Innovation Models

Enabling new defence solutions and enhanced benefits from science and technology

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RAND EUROPE

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Published by the RAND Corporation, Santa Monica, Calif., and Cambridge, UK

Preface

The UK Ministry of Defence (MOD) is interested in innovation models and the ways in which they can be used to better harness and absorb innovation from external sources. To this end, the MOD commissioned RAND Europe to conduct a study of innovation models and make recommendations on changes the MOD could make.

The research considered different innovation models and developed a framework that describes innovation systems in general and is applicable to defence in particular. The analysis was built around this framework, with four recommendations being developed for changes the MOD should make internally. These recommendations are based on how the MOD engages with external actors, how it should create and participate in innovation networks and how it could create and use spaces for innovation.

This report has been prepared for the Defence Science and Technology (DST) staff in the MOD and for the Defence Science and Technology Laboratory (Dstl). It will be of interest to those working in innovation, science, and technology policy more generally and those with a specific interest in defence research and technology development.

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This study aims to help the MOD enhance the benefits from engagement with external sources of innovation

This study was commissioned by the MOD Chief Scientific Adviser (CSA) through Dstl to help the MOD enhance the benefit and value its science and technology (S&T) programme obtains from external sources of innovation. To this end, it aims to identify ways in which the MOD can better harness and absorb innovation from actors across academia, industry and the public sector. The goal of the study is to deliver a set of evidence-based recommendations that could lead to improved outcomes for the MOD's S&T research investment, considering both the national and global innovation ecosystems. Our evidence was gathered from a literature review, key informant interviews and expert workshops.

Innovation can be understood broadly as the creation and application of new products, services and processes. It encompasses new technology as well as new ways of doing things. While the term has become a widespread buzzword for the emergence of new ideas across diverse sectors, innovation is more than just the creation of novel concepts. Innovation includes the process of invention; however, it goes one step further to 'make good ideas stick' by ensuring that new ideas are applied to the benefit of end-users.

Innovation systems can be described by a framework of eight key factors

Our research revealed a consistent set of factors which were emphasised as critical to the innovation process which the study team used to create an analytical framework of innovation consisting of eight key factors as illustrated in Figure 1.

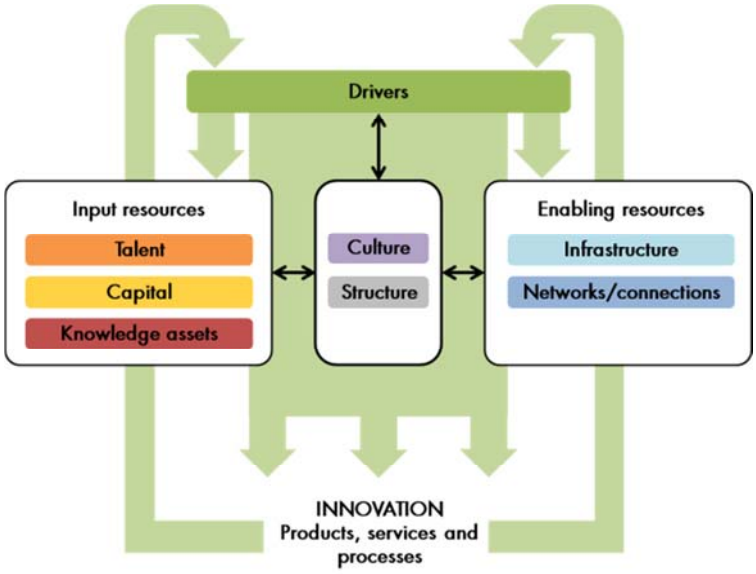
Any innovation process begins with an impetus. **Drivers** are the motivations which spur innovation to occur. The key drivers for innovation will vary by sector depending on the incentives and perceived benefits of innovation; for defence drivers include enhancing military capability, whereas for companies the key driver is profit.

Input resources are the primary components required for an organisation to innovate, which we have identified as knowledge assets, talent and capital. **Knowledge** is required to discover the new ideas that spur innovation as well as to refine, catalyse, apply, share and market these ideas in a usable form. **Talent** refers to both the technical and managerial expertise necessary to support successful innovation processes. **Capital** is required not only to fund the creation of ideas but also to effectively package and deliver this knowledge as an innovation.

Enabling resources such as infrastructure and networks and connections allows an organisation to bolster its knowledge assets, talent and capital through engagement with other actors. **Infrastructure** includes facilities and research hubs that provide a physical space for innovation, such as universities, science parks and test facilities. **Networks and connections** encourage the exchange of knowledge, the mingling of talented individuals and the connection of suppliers to end users.

Influencing the drivers and resources throughout our analytical framework are two shaping factors – culture and structure – which are highly interdependent in the innovation process. Innovation thrives in organisations with a **culture** that is open, trusting, and conducive to risk-taking and learning from failure rather than avoiding it. A supportive culture of innovation is often linked to leadership which is future-orientated and willing to support creative solutions. Closely linked with culture is **structure**, which includes organisational, management and bureaucratic structures. Bureaucracy and formal rules may act to constrain innovation by restricting knowledge exchange or productive partnerships.

Figure 1: Our analytical framework for understanding the innovation process



SOURCE: RAND Europe analysis.

The MOD performance against the innovation framework as a whole needs to improve to ensure that it can access innovation

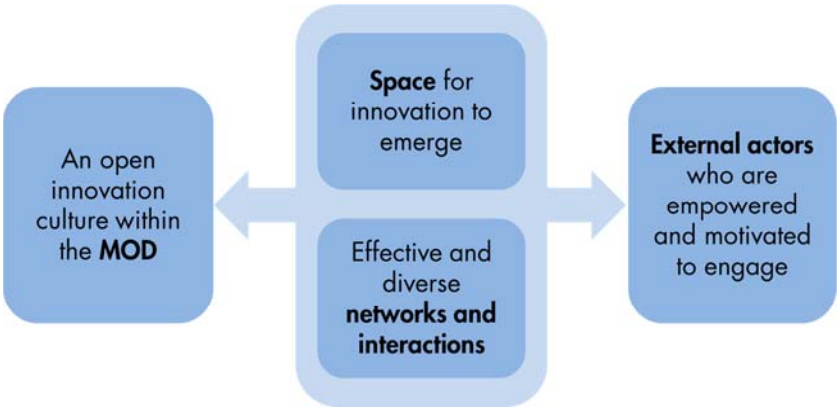
The MOD has clear drivers of innovation, but these are not communicated in a clear and compelling way to the wider innovation ecosystem. Furthermore, the MOD has considerable knowledge, talent and capital, but these will not be sufficient for it to harness innovation in all areas, particularly the broad range of emerging technologies relevant to defence. The MOD will need leadership as well as technical and managerial talent to leverage its resources to achieve greater innovation effect. The MOD's facilities are relevant for defence testing and evaluation but it needs to network and take advantage of the wider innovation infrastructure across the UK. Perhaps most importantly, the MOD cultures and structures (ways of working and processes) are notably risk averse and need to be changed to ensure the MOD can

harness innovation.

Recommended changes for the MOD comprise four thematic levels

Having assessed the MOD against our innovation framework, the study team identified various options for improving performance against each factor and in our analysis we identified four areas that should be addressed in order to develop a comprehensive and effective innovation model (modelled in Figure 2). As a starting point, changes must be made to the ways of working within the MOD itself; without an internal environment that is conducive to innovation, new opportunities for collaboration will be ineffectively exploited. At the same time, external actors must also be incentivised and able to participate in innovation with and for the MOD. Once both internal and external players are open to engaging on innovation, it becomes necessary to improve the ways in which their connection occurs. The dynamics of interactions should thus be adapted to encourage a range of engagement mechanisms. At the same time, new space should be created for diverse actors to come together and develop new solutions.

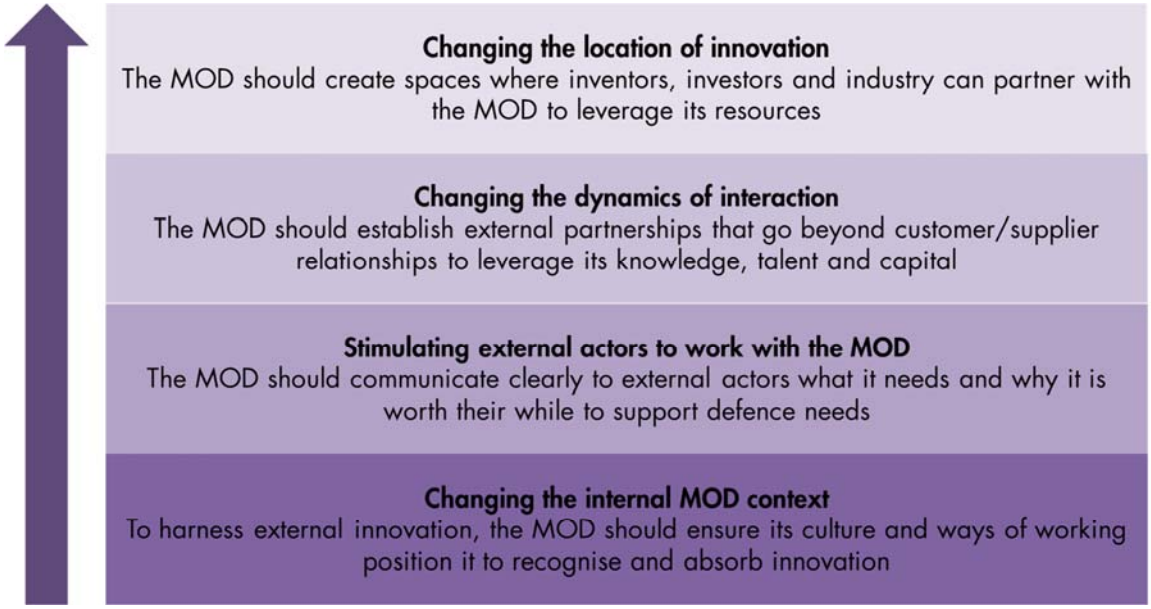
Figure 2: A comprehensive innovation model of MOD engagement



SOURCE: RAND Europe analysis.

To work towards an innovation system in which the MOD engages with external actors through a productive two-way process, each of the four areas is accompanied by an overarching recommendation for the MOD. For implementation to be most effective, these areas should be pursued in a cumulative manner. Figure 3 shows how the four areas of change act as 'building blocks' towards an effective innovation system, starting with basic internal changes to the MOD and eventually reaching more radical development of external shared spaces.

Figure 3: A tiered approach to improving the MOD's innovation model



SOURCE: RAND Europe analysis.

Note on terminology

For the purpose of this study, the term 'should' means that the evidence gathered through our research suggests that what is stated is the recommended course of action; while there may exist valid reasons in particular circumstances to ignore a particular aspect, the full implications must be understood and carefully weighed before choosing a different course.

To harness external innovation, the MOD should ensure its culture and ways of working position it to recognise and absorb innovation

The first step in improving the MOD's innovation model is to change the internal MOD context. This stage is a critical enabler of all other engagement reforms, as external engagement can only be productive if its outputs resonate with MOD internal priorities and processes. This includes specifically ensuring that the innovation process adopts only the minimum bureaucracy necessary, and the MOD should undertake a 'red tape review' of the innovation process to eliminate administrative procedures that do not support innovation. Innovation should be measured in terms of maturity and the innovation framework to ensure that internal and external collaborators understand what is required to develop new solutions. The MOD should act to reduce any constraints to innovation that arise from within the organisation, for example Defence Standards that effectively make solutions bespoke to the UK market. MOD staff should be given, and feel that they have, time and opportunity to try new ideas, and incentives should be available to encourage this. An observation from our interviews and workshops is that the MOD internal customer/supplier relationships are very contractual in nature and should instead be focused on innovation in partnership towards a shared endeavour.

The MOD should communicate clearly to external actors what it needs and why it is worth their while to support defence needs

Even if a positive innovation culture is established internally, the MOD still requires buy-in from external actors to benefit from engagement with the wider innovation landscape. The MOD must thus also ensure that external actors are motivated and equipped to engage effectively with the defence innovation space. The MOD should publish an innovation policy setting out why and where it needs innovation, and how it wishes to work with others to achieve this. Competition is a key driver of innovation and the innovation policy should set out the MOD's approach to competition at different stages from early ideas through to development. But competition is one tool amongst many to support innovation; at the early stages of development, competition can encourage the generation of a whole range of excellent ideas, whereas at the later stage of development it risks reducing the incentives to industry to invest much of their own capital. Competition is, therefore, a tool to be used appropriately; the 'red tape review' should identify which tools are appropriate at which stage of the innovation process.

The MOD should have external networks of technical and managerial experts it can call on to support the innovation process. The MOD should improve the accessibility of the innovation process. The United States Department of Defense, for example, has the Defense Innovation Marketplace, which provides a place where all the relevant information is brought together.

The MOD should establish external partnerships that go beyond customer/supplier relationships to leverage its knowledge, talent and capital

The MOD should make an explicit shift from a customer/supplier relationship to more partnership-orientated relations with external actors. Efforts to change the cultural dynamic would be complemented by the establishment of an honest broker, an organisation that can actively begin to seek such relationships, encourage them, as well as to identify the opportunities that are most attractive to the MOD, upon which these partnerships should focus. Through the auspices of such a broker, the networks would be enhanced; greater cross-sector partnerships would be developed; and knowledge assets would be leveraged. Finally, in addition to these benefits, better and more active identification of opportunities, and a turn to partnership relationships would allow the MOD to better leverage private investment and the skills and knowledge of venture capitalists and other investors.

The MOD should create spaces where inventors, investors and industry can partner with the MOD to leverage its resources

In a thriving innovation ecosystem, there should be not only motivated actors and productive interactions but also the space (physical or virtual) to come together to explore new relationships and ideas. Our final recommendation considers how the MOD can help create and facilitate this type of space by providing and participating in innovation infrastructure.

MOD efforts to engage with external innovation actors would be greatly supported by a central 'marketplace' providing a space for stakeholders to interact and share knowledge. A thriving marketplace hub would raise awareness of opportunities for procurement or investment while facilitating new relationships among stakeholders.

The reviewed literature and stakeholder interviews confirm the positive impacts of establishing facilities where knowledge can be shared and inputs and enablers combined. To provide an open space for facilitating innovation, the MOD should establish external facilities, accessible to the public and hosted by partner organisations, to leverage knowledge assets and stimulate information exchange and experimentation.

We have suggested specific actions against our recommendations that the MOD could consider in the context of the academic sector

We were asked to extend the project by providing further detailed analysis of what our recommendations would mean in the context of the academic sector. Our approach was to identify specific actions that the MOD could take against each of the four recommendations and to test these against the literature and through further key informant interviews, in particular to identify rough order of magnitude (ROM) costs for implementing the specific actions. These estimates should be treated as indicative – to inform discussion about implementation – rather than as a definitive implementation plan.

Our analysis showed that actions to address the internal MOD context, such as appointing an innovation champion, can be achieved relatively quickly and at relatively little cost. Similarly, actions to help communicate the MOD's needs such as publishing an innovation policy and an academic engagement plan could be delivered fairly quickly using MOD internal resources, with external support as necessary, for a ROM estimate of £250,000–500,000.

Actions to change the dynamics of interaction with the academic sector could be more costly, and our research showed that honest broker initiatives in other countries have cost between £1m–3m per annum. We have suggested that the MOD could use funding mechanisms that encourage partnership to establish outstations at centres of expertise in emerging technologies, and we identified examples that enable us to estimate a ROM cost of £4m–8m for each outstation.

A further option we suggested is that the MOD could establish an open innovation campus centred around an MOD site, where the MOD, academia, industry and investors can work together. Examples of similar initiatives we identified allow us to offer a ROM estimate of £38m–150m for the first phase of such a project, for which the funding can be shared between various actors.

The barriers to change are neither insignificant nor insurmountable

The findings from our expert workshop, with representatives from the MOD, Dstl, defence industry, SMEs and entrepreneurs, confirm that the recommendations should have a significant beneficial impact for the MOD, and the specific actions within them are fairly evenly split between low and high feasibility. The barriers to implementation identified at the workshop include the difficulty of changing attitudes, in

particular with regards to risk and reward, the difficulty in achieving consensus amongst internal stakeholders and the challenge of taking defence prime contractors along with the MOD through a process of change.

For any significant programme of change the constraints identified are familiar challenges and whilst we do not consider them to be trivial nor do we consider them to be insurmountable. The innovation framework provides a useful tool for thinking about what is required to develop a thriving innovation ecosystem, and our framework has identified eight key factors for innovation that the MOD should consider. The recommendations we have presented are incremental. They range from what the MOD can do to improve its own culture and processes through to more ambitious recommendations about how to develop new partnerships for innovation and create new spaces in which to bring together experts in support of innovation for defence. The degree to which the MOD implements these recommendations will be dependent on its appetite for significant change and its ability (in time and resources) to support such changes.

Acknowledgements

In conducting this study we owe a debt of gratitude to many people who have provided their time, advice and support throughout the process.

We are particularly grateful to Louise Owen, Laura Shaw and Dan Cassidy in the Ministry of Defence (MOD) and Ian Youngs, Joe Capitelli and Glynn Field in the Defence Science and Technology Laboratory (Dstl) who, in addition to sponsoring and managing this study, have provided numerous contacts and sources of information and have always engaged in stimulating dialogue as the study progressed and provided invaluable feedback.

Within RAND Europe we are particularly grateful to Matt Bassford and Joanna Chataway for providing advice and guidance on the conduct of the study and for contributing their expertise on defence and innovation to the workshops.

Several other staff and interns at RAND Europe deserve particular mention for their considerable contribution to the literature review and analysis and their support in preparing for the workshops and our thanks is extended particularly to Filip Tucek, John Watts, Margaux Pinaud, Alex Hull, Alex Kokkoris, Louise Taggart and Jacopo Bellasio.

The final words of thanks are for our quality assurers in RAND Europe, Magda Long and Catriona Manville, whose comments and questions were gratefully received and made sure the final report was as rigorous and robust as it could be.

Abbreviations

AC	Absorptive Capacity
ARL	Army Research Laboratory
AWE	Atomic Weapons Establishment
BIS	Department for Business, Innovation & Skills
BT	British Telecom
CDEL	Capital Departmental Expenditure Limit
CSA	Chief Scientific Advisor
DE&S	Defence Equipment and Support
DERA	Defence Evaluation and Research Agency
DeVenCi	Defence Venture Catalyst Initiative
DST	Defence Science and Technology
Dstl	Defence Science and Technology Laboratory
DefStans	Defence Standards
DOD	United States Department of Defense
EPSRC	Engineering and Physical Sciences Research Council
FLCs	Front Line Commands
GBAORD	Government Budget Appropriation or Outlays for Research & Development
IC	Innovation Champion
ICT	Information and Communications Technology
IPR	Intellectual Property Rights
ITAR	International Trade in Armaments Regulations
KTN	Knowledge Transfer Network

LTPA	Long-Term Partnering Agreement
MOD	Ministry of Defence
NASA	National Aeronautics and Space Administration
NHS	National Health Service
NPR	NASA Research Park
ONS	Office for National Statistics
PAF	Project AIR FORCE
QQ	QinetiQ
RAE	Research Assessment Exercise
R&D	Research and Development
R&T	Research and Technology
RCUK	Research Councils UK
RDEL	Resource Departmental Expenditure Limit
REF	Research Excellence Framework
ROM	Rough Order of Magnitude
S&T	Science & Technology
SGC	Structural Genomics Consortium
STFC	Science and Technology Facilities Centre
SMEs	Small and Medium sized Enterprises
STEM	Science, Technology, Engineering and Mathematics
TSB	Technology Strategy Board
UARCs	University Affiliated Research Centres
UDRC	University Defence Research Collaboration
UK	United Kingdom
UORs	Urgent Operational Requirements
VC	Venture Capitalist
WIL	Work-Integrated-Learning

1. Scene setting: a narrative for the potential future of innovation in the MOD

The future is uncertain, but aspirations can help shape what the future might become. Innovation, a seemingly simple subject, holds much potential for the UK Ministry of Defence (MOD), but what should be the radical vision of the future to which the MOD aspires? A future commentator might write:

The scientific and technical staffs of the MOD have become national exemplars of the process of rapidly fielding new products, services and processes that provide excellent military capability, even though the resources available are fewer than desired. The scientific leadership in the MOD has pulled off this remarkable feat by setting an ambitious innovation policy that shakes off traditional ways of working and focuses on creating an innovation culture across the MOD. The managerial cadre in the MOD has been strengthened with expertise in innovation practices which is driving the change in all areas. A defining feature is the relationship with external partners from academia, small companies and defence industries that is centred on working together to quickly test ideas that offer incremental and radical improvements. The streamlined process is focused on testing ideas, learning from the experience and sharing findings to create collaborations that are prepared to invest their talent, knowledge and capital in taking each idea to the next level. The former fear of failure has been replaced by a climate of critical optimism where risks are encouraged, provided that substantial learning can be achieved whatever the outcome.

This new approach has had a galvanising effect on inventors, industry and investors, many of whom have never worked before with the MOD. By providing an innovation brokerage supported by an agile and responsive commercial process, the MOD has brought together all of these parties and stimulated them to work together both on proofs of concept and also more developed solutions. The broker, operating from purpose-built maker spaces and test and demonstration facilities, matches up ideas with investors and industry to ensure talent, knowledge and capital are pooled for each step of the development process and the rights of each party are adequately protected. The MOD contributes knowledge of the needs of the military and the likely market it could offer for any new solution, but it does not provide all of the funding. Part of the broker's role is to leverage MOD funding and expertise to catalyse the innovation process rather than be the complete life-support system.

And the outcomes of this new approach? New ideas are becoming reality much faster because the right technical experts are matching their ideas with military needs, industry programmes and funding opportunities. The MOD has leveraged its research budget by 100 per cent and the network of experts taking part in competitions of ideas and providing entrepreneurial advice has boomed. And, at the end of the day, the MOD is getting more military capability for its money including innovations that actually reduce the cost of current operations.

There is no way of proving that these outcomes would be the future of innovation in the MOD and its supply base. Nevertheless our analysis in the following pages identifies clear evidence that points to different areas where changes could be made to make sure that this vision for the future, though challenging, is not unrealistic. Through our review of the evidence, which has included interviews and workshops, we have seen that the MOD has some of the resources necessary to support innovation, but there are inherent cultural challenges, in particular risk aversion, which already limit its ability to harness innovation and will continue to do so unless significant changes are made. To better harness innovation in the future the MOD will need to change its ways of working, leveraging its resources and working differently with a range of partners to take advantage of a broad range of opportunities.

2. Study objectives and methodology

2.1. Defence innovation has been shaped by an evolving fiscal context and research infrastructure

The MOD has long had an active research programme which has produced innovations in the defence context as well as spin-outs into wider civil society. Over the past 25 years, however, shifts in the defence research infrastructure and national fiscal climate have changed the capabilities and resources available for defence innovation. This evolving context has led the MOD to consider new ways to leverage and benefit from research and innovation beyond the defence sphere.

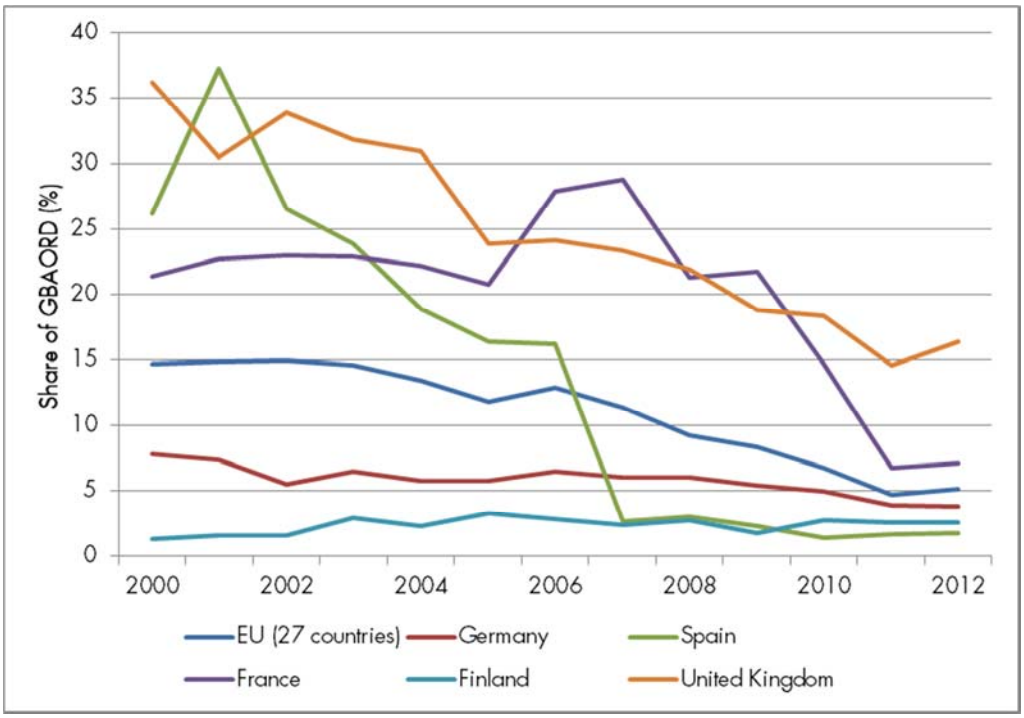
The past 15 years have brought significant transformation to the UK defence research establishment. Through the late 1990s, the Defence Evaluation and Research Agency (DERA) and its predecessors aimed to deliver objective research and analysis to the MOD through government owned and operated laboratories. In 2001, DERA was divided into two new institutions. Much of the technical expertise formerly held by DERA was moved into the new private company QinetiQ (QQ) while certain key competencies were retained by the MOD through the Defence Science and Technology Laboratory (Dstl).[1] By transferring a significant portion of the defence research infrastructure to the private sector, this reorganisation established a heightened need for the MOD to engage with external actors in order to further defence innovation.

Since the establishment of Dstl in 2001, the need for external engagement has been further exacerbated by a steep decline in public funding for defence research and development (R&D). Echoing a wider trend in European defence spending, the share of government budget appropriations or outlays for R&D (GBAORD) allocated to defence in the UK fell by more than 50 per cent from 2000 to 2012 (see Figure 2.1). Such reductions in defence research budgets have forced decision-makers to consider 'value for money' and market-based incentives as part of how innovation can be brought into the MOD.[2] At the same time, the gap between total expenditure on civil and defence R&D has widened steadily since 1989 (see Figure 2.2). This context has contributed to the need for the MOD to establish and benefit from enhanced engagement with research and innovation in the civil sphere.

[1] James et al. (2005).

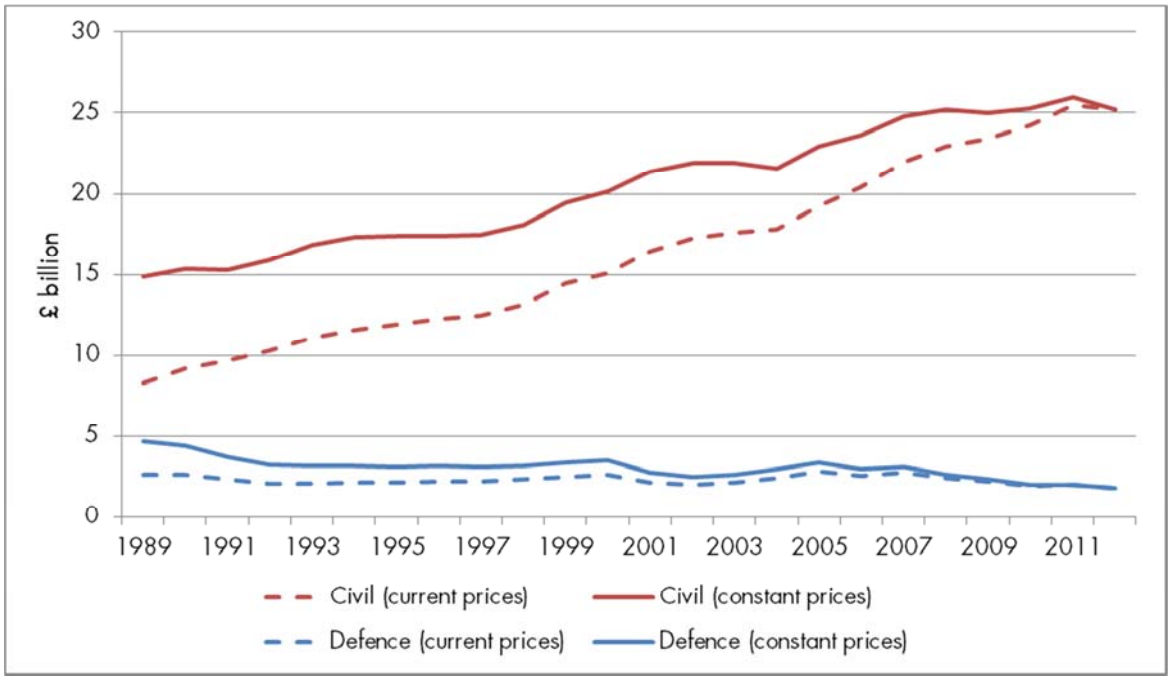
[2] Avadikyan & Cohendet (2009).

Figure 2.1: Share of GBAORD allocated to defence objectives



SOURCE: Eurostat (2014).

Figure 2.2: Expenditure on civil and defence R&D performed in the UK, 1989 to 2012



SOURCE: Office for National Statistics (ONS) (2014, 8).

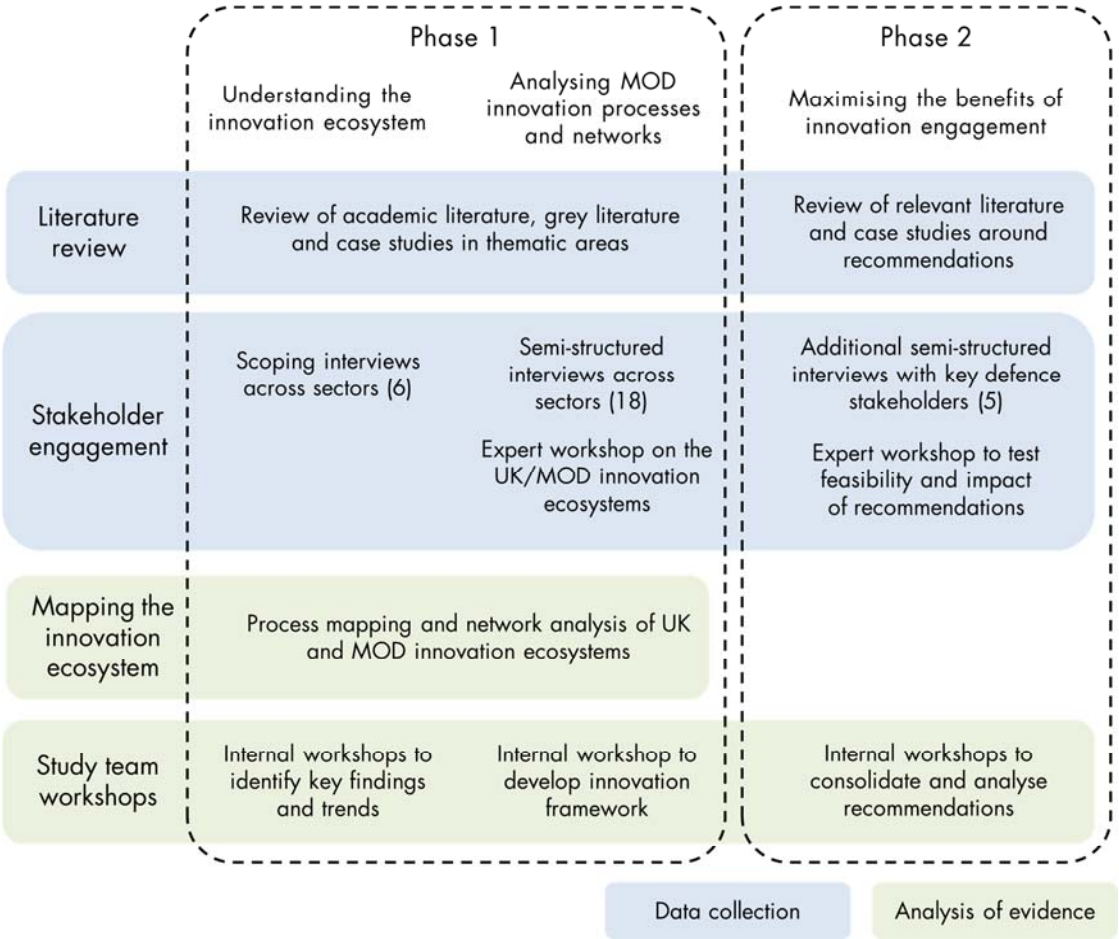
2.2. This study aims to help the MOD enhance the benefits from engagement with external sources of innovation

This study was commissioned by the MOD Chief Scientific Adviser (CSA) through Dstl to help the MOD enhance the benefit and value its science and technology (S&T) programme obtains from external sources of innovation. To this end, it aims to identify ways in which the MOD can better harness and absorb innovation from actors across academia, industry and the public sector. The goal of the study is to deliver a set of evidence-based recommendations which could lead to improved outcomes for the MOD's S&T research investment, considering both the national and global innovation ecosystems.

2.3. The project team applied a structured methodology to meet the study objectives

The RAND Europe project team devised a structured methodology to address the study objectives, building in distinct steps for both collection and analysis of evidence (as shown in Figure 2.3).

Figure 2.3: Overview of study methodology



2.3.1. The study was carried out in three main phases to enable the creation of recommendations emerging from a robust evidence base

The study took place between April and November 2014 and was organised into three main phases:

- **Phase 1** focused on the mechanisms and relationships within the innovation ecosystem and the role of the MOD in this context. Drawing from an evidence base of literature review and stakeholder engagement, the study team identified eight factors that were critical to a successful innovation process. These factors were used to create an evidence-based framework for innovation, described in more depth in Chapter 2.
- **Phase 2** involved the formation and validation of a set of recommendations for the MOD. These recommendations emerged from our initial evidence base and were rigorously validated through additional targeted literature review, drawing upon relevant case studies where possible. They were further tested and refined through select stakeholder interviews and a final expert workshop.
- **Phase 3** was an extension to the main study to investigate how the recommendations of the main report could be applied in the context of the academic sector. This phase took place during three weeks between October and November 2014.

A more detailed description of the components of the study methodology is provided in the annex and appendices.

2.4. This report presents our findings and recommendations through an analytical framework of innovation

This report consists of six chapters, which capture our understanding of the MOD's role in the wider innovation ecosystem and present structured recommendations for improving its engagement with external actors. It is structured around an evidence-based framework of analysis developed by the study team. In addition to this introductory chapter, the report contains the following elements:

- **Chapter 3** presents our analytical framework for understanding the innovation process, elaborating eight key factors in the context of the MOD.
- **Chapter 4** describes our recommendations through a thematic approach, focusing on four levels of change within the MOD innovation model.
- **Chapter 5** evaluates our recommendations for the MOD based on their feasibility and impact.
- **Chapter 6** concludes with our key findings and prioritised recommendations for the MOD.
- **Annex 1** provides the findings of Phase 3, the study extension that considered how the recommendations could be applied in the context of the academic sector.

A number of appendices are also provided to explain aspects of our methodology in more detail.

Note on terminology

For the purpose of this study, the term 'should' means that the evidence gathered through our research suggests that what is stated is the recommended course of action; while there may exist valid reasons in particular circumstances to ignore a particular aspect, the full implications must be understood and carefully weighed before choosing a different course.

3. An analytical framework for understanding innovation

This chapter presents the mechanisms and processes involved in innovation, drawing upon an analytical framework developed by the study team. It then elaborates on eight critical innovation factors in the context of the MOD.

3.1. Innovation involves the creation and application of new products, services and processes

Innovation can be understood broadly as the creation and application of new products, services and processes. It encompasses new technology as well as new ways of doing things.[3] While the term has become a widespread buzzword for the emergence of new ideas across diverse sectors, innovation is more than just the creation of novel concepts. Innovation includes the process of invention; however, it goes one step further to 'make good ideas stick' by ensuring that new ideas are applied to the benefit of end-users.[4]

The impact of innovation can vary widely. **Radical innovation** involves the introduction or 'breakthrough' of completely new products, services or processes.[5] **Incremental innovation** involves the refinement over time of existing products and processes to provide gradual improvements in quality or value.[6] Although this type of progress is not as extreme as radical innovation, it produces significant advances over the long term. While the creation of the first automobile can be considered a radical innovation, for example, the subsequent refinement over many decades has produced a much safer, more efficient and comfortable product than the original model. Whether a given innovation has radical or incremental impact will depend on a range of factors, including market alternatives and both direct and indirect costs of its uptake across a given sector.[7]

[3] Porter (1990).

[4] Interviews conducted by RAND Europe (2014).

[5] Bierly et al. (2009); Kang & Snell (2009).

[6] Bierly et al. (2009); March (1991).

[7] Bierly et al. (2009); Wejnert (2002).

3.1.1. Innovation systems require a range of different actors serving different functions

While innovation can be carried out by individual organisations, it does not happen in a vacuum. Innovation processes occur within systems that are broader than a single firm, organisation, or even group of producers (which in the defence context is often referred to as the 'defence enterprise'). Innovation system models aim to capture the wider level of features, functions and resources that are necessary for innovation to thrive.[8] Systems thus account for variables such as: the R&D structure of a region or country; available skill sets within a society or locale; access to funding and investment capital available; and the surrounding policy environment. They also involve a range of actors playing complementary and interlinked roles in the innovation process.

Innovation has generally been described as being carried out by a firm of some sort (from large multinationals to individual entrepreneurs launching a new start-up). The system models acknowledge, however, that there are other key actors in the system. Other **businesses and firms** may provide industry partnerships, training opportunities, R&D labs and market competition that support the overall innovation process. **Universities and public research organisations** are crucial contributors to the knowledge creation process in terms of identifying new areas of research, conducting blue sky research,[9] and interacting with industry in areas spanning the spectrum of applied research. Academic and research institutions also may play a role in lobbying for new resources or policies that can impact knowledge creation and use. **Government and public bodies** provide many support mechanisms, resources and infrastructures that firms require in order to create and market their innovations. **Investors** are also crucial, and may take the form of private venture capitalists and angels,[10] public sector investment bodies, or large institutional investors such as pension funds. Finally, there are also **intermediary actors** who provide other interactions that facilitate the innovation process, including actors such as suppliers, patent lawyers, technology transfer organisations and other service providers.[11] The roles of the key actors in the UK innovation ecosystem are illustrated in more detail in Appendix A.

While taking into account this range of complementary actors, innovation systems models are orientated towards different aspects of the innovation process. Some systems of innovation focus on interactions within a bounded jurisdiction: **national systems** consider actors and networks on a national scale, while **regional systems** take a more localised view.[12] **Cluster theory** models similarly concentrate on proximity by considering various actors and resources that are generally 'clustered' around a major urban area.[13]

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[8] Hekkert et al. (2007).

[9] Blue sky research is also known as basic research; it is essentially research which has not yet developed any applications, but rather a pursuit of discovery or knowledge building before applications can be determined.

[10] Angel investors are private individuals who invest in entrepreneurial ventures, generally at the start-up phase. In most cases they invest and take a share of equity before larger venture capital or institutional investors come in.

[11] Porter (1990).

[12] Cooke (2001); Lundvall (2007).

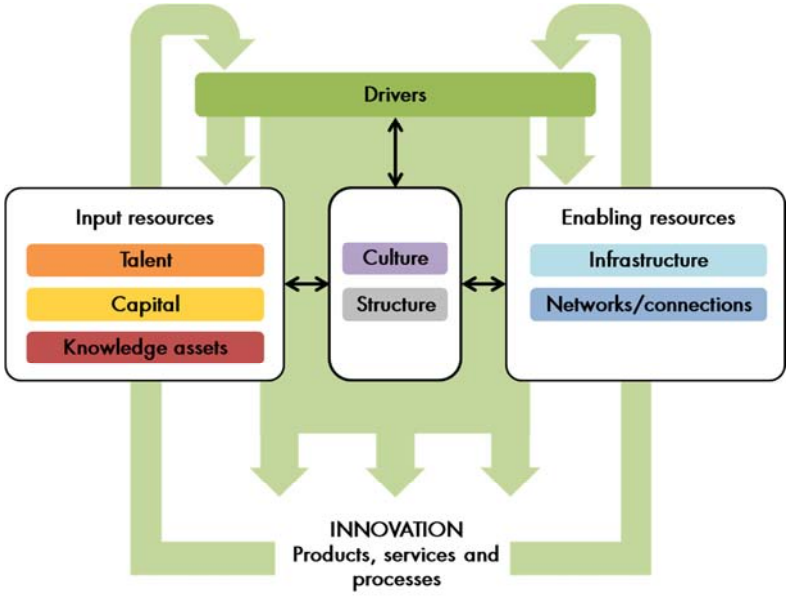
[13] Porter (1990).

Other systems focus more directly on the type of actors involved in the process. **Sectoral systems** consider how the unique needs, practices, interactions and development timelines of a specific sector (such as biotech or information technology) shape their overall innovation processes.[14] The **Triple Helix** model focuses on the nature of different actors, viewing innovation as being equally influenced by interactions between the domains of industry, academia and government.[15] The overlap between these models is significant, with most of the differences pertaining to the emphasis placed on different components rather than the actual factors identified.

3.2. Our framework for innovation draws upon eight key interactive factors

As reflected in the system models of innovation described above, our research revealed a consistent set of factors which were emphasised as critical to the innovation process. Using the evidence emerging from our literature review and stakeholder engagement, the study team created an analytical framework of innovation consisting of eight key factors. Informed by frameworks presented in a range of studies,[16] this new framework (illustrated in Figure 3.1) facilitates an evaluation of the MOD's innovation model against a set of overarching criteria.

Figure 3.1: Our analytical framework for understanding the innovation process



SOURCE: RAND Europe analysis.

[14] Malerba (2005).

[15] Etzkowitz (2003).

[16] Allas (2014, 19); Drezner (2009); Levy & Samee (2013, 7); Penny et al. (2013, 15–16).

3.3. To understand the defence innovation process, our analytical framework should be considered in the context of the MOD

While the eight factors identified in our framework can be applied to any innovative organisation, their realisation and relative importance will vary greatly depending on the actor in question. In describing each component of the framework, it is thus important to consider these factors within the context of the MOD.

3.3.1. Drivers spur the innovation process

Any innovation process begins with an impetus. **Drivers** are the motivations that spur innovation to occur.[17] The key drivers for innovation will vary by sector depending on the incentives and perceived benefits of innovation. From a societal perspective, innovation may be driven by the need to respond to public challenges such as environmental change and sustainability, energy, health, ageing populations, and security issues.[18] For private companies, conversely, the motivation for innovation is that it provides additional profits by introducing a new design, service, approach or way of doing business that establishes a temporary monopoly in a given market.[19] In some cases, constraints such as regulations or standards may also act as drivers by setting new boundaries within which to innovate.[20] Understanding the drivers in the defence sphere is the first step to understanding the motivations to engage with innovation, both for the MOD and for external stakeholders.

MOD drivers include military demand as well as market context and relevant regulation

Innovation in the MOD context is driven by the primary demand of enhancing the UK's operational military capability.[21] The MOD accesses innovation through several organisations. For example, Dstl procures research whereas Defence Equipment & Support (DE&S) can seek innovation as part of the equipment procurement process. In addition, process innovation can be sought by the Front Line Commands and the Head Office. In our research we did not identify an overarching MOD innovation policy or similar documents stating the MOD's needs for innovation nor the needs of the separate parts of the MOD.

Criticality of need adds impetus to the MOD's demands. Defence stakeholders emphasised the special influence of Urgent Operational Requirements (UORs), pointing out past examples of high-quality, radical innovation occurring when there was a pressing need to ensure superior operational effect. One interviewee, however, voiced the concern that UORs often set a narrow specification, so the scope for

[17] Nataraj et al. (2012).

[18] Foray et al. (2012).

[19] Amable et al. (2009); Schumpeter (1934).

[20] Tait et al. (2011).

[21] Interview conducted by RAND Europe (2014).

innovation is limited and the differential is instead the speed of delivery.[22] The recent prioritisation of 'value for money' reforms has also added a demand for innovation which heightens cost effectiveness in defence procurement and operations.[23]

The market context of the MOD is another driver that presents its own challenges to suppliers and investors. In seeking defence solutions from traditional defence companies the MOD often finds itself in a monopoly/monopsony arrangement[24] – especially at later stages of development – in which innovation suffers from a lack of competition.[25] For the broader stakeholder base, the restricted market and limited R&T budget for defence are unlikely to incentivise companies to innovate for the MOD alone. In pursuing wider innovation solutions, the MOD must therefore accept that it cannot be the main customer of civil companies.[26]

Defence innovation is also shaped by the presence of legislation and regulation, with policies such as the US International Trade in Armaments Regulations (ITAR) posing particular constraints on sharing defence innovations in the international market. Regulations regarding intellectual property rights (IPR) are another driver, as innovators are more likely to engage with defence if they feel that they can retain IPR for future market advantage. While our interviews suggest that the MOD's overall approach is conducive to IPR protections through the application of DEFCONs 703 and 705, not all stakeholders were clear about the MOD's policy and one interviewee expressed concern that the MOD might end up sharing use-rights from previous research with new/additional companies.[27] Along with regulatory drivers such as international legislation and IPR policy, defence standards (DefStans) can also pose a structural barrier to entry for smaller companies without the resources or experience to understand and prove compliance. This can reduce the diversity of stakeholders who are empowered to engage with the MOD in practice. When DefStans are inconsistent with other nations' military standards, they also contribute to a restricted market for UK defence innovations.

3.3.2. Input resources are necessary components of the innovation process

Once a driver for innovation exists, relevant actors must have the appropriate resources to exploit this opportunity. **Input resources** are the primary components required for an organisation to innovate.

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[22] First Expert Workshop (2014); Interview conducted by RAND Europe (2014).

[23] Interview conducted by RAND Europe (2014).

[24] Monopsony refers to a situation in which there is one dominant purchaser of a product or set of industrial outputs, providing the consumer with power to set market conditions. Monopoly refers to a situation where there is one dominant supplier in the economy, therefore giving the supplier power to set market conditions, in contrast to monopsony situations.

[25] Drezner (2009, 35).

[26] Interview conducted by RAND Europe (2014).

[27] Interview conducted by RAND Europe (2014).

For an innovation to succeed, there must be an idea that is created, adapted and supported through to successful exploitation. **Knowledge assets** are thus a primary input into the innovation process. Knowledge feeds into the innovation in a non-linear process: it is required to discover the new ideas that spur innovation as well as to refine, catalyse, apply, share and market these ideas in a usable form. For a given entity, the knowledge assets necessary for innovation may be either *codified* (explicitly stated and documented) or *tacit* (established by experience and learning-by-doing).[28] Along with effectively utilising different types of internal knowledge assets, organisations must also be able to access and apply external knowledge. This *absorptive capacity* (AC) of an organisation will depend on its own skillset and knowledge base as well as its organisational structure and capacity.[29]

The application of knowledge assets in an innovation process requires skilled individuals. **Talent** is therefore the second input resource that is necessary for innovation. Defined as 'individuals with high levels of capital', talent refers to both the technical and managerial expertise necessary to support successful innovation processes.[30] While innovation is often associated with technical expertise in the STEM areas (science, technology, engineering and mathematics), the expertise needed throughout the innovation process thus also includes business, marketing, policy, regulatory and social knowledge.[31] Talent involves the creativity to create and apply new ideas as well as the expertise upon which this creativity is built.[32] There is no single type of talent that enables an innovation process; instead, an entity's ability to innovate requires a trained and experienced workforce with a balanced mix of relevant skills.[33] A healthy innovation process must therefore provide or facilitate skills development amongst its participants, and/or attract new talent into its system, in order to maintain the creative energy and practical skills necessary to enable innovation.

To mobilise knowledge assets and talent, at least a minimal amount of **capital** is required not only to fund the creation of ideas, but also to effectively package and deliver this knowledge as an innovation. While capital can mean equipment and physical assets held by firms to produce or manufacture their goods/services, for the purposes of this report capital refers to the monetary or financial capital that organisations can access. Capital can be infused into different stages of the innovation process in a variety of forms, from research grants for basic and applied research to risk/venture capital investments to support the growth of start-up and spin-off firms.[34]

[28] Teece (1998).

[29] Cohen & Levinthal (1990).

[30] Florida (2002).

[31] Kline & Rosenberg (1986); Caraca et al. (2009).

[32] Amabile (1996, 5).

[33] Birkler et al. (2003); Interview conducted by RAND Europe (2014).

[34] Edquist (2004); Lundvall (2007); Nelson (1996); Tylecote (1994).

The MOD possesses significant knowledge assets, talent and capital but could improve how these resources are leveraged

The input resources for innovation are all highly relevant in the defence context. Both formal and informal knowledge assets within the MOD are extensive, ranging from tacit knowledge that can be applied to new operational requirements to the Athena system which codifies and records past research. However, the MOD is limited in its ability to access the full range of knowledge assets available online. Security concerns have resulted in parts of the internet being blocked because they are considered to present too much risk, thus limiting the accessibility of online information.[35] Related to this, the separation of information and communications technology (ICT) systems between the MOD and Dstl poses a barrier to internal information sharing.[36]

The MOD has considerable internal technical talent, with a particular concentration of scientific and engineering expertise in Dstl and DE&S. However, our literature review suggests that managerial and commercial skills are also critical to the development and application of innovation. For the MOD to be well placed to harness and absorb innovation, it needs to ensure it either recruits or trains for this type of corporate expertise. Many of our interviewees also cited the importance of giving talented individuals the time and space to innovate; several defence stakeholders suggested that there is not enough time to step back, think and pursue new ideas within the MOD or Dstl.[37]

The capital the MOD has to invest in innovation is considerable in terms of any single organisation. Application of this capital, however, is somewhat challenged by an apparent disconnect between the missions of internal actors such as the Front Line Commands (FLCs), Defence Science & Technology (DST), DE&S and Dstl.[38] These entities' competing needs and funding demands tend to frustrate a strategic approach to R&D investment in innovation.[39] Efforts to leverage joint funding beyond the defence budget are not always successful, as explained in greater depth in Sections 4.4.3 and 4.4.4.

3.3.3. Enabling resources benefit innovation actors through engagement with the external environment

The presence of input resources is necessary to innovation, but in many cases it is not sufficient on its own. Actors should also be able to access resources from their external environment. These **enabling**

[35] Based on study team experience (Jon Freeman was previously employed by the MOD and has confirmed in recent conversations with MOD personnel that access to many web sources is restricted).

[36] Based on study team experience (Jon Freeman was previously employed by the MOD and Dstl and the two organisations are still operating separate IT systems).

[37] Interviews (twenty) conducted by RAND Europe (2014).

[38] Interviews (3) conducted by RAND Europe (2014).

[39] Interview conducted by RAND Europe (2014).

resources allow an organisation to bolster its knowledge assets, talent and capital through engagement with other actors.

Enabling resources include the external **infrastructure** of resources, facilities and research hubs that exist outside a given innovation actor. In some cases, this infrastructure provides a physical space with the correct amenities and capabilities for in-depth research or experimentation on emerging innovations, as with 'big science' resources like Switzerland's Large Hadron Collider.[40] Science park infrastructure also facilitates the sharing of physical resources and ideas by enabling proximity of different innovation actors.[41] Infrastructure may also include the wider business environment, such as 'support industries' (vendors and suppliers) which provide crucial components and subsystems for innovation across sectors.[42] An example of open access facilities is the Atomic Weapon Establishment's Orion Laser facility which makes 15% of its time available to academics.

Networks and connections that encourage the exchange of knowledge, the mingling of talented individuals and the connection of suppliers with recipients are also a key enabler of the innovation process. The specific nature of these networks may be formal (such as secondments and fellowships, structured partnerships and advisory groups) or informal (such as personal contacts and virtual networks).[43]

The MOD already benefits from extensive infrastructure and networks, but a number of inherent challenges exist to cross-sector connections

The MOD is fortunate to have a significant infrastructure which reflects many of the elements conducive to successful innovation. MOD knowledge assets are concentrated in a few key sites, such as the Dstl sites at Porton Down and Portsdown West, which bring technical experts together in close proximity. The MOD also enjoys the benefit of seventeen principle test and evaluation sites, such as Boscombe Down, whose services are provided by QQ through the Long Term Partnering Agreement (LTPA). When these sites are not in use by the MOD, their facilities can be used by other organisations (with MOD's approval); yet many of these sites are remote, making them appropriate for test and evaluation, but less suited as stakeholder hubs. The MOD also has access to wider UK infrastructure, such as agreements to use infrastructure of the Science and Technology Facilities Centre (STFC) when required. However, the greater part of the UK innovation infrastructure, for example research centres and science parks, exists independently of MOD and is difficult for the MOD to influence.

The MOD is also actively engaged with both general and defence-specific innovation networks in the UK and internationally. MOD staff are encouraged to engage in professional bodies in their respective fields,

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[40] STFC (2014a).

[41] Anaya-Carlsson & Lundberg (2012); Hughes & Kitson (2013); Mastroeni & Rosiello (2013).

[42] Porter (1990, 100) in Birkler et al. (2003, 47).

[43] AWE (2014); Government Office for Science (2013); Hughes & Kitson (2013, vii); National Centre for Universities and Business (2014, 81); TSB (2014); Interviews conducted by RAND Europe (2014).

which helps ensure that scientists and engineers are connected with their peers and kept abreast of the latest technological developments. The MOD also supports networking organisations such as the Knowledge Transfer Network (KTN) and the Technology Strategy Board (TSB), working together where common goals are identified.[44] Within Dstl, the Centre for Defence Enterprise (CDE) is a notable channel through which the MOD has communicated some of its needs to external actors and encouraged online submission of technical proposals to these challenges.[45] The MOD's Science Gateways also provide a formal mechanism for internal networking by placing embedded technical experts with the Front Line Commands (FLCs), DE&S and the MOD Head Office (often referred to as the 'customers') to ensure that the needs of these 'customers' are being adequately captured and fed back to technical staff at Dstl.[46]

Despite the presence of these various networks, a number of inherent challenges exist for the MOD's engagement with external stakeholders. A lack of awareness about opportunities for productive collaboration can discourage connections between the MOD and non-traditional suppliers (e.g. SMEs, academia and inventors who have not worked before with the MOD).[47] Defence actors also often work under very different priorities from actors in business or academia, and misaligned incentives are therefore more likely.[48] Differences in the timeline and format of outputs can also pose a barrier to cross-sector networks.[49] Rotating posts in the MOD pose an additional challenge by making it easier to lose networks that were established through interpersonal contacts.[50] Finally, the heightened security concerns in the defence context restrict information sharing at both the interpersonal and virtual levels.[51]

3.3.4. Shaping factors influence the opportunities and challenges of the innovation process

Influencing the drivers and resources throughout our analytical framework are two **shaping factors**: culture and structure. Rather than working in isolation, these factors are highly interdependent and are pervasive throughout the realisation of any innovation process.

Culture can be described as patterns of organisational behaviour. Innovation thrives in organisations with open, trusting, and encouraging environments in which individuals can experiment. This includes a climate conducive to risk-taking that seeks to learn from failure rather than to avoid it.[52] A supportive

[44] Based on study team experience and interviews conducted by RAND Europe (2014).

[45] Interview conducted by RAND Europe (2014).

[46] Interview conducted by RAND Europe (2014).

[47] Interview conducted by RAND Europe (2014).

[48] National Centre for Universities and Business (2014, 14).

[49] Council for Science and Technology (2008, 10).

[50] Council for Science and Technology (2008, 9).

[51] Interview conducted by RAND Europe (2014).

[52] Leavy (2005, 39).

culture of innovation is often linked to leadership which is future-oriented and willing to support creative solutions, even in the face of potential failure.[53]

Closely linked with culture is the element of **structure**, both within an organisation itself and in its interactions with external actors. Institutional practices of sharing information and enabling collaboration will impact an organisation's ability to absorb and create innovation. Bureaucracy and formal rules may act to constrain processes of innovation by restricting knowledge exchange or productive partnerships.[54] Organisational structures which incentivise innovation, on the other hand, can facilitate the emergence and application of new ideas.[55]

Despite a 'can do' attitude in response to critical needs, typical MOD procedures are risk averse and may be constrained by bureaucratic structures

MOD culture displays both strengths and weaknesses for supporting innovation. In the context of a perceived 'crisis' or critical need, the MOD can mobilise a strong 'can do' culture that brings considerable talent and force to bear on finding innovative solutions that deliver operational advantage. While urgent operational requirements can thus inspire higher thresholds of risk, in normal operating circumstance, however, MOD procedures are argued to favour low-risk, low-payoff innovation (which is likely to be incremental).[56] The context of public sector accountability makes it particularly difficult for the MOD to embrace risk and view 'failure' as a learning opportunity, as a 'successful' outcome cannot be linked to the expenditure recorded in financial accounts.[57] This risk-averse culture can act as a notable barrier to innovation.[58] The presence of 'customer/supplier' relationships between Dstl and the FLCs, DE&S and DST also contributes to a culture of contractual relationships rather than partnerships with shared endeavours.[59] While this is not necessarily a problem, it may create an expectation that a project is failing if it does not mature as rapidly as the 'contract' had stated.

Evidence suggests that several elements of MOD structures could constrain innovation. One interviewee suggested that the MOD's focus on compliance with policy and strategy may encourage rigid adherence to these that does not facilitate innovation.[60] Bureaucratic processes may also have a tendency to discourage innovation.[61] While MOD bureaucracy was not directly cited by interviewees as an innovation constraint, two stakeholders within the MOD commented on the lack of time available to MOD

[53] Edinger (2012); Sarros et al (2008);.

[54] Drezner (2009, 39); Interview conducted by RAND Europe (2014).

[55] Cooper (2013).

[56] Interviews (3) conducted by RAND Europe (2014) and First Expert Workshop

[57] Interviews conducted by RAND Europe (2014).

[58] Interviews (four) conducted by RAND Europe (2014).

[59] Interviews (four) conducted by RAND Europe (2014); First Expert Workshop (2014).

[60] Interview conducted by RAND Europe (2014).

[61] Interview conducted by RAND Europe (2014).

personnel to think innovatively or to support innovation.[62] This may be an indicator that internal processes either remove time from innovative activities or that time for innovation is not formally recognised as part of the duties of officials. Another interviewee pointed out that output-focused metrics can prevent innovation from developing fully, which could present a risk for the MOD given its emphasis on 'value for money' results.[63]

3.4. An assessment of the MOD against our framework leads to four recommendations

Having assessed the MOD against our innovation framework, the study team identified 24 options for action for the MOD to improve its innovation model across all eight framework factors (see Appendix E for the full list) which we tested against the evidence in order to prepare focused recommendations. As demonstrated in the sections above, the MOD already demonstrates many elements of a thriving and comprehensive innovation ecosystem. Nevertheless, a number of barriers to innovation are present in the MOD's current ways of working. Our analysis of the options enabled us to identify four areas for making recommendation which focus on strengthening existing initiatives as well as overcoming current constraints. Chapter 4 provides an in-depth, thematic assessment of these four recommendations.

[62] Interviews conducted by RAND Europe (2014).

[63] Interview conducted by RAND Europe (2014).

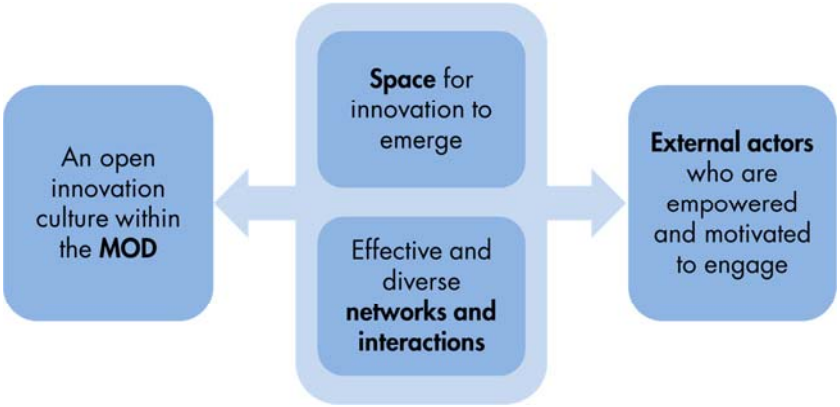
4. Recommendations for the MOD: four levels of change

The options for action identified from our evidence base fall into four levels of change for the MOD which we have distilled into four recommendations, which we describe in this chapter.

4.1. Recommended changes for the MOD comprise four thematic levels

In recommending reforms to the MOD's innovation processes, the study team considered how our factor-based options for action fit into a broader model of change. Through internal workshop discussions drawing from the evidence gathered through our research, we identified four areas of the defence innovation system that should be addressed in order to develop a comprehensive and effective innovation model (modelled in Figure 4.1). As a starting point, changes should be made to the **ways of working within the MOD** itself; without an internal environment that is conducive to innovation, new opportunities for collaboration are likely to be ineffectively exploited. At the same time, **external actors** should also be incentivised and able to participate in innovation with and for the MOD. Once both internal and external players are open to engaging with each other on innovation, it becomes necessary to improve the ways in which their connection occurs. The **dynamics of interactions** should thus be adapted to encourage a range of engagement mechanisms and new **space** should be created for diverse actors to come together and develop new solutions.

Figure 4.1: A comprehensive innovation model of MOD engagement

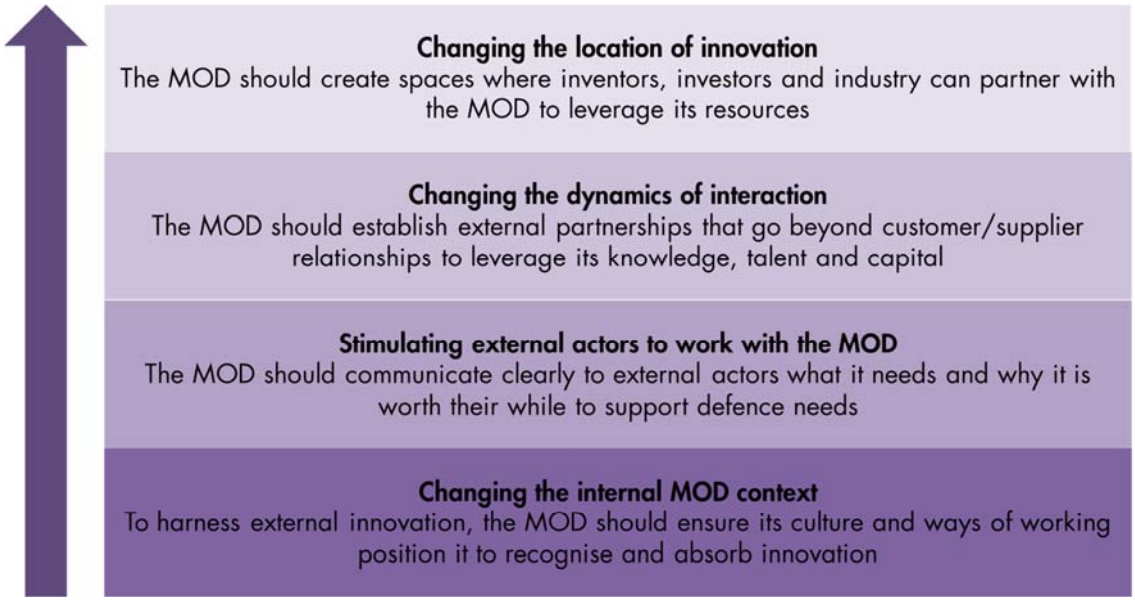


SOURCE: RAND Europe analysis.

4.1.1. Four overarching recommendations can guide a cumulative process of change

To work towards an innovation system in which the MOD engages with external actors through a productive two-way process, each of our thematic levels is accompanied by an overarching recommendation for the MOD. Figure 4.2 shows how the four areas of change act as 'building blocks' towards an effective innovation system, starting with basic internal changes to the MOD and eventually reaching more radical development of external shared spaces.

Figure 4.2: A tiered approach to improving the MOD's innovation model



SOURCE: RAND Europe analysis.

It is important to note that the order of recommendations denoted above is not set in stone. In practice, it is possible to move between the levels of change to pursue specific reforms on a case-by-case basis. Indeed, each level contains a range of specific actions that may vary significantly in their overall feasibility and impact (see The feasibility and impact of the proposed changes). However, the cumulative direction suggested here is intended to produce the strongest foundation for a thriving MOD innovation model. Improving the dynamics of interaction, for example, will always be beneficial to the overall innovation process; however, if the MOD's own environment is not ready to absorb the resultant innovation, or if external actors are not poised to participate in these relationships, the impact of this change will be limited. Furthermore, creating new networks and spaces for innovation will yield the greatest benefit only if it is clear to the wider innovation community what MOD is seeking to achieve and what the benefits are to them in taking part.

4.2. To harness external innovation, the MOD should ensure its culture and ways of working position it to recognise and absorb innovation

The first step in improving the MOD's innovation model is to change the internal MOD context. This stage is, in our opinion, a critical enabler of all other engagement reforms, as external engagement can

only be productive if its outputs resonate with MOD internal priorities and processes. To that end, there are five actions included in this recommendation that aim to enhance the MOD's ways of working in order to improve its absorption of external innovation (see Table 4.1).

Table 4.1: Recommendations and associated actions for changing the internal MOD context

1	To harness external innovation, the MOD should ensure that its culture and ways of working position it to recognise and absorb innovation
Structures	To adopt the minimum bureaucracy necessary, the MOD should undertake a 'red-tape review' of the innovation process to eliminate admin that does not support innovation
	Innovation should be measured in terms of maturity and the innovation framework to ensure partners understand what is required to develop new solutions
Drivers/ Constraints	As part of the 'red tape review' the MOD should identify specific constraints it can eliminate, for example specific aspects of DefStans that constrain the scale of the potential market for innovations
Culture	MOD staff should be given, and feel that they have, time and opportunity to try new ideas, and incentives should be available to encourage success
	The MOD internal customer/supplier relationships are very contractual in nature and should instead be focused on innovation in partnership

SOURCE: RAND Europe analysis.

4.2.1. To adopt the minimum bureaucracy necessary, the MOD should undertake a 'red tape review' of the innovation process to eliminate or change admin that does not support innovation

Reducing bureaucracy would improve the MOD's ability to take advantage of innovative ideas and give a range of individuals the opportunity to move ideas forward. Eliminating red tape, or at least ensuring that regulations do not hinder the process unnecessarily, can allow innovations to survive long enough to come to fruition, rather than losing them in requirements which shut down ideas before they have the opportunity to mature.[64] Three of the people we interviewed made the case that requirements are often too specific, which inevitably limits the opportunity for innovation and this can perpetuate the procurement of outdated solutions at the expense of innovation. Our evidence base suggests that there is a need to address overly regimented bureaucratic processes, noting that 'a preoccupation with rules and processes does not provide organisational members with the freedom to think independently and propose

[64] Chaffey (n.d.); Interview conducted by RAND Europe (2014).

new approaches.'[65] With respect to the defence sector, a 1999 RAND analysis showed that even when operational need is present, military innovation often has to overcome the 'gravitational pull' of bureaucracy in order to succeed.[66] The MOD has already taken steps to reduce bureaucracy in recent years, particularly following Lord Levene's 2011 Defence Reform report.[67] Looking ahead, it would be worthwhile to undertake a more targeted review of bureaucratic processes, a so-called 'red tape review', focusing on the question of which reforms would specifically improve the innovation process. This would need to be underpinned by a detailed mapping of the innovation process in the MOD and the bureaucracy attendant with each step.

4.2.2. Innovation should be measured in terms of maturity and the innovation framework to ensure partners understand what is required to develop new solutions

As Westlake et al. note, 'there is a particularly pressing need for good measures in the field of innovation'.[68] Finding effective metrics is especially important for the MOD in justifying a focus on innovation in the context of public sector accountability.[69] While defence-specific metrics were lacking in the evidence we reviewed, there is support for the notion that innovation is best measured using metrics that go beyond financial viability or accounting.[70] Given the often inconsistent or uncertain returns on innovation efforts, measuring an initiative through success or failure risks eliminating valuable innovation opportunities before they have the chance to come to fruition. Measuring the *features/inputs* of the innovation process is therefore just as important as measuring the *outcomes/outputs.*[71] Innovation should be measured in terms of the maturity of the technology and the framework presented in this report, particularly the input resources, so that all actors can understand what investment of talent, knowledge and capital is required to develop the solution to the next level of maturity. Further discussion on how to measure innovation is provided in Appendix G.

[65] Jantz (2012, 530).

[66] Isaacson et al. (1999) in Taylor and Finney (2014, 46).

[67] Levene et al. (2011).

[68] Westlake et al. (71).

[69] Doss (2013).

[70] Interview conducted by RAND Europe (2014).

[71] Doss (2013).

4.2.3. As part of the 'red tape review', the MOD should identify specific constraints it can eliminate, for example Defence Standards that unnecessarily constrain the scale of the potential market for innovation

Just as the drivers can stimulate innovation so constraints can stifle and hamper it. Bureaucracy has already been identified as a constraint that the MOD should tackle. Another area that should be considered is standards. Standards can be an enabler of innovation by defining the space in which innovation should be sought and ensuring a level playing field for innovation and commercialisation of ideas.[72] At the same time, standards risk being restrictive, outdated or contradictory with the standards of other nations. Each of these risks could become a major inhibition by reducing the potential market for an innovation and thereby reducing the likelihood of securing investment for development.[73] In the worst cases, standards can become significant barriers to entering the potential market; large companies can increase their dominance of the market because only they have the scale and resources to be able to address all of the standards.[74] It is recommended that as part of the 'red tape review' the MOD should analyse the need for and effect of DefStans on the innovation process and identify those standards that need to be updated to allow for greater innovation. Needless to say, the recommendation is not for the wholesale disposal of standards as they perform a useful and necessary function; however, alignment to standards that offer access to a wider market (such as the US Military Standards or British Standards) would increase the incentive for investors.

4.2.4. MOD staff should be given, and feel that they have, the time and opportunity to try new ideas, and incentives should be available to encourage success

Organisational culture is established as a critical enabler of innovation in the literature, which draws attention to the need to empower individuals, create an environment conducive to idea sharing and promote a shared vision of innovation goals.[75] The need for the MOD's organisational culture to be conducive to innovation was brought up by multiple interviewees (at least eight discussed internal culture).[76] The MOD's low-risk attitude was also mentioned (by at least four interviewees and during the workshop) to be an impediment to innovation; one interviewee described the value in 'failing fast and failing often' to find the right solution.[77] At a basic level, as another interviewee stated, 'what is essential is creating the desire (through culture) and the ability (through processes)' to innovate.[78]

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[72] European Commission (2012).

[73] Interview conducted by RAND Europe (2014).

[74] Drezner (2009, 39); Tait et al. (2011).

[75] Anderson et al. (2014); Raj & Srivastava (2013, 203).

[76] Interviews conducted by RAND Europe (2014).

[77] Interview conducted by RAND Europe (2014).

[78] Interview conducted by RAND Europe (2014).

Examples from the corporate world demonstrate the value of incorporating innovation more actively into internal organisational culture. The success of leading innovative firms is attributed largely to the ways in which their businesses formally incorporate innovation into company policies and procedures (for example, Google's '9 principles of innovation' and 3M's '10 commandments').[79-80] Three of our interviews mentioned that 'failure' should be considered as acceptable and a learning opportunity, rather than having individuals and managers avoiding risk for fear of adverse consequences.[81] These cases show that an environment which supports and even rewards innovation – while not overly punishing failure – is critical in allowing new solutions to emerge. The company 3M is well known for making up to 15 per cent of staff time available for their own ideas, and one large defence company interviewed for this study had a company-wide online ideas portal which was administered by local managers to ensure prompt decisions on which ideas would be given a small amount of resources to undergo a quick proof of concept.[82]

As discussed in Section 3.3.3, the MOD already engages with a number of general and defence-specific networks. The MOD should continue to encourage personnel to participate in a wide variety of networks, whether focused on professional skills or particular technology areas, to benefit from the cross-fertilisation of ideas and solutions that these interactions engender.

The MOD needs to ensure that staff know: how and to whom they can suggest ideas; that they will be supported by their management in trying these ideas; and that resources and time are available to try these ideas out properly.

4.2.5. The MOD internal customer/supplier relationships are very contractual in nature and should instead be focused on innovation in partnership

Many of the interactions between Dstl and the FLCs, DE&S and even DST were described to us in terms of 'customer/supplier' relationships, with one interviewee describing the MOD Unified Customer as the ultimate user of Dstl's output.[83] This suggests that the innovation relationships are viewed as very contractual in nature, rather than as partnerships with shared endeavours. Whilst this perception is not necessarily a problem, it may create an expectation that if a solution does not mature as rapidly as the 'contract' had stated that the project is in some way failing. There is a lack of attention to the holistic innovation process; one interviewee explained that 'programming lines to cover the whole innovation life cycle are lacking due to the organisational boundaries, inconsistencies and varying interests.'[84]

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[79] Tay (2013).

[80] Caspin-Wagner et al. (2013, 38).

[81] Interviews (3) conducted by RAND Europe (2014).

[82] Interview conducted by RAND Europe (2014).

[83] Interviews (four) conducted by RAND Europe (2014); First Expert Workshop (2014).

[84] Interview conducted by RAND Europe (2014).

This recommendation is deeply connected to the internal structures and working dynamics of the MOD. Given that some of the evidence came from interviews without corroborating evidence being available from the published literature, a first step for the MOD could be to assess the current situation and identify the cross-agency barriers that exist to furthering innovation throughout the lifecycle.[85] As previously stated, the MOD needs to define its innovation process (as part of the 'red tape review') and understand the different MOD actors that have a role at the different stages of that process. With this understanding it can then clearly define which organisations should be partnering in the innovation process.

4.3. The MOD should communicate clearly to external actors what it needs and why it is worth their while to support defence needs

Even if a positive innovation culture is established internally, the MOD would still require buy-in from external actors to benefit from engagement with the wider innovation landscape. The MOD must thus also ensure that external actors are motivated and equipped to engage effectively with the defence innovation space. In interviews we were told how important it is for the MOD to tell suppliers what it wants, without necessarily over-specifying the solution; our research showed that the MOD does not have a clear innovation policy. Although the MOD's influence on external actors' behaviour is limited, we have identified four actions that can encourage these stakeholders to work with the MOD (see Table 4.2).

Table 4.2: Recommendations and associated actions for stimulating external actors to work with the MOD

2	The MOD should communicate clearly to external actors what it needs and why it is worth their while to support defence needs
Drivers	The MOD should publish an innovation policy setting out why and where it needs innovation and how it wishes to work with others to achieve this
	Competition is a key driver of innovation. The innovation policy should set out the MOD's approach to competition at different stages from early ideas through to development. This should include a realistic sense of the likely market to give innovators a clear idea of why they should get involved
Talent	The MOD should have external networks of technical and managerial experts it can call on to support the innovation process
Knowledge assets	The MOD should improve the accessibility of the innovation process. The DOD Defense Innovation Marketplace provides an example of where all the relevant information is brought together in one place

SOURCE: RAND Europe analysis.

[85] Interview conducted by RAND Europe (2014).

4.3.1. The MOD should publish an innovation policy setting out why and where it needs innovation and how it wishes to work with others to achieve this

Without a clear sense of defence priorities, it is very difficult for external actors (particularly non-traditional defence stakeholders) to know where and how to get involved with the MOD in a way that adds value to both parties. Clear priorities are likely to enable external stakeholders to invest in areas of greater importance to the MOD and increase the likelihood of profitable return on their innovation efforts. An effective policy will better communicate defence requirements in a manner that is clear without stifling creativity.[86] To develop such a policy, the MOD would need to consider how it will manage IPR, the likely future demand for particular equipment/platforms and the level of risk that it is willing to take when funding particular innovations.[87] This would require collaboration with industry and other aspects of the MOD, such as DE&S.

Developing and implementing an effective innovation policy will require strategic thinking about long-term innovative solutions, rather than focusing on short-term procurement aims.[88] A lasting policy is also likely to be challenged by shifting security threats and political leadership. For an innovation policy to be effective, stakeholders would need to have confidence that overarching priorities are somewhat sustainable in order to justify investment in defence-relevant innovation.

Developing a clear innovation policy will result in benefits to both the MOD and external actors. Without a clear sense of defence priorities, it is very difficult for external actors (particularly non-traditional defence stakeholders) to know where and how to get involved with the MOD in a way that adds value to both parties.

4.3.2. Competition is a key driver of innovation and the innovation policy should set out the MOD's approach to competition at the different stages of the innovation process

Literature and interviews emphasise that the right type of competition can be a key driver of innovation.[89] Competition could benefit the MOD by increasing chances not only for cost-effectiveness, but also for innovative offerings from defence suppliers. Reduced barriers to entry (into the market) could also facilitate a greater role for small and medium sized enterprises (SMEs), thereby increasing their ability to compete for more opportunities.

However, competition is one tool amongst many to support innovation; at the early stages of development, competition can encourage the generation of a whole range of excellent ideas, whereas at the later stage of development it risks reducing the incentives to industry to invest much of their own

[86] Georgsdottir et al (2003); Interview conducted by RAND Europe (2014); MOD (2012).

[87] Interviews (six) conducted by RAND Europe (2014); Drezner (2009).

[88] Interview conducted by RAND Europe (2014).

[89] Interview conducted by RAND Europe (2014); MOD (2012; 2013); Jane's Defence Industry (2009).

capital.[90] Competition is, therefore, a tool to be used appropriately; the 'red tape review' should help identify which tools are appropriate at which stage of the innovation process. There are some concerns about the difficulty of balancing competition with partnership. There are, however, examples in the defence sector of how competition mechanisms can be created even within partnering situations, such as internal competition within the partner organisation or opening the partnership arrangement to competition at regular intervals.[91]

In opening up competition, there are a number of significant challenges for the MOD. Competition has differing effects upon innovation depending upon the relative strength of the competing firms. When competing firms are of equal strength then innovation is incentivised; when firms are of diverse strength (as in the UK), competition may reduce the incentive for smaller firms to invest in innovation.[92]

4.3.3. The MOD should have networks of external technical and managerial experts it can call on to support the innovation process

The MOD needs to have a good quality, in-house technical and managerial team to ensure that it can commission research and manage the innovation process. The literature highlights the importance of investing in human capital and leveraging highly skilled talent when supporting innovation.[93] These points were reflected in stakeholder interviews, which emphasised the need for the MOD to attract and invest in talent to enhance its efficiency, facilitate innovation and improve its accessibility and networking with other organisations and institutions.[94] Recruiting talent into the MOD would likely bring new tools, techniques and creative thinking, thus helping to enhance the organisation's absorptive capacity.[95] Investing in the professional development of internal personnel can also ensure that the MOD has the full range of complementary skills necessary to support innovation.[96] Such investment would include offering training courses to personnel who need to gain the managerial or commercial expertise necessary to better facilitate innovation. However, the burgeoning range of disciplines in which the MOD needs to keep current and the competitive market for managerial skills means that the MOD will not realistically be able to maintain in-house talent in all of the required areas.

[90] Interview conducted by RAND Europe (2014); Second Expert Workshop (2014).

[91] The complex weapons sector is a monopoly/monopsony situation, but internal competitions can still drive the creation of new solutions.

[92] Aghion et al. (2005).

[93] Amabile (1996); Dakhli & De Clercq (2004); Florida (1999; 2002); Nelson & Phelps (1966).

[94] Interview conducted by RAND Europe (2014).

[95] Lane & Lubatkin (1998).

[96] Interviews (eight) conducted by RAND Europe (2014).

Our evidence base emphasises the positive impact of engaging with talent across sectors.[97] A number of stakeholders highlighted the need for the MOD to interact more with academia and industry, supporting literature about the beneficial impacts of university-industry interactions.[98] In addition to facilitating benefits from shared expertise, access to external talent can enhance knowledge sharing and improve problem solving capacity in an innovation context.[99] The MOD could invoke a number of mechanisms to attract this type of talent, ranging from funding basic research to developing apprenticeship schemes geared towards external expertise, to permitting senior MOD officials to be on external boards and inviting senior expertise onto MOD boards.

Contracting frameworks such as Niteworks demonstrate that the MOD can readily access technical and management expertise as required by projects and programmes (full disclosure: RAND Europe is an associate partner of Niteworks).[100] The MOD should consider whether a similar arrangement could be used to bring in specific managerial expertise to facilitate the innovation process, for example to bring together inventors, investors and industry at particular stages in the development of a solution.

4.3.4. The MOD should improve the accessibility of its innovation processes to encourage innovative participation from new actors.

Defence procurement processes have been identified as a particular challenge to innovation by the literature, interviewees and in the first expert workshop.[101] As one interviewee explained, 'criteria for selection often do not match needs for innovation…since a product has to be specified, any space for innovative thinking is limited.'[102] By involving new suppliers from different backgrounds and schools of thought, the MOD can gain new perspectives and solutions to problems it faces, enabling innovative responses to both short- and long-term challenges. There is a need to make the MOD's processes 'more transparent, simpler and faster' to attract new suppliers, particularly from smaller companies which may have innovative potential but are challenged by the existing procurement regime.[103] It is also important for the MOD to work on setting thematic and challenge-driven requirements rather than prescribing solutions.[104] The MOD could also be more proactive in identifying and reaching out to new types of

[97] Bishop et al. (2010); Bramwell & Wolfe (2008); Bramwell et al. (2010); Doutriaux (2003); George et al. (2002); Gibbons & Johnston (1974); Lane & Lubatkin (1998); Laursen & Salter (2004); Link & Rees (1990); Mansfield (1991); Rosenberg (1992); Wolfe (2005).

[98] Interviews conducted by RAND Europe (2014); Bishop et al. (2010); George et al (2002); Laursen & Salter (2004); Link & Rees (1990); Mansfield (1991).

[99] Bishop et al. (2010).

[100] Niteworks (2014).

[101] Penny et al. (2013).

[102] Interviews (two) conducted by RAND Europe (2014).

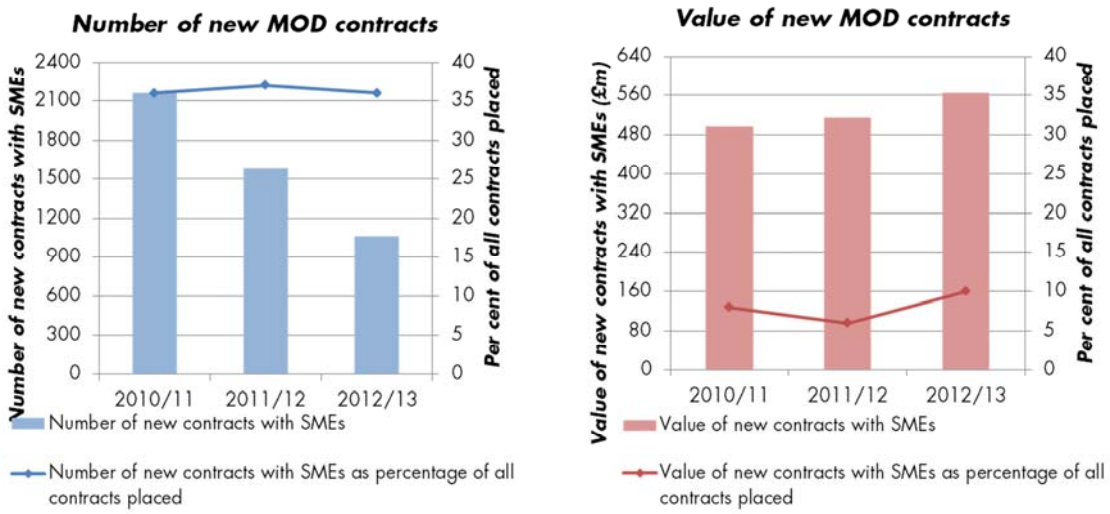
[103] MOD (2014c).

[104] Interviews (two) conducted by RAND Europe (2014).

suppliers. For example, while approximately one-third of new MOD contracts have been placed with SMEs in the past three years, the overall value of these contracts has hovered at 8–10 per cent of the total value of MOD contracts – far below the government target of 25 per cent (see Figure 4.3).[105]

Reforming procurement processes is difficult in practice, as many current challenges are due to the inherent nature of defence, technical requirements, and the pace of public sector procurement in general. The size and type of projects required in defence is an additional barrier that will not realistically change. The MOD's motivation to open up current procurement also appears to be limited by the existing dominance of a small number of defence primes, meaning that the 'MOD does not wish to interfere unreasonably in the business procedures of our major suppliers, or to create bureaucracy or impediments to their business operations.'[106]

Figure 4.3: SME contracts as a percentage of the quantity and value of all new MOD contracts



SOURCE: RAND Europe analysis of data from MOD (2013).

It is also important for the MOD to make information readily available about its procurement processes and the context for its innovation needs by providing background information on how and why solutions are required to meet different challenges. Other nations bring this information together in a single online location making it relatively easy for new potential suppliers to identify how they can interact with the MOD. One such example is the Defense Innovation Marketplace from the US DOD, which provides a portal with information spanning the many different defence agencies and their needs and providing extensive information for industry.[107] Some of the key features of the Defense Innovation Marketplace are summarised in box 4.1.

[105] MOD (2014c).

[106] MOD (2014c, 2).

[107] Defense Innovation Marketplace (2014).

Box 4.1: The Defense Innovation Marketplace

The Defense Innovation Marketplace website provides a consolidated resource for both the DOD and industry. It provides industry with information about the DOD's investment priorities so they can plan their own investment in innovation. A key feature is that the information is largely available without having to register.

The organisations represented on the portal include the Army, Navy, Air Force, US Marine Corps, Combatant Commands, other DOD agencies such as DARPA, DOD laboratories and Federally Funded Research and Development Centers.

The sort of information that can be found includes strategic overview documents about priorities for the different services and defence agencies, and guidance on doing business with the DOD.

There is also a section on news and events, which keeps industry up to date with relevant developments from the DOD and enables them to participate in events that can help them understand the DOD's requirements for innovative solutions.

Box 4.2 illustrates the benefits that could derive from opening and leveraging the MOD's knowledge assets and provides a more detailed analysis of some specific actions.

Box 4.2: Leveraging MOD's knowledge assets with those of other organisations

By opening up its existing knowledge assets, the MOD would ensure that external actors have access to the research necessary to develop their innovations for the defence context. Leveraging knowledge assets can increase efficiency of research funding, help strengthen stakeholder networks, and decrease the number of 'sunk' projects by enabling external actors to take research forward using shared knowledge. Declassification of old R&D outputs (where security concerns allow) would help leverage knowledge, as occurred with the publication of technical research in the aftermath of WWII.[108] First-look agreements could also be beneficial by sharing information in a controlled manner with key actors involved in technology development.[109] A platform (virtual or physical) for sharing knowledge would also provide an interface for engaging with external actors, as is already being done at Defence Research and Development Canada, an agency of Canada's Department of National Defence which leverages other organisations' expertise in order to provide the Canadian forces with a strategic knowledge and technology advantage.[110]

[108] The materials from the Office of Scientific Research and Development represent original research conducted by the Allies during World War II and include tens of thousands of items such as technical reports, drawings, memos, medical research results, and other documents. In 1960, all of them were declassified and made available to public (The Library of Congress). More information can be found for example in: The American Presidency Project (2014); The Library of Congress (2012); The National Archives (n.d).

[109] Dreamworks Studios (2008); Graser & McNary (2013); Hayden (2014); Weprin (2014).

[110] Defence Research and Development Canada (2014).

4.4. The MOD should establish external partnerships that go beyond customer/supplier relationships to leverage its knowledge, talent and capital

Once the context for innovation engagement is favourable for both the MOD and its external stakeholders, effort should be focused on improving the dynamics of the relationship between participating parties. The best intentions of collaboration will only be successful if there are enabling mechanisms in place to bring actors together, allowing them to share ideas and work together on common goals. The academic literature notes the importance of networks in terms of allowing firms access to information and the exchange of different kinds of knowledge, and awareness of opportunity.[111] Our third recommendation therefore focuses on how the MOD can create new connections, forge new relationships and facilitate others interacting in a way that maximises knowledge exchange and innovative output.

Table 4.3: Recommendations and associated actions for changing the dynamics of interaction

3	The MOD should establish external partnerships that go beyond customer/supplier relationships to leverage its knowledge, talent and capital
Networks / connections	Building on its innovation policy, the MOD should embed the culture of external innovation partnerships in how it engages with inventors in academia and SMEs
	The MOD should establish an 'honest broker' to bring together inventors in academia and SMEs with investors and industry primes to facilitate the development of ideas into solutions
Capital	The MOD should partner with venture capital and/or angel firms, where appropriate, to develop solutions to higher readiness levels
	The MOD should seek to increase the technical and financial scope of its R&D funding with new partners

SOURCE: RAND Europe analysis.

The third recommendation begins with changes to MOD culture and that of the organisations it seeks to interact with, including in particular changes to the mind-set and view of what kinds of relationships MOD should establish, making an explicit shift from a customer/supplier relationship to a more partnership-orientated one. Efforts to change the cultural dynamic could be complemented by the establishment of an honest broker, an organisation that can actively begin to seek such relationships, encourage them, as well as to identify the opportunities that are most attractive to the MOD upon which these partnerships should focus. Through the auspices of such a broker, the Networks could be enhanced, greater cross-sector partnerships could be developed, and Knowledge Assets could be leveraged. Finally, in

[111] Hippel (2007); Schilling & Phelps (2007).

addition to these benefits, better and more active identification of opportunities, and a turn to partnership relationships would allow the MOD to better leverage private investment and the skills and knowledge of venture capitalists and other investors.

4.4.1. Building on its innovation policy, the MOD should embed the culture of external innovation partnerships in how it engages with inventors in academia and SMEs

An essential part of the necessary network building will require a reframing of how MOD bodies, its suppliers and external research bodies interact. As described in Section 4.2.5, the interviews and workshop highlighted that the MOD too often acts within a defined customer/supplier dynamic. This is true not only for internal departments, but also for external actors. Interviewees stressed that the MOD should play a wider role in its networks with external organisations, stating that 'MOD needs to modify the chain of suppliers, look beyond its immediate supply base and accept innovation coming from different sources.'[112] More open forms of collaboration with external actors will allow the MOD to benefit from the expertise and resources of other valuable stakeholders in the innovation ecosystem.[113] While customer/supplier relationships impose a very particular dynamic, and restrict the number of partners involved, non-competitive engagement would allow the MOD to be more aware of opportunities and skills in the wider marketplace which could ultimately benefit the defence sphere. A partnership focus also gives other actors space to learn about defence needs and bring a fresh perspective to lasting challenges in a low-pressure environment, allowing them to explore opportunities without competing with established defence suppliers or dealing with difficult requirements.[114]

Some specific actions can be undertaken by the MOD to encourage this cultural change. For example, the MOD can begin by articulating thematic priorities to help structure and guide research collaborations with external actors (both national and international).[115] Entry points can be created for external organisations explicitly if, for example, at least one external organisation is to be involved in every Dstl research project in some capacity.[116]

In addition, the MOD could actively scout for partners in defined research areas, reaching out particularly into new areas to expand scope for collaboration,[117] and highlight and publicise successful collaborations to create a positive feedback loop for future initiatives.[118]

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[112] Interview conducted by RAND Europe (2014).

[113] James (2013, 64).

[114] Sorenson & Torfing (2012).

[115] Interview conducted by RAND Europe (2014).

[116] Interview conducted by RAND Europe (2014).

[117] Stark (2011).

[118] Stark (2011).

To further reach out to partners, MOD can develop the Defence and Science blog and use this outlet as an opportunity for engaging with external partners to learn about their scientific developments,[119] and build on the Defence and Security Special Interest Group portal to provide more tangible materials and announcements of collaboration opportunities.[120]

Finally, good cooperation and collaboration will require establishing some kind of confidentiality agreements to help create atmosphere for sharing strategic priorities and long-term goals with external partners.[121]

In summary, while the MOD – particularly the CDE – has already made efforts to bring external actors together in settings that are not purely commercial, such as the Innovation Network events and the Defence and Security Special Interest Group,[122] these initiatives could be substantially developed and better publicised to attract a more diverse range of external actors to share ideas and bring their unique expertise to the MOD's issues.

4.4.2. The MOD should establish an 'honest broker' to bring together inventors in academia and SMEs with investors and industry primes to facilitate the development of ideas into solutions

One interviewee noted that SMEs are discouraged from engaging with the MOD due to a lack of transparent demand by the MOD bodies, and mistrust of engaging with dominant prime contractors.[123] These challenges could be addressed if the MOD were to act as an 'honest broker' that helps communicate requirements more clearly and facilitate access to the providers and consumers of different technologies. The MOD would benefit from increased breadth and efficiency of innovation, while SMEs and investors would be able to take advantage of new market opportunities. This recommendation could be carried out through a specific MOD office or team, supported by the wider MOD establishment, which is responsible for acting as a liaison with external actors. Further description of the role of the honest broker is provided in Box 4.3.

In the US, for example, grey literature describes the Navy's Commercial Technology Transition Office as acting as a 'matchmaker' or 'deal broker' to transition the best technologies between industry and naval acquisition programmes.[124] The grey literature also described how the US army has a similar organisation: the Defense Venture Catalyst Initiative (DeVenCI), whose focus is on emerging technologies and acts as a broker between the Department of Defense and SMEs. DeVenCI focuses on emerging technologies and

[119] Gov.uk (2014b).

[120] Defence and Security Connect (n.d.).

[121] Stark (2011).

[122] Gov.uk (2014a); Defence and Security Connect (n.d.).

[123] Interview conducted by RAND Europe (2014).

[124] Brown et al. (2008).

uses various methods to increase awareness within the DoD of these emerging technologies. DeVenCI is structured to 'broker' information exchanges between the DoD and small, innovative companies, with the purpose of identifying emerging technologies that meet a current warfighter need. As described, DeVenCI does not provide any direct funding to the VC industry. According to DeVenCI, the initiative has been a catalyst for improved communication between warfighters and small, innovative companies;[125] It is supported by 11 venture capitalists that volunteered to help foster communication and collaboration.[126]

The benefits of an honest broker are seen to go beyond relations with SMEs to broader stakeholder engagement. Our review of relevant literature highlights the positive impact of a cross-sector approach to innovation.[127] Through an honest broker, cross-sector stakeholders can be drawn in to not only formal and informal networks, but also to establish mutual understanding of innovation needs, constraints, regulations and challenges. Such stakeholder relations also contribute to building capacity, trust and awareness through a wider supplier base.

Box 4.3: The role of the honest broker

'Honest broker' is a role that can be carried out by any organisation or group that can earn the trust and respect of the different MOD stakeholders. We envisage this role as one that includes facilitating the development of networks and partnerships across the whole value chain between the MOD, the prime contractors and the potential stakeholders whose involvement should be increased in order to enhance the MOD's innovative capacity and the defence-related innovation system. The need for an honest broker was mentioned during one of the interviews where it was noted that small- and medium-sized firms may hesitate to get involved with the MOD because they felt that there was a power disadvantage with prime contractors, and that having to go through prime contractors without a mediating body to ensure that all were treated fairly. An honest broker would therefore be present to ensure that the value of the innovation would be delivered to the MOD, while ensuring that the firms involved were treated fairly and would, therefore, be willing to continue treating with the MOD.

We also identified the 'honest broker' role in other activities: initiating contact with new industrial partners, and academia. Approaching organisations that could act as co-investors; in this case it could be approaching venture capitalists who may wish to help take a defence product forward if they see a large enough return on it, or private and public sector participants who may wish to take a dual-use technology forward that would help the MOD's capacity. The honest broker would therefore have to contact and maintain networks with a range of organisations in the public and private sector, and within the civilian and defence spheres. It would also, however, have to be able to identify new

[125] Brown et al. (2008).

[126] Brown et al. (2008).

[127] Cooke (2010); Cooke (2000); Cooke & Eriksson (2011); Dowdall (2004); Fischer (2001); Government Office for Science (2013); Hughes (2013); Johnson (2012); National Centre for Universities and Business (2014); Witty (2013).

innovations and then apply its networks to develop the innovative opportunities.

Given these different functions, and the need to be able to interact with different stakeholders and across project timelines, the role of the honest broker that could be carried out by an organisation set up, or contracted, by the MOD, but which has the legitimacy and authority to access all stakeholders across the defence value-chain, including going beyond established pathways and inviting new participants. It would have to be seen as having little to no vested interest in the benefits to any one set of stakeholders beyond the ability to deliver effective innovation to meet the MOD's needs. Effectively, the honest broker would be the vehicle through which the MOD's innovation strategy is carried out, and the personnel and knowledge resources to be able to effectively communicate and understand the drivers that are motivating the different stakeholders from academic researchers, scientists, and innovative SMEs to venture capital investors, prime contractors and the final users within the MOD.

4.4.3. The MOD should partner with venture capital and/or angel firms, where appropriate, to develop solutions to higher readiness levels

Some obvious benefits of the changes would be an increased possibility to leverage private sector funds and resources. The cited example of US organisations acting as honest brokers and connecting different stakeholders to develop technologies of interest were actually spurred by the goal of involving private sector venture capital investors and leveraging their funds and experience in commercialisation. Interviews with entrepreneurs and incubators emphasised the importance of venture capital and venture capital networks in identifying innovation, facilitating cross-company collaboration to ensure an innovative idea can get to market, and assessing the quality of innovation opportunities.[128] One study of government VC programmes in the US context identified diverse benefits, including heightened awareness of technology developments, an expanded supplier base, improved leverage of private funding and faster acquisition of key innovations.[129]

Greater engagement with VC and private sector investors could complement the variety of joint funding initiatives with academia and industry that the MOD is already engaged with.[130] Two examples can be seen in the US: the Multidisciplinary University Research Initiative (MURI) and the SwampWorks programme.[131] MURI, in 2014, provided $167m over five years to academic institutions to perform basic, multidisciplinary basic research; the goal being to encourage work at the cross section of disciplines and encourage the training of graduate students. While some MOD programmes may be similar, the scope of this programme is worth noting. The SwampWorks programme takes on high-risk disruptive technologies and concepts. It leverages short exploratory studies to examine a proposal before investing significant amounts. Furthermore, it is a streamlined decision-making process that facilitates a shorter tech

[128] Interview conducted by RAND Europe (2014).

[129] Mara (2011).

[130] Interviews (four) conducted by RAND Europe (2014).

[131] United States Army Research Laboratory (2012); Office of Naval Research (n.d.b).

development timeframe; to aid this, it also has flexible funding and execution structures – details of which may be useful to build upon.

4.4.4. The MOD should seek to increase the technical and financial scope of its R&D funding with new partners

The major challenge in implementing this recommendation is incentivising external actors to contribute their portion of joint funding. An interviewee noted that it was difficult to offer funding for defence innovation due to the uncertainty of a return on investment.[132] More tellingly, one stakeholder explained that some parts of industry do not offer funding because they expect that if the MOD really wants something to happen, it will eventually proffer the funds itself.[133] A 2011 Dstl review of contracting mechanisms showed that over the past two decades, several research initiatives intended to leverage matched funding from industry had all ultimately concluded with the MOD as the sole provider of capital.[134] However, programmes such as SwampWorks, which seed interesting innovation opportunities, may help in this regard. Literature also suggests that the oft-cited 'valley of death' in bringing innovation to market is often due to a break in funding when seed or proof-of-concept capital runs out, but sufficient uncertainty still exists to discourage the private sector.[135] Funding that can help remove some uncertainty (and demonstrate the MOD's commitment to a technology), or otherwise share the risk, may attract reticent investors.

By getting other partners to contribute their share of funding, the MOD can use its resources to cover a greater breadth of areas. The key opportunity is the combined development of science that is of particular interest to the MOD, as well as exposure to new developments that would otherwise have escaped the MOD's notice (not because they are not important, but because there was no connecting mechanism). It would also provide the benefit of creating greater links between scientists and the MOD, and creating awareness and a 'path of involvement' to the MOD and related industry amongst young researchers.[136] This last point demonstrates that by creating a more partnership-orientated environment, the MOD may also reap the benefits of becoming more open and accessible to talent from academia and industry.[137] In addition to seeking out external talent itself, the MOD also needs to ensure that external actors are motivated and capable of engaging based on their own initiative. An open environment, and one that is known to encourage innovative activity, is more likely to attract talent with the right skills, helping the MOD maximise its potential to access or convert good science to innovation.[138]

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[132] Interview conducted by RAND Europe (2014).

[133] First Expert Workshop (2014).

[134] Dstl (2011).

[135] Auerswald & Branscomb (2003).

[136] Office of Naval Research (n.d.a).

[137] Interview conducted by RAND Europe (2014).

[138] Interview conducted by RAND Europe (2014).

4.5. The MOD should create spaces where inventors, investors and industry can partner with the MOD to leverage its resources

In a thriving innovation ecosystem, there should be not only motivated actors and productive interactions, but also the space (physical or virtual) to come together to explore new relationships and ideas. Our final recommendation considers how the MOD can help create and facilitate this type of space by providing and participating in innovation infrastructure.

Table 4.4: Recommendations and associated actions for changing the location of innovation

4	The MOD should create spaces where inventors, investors and industry can partner with the MOD to leverage its resources
Infrastructure	The MOD should develop a 'marketplace' to support research and to provide stakeholders with a space to interact
	The MOD should provide open innovation spaces to facilitate research in areas specific for defence and security, and leverage the use of spaces already available in the UK

SOURCE: RAND Europe analysis.

4.5.1. The MOD should develop a 'marketplace' to support research and to provide stakeholders with a space to interact

MOD efforts to engage with external innovation actors would be greatly supported by a central 'marketplace' which provides a space for stakeholders to interact and share knowledge. A thriving marketplace hub would raise awareness of opportunities for procurement or investment while facilitating new relationships among stakeholders.

There are several different options for manifesting a marketplace space. This marketplace could be virtual, such as a portal or web-based network where MOD bodies, industry stakeholders, investors, researchers and other public bodies can 'browse' opportunities and then follow up through the specific channels provided (as in the example of the US Defense Innovation Marketplace).[139] A second option is to combine a virtual marketplace with a physical anchor space. This is the case in Helsinki's International VC Zone, where an intermediary organisation provides physical office space that is supplemented by a strong online service.[140] A third option would consist of a network which provides stakeholder members

[139] See for example: Defense Innovation Marketplace (n.d.).

[140] See for example: International VC Zone (n.d.); Technopolis Online (2014).

with information about opportunities for contracts and capacity building (e.g. CONNECT San Diego).[141]

4.5.2. The MOD should provide open innovation spaces to facilitate research in areas specific for defence and security, and leverage the use of spaces already available in the UK

The reviewed literature and stakeholder interviews confirm the positive impacts of establishing facilities where knowledge can be shared and inputs and enablers combined.[142] To provide an open space for facilitating innovation, the MOD should establish external facilities, accessible to the public and hosted by partner organisations, to leverage knowledge assets and stimulate information exchange and experimentation. These shared spaces could range from innovation incubators, such as the Surrey Space Incubator, to 'maker spaces' in public libraries which offer tools and information to support on-site idea development and trialling.[143] Such open facilities bring input resources together in a communal space to provide actors with heightened capabilities for research and development in a collective environment of exchange. An example of such a space that is working well is the Structural Genomics Consortium based in Oxford and Toronto.[144]

Academic literature suggests that shared spaces and facilities encourage greater innovation.[145] A number of stakeholders interviewed also supported the idea of new shared spaces, such as innovation laboratories, to enhance connectedness between industry and universities and to facilitate the commercialisation of innovative ideas.[146] Shared physical infrastructure can help SMEs have their ideas noticed by the MOD, thus encouraging competition in the defence market. By bringing actors together, physical infrastructure can also support better value for money in MOD procurement by facilitating idea and information exchange.[147] In considering different types of physical infrastructure development, the MOD could learn

[141] See for example: Connect (2014). Other examples include LINC Scotland (2014), Tech Cube (see Moules, 2013). A final option may be a very light touch network such as the LinkedIn group Defence and Aerospace Venture Capital.

[142] Anaya-Carlsson (2012); Government Office for Science (2013); Hughes (2013); National Centre for Universities and Business (2014); Roslund (2014); Science & Technology Facilities Council (2014); Technology Strategy Board (2014); Wellcome Trust (2014); Witty (2013).

[143] Benton et al. (2013); Egan (2014); The Library as Incubator Project (2014); Rutkin, (2014); SET Squared Partnership (n.d.); Surrey Space Incubator (n.d.); Schenider (2012).

[144] Morgan Jones et al. (2014).

[145] Rustam (2002); Tether (2002).

[146] Interviews (three) conducted by RAND Europe (2014).

[147] Squicciarini (2009).

from the strengths and weaknesses of the Catapult Centres, the success of which is currently being examined by the Hauser Review.[148]

In addition to providing its own physical and virtual infrastructure to encourage stakeholder engagement, the MOD should also engage with innovation spaces provided throughout the UK landscape. These shared resources, particularly at the university level, offer opportunities to engage with varied stakeholders on mutual interests outside of the strictly defence sphere. The benefits would include creation of networks, sharing of knowledge assets and development of trust and awareness between the MOD and new stakeholders.[149] It would also enhance the MOD's ability to identify potentially important developments in external R&D.[150]

In addition to physical infrastructure, the MOD has a strong need to adapt its IT infrastructure, both to share information more easily internally and to engage with external actors more effectively. Box 4.4 illustrates some specific actions that could be undertaken in this field as well as the resulting benefits.

Box 4.4: Adapting the MOD's IT infrastructure to facilitate information sharing and external engagement

Virtual infrastructure can be a strong enabler of innovation processes.[151] An effective IT system could include systems enabling central storage and exchange of contacts and shared information within the MOD. It also would benefit from an external interface for suppliers and external actors to access MOD information which is relevant but not sensitive. However, current MOD systems are highly restricted and would be difficult to use to access and share information externally.[152] Changes to the IT structure to facilitate information sharing would reduce operational costs through better data management, improve the information available for decision-making, and enhance data sharing and cooperation.[153] They would also empower external stakeholders to engage more easily with the MOD and its relevant research in support of innovation.

Initiating major changes to the MOD IT structure would require buy-in from across the organisation. Security concerns and organisational resistance to change would be the most notable impediments to implementing best practice in IT management of knowledge assets. One possible solution could be to keep interior MOD IT systems and data firewalled, but to open a competition for a vetted contractor to analyse the data and begin to identify value from it as a pilot for larger scale efforts.

[148] BIS (2014). Further to note, the Catapult Centres represent the extreme end of the investment spectrum for such spaces. As of August 2013 the BIS had invested £1.4bn in seven Catapult Centres, an average overall cost of £200m per centre (Gov.uk, 2013).

[149] Hughes & Kitson (2013). Interview conducted by RAND Europe (2014).

[150] Interview conducted by RAND Europe (2014).

[151] Fischer (2001); Nesta (2013); Nonaka et al. (2000); Teece (2000); Teece (1998).

[152] Based on study team expertise.

[153] Fischer (2001); Nonaka et al. (2000); Interview conducted by RAND Europe (2014).

4.6. The four recommendations taken together provide an overall approach to improving the MOD's ability to harness and absorb innovation

Each of the four recommendations discussed here, from changes within the MOD to how it engages with its current partners, and how it improves its networks and actively seeks out and encourages new partners, are described in a manner that would encourage enhanced development of and access to innovation. Greater clarity of purpose and intent, improved relations built on partnership and trust, are part of the improvements we see as leading to more effectively leveraging the MOD's resources, and more importantly those of industry and academia that may hold the future answers to MOD's innovative needs. The next section analyses briefly the feasibility and impact of the changes we have discussed here.

5. The feasibility and impact of the proposed changes

In making recommendations it is necessary to consider whether they are feasible and will have impact. As part of the literature search to validate the options for change, we specifically looked for any evaluations that had been conducted of similar innovation initiatives but we found little or no evidence was available. Any comment on cost or benefit is necessarily a rough order approximation.

5.1. The second expert workshop was used to consider the feasibility and impact of the recommendations

The second expert workshop gathered entrepreneurs with experts from the MOD and industry to discuss the feasibility and impact of the recommendations and the supporting actions grouped under each recommendation. In the discussion it was noted that many of the actions are linked to each other, which supported the approach we have taken to grouping the actions.

5.2. While the positive impact of our recommendations has been confirmed, there are barriers to their implementation

The findings from the workshop confirm that, in most cases, the recommendations should have a significant beneficial impact for the MOD and the actions beneath each recommendation are fairly evenly split between low and high feasibility.[154] The options that were considered to be high feasibility and high impact are shown in Table 5.1. Creating an MOD innovation policy was recognised as being within MOD's gift and would pay dividends but the main challenge would be in obtaining stakeholder buy-in and support for the policy, all of which would require leadership to help ensure it would happen. Increasing competition in the supplier base was thought to be beneficial at the earlier stages of the innovation process. With regards to talent it was agreed that recruiting and developing talent, accessing external talent and creating mechanisms to enable external talent to access the MOD should all be feasible and beneficial. For capital it was agreed that venture capitalists and angel firms could relatively easily be engaged to support innovation in the early stages, which supports recommendation three. For knowledge assets it was considered that establishing places for information sharing to take place would be feasible

[154] Second Expert Workshop (2014).

which supports the recommendation for innovation spaces. It was also agreed that knowledge could relatively easily be shared by involving stakeholders from a range of sectors as both observers and participants. Using the wider innovation infrastructure, which is a key part of recommendation four, was widely agreed to be feasible and beneficial. To support networking the workshop participants agreed that MOD staff should be encouraged to participate in networks. And there was broad agreement at the workshop that external innovation partnerships should be developed rather than just customer/supplier relationships, which supports recommendation three.

Table 5.1: The actions that were ranked as high feasibility and high impact

Factor	Options for action
	The MOD should:
Drivers	Develop a clear and communicable innovation policy based on a strategic assessment of its needs and priorities. Increase competition in its supply chain as a means of stimulating innovation, not just securing value for money.
Talent	Recruit and develop individuals to ensure it has talent inside the organisation. Develop mechanisms to access external talent. Develop mechanisms to ensure that external talent can access the MOD.
Capital	Engage with VC and angel firms to support breakthrough and early-stage innovations.
Knowledge assets	Establish facilities where its knowledge can be shared with innovators and where small-scale tests and proof of concept can be conducted. Involve cross-sector stakeholders in its S&T activities as both observers and participants where possible.
Infra-structure	Utilise the wider innovation infrastructure (especially from universities) to encourage innovation.
Networks/ connections	Encourage staff participation in networks to develop talent, access knowledge and identify wider exploitation opportunities for defence research.
Culture	Develop external innovation partnerships, rather than customer/supplier relationships, to enable technology development from the early stages to marketed solution.

SOURCE: RAND Europe analysis.

The actions that were considered to be low feasibility but high impact are listed in Table 5.2. One of the reasons given for the low feasibility of several actions was 'risk aversion – people don't get promoted for taking risks' which underlines the need for a significant change in the culture if the MOD is to reap significant benefits from changes to its innovation model.

The main barrier to developing a defence innovation policy was considered to be the 'difficulty in getting consensus' across the different stakeholders within the MOD as well as across the defence enterprise.[155] Whilst the formation of a consensus is undeniably challenging, the high impact rating for this option suggests that it is a goal worth pursuing. In a similar vein, a constraint articulated several times was 'the

[155] The defence enterprise was described in the workshop as being the MOD and defence industry.

difficulty of changing the defence enterprise – if you want change to be effective the defence prime contractors have to be supportive'.[156] In preparing our recommendations we recognise that there is a challenge in undertaking large-scale change; our recommendations are therefore presented in four incremental levels which the MOD can select on the basis of its appetite for change. Part of the MOD's appetite for change should be to consider how it should exercise its role in the monopsony/monopoly arrangement that describes much of the defence market. Where the MOD is a small buyer in a large market it cannot exert much influence. Where it is the main buyer, on the other hand, then, within the limits of responsible behaviour, the MOD can push for and lead change.

Table 5.2: The actions that were ranked as low feasibility but high impact

Factor	Options for action
	The MOD should:
Drivers	Reduce innovation constraints that originate within the MOD.
Capital	Develop a 'marketplace' where it can develop funding partnerships with industry, other government departments and academia to support research into cutting-edge technologies and development through to marketed solutions. Engage strategically to provide joint funding for research and development.
Knowledge assets	Establish facilities where its knowledge can be shared with innovators and where small-scale tests and proof of concept can be conducted [for early development stages].
Infra-structure	Consider how its physical infrastructure can be used (and adapted) to encourage innovation.
Networks/ connections	Act as an 'honest broker' of inventors, funders and industry to facilitate knowledge sharing across these groups. Support structured cross-sector partnerships which enable personnel to gain cross-sector experience and knowledge.
Culture	Encourage and incentivise internal innovation from individuals within the organisation, supporting a culture that permits risk. Develop internal innovation partnerships, rather than customer/supplier relationships, to enable technology development from the early stage to marketed solution.
Structures	Improve the accessibility of its procurement processes to encourage innovative participation from new actors. Adopt the minimum bureaucracy necessary to enable the innovation process.

SOURCE: RAND Europe analysis.

In discussing the differences between competition and partnership it was said that the competition rules that apply to public procurement could be a barrier to developing partnerships and that partnership itself could limit competition. We acknowledge this point and accept that competition is one means of developing innovations, as is partnership; they are different approaches that can be used at different stages in the innovation process. We would also argue that some partnerships can be open to competition and

[156] Second Expert Workshop (2014).

do not have to be indefinite, for example developing innovation sites at universities or technology parks could be the subject of competition for the opportunity to host such a facility. Several attendees made the point that competition was not necessarily appropriate at a later stage in the development of innovation as there are concerns over the need to protect IPR and industry would be less willing to invest capital if there was a higher risk of not being successful. These arguments underline the importance of recognising that different approaches are appropriate at different stages in the innovation process.

The action that was considered to be least feasible was 'The MOD should consider how its IT infrastructure can be used (and adapted) to encourage innovation'. Stakeholders considered the difficulties in changing the defence information infrastructure (DII) were too significant, particularly as they were linked to security constraints that are considered very difficult to overcome.

The action 'The MOD should establish facilities where its knowledge can be shared with innovators and where small-scale tests and proof of concept can be conducted' was considered by stakeholders to have variable feasibility dependent on the stage of development of the innovation. For early-stage developments this was considered to be low feasibility because the infrastructure did not exist to do this, whereas for later development stages it was considered to be highly feasible because extensive experience already exists in the supplier base.

5.3. The barriers to change are neither insignificant nor insurmountable

The findings from our expert workshop confirm that the recommendations should have a significant beneficial impact for the MOD. For any significant programme of change the constraints identified are familiar challenges and whilst we do not consider them to be trivial nor do we consider them to be insurmountable. The innovation framework provides a useful tool for thinking about what is required to develop a thriving innovation ecosystem, and our framework has identified eight key factors for innovation that the MOD should consider. The recommendations we have presented are incremental, starting with what the MOD can do to improve its own culture and processes through to more ambitious recommendations about how to develop new partnerships for innovation and create new spaces in which to bring together experts in support of innovation for defence. The degree to which the MOD implements these recommendations will be dependent on its appetite for significant change and its ability (in time and resources) to support such changes.

6. Conclusions

An innovation framework is a useful tool for thinking about what is required to develop a thriving innovation ecosystem, and our framework has identified eight key factors for innovation that the MOD should consider. It should be noted that innovation takes place in a system which means it is not easy to single out one factor to change that will yield the greatest benefit. To improve against any one of the factors in the framework it is necessary to consider which other factors may also need to be adapted to increase the likelihood of achieving significant and lasting change.

The MOD performs well against some aspects of the innovation framework, but there is room for improvement. The MOD has clear drivers of innovation, but these are not communicated in a clear and compelling way to the wider innovation ecosystem. Furthermore, the MOD has considerable knowledge, talent and capital, but these will not be sufficient for it to harness innovation in all areas, particularly the broad range of emerging technologies relevant to defence. The MOD will need leadership as well as technical and managerial talent to leverage its resources to achieve greater innovation effect. The MOD's facilities are relevant for defence testing and evaluation but it needs to network and take advantage of the wider innovation infrastructure across the UK. Perhaps most importantly, the MOD cultures and structures (ways of working and processes) are notably risk averse and need to be changed to ensure the MOD can harness innovation.

The recommendations we have presented are incremental, starting with what the MOD can do to improve its own culture and processes through to more ambitious recommendations about how to develop new partnerships for innovation and create new spaces in which to bring together experts in support of innovation for defence. The degree to which the MOD implements these recommendations will be dependent on its appetite for significant change and its ability (in time and resources) to support such changes. Our four overarching recommendations are:

1) To harness external innovation, the MOD must ensure its culture and ways of working position it to recognise and absorb innovation.
2) The MOD must communicate clearly to external actors what it requires and why it is worth their while to support defence needs.
3) The MOD should establish external partnerships that go beyond customer/supplier relationships to leverage its knowledge, talent and capital.
4) The MOD should create spaces where inventors, investors and industry can partner with the MOD to leverage its resources.

It should not be considered that internal change is necessarily the easiest path to the future as much of this will depend on changing the cultures and structures of the organisation to support new ways of working. At the same time, action on the ambitious changes to networks and infrastructure can be initiated before internal changes in the MOD have been completed, however we would argue that the maximum benefit of these recommendations will not be experienced unless the MOD leads a process of change to increase its absorptive capacity for innovation and communicated clearly its priorities for innovation in a policy statement.

Innovation Models for Defence

Harnessing innovation from academia

A1. Study objective and methodology

A1.1. Introduction

Further to the study on Innovation Models for Defence, RAND Europe was asked by the UK Ministry of Defence (MOD) to extend the project by providing further detailed analysis of what our recommendations would mean in the context of the academic sector. In particular we were asked to identify any specific areas the MOD should focus on in order to enable it to harness and absorb innovation from academia, outlining actions that could be applied to facilitate the MOD's ability to access innovation in emerging technology areas. Given that this additional research and analysis was conducted in a limited period of time (three weeks), the research focused on the areas of our main report that were considered most relevant to the MOD's interactions with the academic sector.

Our approach has been to identify specific actions that the MOD could take against each of the four recommendations in the main report and to test these, both against the literature and through key informant interviews. We added a further line of inquiry to estimate how much it might cost to implement these specific actions; we have been able to identify some case studies and so offer rough order of magnitude costs where evidence was available. In each case we have also sought to identify answers to questions relating to 'why?', 'when?', 'who?', 'where?' and 'how?' to give a greater degree of specificity and as much context as possible. These answers are based on a mixture of evidence, analysis and judgment.

A1.2. The project team applied a structured methodology to meet the study objectives

To address the study objectives, the RAND Europe project team devised a structured methodology, building in separate steps for both collection and analysis of evidence, in a process similar to that used for the main study (as shown in Figure A1.1). The time constraints associated with this project extension have limited the number of interviews conducted (16), resulting in potential bias in the selection and nature of the interviewees.

This annex is intended to inform implementation rather than be an implementation plan. The MOD should review what is presented here and make allowances for other considerations that could impact these proposals. The timings, costs and any duration of the proposals are rough order of magnitude (ROM) estimates, prepared in a very short time, in line with the requirements for the extension. As these are rough order estimates we advise that the MOD undertake further analysis before making any policy or investment decisions based on our estimates. When estimating MOD costs we have made an assumption

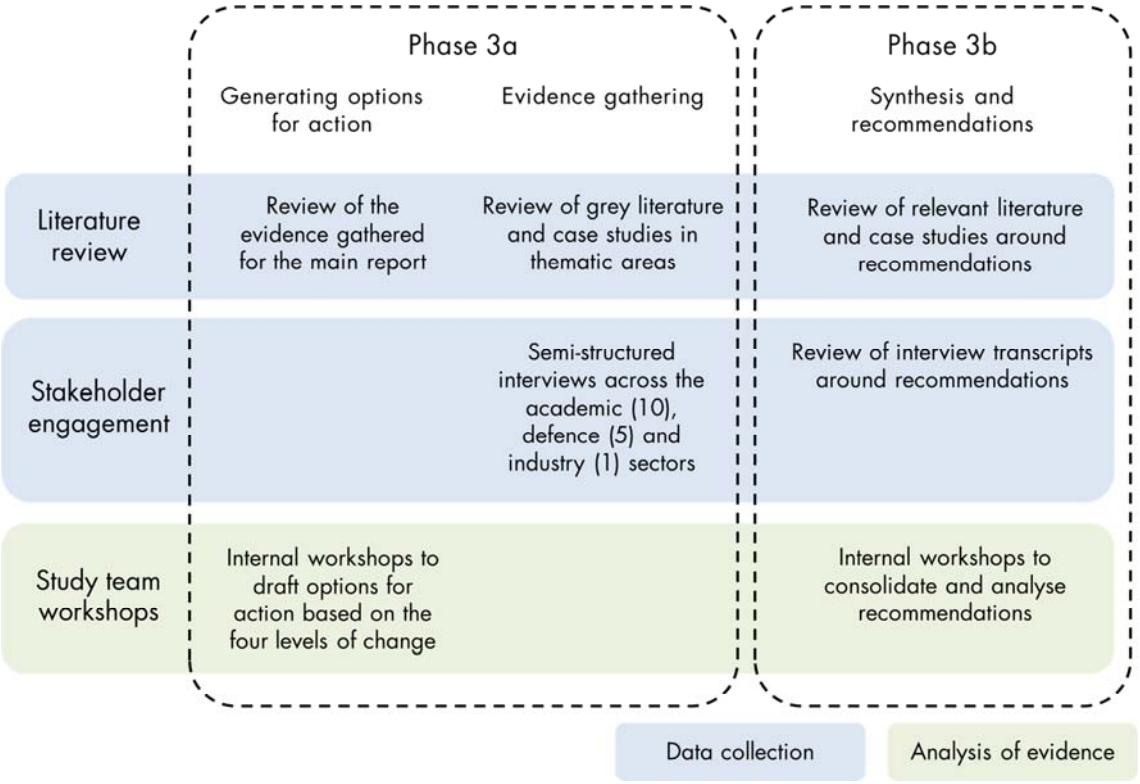
that a Grade C1 civil servant working for one year would carry a capitation cost of approximately £100,000. The time taken to complete a task is also a ROM estimate, based on the study team experience of working in both the public and private sectors, and giving consideration to the complexity of the stakeholder engagement or commercial negotiations that may be required for any of the proposals. The evidence we have gathered derives from sources including example cases from within the MOD and elsewhere, and from key informant interviews, and has been supplemented by the experience and expertise of the study team in change management. The sequencing of the proposed actions is based on change and project management principles as some actions are better executed before others, and it would be beyond the capacity of most organisations to make all of these changes at once.

A1.3. The study extension was carried out in two main phases to enable the creation of options for action validated against our evidence base

This extension to the study took place during three weeks between October and November 2014 and was organised into two main phases:

- **Phase 3a** was initiated by the development of draft options for action to implement the recommendations illustrated in the main report to the specific engagement between the MOD and the academic sector. The draft options for action were then used to develop different interview protocols (aimed at stakeholders in the academic and defence sectors) and to target the literature review.
- **Phase 3b** involved the review and validation of the options for action for the MOD. These options for action were validated against the evidence collected, drawing upon relevant case studies where possible.

Figure A1.1: Overview of study methodology



A1.4. Structure of the annex

Section 1 of the annex has set out the methodology used to conduct the research for the extension. Section 2 sets out the options for action that were generated and provides our assessment, based on the available evidence, of why this option is relevant, when, where, how and by whom it should be done and our ROM estimate of the resources required to achieve it. Section 3 provides an overall summary and conclusion of the extension, including more discussion of the estimated costs of implementing these changes.

A2. Implementing the four levels of change

A2.1. To harness innovation from the academic sector, the MOD should ensure its culture and ways of working position it to recognise and absorb such innovation

In our main report we highlighted that the MOD needed to change its internal context to create conditions that enhance the MOD's absorptive capacity for innovation, and we identified culture and ways of working as being particularly important. The need for tangible senior commitment to cultural change is important. Creating a champion for this change would demonstrate this commitment and provide leadership for future absorption of innovation.

Table A2.1: Recommendations and associated actions for changing the internal MOD context

A1	To harness innovation from the academic sector, the MOD should ensure its culture and ways of working position it to recognise and absorb such innovation
Culture Structures	The MOD should appoint an innovation champion to drive forward its internal culture change

SOURCE: RAND Europe analysis.

A2.1.1. The MOD should appoint an innovation champion to drive forward its internal culture change

Why?

The MOD's commitment to change would be demonstrated both to the academic sector and internally to the organisation by appointing an innovation champion (IC). The IC would promote the organisational and cultural changes necessary to enable the MOD to absorb innovation. The interviews highlighted four main cultural and structural issues within the MOD (discussed below) that threaten to slow down progress and overwhelm the intentions of change, which the IC should address.

Firstly, some academic stakeholders perceive there to be an 'inner-circle' culture regarding the MOD's relationships with universities.[157] This appears to be linked to the perception that MOD has developed strong relationships with five or six UK institutions, including Cranfield University and Imperial College London, while not investing the same time or resources in other institutions.[158] According to one academic interviewee, interaction with universities tends to be based more on personal contacts than standardised procedures, and the MOD's selective engagement – whether real or perceived – has the potential to alienate valuable talent, knowledge and infrastructure.

Secondly, the MOD's requirements-led approach[159] to procurement that is based on government policy can be a deterrent to academics because of the perception that they are excluded from the process of drawing up requirements.[160] Where security is not an issue, there may be scope for academic involvement in the requirement-setting process. The designated IC could encourage a more open culture in the MOD through this new needs-led approach.[161]

Thirdly, impact timescales and assessment are not understood and reflected in research requirements. The interviews highlighted that MOD officials often expect immediate impact whereas research impacts may be experienced long after the initial work was conducted.[162] Academics are required to demonstrate the impact of their work to support the Research Excellence Framework (REF) process (the REF is discussed in more detail in Box A2.1). The IC should ensure that the need to measure impacts is included in requirements and procurement processes.

Fourthly, the MOD releasing its calls for research via a competitive process presents a barrier to entry for the academic sector. While companies may have teams responsible for managing the commercial process, universities often lack these resources.[163] The IC should drive the introduction of alternative approaches such as pre-contract partnerships (see Section A2.3) as these would not present the same barriers to entry and may therefore encourage greater academic participation.

The responsibilities of the IC role should be clearly defined. There was consensus amongst interviewees that an IC would be useful in promoting culture change and stimulating engagement with academia.[164] The same interviews also showed differing understandings on whether such a role already exists within the

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[157] Interviews (two) conducted by RAND Europe (2014).

[158] Interview conducted by RAND Europe (2014).

[159] In the MOD context, a requirements-led approach is one where the MOD issues a call for a supplier to respond to. This contrasts with a more open approach where stakeholders from academia or industry can bring research ideas to the MOD.

[160] Interview conducted by RAND Europe (2014).

[161] Interview conducted by RAND Europe (2014).

[162] Interview conducted by RAND Europe (2014).

[163] Interview conducted by RAND Europe (2014).

[164] Interviews (five) conducted by RAND Europe (2014).

MOD and with whom it currently resides.[165] Interviewees suggested that there should to be a clearly appointed IC who maintains the pressure for change, who can be held accountable to the Defence R&D Board for making the change happen and can be seen by the academic sector as the person leading the change.[166]

When?

There is no firm rationale for how soon an IC should be appointed, but we would suggest that this is a symbolically important step that should be done within a ROM time of three months. The work of Kotter (1996) and others acknowledges the need for pace as being a fundamental principle of change management.[167] The IC would assume responsibility for driving the change for the duration of any change programme. The role should endure afterwards to ensure there is an identifiable IC for all external innovation actors.

Where?

This is not applicable to this action.

Who?

The IC would need to be someone senior in the MOD with a remit that relates to the innovation process. Furthermore, it should be someone who has the support of the Defence R&D Board and access to the wider MOD. The Director General Finance or the Corporate Strategy Director both have roles that span the MOD and could champion innovation in all its forms. The MOD Chief Scientific Adviser could instead be the champion but this could send the message that the MOD is focusing only on technological innovation and may be perceived externally as being linked to certain universities.

How?

The creation of the IC role and appointment to that role should be made by the Defence R&D Board. The board should also specify what the role is expected to deliver as part of the MOD-wide culture change with respect to innovation.

Estimated resource requirement?

We did not identify from our evidence any examples of the cost to create such a role but we judge it to require relatively few resources. The main requirement would be for the MOD staff to define the role (a ROM time of a few months' work) and provide ongoing support to the IC in delivering this role. The MOD would need to determine the opportunity cost of committing officials to such a task. In the first year of an overall change programme, the officials supporting the IC may need external support to provide

[165] Interviews (five) conducted by RAND Europe (2014).

[166] Interviews (two) conducted by RAND Europe (2014).

[167] Kotter (1996).

expertise on change management. We estimate that the ROM cost would be £100,000–250,000 depending on how much internal and external support is required. This does not account for opportunity cost.

A2.2. The MOD should communicate clearly to the academic sector what it needs and why it is worth supporting defence needs

The main report has identified the importance of drivers for stimulating innovation and the MOD communicating its needs to external actors. In Section 4.3.1 of the main report we have already advocated the need for an innovation policy and in this section we explore the need for an academic engagement plan to support that. We also discuss the benefit of MOD forecasting its knowledge and talent needs and communicating this to the academic sector who are key suppliers in both these areas. From our interviews it was also apparent that whilst funding is a key driver for the academic sector,[168] so too is being able to demonstrate the impact of research and use this in the REF, which is the national assessment of research quality.[169]

Table A2.2: Recommendations and associated actions for stimulating academic actors to work with the MOD

A2	The MOD should communicate clearly to the academic sector what it needs and why it is worth supporting defence needs
Drivers	The MOD should publish an innovation policy that includes an academic engagement plan
	The MOD should support academic suppliers in assessing the impact of the research they provide
Talent	The MOD should develop and publish a 5–10 year forecast of its scientific/technical and talent needs
Knowledge assets	

SOURCE: RAND Europe analysis.

[168] Interviews (thirteen) conducted by RAND Europe (2014).

[169] Interviews (six) conducted by RAND Europe (2014).

A2.2.1. The MOD should publish an innovation policy that includes an academic engagement plan

As set out in Section 4.3.1 of the main report, the MOD should publish an innovation policy that sets out its strategic approach to innovation. This would be the principal document detailing the MOD's commitment to innovation, and would inform decision-making both within and outside the organisation.

In addition to this overarching policy, the MOD should provide a clear statement on how it wants to work with different external groups, including academia. Such a plan should make clear why and how the MOD wants to engage with the academic sector, explaining the opportunities that would be available and why it is worth supporting defence needs.

Why?

Without a clear statement of the MOD's needs, the academic sector can only draw inferences as to what these might be from the procurement of research. A policy document would communicate the MOD's approach to innovation and help to address the present asymmetry of information, helping clarify goals and motivations and so building trust into its partnerships with academia. One interviewee from the academic sector noted that innovation involves high risk activity and that trust is therefore essential.[170] A clearer understanding of the MOD's motivations in supporting innovation would lend additional credibility to its function as an 'honest broker' (see Section A2.3.1).

An innovation policy would help external partners to better understand the MOD's expectations in relation to issues such as risk, intellectual property, economic spillovers from research and the role to be played by different actors.

Building on the innovation policy, an academic engagement plan would help to raise awareness within academia of the MOD's ongoing programmes for working with that sector specifically. We note that such a plan already exists and this should be aligned with our proposed innovation policy and made publically available.[171] Our research found that even academics with a long history of work in defence research often had a limited or inaccurate understanding of the different ways to work with the MOD.[172] An engagement plan linked to the policy would help to dispel some of these myths and misperceptions and communicate the different opportunities for working with the MOD.

When?

Based on our understanding of change management and the need to maintain pace we suggest that the policy should be published within 6–12 months of the appointment of an innovation champion. This reflects the time likely to be required to involve stakeholders in the preparation of both documents and

[170] Interview conducted by RAND Europe (2014).

[171] Dstl (2014b).

[172] Interviews (three) conducted by RAND Europe (2014).

seek ministerial approval. The policy and academic engagement plan should be reviewed regularly, perhaps every three to five years.

Where?

The innovation policy and engagement plan should be published online and promoted (in either electronic or hard copy) to university research and strategic planning offices.

Who?

It should be prepared by DST under the authority of the CSA with the backing of the Defence R&D Board, and should be published by a relevant government minister to give it significant public profile.

How?

Both the innovation policy and academic engagement plan should be developed through a process of engagement with internal MOD stakeholders and external actors from academia, funding bodies, industry and other government departments. At the second expert workshop there was concern expressed over the challenge of getting stakeholder buy-in to engagement, both within MOD and also with wider stakeholders such as industry. Developing a policy will require leadership, probably by the CSA, and the full support of the Defence R&D Board. In its simplest form, a policy could be written quickly, which would rapidly communicate the MOD's aims and ambitions. More time would be required to develop the plans for delivering and engaging with different stakeholders to support the effective delivery against the policy.

Estimated resource requirement?

A policy could be prepared very quickly, but the effort would increase significantly across the number of stakeholders involved. MOD staff resources would be required to prepare the policy, and conduct the stakeholder engagement, which could be staffed at Grade C1 level with management support from a Band B. The cost estimate needs also to consider the cost of involving staff from other parts of the MOD in consultation and discussion. To support the MOD staff it may be beneficial to engage external support to conduct structured elicitation events (such as Delphi exercises) to help understand the various aims and ambitions of different stakeholders for the policy. It is estimated that the ROM cost of preparing the policy and engagement plan would be approximately £250,000–500,000, with the lower estimate being for lower levels of engagement and no external support. This range does not account for opportunity cost.

A2.2.2. The MOD should develop and publish a 5–10 year forecast of its scientific/technical and talent needs

Building on the Dstl Corporate Plan 2014–2019[173] and the Dstl academic engagement plan[174], the MOD should publish a 5–10 year forecast detailing:

[173] Dstl (2014a).

- The MOD's needs for scientific and technical knowledge in different technology areas.
- The MOD's needs for talent in different technology areas.
- Where the MOD would like to strengthen networks for innovation (both in terms of links from the MOD to knowledge centres and links between those external actors).

While the innovation policy and engagement plan for the academic sector would provide a vision of how the MOD can best partner with academia and fulfil both actors' needs, its 5–10 year forecast would offer granular detail as to upcoming needs for knowledge and talent from the academic pipeline.

Why?

By articulating its needs in terms of the input resources of talent and knowledge the MOD will be sending a clear signal to academia about the opportunities for supplying MOD with both talented individuals (graduates) and technical expertise (research collaboration and/or contracts). It could also encourage strategic collaboration between different academic institutions and/or industry, where the MOD's forecast identifies areas of future strategic importance in which networks are currently underdeveloped.

Our research showed that universities are increasingly responsive to such statements of need in light of the 'impact agenda' and the accompanying creation of dedicated teams within universities to engage with government and industry needs.[175] A clear vision of the MOD's needs for the coming decade would also align with the timeframes currently used for strategic planning within academic research, with a number of surveyed academics emphasising the long-term view taken in the sector as a result of the uncertainties of basic research, the demands of the REF cycle and the structure of the academic calendar.[176]

As well as influencing potential external partners, a 5–10 year forecast would also help to inform the MOD's internal processes and outreach efforts as an 'honest broker'. It would contribute to greater internal understanding of key S&T talent priorities, as well as informing the MOD's market intelligence function and attempts to target the key actors, opportunities and knowledge/talent bottlenecks in academia for the MOD's priority areas of emerging technology.

When?

Based on the time needed to prepare this kind of document and the need to logically sequence the publication of new material, we suggest that the forecast should be published within six months of the publication of the innovation policy. The forecast should be revised periodically, perhaps every three to five years.

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[174] Dstl (2014b).

[175] Interviews (ten) conducted by RAND Europe (2014).

[176] Interviews (five) conducted by RAND Europe (2014).

Where?

The forecast should be published online and promoted (in either electronic or hard copy) to university research and strategic planning offices.

Who?

It should be coordinated by Dstl under the authority of the CSA with the support of the Defence R&D Board. The MOD and Dstl human resources teams should also be involved.

How?

The technical and talent needs should be established through a rigorous methodology that is not overly burdensome. A process should be developed that works from the priority areas outlined in the Dstl Corporate Plan (and anywhere else priorities are stated) and breaks those down into talent and technical requirements.

The process should gather its evidence from across the MOD, working particularly closely with Dstl, DE&S and the personnel function within the MOD to determine requirements, as well as collaborating with external partners in academia and industry to forecast the pipeline of knowledge and talent available in priority areas of emerging technology.

External support could be used both for developing the process and for conducting the analysis.

Estimated resource requirement?

MOD staff resources will be required to define the requirement and to project manage the assessment of MOD's scientific/technical and talent needs. We estimate that this could be conducted in-house if staffed by two Grade C1 civil servants with management support from a Band B. If external support was used, it could be project managed by one Grade C1 with support from a Band B. The cost needs also to consider the cost of involving staff from other parts of the MOD in consultation and discussion. Based on study team experience of public and private sector projects, this task is estimated to need six to nine months of work. It is estimated that the ROM cost of developing a repeatable methodology and conducting the assessment would be approximately £250,000–500,000, with the lower estimate not including external support. This range does not account for opportunity cost.

A2.2.3. The MOD should support academic suppliers in assessing the impact of the research they provide

The MOD should develop a process for creating and disseminating impact reports as part of the research procurement process. Such reports would support both the impact agenda of the academic sector and the MOD's ability to evaluate its own research. Conducting impact assessment for the whole research programme would be ambitious and it would be appropriate to pilot the process, learn from lessons and expand to cover more of the programme in due course.

Why?

For the academic sector, a key driver for engaging with the MOD could be the opportunity to demonstrate the impact of the research,[177] which since 2008 has been one of the parameters used to determine funding allocation in the REF (see Box A2.1).[178] By actively supporting the academic sector in assessing the impact of its research, the MOD would make itself an attractive organisation for academia to work with. Furthermore, understanding the impact of research is likely to be beneficial to the MOD also. The scale of effort needs, however, to be appropriate to the MOD's requirements and ambitions.

When?

Specific reports should be released at the end of each project/programme/initiative to highlight already measurable impact as well as include consideration of potential future impacts. Depending on the scale of ambition, ongoing impact assessments and reports should then be prepared at regular intervals. Five year intervals would align with government spending reviews, but longer intervals may be required as research has shown a time-delay of approximately 15 years between R&D investment and impacts on the quality of defence equipment.[179]

Where?

This is not applicable to this action.

Who?

The impact reporting process should be developed with the involvement of a range of stakeholders including the Research Councils and representatives from universities (possibly Universities UK). The process could be developed by a team of officials or it could be contracted out to a supplier with expertise in evaluating research and its impacts. Once the process is established, reports could be prepared and issued by Dstl on behalf of the MOD, as one of the main contractors of academic research. Alternatively, the MOD could consider contracting the impact measurement task to a supplier with the relevant expertise. This should be conducted under the authority of the CSA.

How?

A pre-requisite of communicating impact is the ability to assess it. Some of the interviewees[180] said that the MOD current attitude towards assessing impact, both in terms of nature and time horizon, is not aligned with some of the fundamental characteristics of research which include:

- Different degrees (and sources) of uncertainty depending on the maturity of the research.

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[177] Interviews (six) conducted by RAND Europe (2014).

[178] Guthrie, Wamae et al. (2013, 77).

[179] Middleton et al. (2006).

[180] Interviews (six) conducted by RAND Europe (2014).

- Difficulty in predicting the real, as opposed to desired, nature and value of outcomes and impacts as a result of longer time horizons (5–10 years and beyond).
- The scientific value of 'failure'.
- 'Cliff edge' and 'tipping point' effects[181] resulting from the non-linear nature of research.

On the other hand, it is recognised that the MOD would benefit from an assessment of the impact generated by the research it funds to account for its investments in research. A possible solution is to divide benefits/impacts from research into different categories that are applicable (and measurable) at different stages of a research project/programme.

We suggest that there are three levels of ambition the MOD should consider:

1. Initially the MOD should, through discussions with academia and stakeholders in MOD, generate a shared understanding of what constitutes impact and how it would be measured. The dialogue alone will be useful in understanding how and when to try to measure impact.
2. Building on this shared understanding the MOD could then develop a framework and test this approach on a part of the overall R&T programme. Developing a framework would lay the foundations for more formally measuring impact, with a standardised approach that could be repeated across other parts of the R&T programme.
3. If the MOD and academia were both finding the impact assessment process beneficial then the MOD could expand its efforts to cover the whole R&T programme.

The Payback research evaluation framework could be used as a basis for each of these stages.[182]

In the Payback framework, there are five main categories of benefits/impacts which are briefly described in Table A2.3. These categories and the associated descriptions are applicable in the MOD context and would allow for the impact assessment of the majority of research projects/programmes which should have contributed to at least one of the five categories.

Once impact has been assessed, to generate impact reports valuable to the academic sector, the MOD should take into consideration how the concept of impact is defined and articulated in the context, and for the purpose, of the REF process (Box A2.1).

Such reports should aim at highlighting research impact 'reach', defined as how widely impacts have been felt, and impact 'significance', defined as how transformative the impacts have been.[183]

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[181] The 'cliff edge' concept refers to a situation when a relatively small cut in funding may result in a disproportionate loss in outcomes and benefits (collapse of all the research efforts). On the other hand, the 'tipping point' concept refers to a situation when a relatively small increase in funding may result in a disproportionate increase in outcomes and benefits.

[182] Buxton & Hanney (1996); Hanney, Grant et al. (2004); Wooding et al. (2004).

[183] Guthrie, Wamae et al. (2013, 80).

Table A2.3: Categories of benefits from research in the Payback framework.

Category	Description
Knowledge production	Advancements in knowledge on a topic, produced through the research
Benefits to future research and research use	Better targeting of future research
	Human resources capacity building: staff recruitment, training and professional
	Physical infrastructure capacity building: lab and office space, equipment, technology
	Critical capacity to utilise existing research appropriately, including that from overseas
Informing policy and product development	Improved information base on which to make policy decisions: research findings can be used to develop new policy, change policy or maintain existing policy
	Feeding research findings into product and technology development efforts (e.g. science commercialisation)
Sector benefits	Increased effectiveness of service provision leading to improved outcomes
	Cost reduction in the delivery of existing services
	Qualitative improvements in the process of service delivery
	Improved allocation and better targeting of resources
Broader socio-economic benefits	Economic benefits from a better public sector outputs
	Economic gains associated with science commercialisation and innovation

SOURCE: Adapted from Ling & Van Dijk (2009, 130).

Estimated resource requirement?

With the time lag to the next national assessment, and the uncertainties about the role of impact in this, there is a risk that uptake of impact reports generated by the MOD may not immediately be maximised by the academic sector. Therefore we suggest the MOD should gradually build up its investment in the area of impact assessment, and engage the academic sector in what would be mutually beneficial.

For the first stage of determining impact, we estimate that this would require a Grade C1 for 6-12 months with some Band B management support. There would need also to be time commitment from staff in different parts of the MOD. It is possible that a small amount of external support to help the MOD understand how to frame impacts and their measurement would be beneficial. We estimate that the ROM cost of the first stage would be £150,000 – 250,000 with the range depending on the length of time and whether or not external support is used.

To progress to the second stage, MOD staff would be required to either develop the process in-house or to project manage external suppliers to do so. A team within MOD would then need to be assigned the responsibility of managing the periodic execution of the assessment process. The amount of resources

necessary to conduct a research impact evaluation can vary depending on the analytical challenges faced, the method(s) used, the complexity of the study design, the data existing and needing to be compiled.184 Also, the intended use of the results and related need for the study to be carefully researched, documented, defensible, and publishable may affect the overall resourced required.185 From the interviews we conducted we estimate that designing and conducting a small-scale impact evaluation would roughly cost £250,000 – 500,000 (mainly focused on the development of the evaluation framework and the reporting process) which would include external support and the cost of MOD staff support.186

The evidence we reviewed suggests that scaling up the process to the third stage would require between 5 – 10 percent of the overall research budget for a wider and more sustained effort.187 None of the estimates presented here account for opportunity cost.

[184] US Department of Energy Office of Energy Efficiency and Renewable Energy (2007, 9).

[185] US Department of Energy Office of Energy Efficiency and Renewable Energy (2007, 9).

[186] Interviews (two) conducted by RAND Europe (2014).

[187] US National Science Foundation (2010, 30); Kellogg Foundation (1998, 71).

Box A2.1: The Research Excellence Framework (REF)

The Research Excellence Framework (REF) is an assessment tool used to assess the quality of research in UK Higher Education Institutions (HEIs). This assessment, which operates on a five-year cycle, forms the basis for core quality-related research funding distribution by the Higher Education Funding Council for England (HEFCE), the Scottish Funding Council (SFC), the Higher Education Funding Council for Wales (HEFCW) and the Department for Employment and Learning, Northern Ireland (DELNI). The stated aims of the REF are to:

- **Inform** the selective allocation of research funding to HEIs on the basis of excellence
- **Provide** benchmarking information
- **Provide** accountability for public investment in research and demonstrate its benefits.[188]

Assessment is conducted at the level of subject-specific sub-panels, which roughly correspond to academic disciplines, although funding is allocated by institution. The assessment, primarily conducted by peer review through 'expert panels' supplemented by some quantitative indicators, is made on the basis of three key elements:

- **Quality of research outputs:** the criteria for the assessment of these academic outputs are 'originality, rigour and significance'. Ratings are made on a scale from 1* to 4*, and are intended to be internationally benchmarked, so 4* corresponds to world-leading research.
- **Impact of research**: Impact is defined as an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life beyond academia.[189] The aim of this element of the assessment is to reward not just the research that is of the highest quality, but also that which is of great utility. Impact is assessed using case studies of specific 'research-driven impacts' and overarching 'impact statements', which describe the breadth and range of interactions with research users and the effects or outcomes of these interactions. The criteria for assessment of case studies are 'reach and significance', where reach is defined as how widely the impacts have been felt, and significance is defined as how transformative the impacts have been.
- **Vitality of the research environment**: The aim of this element of the assessment is to reward HEIs which have a research environment that supports high-quality research and dissemination or application. The assessment criteria for the research environment are 'vitality and sustainability', covering not only the 'vitality and sustainability' of the submitted unit, but also its contribution to the 'vitality and sustainability' of the wider research base.

The final outcome for each assessed HEI consists of a sub-profile for each of the three elements, along with an overall excellence profile, which combines the three sub-profiles. In 2014 the sub-profiles are combined using the following weightings: output 65 per cent, impact 20 per cent, and environment 15 per cent.[190] Nevertheless, there is a call from some to increase the weighting for the impact element to 25 per cent,[191] reducing the output component to 60 percent.

SOURCE: Adapted from Guthrie, Wamae et al. (2013, *77 - 87*).

[188] HEFCE (2009, 5).

[189] REF (2011b, 48).

[190] REF (2011a, 1).

[191] Witty (2013, 9).

A2.3. The MOD should establish partnerships with the academic sector that go beyond customer/supplier relationships to leverage its knowledge, talent and capital

As outlined in Section 4.4 of the main report, the MOD would further its ability to harness innovation if it moved beyond traditional contract based research. There are examples of this being done with public funding, usually as part of a consortium with other private and charitable funders, which demonstrate that this is achievable within public expenditure rules. We have sought to illustrate how new funding mechanisms could be used, supported by a case study of the Structural Genomics Consortium. We have also discussed in more detail what would be the role of the honest broker in the context of the academic sector and so illustrate the benefits of this approach.

Table A2.4: Recommendations and associated actions for changing the dynamics of interaction

A3	The MOD should establish partnerships with the academic sector that go beyond customer/supplier relationships to leverage its knowledge, talent and capital
Networks / connections	The honest broker should facilitate new ways of partnering with academia
Capital	The MOD should develop and adopt new funding mechanisms that go beyond a customer/supplier relationship with academia

SOURCE: RAND Europe analysis.

A2.3.1. The honest broker should facilitate new ways of partnering with academia

The MOD should develop and maintain key liaison functions for academia through an 'honest broker' that brings together different innovation actors, as well as promoting greater awareness within the academic sector of the MOD's innovation requirements.

Why?

The need for the honest broker is set out in Section 4.4.2 of the main report and its role will be to facilitate the development of networks and partnerships across the whole value chain between the MOD, the prime contractors and potential academic stakeholders. The broker will be key for the MOD to use its resources to leverage greater value from academic partners.

The honest broker would take on a proactive 'market-scouting' role, seeking out opportunities for collaboration on subjects of innovation and bringing together the necessary actors from government, industry and academia.[192] As shown by the DeVenCI programme and other similar initiatives the broker

[192] Weiss (2014, 73).

would provide information to facilitate collaboration and search for new areas of work being pioneered in the academic sector in a constant process of horizon mapping and stakeholder engagement. [193]

Several of the interviews demonstrated a lack of awareness among academics about current ways to work with the MOD, even among those who had worked with the MOD before.[194] Seven of the ten academics we interviewed felt that working with the MOD was dependent on personal contacts (or lack thereof), noting that they were not aware of formal channels of communication beyond these personal links.[195] This dependency on personal networks also contributes to a perception of a 'closed circle' between the MOD and a sub-set of universities which was claimed to deter other academics from engaging.[196] An 'honest broker' would provide a clear entry point to the MOD, and would also establish new networks to create beneficial new research and commercialisation pipelines between other actors in the innovation ecosystem.

Interviews also raised the need for a broker to 'translate' and communicate each side's needs, motivations and goals to other parties.[197] The applicability of academic research is not always readily apparent to MOD users, and the MOD and military needs and terminology is unfamiliar to many academics. More clearly communicating the opportunities that the MOD offers may mitigate the concerns held by some academics about the barriers posed by MOD procurement processes.[198] Furthermore, it could make it easier for academics to understand other opportunities to work with the MOD such as studentships and personnel exchanges.

The honest broker could build on a range of successful international models, such as the 'co-op' talent exchange programmes of the University of Waterloo (see Box A2.2),[199] the 'matchmaker' or 'deal broker' role of the US Navy's Commercial Technology Transition Office, or the activities of the not-for-profit DeVenCI organisation, which performs a horizon-scanning and brokering role for emerging technologies, as well as hosting demonstration events to raise awareness within the US Department of Defense.[200]

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[193] Brown et al. (2008).

[194] Interviews (three) conducted by RAND Europe (2014).

[195] Interviews (seven) conducted by RAND Europe (2014)

[196] Interviews (four) conducted by RAND Europe (2014).

[197] Interviews (four) conducted by RAND Europe (2014).

[198] Interviews (five) conducted by RAND Europe (2014).

[199] Bramwell and Wolfe (2008); DeClou et al. (2013); Nelles et al. (2005).

[200] Brown et al. (2008).

Box A2.2: The University of Waterloo

As the largest initiative of its kind in the world, the co-operative education programme run by University of Waterloo in Ontario, Canada is a particularly successful example of engagement between academia and industry. The programme currently has 17,300 co-op students enrolled in 140 courses and Waterloo co-op graduates working for 5,200 employers.[201] The co-op system is a form of work-integrated-learning (WIL) that combines academic studies with work terms in industry.[202] It fosters cross-sector engagement by providing students with work placements and local companies with talent and inexpensive labour.

Waterloo's system of co-operative learning stimulates innovation in several key ways. Firstly, the programme creates human capital by attracting and generating a large pool of highly qualified scientists who are attuned to the research needs of industry.[203] A further benefit of co-op placements is the commercialisable ideas that students generate. Exposed to new ideas in their academic courses, students can bring cutting-edge knowledge to their work placements.[204] Waterloo students also enable knowledge circulation between firms by transferring ideas and know-how between different firms as they move from placement to placement.

From the employer's perspective, co-op placements are an effective means of providing inexpensive, short-term labour. As part of a survey conducted by the Academica Group in Spring 2011 and Spring 2012, employers in the Waterloo region said that WIL helped them to 'manage short-term pressures or complete special projects'.[205] The co-op programme is also a valuable source of new hires for local firms in the Waterloo region. In the Academica Group survey, one-quarter of co-op employers cited pre-screening potential hires as an important reason for providing WIL.[206]

Beyond its co-op programme, the University of Waterloo engages with industry through joint research ventures and project oriented consulting.[207] When firms want to invest in R&D for incremental innovation of an existing product or process, or to act as 'test beds' to solve a problem that requires university expertise and/or research facilities, they often enter into short-term, project-focused fee-for-service R&D agreements.[208] These joint ventures attract industry as they offer a 'first look' into cutting-edge research developments. By subsidising or fully funding university research, a firm can gain preferential access to research results.[209]

[201] University of Waterloo (n.d.).

[202] DeClou et al. (2013, 8); Nelles et al. (2005).

[203] Bramwell and Wolfe (2008, 1180).

[204] Bramwell and Wolfe (2008, 1181); Senker (1995).

[205] DeClou et al. (2013, 100–101).

[206] DeClou et al. (2013, 100–101).

[207] Bramwell and Wolfe (2008, 1180).

[208] Grossman et al. (2001).

[209] Bramwell and Wolfe (2008, 1182).

When?

The MOD would need to take time to develop a clear set of requirements for the honest broker function, which could be achieved with three months of concerted effort. Time would then be required to establish the unit in-house, perhaps a further three months. If the function were to be contracted out, then depending on the contracting mechanism it would be appropriate to allow three to six months to identify the honest broker. We suggest that the honest broker could be established within 12 months, although this may need to be sequenced with the publication of a policy. After the honest broker is established, it should be subjected to periodic review, and in the case of a contracted service the opportunity should be re-competed after a defined period of time, perhaps every three to five years.

Where?

The honest broker function could be housed in a dedicated MOD unit or at an easily-accessible external site that has established activity in brokerage between innovation actors. Relevant details should be published online and promoted to university research directors (e.g. through organisational charts or infographics).

Who?

The honest broker could be a group of officials, in the MOD or Dstl, which would carry the commercial impartiality that is attributed to government bodies, but the MOD would need to consider carefully whether it has the talent and knowledge to adequately perform this function. Alternatively, the function could be carried out by any contracted organisation or group (sourced through a competitive tendering process) that can hold the trust and respect of the different stakeholders. A further alternative that could be considered is how to work with the Research Councils to harness their networks and resources to perform many of the functions that we have described for an honest broker. In whichever case, the honest broker should be established under the authority of the CSA with the backing of the Defence R&D Board.

How?

Interviewees suggested that the honest broker should provide the following functions, which is also illustrated in Figure A2.1:

- **Entry portal:** Provide and clearly advertise a single point of contact for academics looking to engage on a subject of innovation and a 'dating service' to connect them to key actors in the MOD or elsewhere. This would include an online gateway directing people to the relevant contact (e.g. the CDE or relevant technical authority within Dstl) and sending visual organisation charts of key MOD contacts to universities (perhaps funded through advertising, much as the organisation charts for DE&S are provided).[210]

[210] Interviews (seven) conducted by RAND Europe (2014).

- **Guidance and FAQs:** Complement the above efforts to assist academics in navigating the organisation with clearly-advertised guidance as to the MOD's innovation needs, upcoming research opportunities and contracting processes (e.g. in online FAQs/primers, on call, using webinars, and through regular short open workshops).[211]
- **Outreach and event coordination:** Raise awareness of the MOD's work and create opportunities for networking through active engagement with universities (faculties, research directors, external engagement teams), Research Councils, and other groupings (e.g. the Russell Group, University Alliance). This would include hosting events about Dstl work and presenting at academic conferences.[212]
- **Impact support:** Provide support in identifying and communicating impact across the life-cycle of a project including supporting publications and advertising case studies of past research impact.[213]
- **Commercialisation support:** The MOD should provide a networking function that fosters links between academics, industry and investors, benefitting the MOD as well as the UK economy.[214]

In order for the MOD to target its outreach efforts, inform internal decision-making and better leverage its innovation resources, interviews suggested that it should complement these broker functions with key strategic activities:

- **Market intelligence:** Landscape mapping exercises (e.g. network analysis, scientometrics, virtual world congresses) conducted in collaboration with both academia and industry to identify the key actors and potential future MOD partners in each priority technology area.[215]
- **Promotion of internal S&T awareness:** Invitation of academics to deliver briefings on cutting-edge innovation topics or hosting technology demonstration events attended by MOD personnel, along with embedding an understanding of S&T in management training courses.[216]
- **Talent exchange:** More long- and short-term placements and fellowships, both bringing academics into the MOD and seconding MOD staff to universities and Research Councils.[217] Provision should also be made to reach out to students and the future generation of innovation talent, whether through PhD studentships, 'co-op' work placements, internships or student innovation competitions and prizes (see also Section A2.4.2).

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[211] Interviews (two) conducted by RAND Europe (2014).

[212] Interviews (seven) conducted by RAND Europe (2014).

[213] Interviews (six) conducted by RAND Europe (2014).

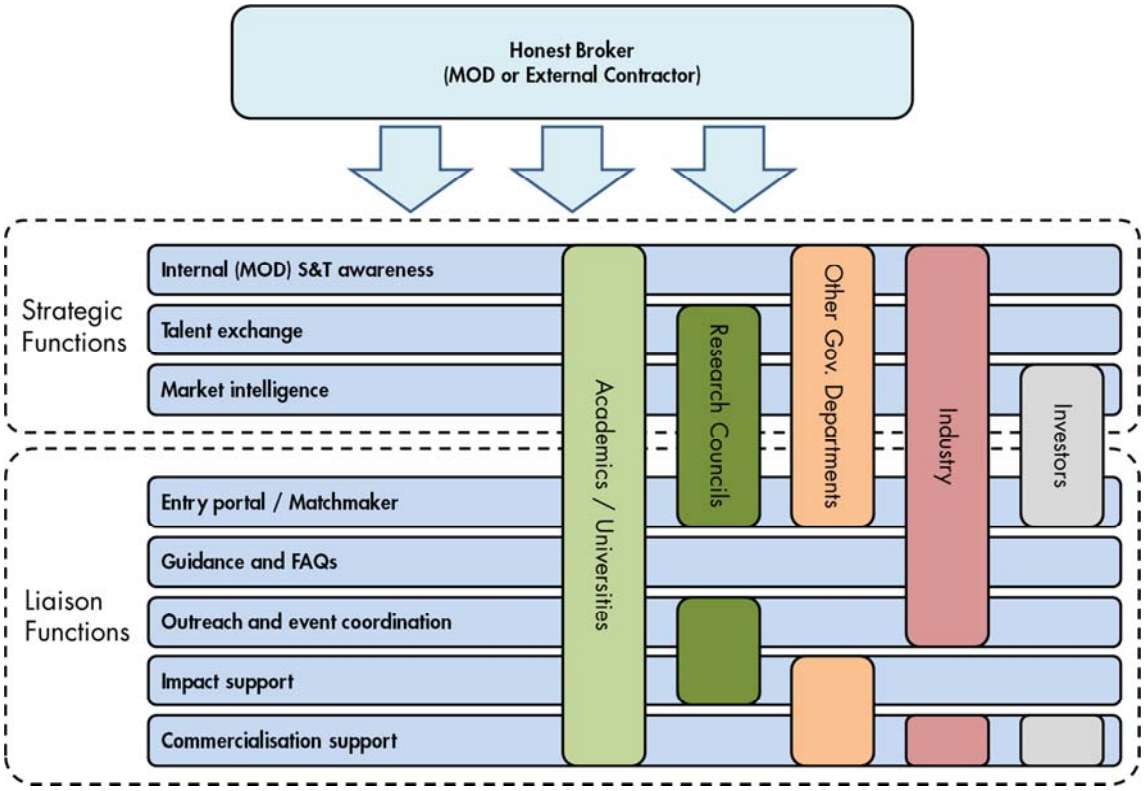
[214] Interviews (six) conducted by RAND Europe (2014).

[215] Interview conducted by RAND Europe (2014).

[216] Paone (2010).

[217] Interviews (two) conducted by RAND Europe (2014).

Figure A2.1: Schematic representation of how an honest broker would function with respect to different stakeholders



SOURCE: RAND Europe analysis.

Estimated resource requirement?

MOD staff resources will be required to define the scope and requirement for the honest broker functions, and the terms of any competitive process if an external supplier is to be used. Funding will be required from the S&T programme to establish the honest broker team or fund the honest broker contract. It may be that DE&S would co-fund if there is sufficient correlation with their areas of interest. It could be made a part of the competitive requirement that the successful bidder will be expected to leverage funding from industry and academia (and possibly the Research Councils or other funding bodies).

With an annual budget around $2.8m,[218] DeVenCI provided a core secretariat, a team of external venture capitalists to identify innovative new ideas, and funds for technology demonstrations events, showcasing new technologies from research teams given grants ranging from $25,000 to $375,000.[219] However, part of the DeVenCI function was provided pro bono by venture capitalists so the realistic cost could be higher.

[218] Lais (2007).

[219] Paone (2010).

We estimate, based on the DeVenCI example, that the ROM cost of establishing an honest broker would be in the range of £1–3m per year, with the range reflecting the scale of ambition the MOD would have for this function.[220] This does not account for opportunity cost.

A2.3.2. The MOD should develop and adopt new funding mechanisms that go beyond a customer/supplier relationship with academia

In order to fully exploit the new engagement opportunities provided by an honest broker function, the MOD should develop and adopt new funding mechanisms that go beyond the traditional customer/supplier relationship.

Why?

Aligning funding mechanisms to the specific needs, processes and goals of the academic sector was identified by many interviewees as something that would incentivise academics to engage more with the MOD.[221] In addition to the need for an interesting research problem, academics emphasised the attraction of contracts that allow researchers to produce publications, demonstrate impact, collaborate with a wide array of partners, and develop talent.[222]

Existing MOD contracting procedures may act as a barrier to engagement from the academic sector. One example provided was of a £10,000 project where an academic was asked to limit their liability to the MOD to £100,000 – far in excess of the university's tolerance of risk.[223] Other points of concern included the levels of administration involved in MOD tenders, the lack of pre-competitive arrangements, a perceived over-reliance on tangible deliverables not necessarily reflective of the uncertainties of basic research, and short lead-in times to respond to calls for research. As one MOD source acknowledged, the discretion to exercise some of these options already exists, but 'a standard way of operating' means that it often 'does not occur to us to tailor a stock contract to the academics' context and the needs of different organisations'.[224]

Different funding mechanisms should be applied depending on the scale, requirements and timeframe of individual projects, with the selection of these mechanisms also taking into account the wider long-term benefits that might be derived outside of a project's immediate goals, e.g. establishing a strategic relationship with a university or developing talent and networks in an emerging technology area.

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[220] This figure is based on a similar figure used to fund DeVenCI. However, it is important to note that part of DeVenCI work was done pro bono by venture capital companies.

[221] Interviews (thirteen) conducted by RAND Europe (2014).

[222] Interviews (eight) conducted by RAND Europe (2014).

[223] Interview conducted by RAND Europe (2014).

[224] Interview conducted by RAND Europe (2014).

Such an approach would allow the MOD to target funding in a manner more reflective of its strategic needs for a specific area of S&T, as well as leveraging capital, talent and networks from other actors. Working with different co-sponsors, meanwhile, further incentivises academics to engage by emphasising the 'dual use' of many S&T breakthroughs for both the defence and civilian sectors, allowing them to demonstrate impact across government departments, contribute to wealth creation and drive further innovation through access to wide networks of different expertise.

Recent engagement initiatives by the MOD provide a range of models around which to innovate and anchor new mechanisms so as to achieve further future success:

- A Royal Society Fellowship initially funded by the MOD for around £100,000 per annum for the first five years has led to that fellow having a research portfolio of almost £15m. This investment has clearly enabled the MOD to develop a relationship that has leveraged access to knowledge and talent of a far greater value than the initial investment.[225]
- The University Defence Research Collaboration in Signal Processing has helped foster new networks within and between two consortia focused on the universities of Edinburgh and Loughborough, sharing funding costs between the EPSRC and Dstl. The two consortia have received funding for £3.8m[226] and £3.6m[227] respectively, over five years.
- In the area of quantum technology, the MOD's contribution of around £30m over five years to a joint national strategy will give it access to the research output produced by almost £270m of total funding from different government departments and Research Councils. It is also emphasising long-term talent development, both for the MOD and the UK, spending £5m to support 40 relevant PhDs.[228]
- The MOD is also emphasising long-term talent development, both for the MOD and the UK. Dstl's £3.2m Defence and Security PhD scheme – where 56 PhDs have been awarded to 23 universities to date[229] – offers students the opportunity to work in industry alongside their studies, allowing them to apply theories and tools learned through their coursework in an industry setting.[230] The benefits of work-integrated-learning are explored in more detail in Box A2.2, which describes the co-operative programme run by the University of Waterloo.

These existing models should be maintained and could be expanded, with greater flexibility and a more collaborative approach applied to other funding mechanisms for academic innovation, drawing on the lessons of initiatives in other S&T sectors, such as the Structural Genomics Consortium (see Box A2.3).

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[225] Interview conducted by RAND Europe (2014).

[226] EPSRC (2012a).

[227] EPSRC (2012b).

[228] Interview conducted by RAND Europe (2014).

[229] Dstl (2014b, 3).

[230] Interview conducted by RAND Europe (2014).

When?

The MOD should not rush to create initiatives without good rationale, but there is evidence that alternative funding mechanisms can be used to effectively access knowledge, talent and networks across the innovation ecosystem.[231] The MOD could reasonably conduct analysis over the next six months to determine which further areas would be suited to novel funding mechanisms. This could then lead to the establishment of further initiatives roughly within 18 months.

Where?

The analysis of which areas could be suited to alternative funding mechanisms can be conducted within the MOD and/or Dstl. Any activity funded by the MOD could be, for example, at the suppliers' organisation, but with the possibility of personnel exchange with the MOD.

Who?

As the main contracting body for research it is logical that Dstl should develop the range of new funding mechanisms, working closely with DST and under the authority of the CSA.

How?

Based on the findings of the red tape review proposed in Section 4.2.1 of the main report, the MOD should assess which new funding mechanisms it could use. This assessment should include consultation with external actors (academia, industry, and other funding bodies).

Interviews and past RAND research identified a range of possible funding options for this assessment process to consider, such as:

- Increasing the amount of co-funded projects with other bodies (e.g. Research Councils), building on what the MOD already does, such as the UDRC and quantum initiatives. [232]
- Using pre-competitive arrangements, especially for early-stage research, such as the model of the Structural Genomics Consortium (SGC), which has proved an effective form of cooperation between industry, academia, charitable funders and government. The SGC shows that competition rules can allow for such a process and that intellectual property rights do not need to be a barrier.[233] Greater use of prizes as a low-risk incentive for innovation that offers academics prestige as well as immediate financial reward for creative solutions to designated problems.[234]

In addition, interviewees identified a number of potential changes to how the MOD sets its requirement for research and manages its commercial processes, including:

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[231] Guthrie, Guerin et al. (2013).

[232] Interviews (five) conducted by RAND Europe (2014).

[233] Morgan Jones et al. (2014).

[234] Brutscher et al. (2009); Ling (2008).

- Specifying deliverables more appropriate for the uncertainties of basic research (i.e. not too tightly bounded), including consideration of how academics might demonstrate impact from a project (e.g. publications).[235]
- Planning for longer lead-in times for calls for academic research compared to contracts with industry, where project teams can be more rapidly assembled.[236]
- Greater use of exemptions for academia from stock contract clauses more applicable to industry.[237]
- More long-term engagements that go beyond simple payment for a research service such as funding PhD studentships or providing opportunities for personnel exchange.[238]

Estimated resource requirement?

MOD personnel would need to conduct the assessment of funding mechanisms which could be conducted at the Grade C1 level, with Band B supervision. This need not be a significant task, but would require careful engagement with finance and commercial officials in the MOD; our ROM estimate is that this would be six months of work and up to £150,000–250,000, which includes the cost of working with stakeholders across the MOD. This does not account for opportunity cost.

Developing new funding models for implementation would require a more significant commitment of resources. If, for example, the MOD wished to create a new funding mechanism that had not already been demonstrated in the MOD then this would require extensive discussion with other funding bodies, including at more senior levels. The scale of the negotiation could require a Grade C1 equivalent for 6–12 months, with significant support at the Band B level and higher, which we roughly estimate might cost £250,000 – 350,000 to establish (again not accounting for opportunity cost).

Based on the cost evidence on initiatives such as the UDRC or the quantum programme, we roughly estimate that funding one initiative would cost £4–8m over five years with the range varying based on the scale of the activity. We address the costs of an SGC type of initiative in Section A2.4.2.

[235] Interviews (six) conducted by RAND Europe (2014).

[236] Interviews (three) conducted by RAND Europe (2014).

[237] Interviews (three) conducted by RAND Europe (2014).

[238] Interviews (five) conducted by RAND Europe (2014).

A2.4. The MOD should create spaces where inventors, investors and industry can partner with the MOD to leverage its resources

In Section 4.5 of the main report, we have recommended that the MOD should create spaces where a range of innovation actors can come together not just from the academic sector. We have, therefore, detailed specific actions the MOD could take that would be very open to, but not limited to, the academic sector. We have explored in more detail the option of creating outstations centred on areas of emerging technology and also the concept of an innovation campus located very close to an MOD site.

Table A2.5: Recommendations and associated actions for changing the location of innovation

A4	The MOD should create spaces where inventors, investors and industry can partner with the MOD to leverage its resources
Infrastructure	The MOD should establish emerging technology outstations
	The MOD should consider establishing an innovation campus centred around an MOD site

SOURCE: RAND Europe analysis.

A2.4.1. The MOD should establish emerging technology outstations

Why?

By identifying emerging technology areas of particular interest to the MOD, and by creating outstations where MOD officials can work alongside technology experts, there would be a significant exchange in knowledge (both about the technologies and also about the MOD's needs) and talent. Depending on the nature of each outstation, there may also be leverage of capital. Building on initiatives such as the UDRC (see Section A2.3.2), the creation of outstations would enable the MOD to gain access to cutting-edge research using the wider innovation infrastructure. Outstations would create opportunities for networking and will become an innovation network in their own right. The outstations would provide the opportunity for the MOD to operate within a culture that has been set up to focus on innovation.

When?

There is no firm rationale for how quickly outstations should be established and how many should be set up. However, there would be advantage in establishing the first outstation fairly swiftly, for example within 18 months, to prove the principle and demonstrate the MOD's new approach to harnessing innovation. Given that the MOD's priority technology areas are likely to change over time, each outstation should be set up for a ROM period of between five and ten years and then re-competed. Five years is a useful timeframe as it enables academics to attract researchers, undertake meaningful research and bid for further work that could further leverage the MOD's investment.

Where?

Each outstation should be established at a university, technology centre or incubator. To avoid promoting the 'inner circle' culture identified in Section A2.1.1, outstations should be spread across the country rather than clustered around a single university.[239] A hub and spoke model involving multiple universities and physical locations would allow the MOD to maintain a more neutral position while attracting buy-in from a larger number of universities.[240]

Outstations should be established in close proximity to the academic communities with which the MOD wants to engage.[241] This would help to address concerns that the financial and time costs required to travel to remotely situated outstations could deter academics and MOD officials from collaborating.[242]

Who?

Outstations should be established by Dstl in agreement with DST. It may be that the MOD wishes to work with the Research Councils to help identify and establish these outstations.

How?

Outstations should be established through a competitive tendering or research grant type process, and each outstation should focus on a single technology area.[243] The breadth of its portfolio means that the MOD should probably establish several outstations that specialise in different technology types.

The MOD might consider selecting emerging technology areas for the outstations based on its nine priority S&T capabilities[244] and the Research Councils' main growth areas.[245] Moreover, each technology area should be of commercial interest and should demonstrate utility to sponsors.[246] Interview participants highlighted cyber, defence manufacturing, and computer sciences as possible areas for MOD consideration.[247]

When designing and developing its outstations, the MOD could draw valuable lessons from existing initiatives that bring together a range of stakeholders on the same physical campus. The UDRC –

[239] Interview conducted by RAND Europe (2014).

[240] Interview conducted by RAND Europe (2014).

[241] Interview conducted by RAND Europe (2014).

[242] Interviews (two) conducted by RAND Europe (2014).

[243] Interview conducted by RAND Europe (2014).

[244] Dstl (2014a).

[245] Interview conducted by RAND Europe (2014).

[246] Interview conducted by RAND Europe (2014).

[247] Interviews (two) conducted by RAND Europe (2014).

described in more detail in Section A2.3.2 – is one such example of an academia led partnership between industry and defence.[248]

The University of Bradford's £12m University Enterprise Zone in digital health innovation is another model for cross-sector engagement that the MOD may wish to draw upon.[249] Partly funded by the Department of Business Innovation and Skills (£3.8m), the programme commenced in July 2014 and is a partnership between the university, BT and the City of Bradford Metropolitan District Council that is strongly supported by key NHS organisations and regional business.[250]

The MOD could also draw valuable lessons from overseas initiatives. In the US, the Army Research Laboratory (ARL) has sponsored 13 University Affiliated Research Centres (UARCs), each of which receives an annual average of over $6m (over £3.7m) in sole source funding.[251] UARCs are university led initiatives that focus on S&T issues of critical importance to the army, and where universities provide facilities and share space with army and industrial participants.[252] These three initiatives could offer the MOD valuable lessons regarding the funding, networks and infrastructure required to establish an outstation.

To encourage collaboration with academic institutions based overseas, the creation of physical outstations could be accompanied by the increasing use of virtual conferences.[253] Virtual platforms would enable the sharing of knowledge and talent across borders by addressing time, cost and travel barriers.

Estimated resource requirement?

The MOD will need to commit resources to deciding which areas should be competed for outstations, and setting the requirements and terms of the competitive process. There would need to be discussion with other potential co-funders such as the Research Councils, which would require additional time. We estimate that this could be done fairly quickly by a Grade C1 with Band B support over a ROM period of six months, so perhaps roughly £150,000–250,000 (not accounting for opportunity cost).

To fund the outstations themselves, we estimate that the ROM cost will be £4–12m for each outstation, based on similar initiatives elsewhere such as ARL's UARCs and the University of Bradford's University Enterprise Zone. Depending on the subject area the MOD may be able to share the funding with other organisations such as the Research Councils UK (RCUK) or BIS. It could also be a requirement of the outstation that the host organisation demonstrates how it would leverage the MOD's funding to bring in funding from other bodies and investors.

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[248] University Defence Research Collaboration (n.d.).

[249] Interview conducted by RAND Europe (2014).

[250] University of Bradford (2014).

[251] Defense Laboratories Office (2013, 5).

[252] Army Research Laboratory (n.d.).

[253] Interview conducted by RAND Europe (2014).

A2.4.2. The MOD should consider establishing an innovation campus centred around an MOD site

Why?

By creating a central innovation campus, the MOD would be sending a significant signal to the wider innovation community that it is serious about harnessing innovation from external sources. Creation of a campus near to, but not on, a secure site would enable ready interaction between the MOD, inventors as well as investors and industry to stimulate the development of technologies and solutions.

This campus would attract academic experts by offering them a site and equipment for testing their experiments. It would enable the ready communication to stakeholders of the drivers of innovation for defence and the processes that stakeholders would need to operate with (the structures). It would also facilitate the exchange of knowledge and talent and potentially the leveraging of capital. A culture conducive to innovation could be established on the campus without the constraints imposed by operating on an existing MOD establishment. The campus could act as a host location for the 'honest broker' function.

The innovation campus could also be based on a novel funding mechanism, such as that described for the SGC, which would enable different innovation actors to participate in a pre-competitive environment with sharing of knowledge and intellectual property.

At the time of writing, there is not much publicly available information about the Defence Solutions Centre that is to be established in Farnborough.[254] It is possible that this might share many of the features we are describing for an innovation campus.

When?

Given the scale of effort involved in establishing an innovation campus, a significant amount of time should go into planning the initiative, in the order of 12–18 months. The Stevenage Bioscience Catalyst, which is campus-based, was announced in October 2009, with construction starting in November 2010 and was opened by David Willetts in July 2011; similar timescales would be relevant to the MOD.[255] Whilst a campus would obviously be a permanent entity, the way in which it operates and associated funding could be the subject of periodic review (as happens with the SGC).[256] It could be established for an initial period of five years, as this is likely to suit academic timescales, with the possibility of extension.

[254] Gov.uk (2014c).

[255] Picardo (2011).

[256] Morgan Jones et al. (2014).

Where?

The innovation campus should be situated close to an existing MOD site in a location that has good communications links. Porton Down is one possibility. Alternatively, North Bristol would offer proximity to MOD Abbey Wood, major defence companies and several universities. The Defence Solutions Centre is to be based in Farnborough which could make this a suitable place to also establish an MOD innovation campus. It has good communications links and is close to many defence industrial sites.

Who?

It should be established by Dstl under the authority of the CSA with the backing of the Defence R&D Board.

How?

The MOD innovation campus could be established through a competitive tendering or research grant process looking for a consortium of organisations to manage the campus infrastructure and deliver the research output. Alternatively, it could be established by a consortium of willing partners, which might include the TSB, industry and universities. The initiative could potentially include the provision of the honest broker function. The requirements (if a contract) or operating vision (if a consortium of willing partners) should be set to maximise collaboration between academia, industry and investors. The campus should be accessible to all universities. The Structural Genomics Consortium (SGC) is a useful example of this open access model and is described in Box A2.3. The SGC, with campuses at the University of Oxford (UK) and University of Toronto (Canada), has received more than $425m (£265m) of funding since its creation in 2004 – over $16m (£10m) of which has been allocated to infrastructure.[257] The first phase of the SGC cost $142m (approximately £90m), which provided for two campuses. The SGC showcases the benefits of pooling talent, collectively leveraging funding, sharing infrastructure, and expanding networks.[258]

The NASA Research Park (NRP) is another example of a shared-use R&D campus for government, academia, industry and non-profits that provides a physical space for innovation and entrepreneurship.[259] The total development cost for NRP and three other NASA campuses – the Ames campus, Bay View and Eastside/Airfield – was set at $1bn (over £600m) in the NASA Ames Development Plan.[260] This included costs for infrastructure upgrades and replacements, in addition to building renovation and construction. The NRP and SGC initiatives are case studies of how cross-sector partnerships can catalyse innovation, and the MOD may wish to consider developing a similar model when designing and running its innovation campus.

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[257] Morgan Jones et al. (2014, 42–43).

[258] Morgan Jones et al. (2014).

[259] NASA (n.d.).

[260] Braukus and Mewhinney (2003).

Box A2.3: Structural Genomics Consortium

Since its establishment in 2004, the Structural Genomics Consortium (SGC) has been supporting drug discovery efforts through a unique, open access model of public-private collaboration and pre-competitive research. Funded by the Wellcome Trust, several public sector investors and nine large pharmaceutical companies, the SGC consists of 20 research groups affiliated with the University of Oxford, UK, and the University of Toronto, Canada.

The SGC was founded with a mission to catalyse research in human biology and drug discovery research by focusing on less-well-studied areas of the human genome. This came as a response to concern that a lack of collaboration meant that academia and the pharmaceutical industry were failing to deliver the throughput of new protein structures important to the future drug development pipeline. The consortium accelerates research in these new domains by making all of its research output available to the scientific community without intellectual property restrictions on its use until later stages of clinical trials. As a large-scale, long-term and multiple-funder initiative, it has not only provided stability to the field but also created an open collaborative network, comprising scientists in hundreds of universities and nine pharmaceutical companies around the world.

Funders jointly choose research topics, and the results are made freely available to anyone, whether or not they invest directly in the SGC. This is a new model for organising and funding drug discovery, and was chosen as one that promotes collaboration, combats duplication of effort in basic research and avoids the delays and conservatism associated with the usual peer review process that precedes funding in other settings. Since its inception in 2004, the SGC has attracted over $425m CAD from a combination of public and private sources.[261]

Though its networks leverage academic talent, the SGC possesses several characteristics of an 'industrial model' for research, with milestones and targets determining the scientific outputs and a commitment to ensuring that findings can be reproduced by others. As well as developing the structures of 1,195 proteins for the Protein Data Bank, the SGC produced 452 peer-reviewed journal publications by August 2013, while its scientists attended and presented at over 250 conferences between 2007 and 2011.[262] In 2014, RAND Europe and the Institute on Governance conducted an evaluation of the SGC as a model for investing in research, generating knowledge and extracting value from innovation. The study found:

- Research by SGC is viewed as reliable and highly reproducible, which is valued by investors.
- Many investors view the SGC as a way to 'de-risk' novel areas of science.
- Open access facilitates extensive collaborations across public and private sectors.
- The mix of public and private investment in the SGC allows it to remain innovative and efficient, in terms of structures, research topics and methods, incentivising investment.
- A clear majority (82 per cent) of surveyed researchers said their research had come to fruition more quickly through the SGC than if they had used traditional approaches.[263]

[261] Morgan Jones et al. (2014, 42).

[262] Morgan Jones et al. (2014, xiii).

[263] Morgan Jones et al. (2014, 31).

The development of this campus could create opportunities for talent placement in order to facilitate the ready exchange of knowledge and expertise. The MOD should establish a talent placement programme for academia on its campus to support Dstl's strategic objective of increasing the number of inward secondments for academic experts.[264] Interviewees suggested that internships or secondments that last for longer than half a year often lead to more productive partnerships than shorter placements,[265] and so the MOD should introduce initiatives that last between nine and twelve months. These placements could be based both at the MOD's innovation campus and its emerging technology outstations.

In order to develop its own talent placement programme(s), the MOD could look to initiatives run by other organisations which have been particularly effective. One such example is the RAND Project AIR FORCE (PAF), which is a federally funded research and development centre that assists the US government with research, analysis and development. As part of PAF's Air Force Fellows Program, Air Force officers are seconded to the centre once a year to participate in PAF research projects, allowing RAND scientific staff to have continuous engagement with professional military training and experience.[266] The MOD could draw on best practice from initiatives such as the PAF Air Force Fellows Program when developing its own talent placement programme(s).

Estimated resource requirement?

MOD staff resources would be needed to define the requirement and the terms of the competitive process, which we estimate would roughly take 12–24 months. Much of the work could be done by two staff the Grade C1 level but there would need to be significant support from Band B management and senior civil service involvement. There would also need to be extensive support from MOD commercial staff. There would be significant negotiation with the consortia bidding for the opportunity. We estimate that the ROM cost of defining and running the competition would be £350,000–700,000.

Funding will be required from the S&T programme to develop the campus and would likely include capital as well as resource costs. It may be that DE&S would co-fund if there is sufficient correlation with their areas of interest. A case could be made for getting the Front Line Commands to co-fund, by providing staff if nothing else. It could be made a part of the competitive requirement that the successful bidder will be expected to leverage funding from industry and academia (and possibly the Research Councils or other funding bodies).

Based on examples such as the NRP, Stevenage Bioscience Catalyst and the SGC, we estimate that the ROM cost of establishing the campus and operating it for the first phase would be between £38–150m,

[264] Dstl (2014b, 5).

[265] Interviews (two) conducted by RAND Europe (2014).

[266] RAND Corporation (n.d.).

which would be shared with other partners.[267] The considerable range reflects the quite different scale of ambitions between the UK examples and the NASA example. If the MOD scaled its ambitions appropriately, the lower end of this estimate range would be reasonable.

[267] These figures are based on the assumption that SGC funding is divided equally between the University of Oxford and the University of Toronto; and that funding under the NASA Ames Development Plan is split evenly between the four NASA campuses.

A3. Conclusions

A3.1. The recommendations of the main report have been expanded in the context of the academic sector

The further research we have conducted into how the MOD might seek to harness innovation from the academic sector has served to reinforce the four recommendations of the main report by highlighting specific actions that can be taken in each area. Furthermore, this suggests that if the MOD wishes to conduct a similar more detailed investigation into the implications of our report for other sectors, for example industry or investors, this should be feasible and should yield useful specific actions.

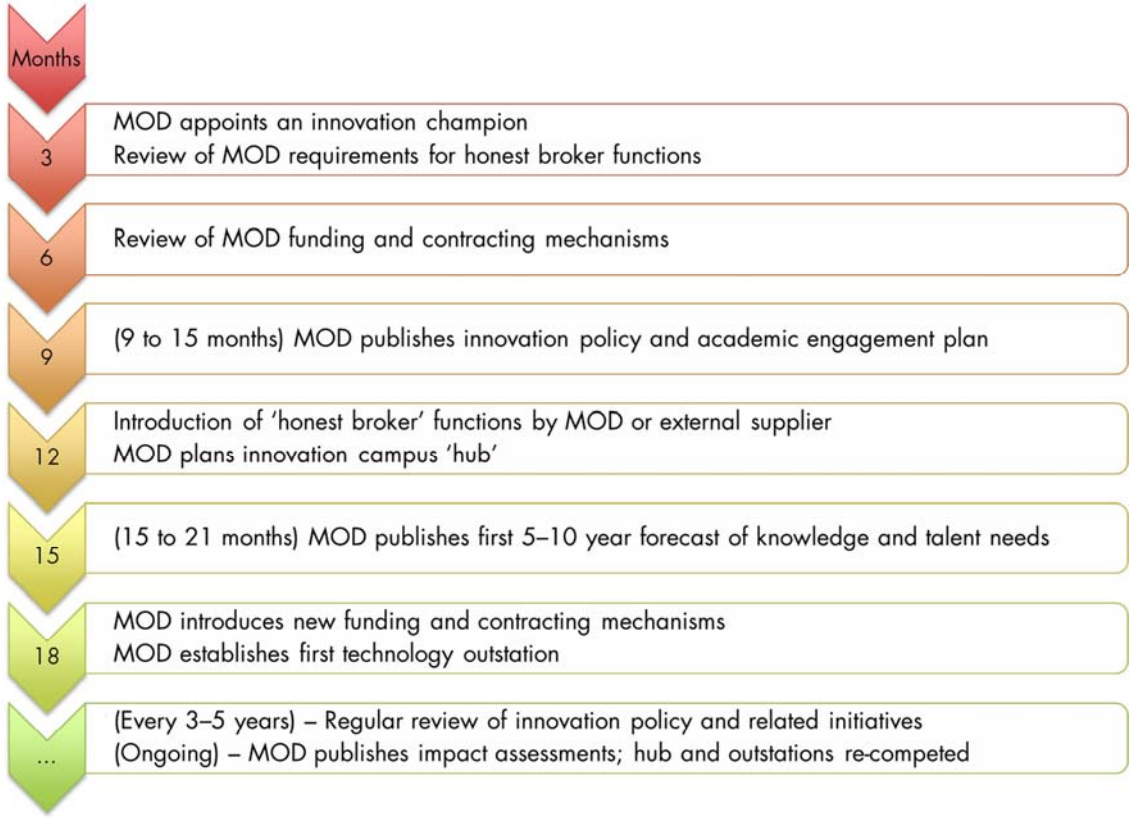
What our research has also confirmed is that the MOD has already taken steps on the path towards engaging with academia to harness innovation and we would encourage the MOD to continue with these. For example, the Dstl Corporate Plan identifies key technology areas which we believe is beneficial, and we would argue that providing further detail on what this might mean would help to prepare the academic sector so that it can provide services to meet these needs.

We would encourage the MOD to take action across all four of our recommendation as this will help the MOD embrace the systems nature of innovation and ensure that all aspects of our innovation framework are addressed which will increase the likelihood of creating the conditions for a productive innovation process. An overview of the proposals in this annex is provided at Figure A3.1.

A3.2. Appointing an innovation champion will help change the MOD's internal context and provide a strong signal to the academic sector of the MOD's commitment to innovation

The importance of changing the internal context in MOD for innovation is largely independent of whichever sector the MOD chooses to work with to harness innovation. Hence, our focus in this section has been on identifying a single concrete action the MOD can take, the appointment of an innovation champion. The champion should ensure the internal changes are made and that the MOD communicates to the academic sector its commitment to undertaking new approaches to innovation.

Figure A3.1: A suggested timeline for implementing our proposals



SOURCE: RAND Europe analysis.

A3.3. By communicating to academia its knowledge and talent needs and by better measuring research impact the MOD could make itself a highly attractive client to the academic sector

The research we conducted has shown that an innovation policy and academic engagement plan would be useful tools for communicating to academic stakeholders what the MOD's aims and ambitions are. Supporting the policy with a forecast of knowledge and talent needs in key areas would give the academic sector information that would help them plan what research areas to maintain and develop and also what areas new students should be trained for. Perhaps most importantly, the academic sector needs to be able to demonstrate research impact and if the MOD can help them achieve this then that would be a powerful incentive for academia to work with the MOD.

A3.4. The MOD can change the dynamic of its interactions with academia by establishing an honest broker and using different funding mechanisms

We have provided further detail of what the honest broker function would entail, based on interviews with academic stakeholders. There are examples of similar broker functions in the defence context, for

example the US Navy's CTTO (Section 4.4.2 of the main report) or DeVenCI. We have also highlighted how different funding mechanism could be applicable for working with the academic sector. It is notable that Dstl is already trying some of these, for example through the UDRC initiative, and we would encourage the further exploration of novel funding approaches. A research funding approach that has proved interesting is the Structural Genomics Consortium, an open innovation partnership established to tackle challenging research problems through partnership between industry, academia and government, leading to high quality research seemingly without encountering major difficulty on intellectual property rights.

A3.5. There is support for establishing new innovation spaces where academia could have a role

The establishment of outstations based on key emerging technology areas, hosted at universities or technology parks, was of interest to many of our interviewees. The attraction for the academic sector is the opportunity for funding, access to the MOD's knowledge and challenges, whilst the MOD would benefit from leveraging its resources to gain access to knowledge, talent, infrastructure and networks. There is also interest in the establishment of an innovation campus close to an MOD site, and we would suggest that the MOD considers the model that has been developed for the Structural Genomics Consortium.

A3.6. The resource requirements for internal changes are relatively modest and quick, whereas developing innovation spaces will require a significant investment over a sustained period

In all of our estimates of cost we have not sought to determine the opportunity cost of any of the proposals. Initiatives such as establishing an innovation champion are not significantly expensive, albeit some staff resources would be required to provide the enduring support necessary to drive the change process and we roughly estimate this at £250,000 or less.

To address our second recommendation, stimulating academic actors to work with the MOD, the resource requirements could be met from within the MOD. Developing an innovation policy would need some MOD staff resources, possibly with some external support, and our estimate of the ROM cost £250,000–500,000. Developing a forecast of knowledge and talent needs we estimate could cost roughly £250,000–500,000, depending on how much external expertise might be required. Developing an initial understanding of impact and how it could be measured we estimate would cost £150,000–250,000. Our estimate of the ROM cost for designing and conducting an initial proof of principle for impact evaluation is £250,000–500,000, but if this was to be scaled up to cover the whole research programme evidence from other sources suggest this could cost 5 to 10 per cent of the total programme cost (which would be approximately £20–40m for the MOD). We think the actual costs of impact assessment could be tailored by taking into consideration factors including the methods used and the intended use of the results which could reduce the cost of this exercise.

Changing the dynamics of interaction (our third recommendation) would require more resources if our proposals were implemented. Establishing an honest broker would require significant resources and we estimate this would require roughly £1–3m per annum; obviously this investment would need to be justified by an anticipated greater return and consideration needs to be given to how this would be defined and measured (monetised). Investigating novel funding mechanisms we do not consider would be a hugely costly exercise and we estimate the ROM cost to be £150,000–250,000. Negotiating a funding mechanism that is novel to the MOD we estimate might cost roughly £250,000–350,000. Actually implementing further initiatives based on the UDRC approach we estimate would cost £4–8 million for each initiative, which would likely run for five years.

Opening new innovation spaces would be the most resource intensive of the proposals. We estimate that the competition process for outstations would cost roughly £150,000–250,000, and we further estimate that these would then cost £4–12m to establish and operate for a period of five years. An innovation campus would require significant resource to define, compete and negotiate, and even more to operate. We estimate that the competition process would cost roughly £350,000–700,000 and the funding for the campus, including infrastructure costs, would cost £38–150m for the first phase, with the range depending on the scale of the MOD's ambition; we think the lower end of this scale is not unreasonable. Furthermore, the MOD should expect that the funding would be shared between MOD, industry and academia.

We have not attempted to define the returns on investment on any of these proposals in financial terms, but in all cases we have set out the reasons why we think the proposal is worthwhile and the qualitative benefits that would be achieved.

A3.7. Implementation of these proposals would be critically dependent on wider initiatives in the MOD and the capacity of MOD staff to support these changes

Our proposals have been made independently of the wider programme of change that is taking place in the MOD. Our proposals should be viewed as information to inform implementation but not an implementation plan. If the MOD decides to pursue any of these options then it will need to ensure that these proposals are implemented coherently with other initiatives in the MOD.

One of the concerns raised at our second expert workshop was the capacity or 'bandwidth' for MOD personnel to properly resource change initiatives. The MOD is undergoing significant change and restructuring and there are plans for further reductions in staff, all of which will make it challenging to undertake even more changes. This can be mitigated to an extent by contracting for these proposals to be delivered externally, but that does not remove the need for some internal support and the supplier/project management that necessarily accompanies any contracting activity.

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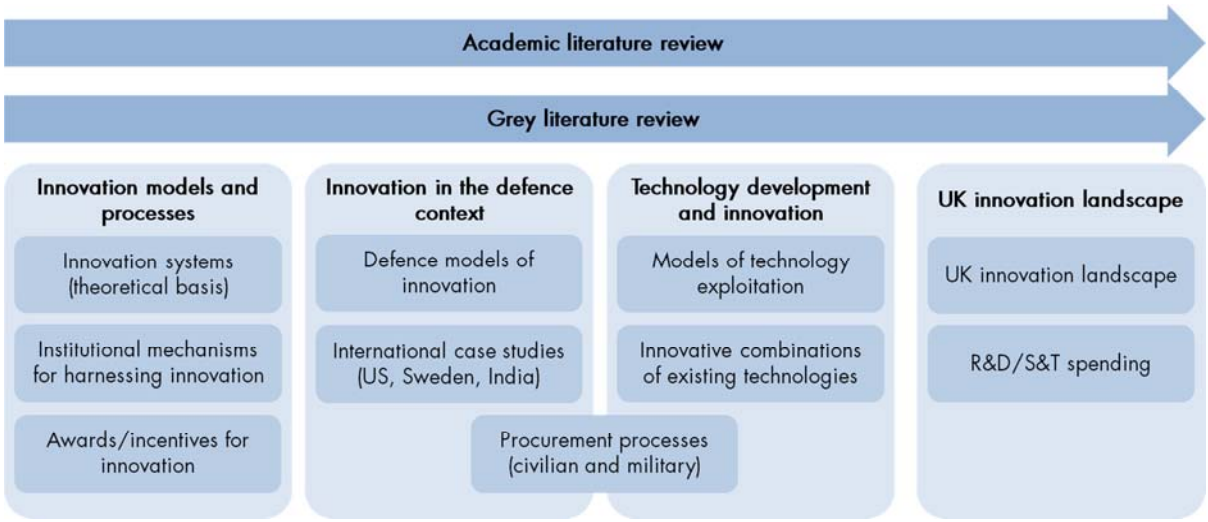
Appendix A. Literature review methodology

This appendix describes the literature review process we used to collect and analyse both academic and grey literature sources for our evidence base.

Initial literature review in Phase 1a took a comprehensive thematic approach

Given the tight timescales of our initial literature review in Phase 1a, we employed a team-based approach to our major stage of literature review. Project team members conducted focused research of academic and grey literature in ten thematic areas, summarised in Figure Ap.1 below, selected for their overall relevance to the questions in the Statement of Requirement. Academic literature was accessed through study team expertise and tailored Google Scholar searches. Grey literature was reviewed from a range of relevant UK and EU sources – including TSB, the Department for Business, Innovation & Skills (BIS), ONS, MOD and the European Commission. We also reviewed sources referred to us by the client.

Figure Ap.1: Thematic areas of Phase 1a literature review

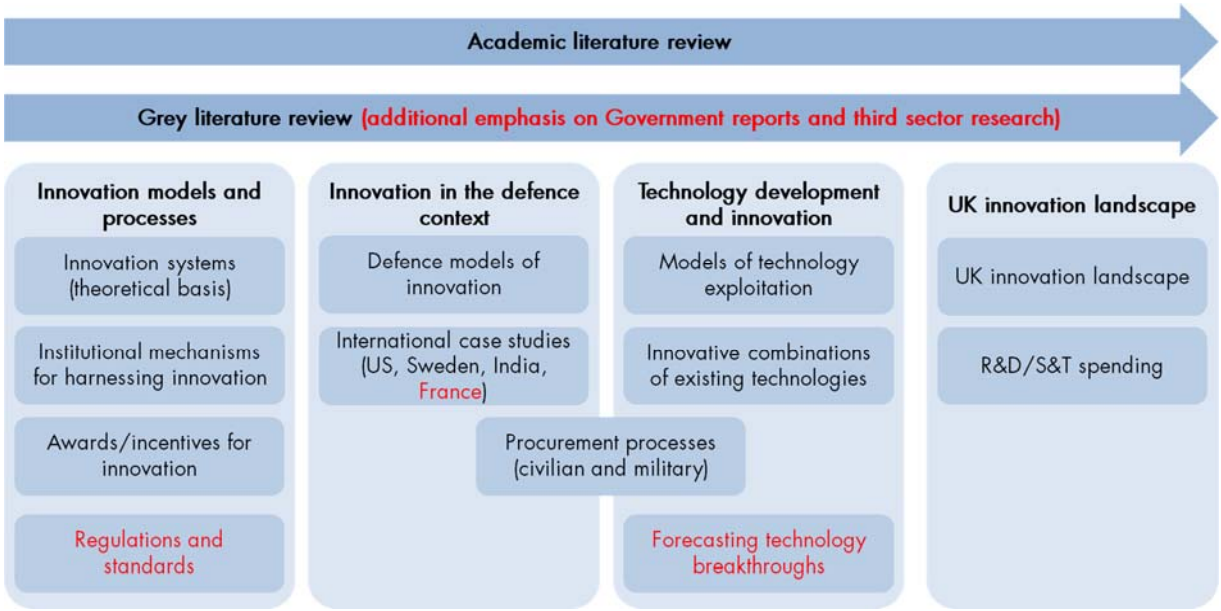


Phase 1b involved continued review of relevant grey literature and supplemental research themes

As per our project plan, Phase 1b was focused primarily on gathering evidence through stakeholder interviews and an expert workshop. However, the study team continued to conduct literature review to supplement our analysis and emerging framework. Focused literature review was conducted in a few specific thematic areas that were deemed important for inclusion. These thematic areas were selected

based on either interest from the client or perceived relevance from the research team following our Phase 1a research. Additional research into relevant grey literature was also conducted, focusing on government and third sector sources (such as the Big Innovation Centre and Nesta). We also followed up on additional sources recommended by expert stakeholders. These supplements to the literature review are summarised in red in Figure Ap.2.

Figure Ap.2: Additional literature review conducted in Phase 1b



The literature directly reviewed by the study team encompasses **over 120 academic and grey literature sources** that were identified through these two stages of systematic literature review.

Appendix B. List of stakeholder interviews

This appendix provides a list of the stakeholders with whom we engaged throughout the study.

For the main report, the study team interviewed 27 stakeholders from both the MOD and the wider innovation landscape

The goal of our stakeholder engagement phase was to gain insights about the processes, characteristics and challenges of innovation. To this end, we engaged with five MOD stakeholders from various departments who could present us with informed perspectives of the opportunities and challenges for defence engagement with external actors. We also spoke with four stakeholders from the defence industry to gain a better understanding of innovation exchange in the wider defence ecosystem. The Chief Technologist at the DOD, also provided a very valuable US perspective.

Although we were seeking insights with relevance to the MOD, we also felt that it was important to speak with non-defence actors to gain learning points from these actors' approaches to innovation. To this end, we spoke with an additional eight actors from industry, academia and the third sector to get a broader sense of techniques, structure and relationships that they felt supported innovation in their spheres. We also spoke with four public sector representatives to understand the role of their organisations and the challenges and opportunities they face.

The 27 stakeholders we interviewed for this report are listed in Table B.1. The protocol we used to standardise our semi-structured engagement is provided in Appendix C.

For the study extension, the study team interviewed 16 stakeholders from the academic, defence and industry sectors

The goal of our stakeholder engagement phase during the study extension was to gain insight on how our four main recommendations could be operationalised by the MOD in the context of its engagement with the academic sector. To this end, we engaged with ten stakeholders from the academic sector, five from the defence sector and one from the industry sector collecting informed perspectives on the opportunities and challenges related to the operationalisation of our recommendations through a set of more specific options for action. The 16 stakeholders we interviewed for the study extension are listed in Table B.2. The protocol we used to standardise our semi-structured engagement is provided in Appendix C.

Table B.1: List of stakeholder interviewees for the main report

Stakeholder group	Organisation	Position/Department
MOD	Dstl, Centre for Defence Enterprise	Head of Supplier Engagement and Head of the Centre for Defence Enterprise
	Dstl	Knowledge, Innovation and Futures Enterprise
	DE&S, Director Technical	Head of Technology Delivery
	DST	DST Director
	Dstl	Accounts Director, responsible for Science Gateways
	Secretary	S&T Customer Board
	Dstl	Head of Knowledge, Innovation, and Futures Enterprise
	Dstl	Programme and Delivery Director
DOD	US Department of Defense	Chief Technologist
Industry	BAE Systems	University Collaborative Programme Manager
	FN Herstal	Strategic Analysis and Relations Executive
	GE Aviation Systems	Technical Manager for Strategic Partnerships
	Thales UK	Managing Director – Research & Technology
	Surrey Incubation	Entrepreneur in Residence
	2iC, Tech UK	CEO
	Imperial Innovations	Chief Executive Officer
	Thales	Chief Scientist – Research & Technology
Academia	Harvard University	Academic Researcher
	Imperial College	Professor of Electrical and Electronic Engineering
	University of Oxford	Director, Institute for Science, Innovation and Society (InSIS)
	University of Sussex	SPRU
	Manchester Business School	Senior Lecturer, Manchester Institute of Innovation Research
Third sector	Royal National Lifeboat Institution (RNLI)	Innovation Manager
Public sector	EPSRC	Senior Manager, User Engagement

	Technology Advisor	Aerospace & Defence Knowledge Transfer Network
	Office for Security and Counter Terrorism	Head of Science & Technology
	TSB	Head of SBRI and Smart

Table B.2: List of stakeholder interviewees for the study extension

Stakeholder group	Organisation	Position/Department
Academia	Open University	Professor of Biotechnology and Development
	University of Bradford	Head of Knowledge Transfer
	Dstl/University of Birmingham	Dstl RAEng professor
	City University London	Professor of Control Theory and Design
	University Alliance	Professor of Control Theory and Design
	University College London	Professor of Engineering Policy and Director of the International Centre for Infrastructure Futures (ICIF)
	King's College London	Professor & Director of the Policy Institute
	Manchester Business School	Senior Research Fellow/Senior Lecturer
	University of Cambridge	Principal Industrial Fellow, Institute for Manufacturing
	City University London	Professor of Electrical and Electronic Engineering
Defence	Dstl	Principal Scientist, Strategy and Capability Development Technical Office
	Dstl	Knowledge, Innovation and Futures Enterprise
	Dstl	Head of Technology Innovation Centre
	Dstl	Principal Scientist-Sensor Concepts, UDRC in Signal Processing
	DSAC/UCL	Professor of Physics and Chairman of the UK National Quantum Technologies Programme Strategic Advisory Board
Industry	BAE Systems	University Collaborative Programme Manager

Appendix C. Interview protocol for stakeholder engagement

This appendix presents the interview protocol which was used as a baseline throughout our cross-sector stakeholder interviews. The questions presented here were used to guide our interviews and were tailored on a case-by-case basis depending on the position and expertise of the interviewee.

Phase 1(main study) – Stakeholder Protocol

- **Introductory text:**
  - The MOD is seeking to enhance the value of its S&T programme through better harnessing and absorbing innovation from a range of sources.
  - RAND Europe has been commissioned by the Defence Science & Technology Laboratory (Dstl) and the MOD Chief Scientific Adviser to undertake a study on innovation models for defence to help them in their aim.
  - We are contacting experts and stakeholders in defence and innovation across a range of sectors to get a range of views to inform our work
  - The interviews are semi-structured; the questions will cover a range of areas include the general factors that enable innovation through to what might be important for the Ministry of Defence in particular.
  - We will be taking notes during the conversation to assist us in capturing your contribution; this information will be used only for this specific study.
- **Please can you briefly explain to us your role and interest in innovation?**
- **What are the particular drivers/incentives/motivations of innovation in your area?**
- **In your area, what are the key factors that enable innovation?**
  - What would you say are the important factors internal to your organisation?
  - And what would you say are the important factors external to your organisation?
  - If you could improve any single thing, what would that be?
- **What do you think are important factors in making an organisation able to absorb innovation?**
  - How does your organisation make itself able to absorb innovation?
- **How does networking and information sharing feature in the innovation process?**
  - What role do networks have in innovation?

Are these internal and/or external to your organisation?

- **What practices (behaviours, processes, etc.) within your organisation facilitate innovation?**
- **What are your views on cross-sectoral innovation?**
  - What are your views on collaborations between different organisations?
  - [Non-defence sector]: What do you think are the opportunities or barriers to operating in or collaborating with defence sector?
  - Innovation can arise through the combination of different technologies; in your sector, have you encountered such opportunities? What differences are evident between innovation in single technology areas versus innovation through the combination of technologies?
- **How would you rank the UK globally in certain areas of innovation?**
  - Is the UK strong in different aspects of innovation? [Looking for information as to whether the UK is stronger on R&D, commercialisation or any other aspect of the innovation process]
  - What could the MOD to reap benefits from these strengths in the UK?
- **Finally, is there anything else you wanted to tell us that we have not asked about?**

Phase 3a (study extension) – Stakeholder Protocol (academic sector)

Section A: Changing the internal MOD context

- What is the perceived culture of the MOD towards academic innovation for defence?
- What would the MOD have to change about its culture, actual or perceived, to make it easier for academia to engage in innovation for defence?
- What do you consider to be the main procedural barriers in the MOD to successful engagement?

Section B: Stimulating external actors to work with the MOD

- How would you respond to the MOD's articulated scientific/talent needs? Who should the MOD target in universities if it wants this statement of need to have the greatest impact: researchers, faculty heads, university strategic directors, etc.?
- What incentivises engagement with the MOD? What would motivate academia to undertake research for the MOD?
- What structures in academia enable or hinder engagement with the MOD?
- How could MOD support the REF process and what would be most useful to you?

- What information and knowledge would academia find most useful as an enabler of innovation for the MOD?

Section C: Changing the dynamics of interaction

- Who would you go to within the current MOD structure if you wanted to engage on a subject of innovation?
- Would the presence of a liaison unit be beneficial?
- With whom should this unit interact?
- What capabilities/responsibilities should this unit have?
- Should this unit be internal to the MOD or external?

Section D: Changing the location of innovation

- Why would you be interested in an outstation established by the MOD? What would motivate a university to host this?
- Does the MOD have any infrastructure that academia would wish to make greater use of?
- Which aspects of infrastructure would you suggest can best be used to support innovation for the MOD?

Closing the interview

- Do you have any contacts with expertise in this area that you would recommend speaking to? If so, please could you give us their details/put us in touch.

Prompts – key terms

Outstation – An MOD-backed 'centre for innovation', established outside of the MOD estate in conjunction with an external academic partner e.g. on a science park or a university campus. The outstation would specialise in a relevant area of emerging technology e.g. biotechnology or quantum physics, and offer a space for academics and MOD employees to share information on innovation in that field. It would create opportunities for networking, help communicate MOD needs, advertise funding opportunities, and allow MOD staff to learn from new ideas in academia.

Phase 3a (study extension) – Stakeholder Protocol (defence sector)

Section A: Changing the internal MOD context

- What MOD structures are currently in place to facilitate engagement with academia?
- What are the main procedural barriers to successful engagement with academia?
- How could the MOD change its procedures and behaviours to enable academia to better engage in innovation?
- What are the MOD's current processes for forecasting its talent needs?
- Does the MOD design its requirements in a way for proper evaluation to be taken?
- Would it be beneficial to appoint an innovation champion (IC) to promote culture change within the MOD – who and at what level? What responsibilities should he/she have? Would it be more useful to have a single designated innovation champion, multiple champions, or none at all?

Section B: Stimulating external actors to work with the MOD

- How could you communicate the MOD's scientific and talent needs and knowledge more effectively?
- How can the MOD incentivise academics to engage?
- What do you consider to be the main structural barriers in academia to successful engagement?
- Are you aware of the Research Excellence Framework? How does the MOD make use of the REF or otherwise incentivise cooperation from academics?

Section C: Changing the dynamics of interaction

- How can the MOD create opportunities for talent placement (internally or externally) given resource constraints?
- How can the MOD create opportunities for talent employment given resource constraints?
- How can the MOD act as 'honest broker' in facilitating collaboration with academia in R&D and innovation? Does this 'honest broker' function already exist?
- Would it be beneficial to have a liaison unit? If so, what responsibilities should it have? Should this liaison unit be internal or external?

Section D: Changing the location of innovation

- If the MOD were to establish an outstation at a non-MOD location – e.g. a science park or university campus – which emerging technology area should it focus on?
- Which criteria would you use to select the technology area and location for the outstation?

- What commercial procedures would the MOD need for establishing an outstation? Does it have these?
- Which aspects of academic infrastructure could MOD take advantage of to stimulate innovation? In turn, which aspects of MOD infrastructure could academia make use of?

Closing the interview

- I have covered my questions. Are there any further comments or observations that you would like to make?
- Do you have any contacts with expertise in this area that you would recommend speaking to? If so, please could you give us their details/put us in touch.

Prompts – key terms

Innovation Champion – A designated leader of change in MOD culture and procedures towards academic engagement. She or he would be tasked with making innovation and external engagement a key priority for all levels of MOD management, driving cultural change and communicating this message internally throughout the organisation.

Honest Broker – An organisation that seeks to create greater transparency over MOD requirements for academia, as well as to better raise awareness of emerging technology within MOD circles.

Outstation – An MOD-backed 'centre for innovation', established outside of the MOD estate with an external academic partner e.g. on a science park or a university campus. The outstation would specialise in a relevant area of emerging technology e.g. biotechnology or quantum physics, and offer a space for academics and MOD employees to share information on innovation in that field.

Appendix D. First expert workshop

This appendix summarises the attendees and content of the first expert workshop held from 10.00–15.00 on Wednesday, 25 June at Prince Philip House in London.

The first expert workshop involved 20 high-level stakeholders from across the UK innovation landscape

Our first expert workshop was intended to bring together a broad spectrum of experts and stakeholders from both defence and innovation backgrounds to discuss the innovation ecosystems of the UK and of the MOD in particular. Table D.1 on the next page shows a list of the stakeholders who participated in the workshop.

Workshop proceedings aimed to enhance our understanding of the UK innovation ecosystem and the role of the MOD within it

The aims of the workshop were threefold:

1. To challenge and expand our understanding of the UK innovation landscape.
2. To discuss the role of the MOD in the UK innovation landscape and its current approach to innovation.
3. To begin exploring how the MOD's approach to innovation could develop in the future (to initiate our consideration of recommendations which will be elaborated in Phase 2).

The workshop used a highly interactive format in which attendees engaged in a series of collaborative mapping exercises and moderated discussions about innovation processes and networks. The workshop agenda is provided in Table D.2.

Table D.1: Attendees at first expert workshop

Organisation	Position/ Department
MBDA UK Ltd	Emergent Technology Manager
RAND Europe	Director, Defence & Security
Nesta	Senior Researcher, Policy and Research
RAND Europe	Senior Research Leader, Innovation Technology & Policy
MOD	Deputy Head S&T Policy
BIS	Head, Innovation, Government Office for Science
Surrey Incubation	Entrepreneur in Residence
EPSRC	Director Strategy and Business Relationships
Thales	Chief Scientist – Research & Technology
AAD KTN	Defence Special Interest Group
DE&S, D Tech	Head of Technology Delivery
BAE Systems	University Collaborative Programme Manager
NERC	Innovation Manager
University of Sussex	Science Policy Research Unit (SPRU)
DST	Deputy Head S&T Strategy
MOD	Defence Strategy & Priorities
Thales	Business Development Manager
BAE Systems	Business Development Executive
MOD	Programme Manager, Defence Strategy and Priorities
Dstl	Fellow, Non Metallics & Functional Materials Platform Sciences Group

Table D.2: Agenda for first expert workshop

Time	Activity
10.00	Arrival and coffee
10.20	Welcome and introductions Introduction to the study and of stakeholders
10.35	Scene-setting activity 1: 'What is innovation?' Small group discussion on the definition of innovation
10.45	Scene-setting activity 2: Cartographers of innovation Individual mapping exercise of innovation ecosystem centred around entity of choice, followed by small group discussion
11.15	Mapping the UK innovation landscape; how does it look from the three main sectors? • Public sector • Academia • Business Collaborative mapping exercise in which three groups rotate around three sector maps, followed by moderated plenary discussion of outcomes
12.30	Lunch
13.15	Understanding the MOD's location in the innovation landscape Collaborative mapping exercise in which three groups construct their own interpretations of the MOD innovation model on blank pages, followed by moderated plenary discussion of outcomes
14.30	Reflections on the workshop Moderated plenary discussion
14.55	Close
15.00	Depart

Workshop discussions helped to deepen our analysis and lay the foundation for the final research phase

The workshop provided confirmation of much of our research findings from the literature and the interviews and provided nuance and context that could only arise in a dynamic setting where individuals from a diverse range of backgrounds can challenge each other and enter into debate. The richness of the discussions was, regrettably, impossible to capture in full, but by having one RAND Europe facilitator attached to each discussion group, and further facilitators capturing notes of the plenary discussions, it was possible to identify many of the key points from the dialogues, including:

- It was a challenge to map and describe the innovation landscape in terms of the actors, their roles and their modes of interaction in a way that enjoys universal agreement.
- The modes of interaction within the innovation ecosystem are both complicated (there are many of them) and complex (there are feedback loops and two way interactions which make it difficult to predict how change in one area will affect the innovation system as a whole).
- Culture is an important factor in innovation, which can include leadership, management, attitudes to risk, the ways in which industry and government interact and many other subtleties.

The great value in the workshop was to hear these discussions and be able to confirm that many of the points made to us through the interviews were independently held views and not points made as a result of interview structure (i.e. the interviewees had not been led to a certain response).

Workshop attendees were also eager to provide suggestions for improving the MOD's current innovation processes. These recommendations were analysed and explored in greater depth as part of our research in Phase 2.

Appendix E. Options for action derived from the framework

In considering our innovation framework we generated 24 options for action describing what the MOD could maintain or improve its performance against the eight innovation factors, which are listed below in Table E.1.

Selection of the options for action occurred through internal team discussions around the eight factors of our analytical framework. Following this identification, research on each option for action was conducted in a systematic fashion using a combination of stakeholder interview transcripts and review of both academic and grey literature. Study team members used a consistent template to investigate the evidence base for each option for action, shown below in Table E.2.

Table E.1: 24 Options for action for the MOD

Factor	Options for action
	The MOD should:
Drivers	1) Develop a clear and communicable innovation policy based on a strategic assessment of its needs and priorities. 2) Reduce innovation constraints that originate within the MOD. 3) Increase competition in its supply chain as a means of stimulating innovation, not just securing value for money.
Talent	4) Recruit and develop individuals to ensure it has talent inside the organisation. 5) Develop mechanisms to access external talent. 6) Develop mechanisms to ensure that external talent can access the MOD.
Capital	7) Develop a 'marketplace' where it can develop funding partnerships with industry, other government departments and academia to support research into cutting-edge technologies and development through to marketed solutions. 8) Engage strategically to provide joint funding for research and development. 9) Engage with venture capital VC and angel firms to support breakthrough and early-stage innovations.
Knowledge assets	10) Develop policies and processes to leverage its knowledge assets with those of other organisations. 11) Establish facilities where its knowledge can be shared with innovators and where small-scale tests and proof of concept can be conducted. 12) Involve cross-sector stakeholders in its S&T activities as both observers and participants where possible.
Infrastructure	13) Consider how its physical infrastructure can be used (and adapted) to encourage innovation. 14) Consider how its IT infrastructure can be used (and adapted) to encourage innovation. 15) Utilise the wider innovation infrastructure (especially from universities) to encourage innovation.
Networks/ connections	16) Act as an 'honest broker' of inventors, funders and industry to facilitate knowledge sharing across these groups. 17) Encourage staff participation in networks to develop talent, access knowledge and identify wider exploitation opportunities for defence research. 18) Support structured cross-sector partnerships which enable personnel to gain cross-sector experience and knowledge.
Culture	19) Encourage and incentivise internal innovation from individuals within the organisation, supporting a culture that permits risk. 20) Develop internal innovation partnerships, rather than customer/supplier relationships, to enable technology development from the early stage to marketed solution. 21) Develop external innovation partnerships, rather than customer/supplier relationships, to enable technology development from the early stage to marketed solution.
Structures	22) Improve the accessibility of its procurement processes to encourage innovative participation from new actors. 23) Develop metrics that evaluate innovation in terms of partnering and progression, rather than pass-fail. 24) Adopt the minimum bureaucracy necessary and ensure it is flexible enough to enable the innovation process.

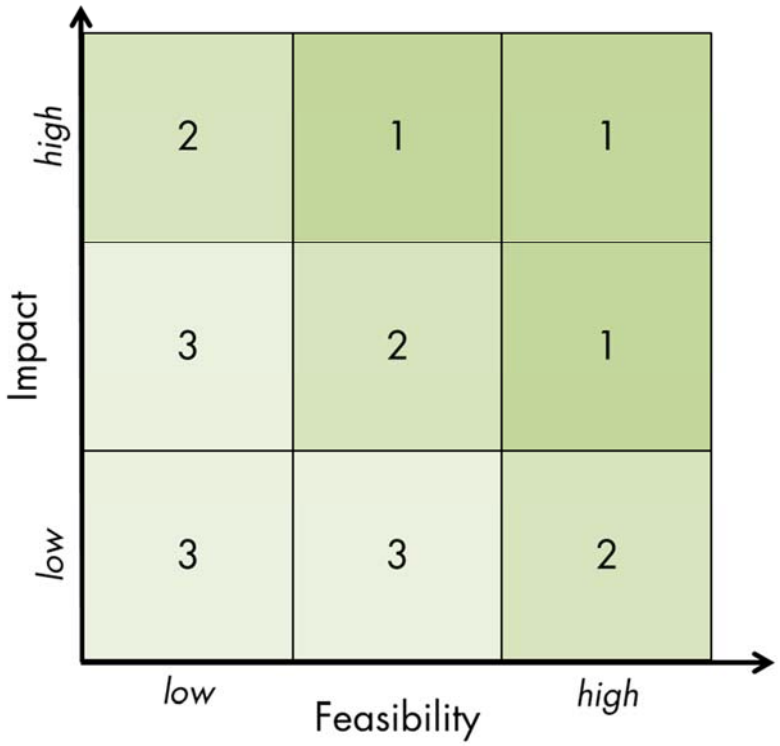
SOURCE: RAND Europe analysis.

Table E.2: Option for action #: XXX

Preliminary assessment	
Overarching recommendation	In one sentence, describe the overarching/thematic recommendation for MOD that this draft recommendation furthers.
Specific recommendations	What specific activity would allow this draft option for action to be tangibly implemented? Are there different options/variations/examples available?
Relevant framework factor(s)	*Drivers, Capital, Talent, Knowledge Assets, Infrastructure, Networks/Connections, Culture or Structure* Indicate the primary factor of relevance as well as any other factors that are linked.
Evidence for selection	Describe (in up to one paragraph) the evidence that was used to select this option for action (using appropriate footnotes!). Which sources from the lit review referenced relevant elements? How did interview and/or workshop data support this selection? Were any specific case studies/examples particularly useful?
Suggested validation strategy	Describe (in up to one paragraph) the recommended evidence and approach to determining the validity of this option for action. Which sources/stakeholders/case studies would be relevant? Are there particular aspects of the recommendation which require particular focus or which are lacking in evidence at this stage?

Characteristics	
Implementation level	*Internal*: Implementation involves the MOD as a sole actor. *Collaborative* (MOD-led): Implementation is led by MOD but requires some support or involvement from other actors. *Collaborative* (partner-led): Implementation involves cooperative efforts from MOD and other stakeholder partners.
Stakeholders impacted	*Industry*: (SMEs, primes, particular sectors, VC, other finance…?) *Academia*: (particular universities/sectors?) *Public sector*: (government departments, TSB, BIS?) *Other*: (charities, third sector, international actors?) *…and describe how*
Level of change	*Incremental*: The option for action can be implemented by adjusting MOD processes that already exists. The resultant change occurs within the MOD's current ways of working. *Moderate*: The option for action adds new elements to existing MOD processes or involves notable adjustments. The resultant change makes an evolution to MOD's current ways of working. *Radical*: The option for action introduces a wholly new element to existing MOD processes or entails a significant reformation of current processes. The resultant change introduces new structures and/or processes and significantly alters certain aspects of the MOD's current ways of working.
Level of resources	*Minor*: The change can be implemented without expending notable time and/or resources as compared to the MOD's current ways of working. *Moderate*: The change requires a dedicated initiative of time and/or resources as compared to the MOD's current ways of working. *Substantial*: The change requires a significant reallocation or addition of time and/or resources as compared to the MOD's current ways of working. *Can we quantify these?*

Implementation	
Details of recommendation	How would this option for action be practically implemented by the MOD? Are there various options for implementation?
MOD actors	Which branches of the MOD would be involved in making this option for action a reality? What roles would they play, and which are most crucial?
Opportunities/ benefits	What are the key opportunities and benefits associated with implementation of this option for action? Are there case studies which illustrate these in practice?
Challenges/ constraints	What are the key challenges and constraints associated with the implementation of this option for action? Are there case studies which illustrate these in practice?
Benefits for UK growth	How would implementation of this option for action benefit the UK more broadly? Is this impact measurable in any way?
Dependencies	Are there any other initiatives/developments which would influence the success of this recommendation?
Uncertainty	Was the evidence strong or weak? Were there any gaps? How confident are we about our findings given our evidence base? (High-medium-low)
Feasibility	Based on the evidence gathered, what is the expected feasibility of successful implementation of this option for action? (*High-medium-low*)
Impact	Based on the evidence gathered, what is the expected positive impact of successful implementation of this option for action? (*High-medium-low*)
Priority	Based on the assessments of feasibility and impact, what level priority do we give to this option for action? (*1-2-3, based on 2x2 matrix of feasibility and impact*)



Appendix F. Second expert workshop

This appendix summarises the attendees and content of the second expert workshop held from 12.00–16.00 on Tuesday, 9 September at One Great George Street in London.

The second expert workshop was used to consider the feasibility and impact of the options for action

The second expert workshop gathered entrepreneurs with experts from MOD and industry to discuss the feasibility and impact of the 24 options for action grouped into the four thematic recommendations. Those attending the workshop were invited to discuss each option and assign it a ranking of 'high' or 'low' against feasibility and impact, with feasibility defined as 'how easy or challenging it is for the MOD to implement this option' and impact defined as 'how much this recommendation will help the MOD harness innovation from external sources'. The workshop used a highly interactive format in which attendees engaged in a series of both individual and group exercises and moderated discussions about the feasibility and impact of the options for action. The list of the stakeholders who participated in the workshop and the workshop agenda are provided in Table F.1 and Table F.2 respectively.

Table F.1: Attendees at second expert workshop

Organisation	Position/ Department
RAND Europe	Director, Defence & Security
Dstl	Chief Technical Officer
2iC, Tech UK	Chief Executive Officer
RAND Europe	Senior Research Leader, Innovation Technology & Policy
Imperial Innovations	Chief Executive Officer
BIS	Head, Innovation, Government Office for Science
Dstl	Knowledge, Innovation and Futures Enterprise
AAD KTN	Defence Special Interest Group
DE&S, D Tech	Head of Technology Delivery
DST	Head S&T Strategy
DST	Deputy Head S&T Strategy
DST	Academic Engagement and Innovation
BAE Systems	Business Development Executive
Dstl	Fellow, Non Metallics & Functional Materials Platform Sciences Group

Table F.2: Agenda for second expert workshop

Time	Activity
12.00	Arrival and lunch
13.00	Welcome and introductions
13.15	Presentation of innovation framework and recommendations for the MOD
14.00	Individual assessments of practical recommendations
14.30	Presentation of four levels of change
14.45	Group assessment of feasibility and impact
15.10	Plenary discussion of recommendations
15.50	Closing remarks
16.00	Depart

The findings from the workshop informed the likely feasibility and impact of our recommendations

The finding from the workshop are recorded in Table F.3, which shows that the majority of the options for action should be considered to be high impact, with the only exceptions being:

- The MOD should develop policies and processes to leverage its knowledge assets with those of other organisations (it was argued that this was already being done to an extent).
- The MOD should increase competition in its supply chain as a means of stimulating innovation, not just securing value for money (this was considered to be high impact for early stages of development, but likely to have a negative impact for later stages of development).
- The MOD should develop metrics that evaluate innovation in terms of partnering and progression, rather than pass/fail (it was felt that it was hard to develop metrics that would be meaningful for decision-makers although it was acknowledged that where this had happened in the health sector it had significant positive impact on decision-making).

These findings confirm that, in most cases, the options for change should have a significant beneficial impact for the MOD. The concerns about competition in the supply chain have been reflected in the recommendation to underline the point that competition is a valuable tool to stimulate innovation, but in the procurement process it may be that other tools are more appropriate to the circumstances surrounding the development stage of the innovation.

The concerns about the metrics for innovation are valid and following the workshop we discussed these with senior stakeholders in the MOD who confirmed that metrics to support innovation would be very beneficial as at present the only widely accepted metrics are accounting measures such as how much has been invested rather than what the potential of an innovation is considered to be.[268] It was also noted that the Department for Business Innovation and Skills is investigating the metrics that could be used for innovation, so there is some high-level support for such an initiative across government.

[268] Interview conducted by RAND Europe (2014).

The options were fairly evenly split between low and high feasibility

Of the 24 options categorised as high impact, these were further categorised as 10 being low feasibility, nine being high feasibility, one was considered virtually impossible and for one the feasibility was considered to be dependent on the stage in the innovation development process.

One of the reasons given for the low feasibility of several options was 'risk aversion – people don't get promoted for taking risks' which underlines the need for a significant change in the culture if the MOD is to reap significant benefits from changes to its innovation model.

The main barrier to developing a defence innovation policy was considered to be the 'difficulty in getting consensus' across the different stakeholders within the MOD as well as across the defence enterprise.[269] Whilst formation of a consensus is undeniably challenging the high impact rating for this option suggests that it is a goal worth pursuing. In a similar vein, a constraint articulated several times was 'the difficulty of changing the defence enterprise – if you want change to be effective the defence prime contractors have to be supportive'. In preparing our recommendations we recognise that there is a challenge in undertaking large-scale change which is why the recommendations are presented in four incremental levels which the MOD can, on the basis of its appetite for change, determine how much change it wishes to effect.

In discussing the differences between competition and partnership it was said that the competition rules that apply to public procurement could be a barrier to developing partnerships and that partnership itself could limit competition. We acknowledge this point and accept that competition is one means of developing innovations as is partnership; they are different approaches that can be used at different stages in the innovation process. We would also argue that some partnerships can be competed and do not have to be indefinite, for example developing innovation sites at universities or technology parks could be the subject of competition for the opportunity to host such a facility. Several attendees made the point that competition was not necessarily appropriate at a later stage in the development of innovation as there are concerns over the need to protect IPR and industry would be less willing to invest capital if there was a higher risk of not being successful, which underlines the point that different approaches are appropriate at different stages in the innovation process.

The option that was considered to not be feasible was 'The MOD should consider how its IT infrastructure can be used (and adapted) to encourage innovation'; it was considered that the difficulties in changing the defence information infrastructure (DII) were too significant, particularly as they were linked to security constraints that are considered very difficult to overcome.

The option with feasibility dependent on the stage of innovation development was 'The MOD should establish facilities where its knowledge can be shared with innovators and where small-scale tests and proof of concept can be conducted'. For early-stage developments this was considered to be low feasibility because the infrastructure did not exist to do this, whereas for later development stages it was considered to be highly feasible because there is already extensive experience in the supplier base to do this.

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[269] The defence enterprise was described in the workshop as being the MOD and defence industry.

Table F.3: Assessment of each option for action by the second expert workshop.

Factor	Options for action	Scoring from workshop
	The MOD should:	*Feasibility/Impact (High/Low)*
Drivers	Develop a clear and communicable innovation policy based on a strategic assessment of its needs and priorities. Reduce innovation constraints that originate within the MOD. Increase competition in its supply chain as a means of stimulating innovation, not just securing value for money.	High/High Low/High High/High (for early stages) High/Low (for development)
Talent	Recruit and develop individuals to ensure it has talent inside the organisation. Develop mechanisms to access external talent. Develop mechanisms to ensure that external talent can access the MOD.	High/High High/High High/High
Capital	Develop a 'marketplace' where it can develop funding partnerships with industry, other government departments and academia to support research into cutting-edge technologies and development through to marketed solutions. Engage strategically to provide joint funding for research and development. Engage with VC and angel firms to support breakthrough and early-stage innovations.	Low/High Low/High High/High
Knowledge assets	Develop policies and processes to leverage its knowledge assets with those of other organisations. Establish facilities where its knowledge can be shared with innovators and where small-scale tests and proof of concept can be conducted. Involve cross-sector stakeholders in its S&T activities as both observers and participants where possible.	High/Low Low/High (academic stage) High/High (development) High/High
Infra-structure	Consider how its physical infrastructure can be used (and adapted) to encourage innovation. Consider how its IT infrastructure can be used (and adapted) to encourage innovation. Utilise the wider innovation infrastructure (especially from universities) to encourage innovation.	Low/High Low/High High/High
Networks/ connections	Act as an 'honest broker' of inventors, funders and industry to facilitate knowledge sharing across these groups Encourage staff participation in networks to develop talent, access knowledge and identify wider exploitation opportunities for defence research. Support structured cross-sector partnerships which enable personnel to gain cross-sector experience and knowledge.	Low/High High/High Low/High
Culture	Encourage and incentivise internal innovation from individuals within the organisation, supporting a culture that permits risk. Develop internal innovation partnerships, rather than customer/supplier relationships, to enable technology development from the early stage to marketed solution. Develop external innovation partnerships, rather than customer/supplier relationships, to enable technology development from the early stage to marketed solution.	Low/High Low/High High/High

Structures	Improve the accessibility of its procurement processes to encourage innovative participation from new actors.	Low/High
	Develop metrics that evaluate innovation in terms of partnering and progression, rather than pass/fail.	Low/Low
	Adopt the minimum bureaucracy necessary to enable the innovation process.	Low/High

Appendix G. Measuring innovation in the MOD

As observed in the report, innovation in the MOD should be measured in terms of maturity and the innovation framework to ensure partners understand what is required to develop new solutions. Much of the literature on measuring innovation is focused on macro levels, such as industry sectors or the nation, which may be of less direct relevance to the MOD. To understand what might constitute appropriate measures, the purpose of the measurement and ultimately the decision it is designed to inform, need to be considered.

The measures of innovation will be different between the MOD and the project levels

On the one hand, the MOD might be interested in measuring innovation at the departmental or enterprise level so that evidence-based decisions can be made in relation to science, technology and development budgets. Alternatively, more focused information might be required to help decide the case for a specific innovation project and whether it has the necessary support to increase likelihood of innovation being successfully developed to the next level of maturity. The information required for each is likely to vary depending on the different nature of the decisions being addressed.

The innovation framework could be used to measure innovation at the departmental level

At the MOD level the amount the department spends on research could be measured, although this is an input metric and provides little information on innovation performance on its own. An output metric might be the number of solutions developed and exploited into a fielded application, which would require information on exploitation to be systematically collected. But such an output metric does not provide information about the state of the innovation pipeline with new solutions being matured but not yet fielded. In addition to these useful pieces of information, a system of measurement based on the factors in the innovation framework could offer additional information to help understand the strength and performance of the MOD innovation system. Some suggestions for what could be measured are provided in Box G.1.

Box G.1: Measuring innovation at the enterprise level

Drivers – Has the MOD need for innovation been clearly articulated and communicated? In which areas in particular does the MOD require innovation and have these been stated?

Input resources

Talent – What technical and managerial talent does the MOD have in respect of its identified innovation requirements? [Possibly demonstrated by means of a skills audit]. What talent has the MOD accessed externally to support its innovation requirements? [Possibly measured through partnerships with academia, industry, investors and framework contracts designed to access talent as needed].

Capital – How much has the MOD invested in S&T? How much in R&D? How many discrete projects does this represent in the innovation pipeline at what levels of maturity? How much capital has the MOD leveraged from external actors?

Knowledge assets – What is the MOD's state of knowledge with regards its innovation requirements? How much knowledge has been generated by MOD investment (patents, papers, research reports on Athena)? How much has MOD knowledge leveraged access to external knowledge assets [Possibly measured through partnerships with academia, industry, investors].

Enabling resources

Infrastructure – What infrastructure is needed to meet MODs innovation requirements? Has MOD secured access to the infrastructure necessary? [Possibly measured through MOD sites and facilities, and agreements with other infrastructure providers e.g. universities, STFC, others].

Networks/connections – is the MOD active in the networks that foster access to knowledge, talent and capital in the areas relevant to the MOD's innovation requirements? Is the MOD using these networks to communicate its innovation needs? [Possibly measured through number of networks engaged in, talks given at relevant events, or perhaps more sophisticated network analysis to identify the strength of the MOD's connection in a given field]

Shaping factors

Culture – inherently difficult to measure. However, the staff satisfaction surveys could be designed to include questions and analysis of how supported they feel in pursuing innovation. Could also include the existence (or not) of an MOD statement on the innovation culture it wants to achieve, supported by an innovation champion. Are there incentives for innovation?

Structures – have the pathways by which MOD accesses innovation been identified and the processes attendant to these been simplified as much as possible? Have these processes been communicated clearly to external innovation actors?

Output

How many innovations have been brought to market and are being used by the MOD and military end-users? How many projects are in the innovation pipeline at what levels of maturity?

The innovation framework can be used with a different focus to measure innovation at the project level

At the project level, where an innovation is being matured steadily to what is hoped to eventually be exploitation in a fielded application, perhaps the most important decision for the MOD is whether or not to continue supporting one project over another. The information to support this is likely to be similar to the due diligence necessary to inform an investment decision. The innovation framework gives a starting point for gathering the information necessary to understand if the relevant factors have been considered adequately before deciding whether to invest further resources and effort in maturing the innovation. The information for an early-stage idea would be expected to carry low confidence and any decision correspondingly higher risk, but the maturation process is about narrowing uncertainty across all of the factors to support more substantial investment decisions as development progresses. Some suggestions for what could be measured are provided in Box G.2.

Box G.2: Measuring innovation at the project level

Drivers – Has an end-user been identified? Has a route to market/exploitation been specified for industrial and investment partners? Has the scale of the potential market been identified?

Input resources

Talent – Has the MOD (and its partners) got the technical talent necessary to mature this innovation? Is the managerial talent in the MOD (and its partners) available to ensure the innovation is matured?

Capital – What has been invested thus far and by whom? What further investment is required, by whom and for what purposes and in what time frame? Who will be seeking to release capital from the innovation and at what stage (e.g. which investors will seek to exit by selling their share at a certain point of maturity?)

Knowledge assets – Does the MOD have the necessary knowledge in-house to mature the innovation? Are further knowledge assets required from elsewhere? How will these be accessed? Is their intellectual property attached to the innovation and, if so, who owns this?

Enabling resources

Infrastructure – Will MOD infrastructure (research, test, evaluation, etc.) facilities be required and, if so, when? Is the infrastructure provided by parties external to MOD and, if so, do they have assured access? Will further access to infrastructure be required (e.g. STFC resources)?

Networks/connections – What are the connections of the parties involved? Are they operating in the correct spheres of influence? By bringing in new technical and/or managerial talent could access to relevant networks be achieved?

Shaping factors

Culture – Are there any particular cultural differences between innovation actors (e.g. end user versus investor) that need to be understood and addressed to ensure successful development of the innovation? Are the interactions between the different parts of the MOD understood and reflected in the management and development plan for the innovation? Are the military end-users actively involved in the shared endeavour of this innovation?

Structures – Are there any particular management processes or decision processes that relate to this innovation that need to be addressed? Are there regulatory requirements that need to be included in the management processes and structures to support the development of this innovation.

Output

Has the innovation been brought to market and is it being used by the MOD?

Measuring maturity of innovation projects

There are various measures for representing the state of development of a technology or a process innovation which the MOD should select on the basis of how appropriate they are for its purposes. Commonly used examples include Technology Readiness Level and System Readiness Level, and becoming more widely used is the concept of Manufacturing Readiness Level. Each method has its utility and could be used to help the MOD understand how well developed an innovation is. We suggest that the maturity level should be determined with reference to the innovation framework presented in this report. As the innovation matures it would be expected that the quantity of and confidence in the information would improve to enable transition to higher maturity levels.

Measuring innovation in the MOD will take time to become fully effective

Measurement of innovation at the MOD level will take several years of data collection and analysis, with refinements in the processes, before firm conclusions can be drawn about what the information is describing. Trends will take time to develop and causality may be inferred but not readily demonstrated in many cases. The MOD will need to accept an investment of time and effort necessary to support the development of an appropriate measurement process. But we do not think this is impossible for the MOD to do; many of the factors we propose should be measured are similar to those outlined in the Department for Business Innovation and Skills Annual Innovation Report.