to Defence and Security, RTIB directed that MOD's core research portfolio must:
- Be aligned and responsive to the priorities and future needs of Defence and Security, particularly MOD's strategic challenges such as affordability, capability and future workforce;

- Deliver a balanced portfolio, addressing short and long-term needs, with an increased emphasis on strategic and speculative (high-risk, high-reward) S&T.¹³ The portfolio aims to enable transformational change in Defence and to support MOD's highest priorities;
- Identify and exploit the most promising emerging technologies and enable them to be exploited by Defence and Security; and
- Sustain critical S&T skills and capabilities to maintain the UK's freedom of action and operational advantage.

Addressing Defence and Security needs through MOD's core research portfolio

50. A new MOD core research portfolio was approved by RTIB in January 2017 (Annex B). DST will fully transition to it by 2019. The portfolio is shaped by strategic drivers, user needs and technology opportunities. It is comprised of programme elements which incorporate all of S&T's downstream activities. Figure 5 illustrates how the programme elements support Defence and Security.

- **Enablers.** Driven by strategic Defence needs, the foundation of MOD's core research portfolio develops key enablers including chemical and biological warfare defence, strategic systems, energetics, understanding future threats, data science, quantum, directed energy weapons, novel materials, autonomy and future workforce.

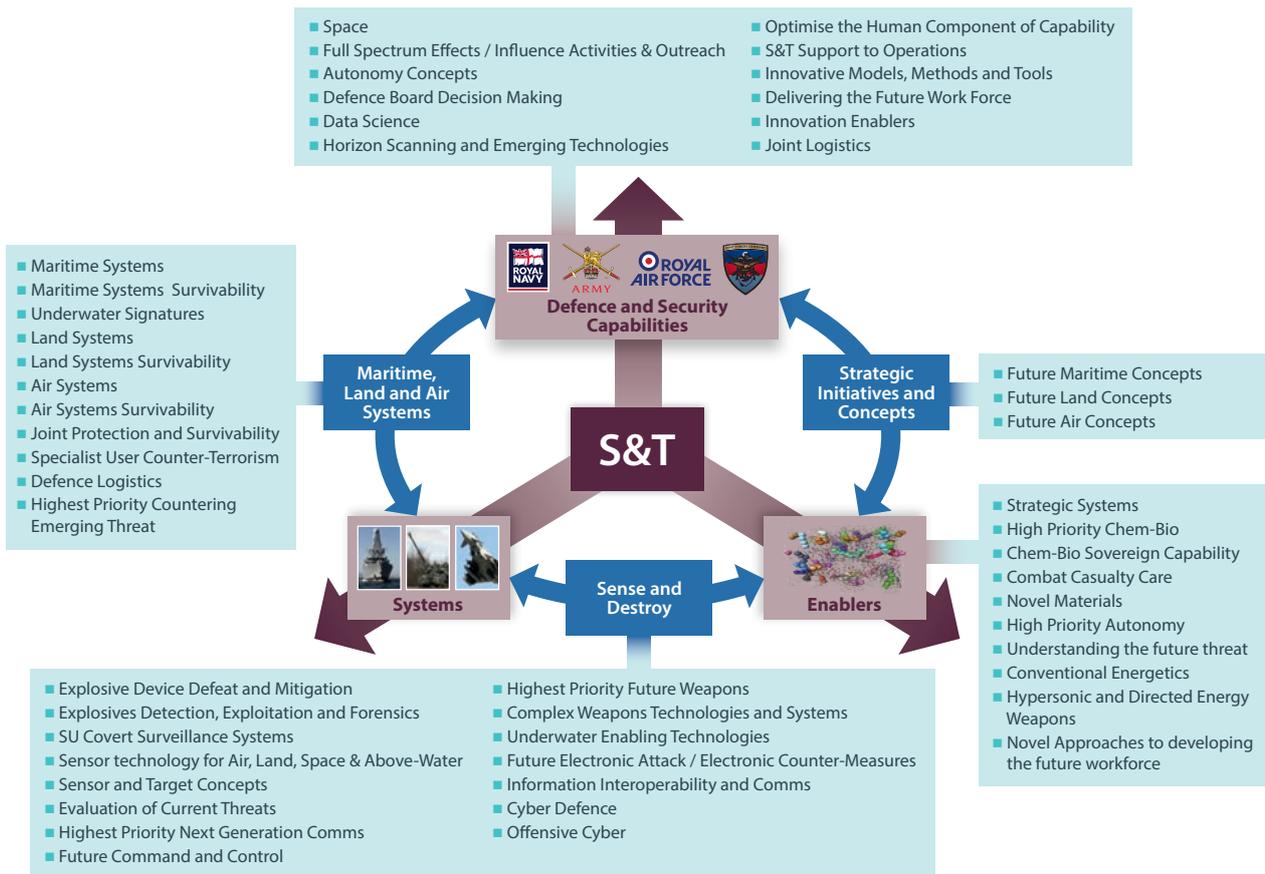
¹⁰ The S&T offer will use the Heilmeier catechism, as detailed in paragraph 25.

¹¹ www.DARPA.mil

¹² Chambers, John, ed., The Oxford Companion to American Military History quoting from DARPA Strategic Plan, US Department of Defence, 2005.

¹³ The core research portfolio is composed of driving elements (55%), responding elements (41%) and servicing elements (4%). These enable easy identification of how and where each aspect of RTIB direction is being fulfilled.

Figure 5. MOD's core research portfolio



- **Defence and Security Capabilities.** These programme elements provide the cross-cutting S&T support to highest priority SDSR 2015 challenges and capabilities: affordability, horizon scanning, space, human capability, full spectrum effects and joint logistics. They also support key strategic and operational decision making in Defence.
- **Future Concepts.** This is the critical S&T support to the identification and development of future technology concepts and is aligned with future operating concepts for Defence. These programme elements harness a range of technology enablers and use scientific

methods to support concept exploration to challenge and inform the Armed Forces in their future concept development.

- **Future Military Systems (Sense & Destroy).** These programme elements address known capability and technology shortfalls to detect and eliminate a broad range of threats. They exploit external technology opportunities where feasible and invest in niche priority areas to deliver unique Defence requirements, including sensors, cyber, electronic attack, communications, command and control, explosives and weapons technologies.

- **Current Military Systems.** These programme elements respond to the Armed Forces' needs for the development of new military systems to address known military capability risks. The S&T activities exploit and integrate a range of technologies for insertion into military systems to enable their survivability and sustainment.

Maintaining MOD's core S&T capabilities

51. Timely delivery of high impact S&T for Defence and Security relies on having access to a range of specialist capabilities in science, technology, engineering, mathematics and social science. Defence benefits from a global market in emerging S&T areas although specialist expertise in areas such as energetics, weapons and chemical and biological warfare defence take many years to develop. In light of this, MOD must understand and actively manage the health of its science base,¹⁴ including by assessing the time taken to develop, or regenerate, specialist areas.

52. An assessment of the critical S&T capabilities which MOD requires access to, now and in the future, is provided in the MOD S&T capability framework (Annex A). MOD defines S&T capability as the people, knowledge, infrastructure (including validated models and data), licences to practice, and mature relationships across government, with external suppliers and international partners.

53. Independent peer review is undertaken to assess the maintenance of appropriate depth and breadth of S&T capability aligned to this strategy. MOD assesses the health of S&T capability using the criteria and indicators shown in Figure 6 and considers whether S&T capability:

- Is achieving the necessary impact;
- Is employed on the required areas of S&T (i.e. has the correct focus);
- Is sustainable for the long-term;
- Has the ability and agility to respond in times of crisis.

Figure 6. Indicators of S&T capability health



¹⁴ Chief Scientific Advisers and their officials: an introduction, GOScience, February 2015, page 6, identifies the need to set out how the department will strategically manage its long-term needs for science and engineering expertise at all levels within the organisation. This should include statements on professional development and the need to maintain and build key external capabilities.

A collaborative approach

54. To maximise the impact and value for money of MOD's core research portfolio, MOD's S&T community will adopt a collaborative approach to deliver the portfolio and to sustain S&T capabilities. The following principles will be the back-bone of this approach:

- **International by design.** MOD will integrate its priorities for International Research Collaboration with the priorities set out in its Defence Engagement Strategy¹⁵ to build enduring partnerships in priority areas. This will reduce the costs of capability development and ownership and improve Defence's resilience and interoperability.
- **Cross-Whitehall integration and improvement.** MOD will enhance collaboration across Whitehall to maximise the value created by government expenditure on S&T and to sustain UK government S&T skills.
- **Prosperity.** S&T will exploit opportunities to enhance UK prosperity and to support industrial policy by: delivering S&T requirements through industry, working with the Department for Business, Energy and Industrial Strategy and Innovate UK, supporting exploitation of S&T into non-Defence sectors, supporting exports and enhancing our engagement with academia.
- **Exploitation.** To enable innovative S&T to be translated into Defence capabilities, MOD must remove or overcome organisational road-blocks. MOD's S&T community will collaborate closely with the Armed Forces, DE&S, MOD's Head Office and wider government to ensure that S&T can be rapidly exploited into systems and Defence and Security capabilities.
- **Core S&T capabilities.** MOD's S&T community will increase its collaboration across government, industry and academia to develop the UK's science, technology, engineering, mathematics and social science skills, ensuring sovereign S&T capabilities are sustained to ensure UK's freedom of action and operational advantage.

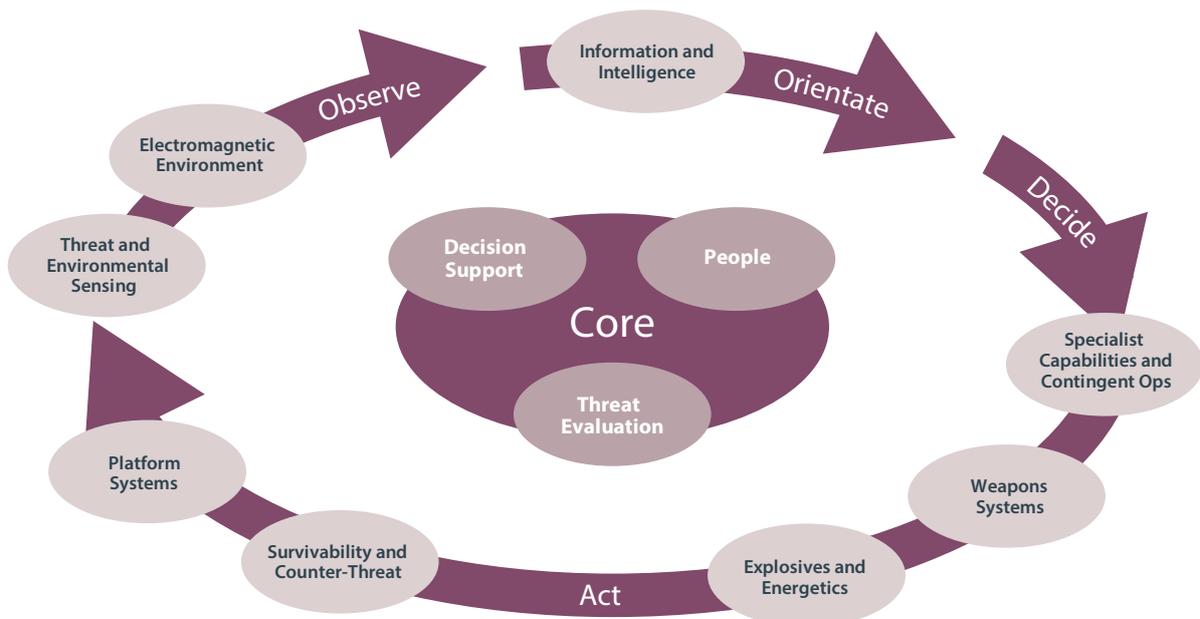
¹⁵ International Defence Engagement Strategy, 2017.

Annex A

MOD's S&T Capability Framework

1. MOD's S&T capabilities are sustained primarily through deploying people to deliver a balanced S&T portfolio. Many of the specialist S&T capabilities required by Defence and Security take a significant time to generate, requiring a clear view of the longer-term need for those capabilities to allow informed choices and effective risk management.
2. MOD has developed an S&T capability framework to support stakeholders' understanding of the S&T capabilities necessary to support Defence and Security's current and future needs. The framework enables senior decision makers to engage in discussions about the impact of strategic S&T investment choices.
3. Figure A-1 illustrates eleven strategic S&T capabilities articulated in terms of their contribution to Defence and Security. At its heart are the core S&T capabilities of People, Decision Support and Threat Evaluation which enable Defence to be prepared to respond to threats, identify technology opportunities and sustain Defence and Security advantage. Building around this core, the placement of remaining capabilities demonstrates how S&T contributes to every point in the "observe, orient, decide and act" decision cycle.¹⁶
4. Strategic S&T capabilities consist of individual capability elements which together form a complete set of technical capabilities that enable the delivery of S&T to meet Defence and Security's priorities. Figure A-2 illustrates the full S&T capability framework including all of the S&T capability elements.

Figure A-1. Strategic S&T capabilities within the 'observe, orientate, decide, act' loop

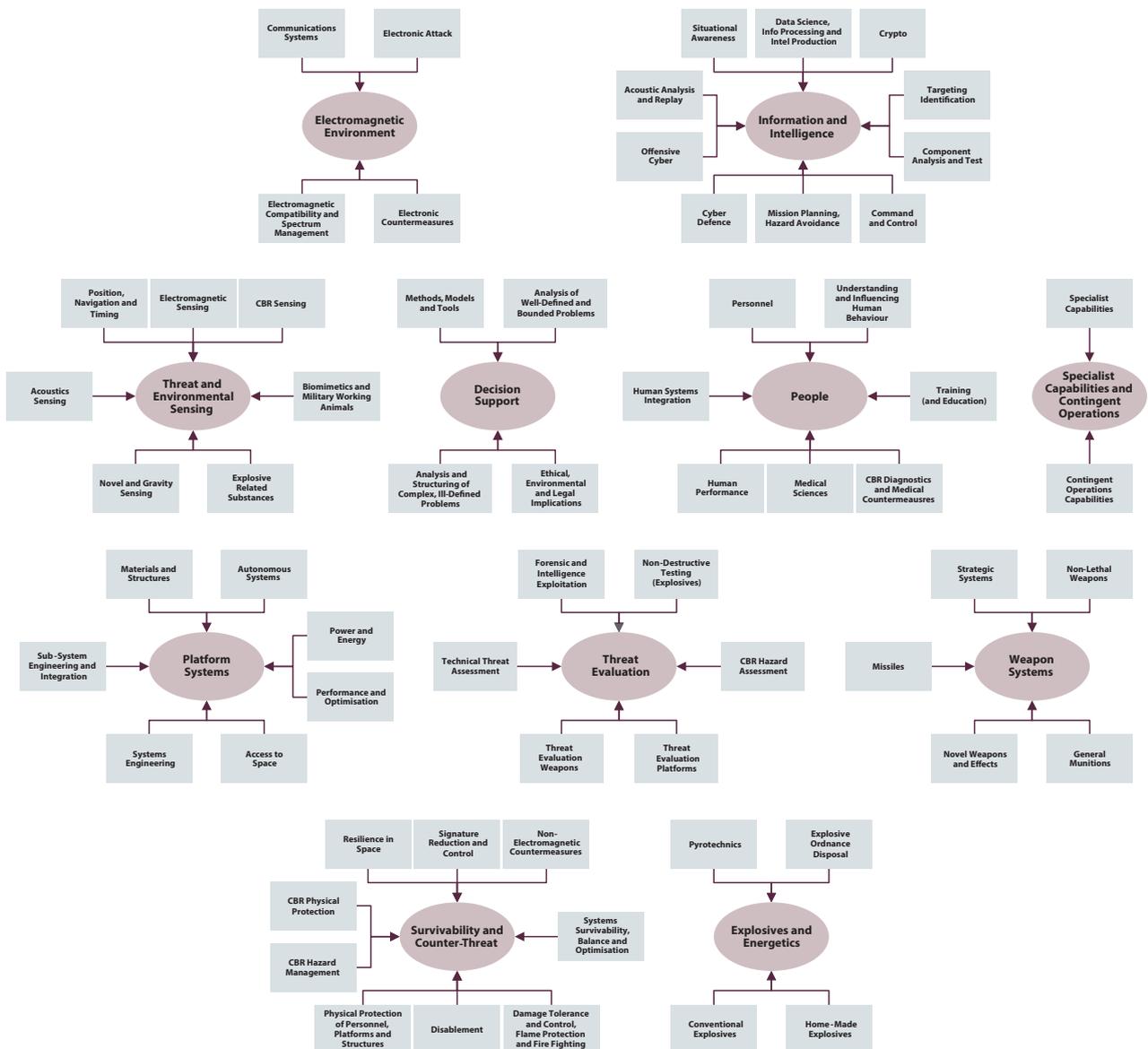


¹⁶ The 'Observe, Orientate, Decide, Act' loop was developed by Col John Boyd and is widely used in Defence.

5. MOD must adapt its approach to the development and sustainment of strategic S&T capabilities. This is driven by the need to maintain agility to respond to an uncertain future, an environment of financial constraint, high levels of global investment and the rapid pace of

technology development. To support capability sustainment this strategy places a greater focus on innovation, different ways of doing business, a greater emphasis on leveraging private sector investment and mutual reliance on the UK's allies and other government departments.

Figure A-2. MOD's S&T Capability Framework



Annex B

MOD's New Core Research Portfolio

Figure B-1. MOD's 2019 Core Research Portfolio

Transition to user funding	Maritime Environment Advice (D)	Air Environment Advice (D)	Land Environment Advice (D)
	Joint Environment Advice (D)	Defence Board Decision Making (D)	
<i>Concepts, Systems and Survivability</i>			
Highest Priority Countering Emerging Threat (D)	Maritime Systems (C)	Air Systems (C)	Land Systems (C)
Joint Protection and Survivability (D)	Maritime Systems Survivability (C)	Air Systems Survivability (C)	Land Systems Survivability (C)
Joint Logistics (D)	Future Maritime Concepts (C)	Future Air Concepts (C)	Future Land Concepts (D)
Defence Logistics (D)	Underwater Signatures (D)		Specialist User Counter-Terrorism (B)
<i>Sense and Destroy</i>			
SU Covert Surveillance Systems (B)	Underwater Enabling Technologies (C)	Sensor technology for Air, Land, Space and Above-Water (C)	Sensor and Target Concepts (A)
	Highest Priority Next Generation Comms (D)	Information Interoperability and Comms (A)	Future Command and Control (C)
Explosives Detection, Exploitation and Forensics (C)	Future Electronic Attack / Electronic Counter-Measures (B)	Highest Priority Future Weapons (D)	Cyber Defence (C)
Explosive Device Defeat and Mitigation (C)	Evaluation of Current Threats (B)	Complex Weapons Technologies and Systems (B)	Offensive Cyber (D)
<i>Supporting Strategic Defence Initiatives</i>			
Space (B)	Full Spectrum Effects/ Influence Activities and Outreach (C)	Optimise the Human Component of Capability (C)	Delivering the Future Work Force (C)
	Autonomy Concepts (C)	Data Science (C)	Innovation Enablers (D)
S&T Support to Operations (D)	Defence Board Decision Making (D)	Innovative Models, Methods and Tools (C)	Horizon Scanning and Emerging Technologies (C)
<i>Enablers</i>			
High Priority Chem-Bio (A)	Conventional Energetics (C)	Combat Casualty Care (C)	High Priority Autonomy (B)
Chem-Bio Sovereign Capability (C)	Hypersonic and Directed Energy Weapons (B)	Novel Approaches to developing the future workforce (C)	Novel Materials (B)
	Strategic Systems (B)	Understanding the future threat (C)	
Key	Driving Programme Element	Responding Programme Element	Servicing Programme Element
	Annual MOD core research investment: £15M+ (A)	£5M-£10M (C)	
	£10M-£15M (B)	£2M-£5M (D)	

Annex C

Lexicon

This lexicon contains acronyms used in this document.

CSA	Chief Scientific Adviser
DE&S	Defence Equipment and Support
DST	Defence Science and Technology
Dstl	Defence Science and Technology Laboratory
MOD	Ministry of Defence
RTIB	Research Technology and Innovation Board
S&T	Science and Technology
SDSR	Strategic Defence and Security Review
UK	United Kingdom

Notes

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