Written evidence submitted by RAND Europe

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Prepared for the House of Commons Defence Select Committee

Preface

This document provides RAND Europe's submission of evidence in relation to the UK House of Commons Defence Select Committee's Call for Evidence on Space Defence.

Part of the global RAND Corporation, RAND Europe is a not-for-profit research institute with a mission to improve policymaking through robust research and analysis. RAND combines academic rigour with a targeted consultancy approach and is committed to the public interest and to making our work accessible.

RAND has 75 years of experience helping governments and militaries navigate complex choices in the space domain, beginning with the first ever published RAND study, which examined the options for a *Preliminary Design of an Experimental World-Circling Spaceship* on behalf of the U.S. Air Force back in 1946.[1] Today, RAND conducts space-related research, analysis, consultancy and gaming for a variety of sponsors. This broad portfolio of both unclassified and classified projects is coordinated through the RAND Space Enterprise Initiative (RSEI), a global hub for RAND's space-related activities.

Our clients include the Ministry of Defence (MOD), the Defence Science and Technology Laboratory (Dstl) and the UK Space Agency (UKSA), along with various government agencies in the United States (including the Air Force, Space Force and the National Aeronautics and Space Administration [NASA]) and European, Australian and Japanese authorities.[2] Given its role supporting government and its not-for-profit status, RAND does not work for defence and aerospace industry prime-contractors, ensuring that all research remains free of any commercial conflicts of interest.

This document draws upon this extensive body of previous RAND research on space strategy, policy and operations. This includes recent studies for the UKSA to support development of the *National Space Strategy*[3] and for the MOD's Development, Concepts and Doctrine Centre (DCDC) on behalf of the Space Directorate.[4] Both are due to be published in the second half of 2021. Each section of this document corresponds to a question posed by the Select Committee.

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[1] RAND Corporation. 1946. *Preliminary Design of a World-Circling Spaceship.* Santa Monica, Calif: RAND. As of 24 June 2021: https://www.rand.org/pubs/special_memoranda/SM11827.html

[2] For more information on the RSEI, see RAND Corporation 2021. 'RAND Space Enterprise Initiative.' Rand.org. As of 24 June 2021: https://www.rand.org/capabilities/space-enterprise-initiative.html

[3] Black, James, Linda Slapakova, Kevin Martin. 2021. *Future Uses of Space to 2050: Emerging Threats and Opportunities for the UK National Space Strategy*. Santa Monica, Calif.: RAND.

[4] Retter, Lucia, James Black, Theodora Ogden. 2021. *Realising the Ambitions of the UK's Defence Space Strategy: Factors Shaping Implementation to 2030*. Santa Monica, Calif: RAND.

Summary

This section summarises the key points emerging from each response to the Select Committee.

Collectively, these responses address the four important themes of: enhancing the benefits of collaboration, responding to threats, making best use of the levers of industrial, acquisition and innovation strategy, and ensuring that Defence – and the national space enterprise – have access to the right people and skills.

1. How should the UK Government seek to further develop its strategic relationships and interoperability with allies?

Though starting from a low base in most areas, the UK should understand, articulate, and capitalise on its strengths when approaching potential partners. This entails building on its existing approach, which is already firmly rooted in collaboration, most notably with the United States on military space programmes and the European Space Agency on civil ones. It also means making use of all resources and levers of influence, including the UK's broader 'soft power' and steadily increasing the UK's level of ambition over time. This growing ambition reflects new and increased investment in the sector (if from a low baseline compared to similar sized economies) and the overarching direction that will be provided by the anticipated *National Space Strategy* and associated *Defence Space Strategy*.

In line with the ambitions set out in the 2021 *Defence and Security Industrial Strategy* (DSIS), the UK Government should also adopt a 'Team UK' approach in close cooperation with industry. Such a holistic approach is needed to ensure that the national space sector captures the full benefits of any international partnerships (e.g., in terms of security, influence and prosperity). Finally, the UK Government should continue to develop a sound understanding of allies' and partners' own space capabilities, ambitions, plans and gaps to identify concrete opportunities for collaboration, whether as a lead, equal or a junior partner.

2. How vulnerable are our space assets to deliberate attack, both physical and otherwise, and what steps can be taken to improve their resilience?

Space assets are inherently vulnerable to natural and human-made threats, though this may not be sufficiently appreciated by government, businesses and the public. This necessitates a role for UK Defence both in securing access to and use of space, and in supporting efforts to mitigate the impact of any future disruption. The space domain is now routinely described as becoming increasingly 'congested, contested and competitive' as both space and counter-space capabilities proliferate. Besides the various natural hazards, human-made threats include kinetic, electronic, or cyber-attacks not only on satellites themselves but also on data links, ground-based infrastructure, and supply chains. These can materialise not only in times of crisis, but also in the 'grey zone' below the threshold of open armed conflict.

There are practical difficulties in protecting satellites and space objects, for instance through hardening or manoeuvring. At the same time, there are also increasing but often overlooked dependencies on space services (most notably satellite communications [SATCOM], positioning, navigation and timing [PNT] and Earth observation [EO] / intelligence, surveillance and reconnaissance [ISR]). This is true not just across government but also the national and global economy and wider society.

Of course, the UK aims to deter others from targeting its space-based assets. It also works closely with allies, such as the United States, who have much greater sovereign capabilities for space domain awareness and protect and defend missions. However, natural hazards such as debris or space weather cannot be 'deterred' and if deterrence of human-made threats fails then this combination of vulnerability and dependency raises the risk of disruption. Degraded or denied access to space services could have an effect not only on networked military operations in all domains (i.e., land, maritime, air, cyber and electromagnetic), but also on critical national infrastructure and a variety of basic societal and economic functions affecting daily life.

In this deteriorating threat environment, mission assurance and resilience are key for secure, reliable, and sustained use of space. Different types of threats, hazards and risks require different responses, but recurring themes in RAND research include the need to learn from theory and practice in other domains and countries; move beyond materiel solutions to consider all Defence Lines of Development (DLODs); invest in redundancy, reversionary modes and a portfolio of different capability solutions to spread risk; and leverage industry capabilities to provide additional capacity and bolster resilience in a cost-efficient manner.

3. How can defence industrial policy ensure that investment and innovation in the private space sector is harnessed to align with the UK's defence requirements?

Defence industrial policy forms part of the space innovation ecosystem and needs to be considered in this wider context for rapid development and acquisition of innovative new space capabilities to succeed. Innovation takes place across various actors within the space ecosystem, including industry (both large primes and small and medium enterprises), academia and government. It is the product of the interaction between different actors' drivers (e.g., motivations such as profit, social benefits, sustainability); inputs and resources (e.g., talent, capital, and knowledge); enablers (e.g., infrastructure, networks); and contextual factors that shape how well innovation can take place (e.g., culture and organisational structure).

Implementing the principles outlined in the new 2021 DSIS provides a starting point for developing a more strategic and constructive relationship between the MOD and industry. The DSIS builds on previous efforts by the MOD to maximise the benefits that it and the UK at large can derive from industrial strategy and acquisition programmes in all domains. These include not only national security considerations, but also influence overseas and a variety of economic and social benefits to both regional and national prosperity.

Industrial strategy towards the space sector also benefits from ongoing efforts to drive greater coherence within government itself, ensuring that all relevant policy levers are brought to bear. Perhaps most notable are the creation of a National Space Council, the MOD's enhanced cooperation with the Department for Business, Energy, and Industrial Strategy (BEIS) and the UK Space Agency (UKSA), and the organisational reforms undertaken within the MOD itself in the wake of the 2019 Forber Review (i.e., establishing the Space Directorate and the new joint Space Command).

With the DSIS and these new organisational structures now coming online, the MOD plans to increase its investment in new space capabilities significantly over the next 10 years. This raises questions for industrial and acquisition strategy. Priorities include finding the balance between sovereignty, cooperation and reliance on the open market, being conscious of the imperative to maintain certain indigenous industrial capabilities for security or economic reasons ('own'), while also partnering with other nations ('collaborate') and accessing innovative new technologies from the global market ('access').

There is similarly a need to recognise the marked shift in the locus of innovation from governments and militaries towards the private sector, amplified in the buoyant commercial space market today. To harness market opportunities and the latest innovation, the MOD will need to be an 'intelligent customer' and enhance its ability to cultivate and absorb innovation, despite its more limited levers for shaping 'dual-use' space technologies compared to many other areas of defence equipment.

Ensuring the MOD is better able to develop and deliver new capability at speed is also essential, given the pace of technological change in the space domain and the heavy investments being made by the UK's competitors. Given sectoral trends, the MOD has an opportunity to build a more agile model of space capability development, embracing the chance for a fresh approach in a 'new' operational domain where it is relatively unencumbered in terms of legacy structures, platforms, or decisions. RAND research suggests ways in which the MOD's approach to capability development and acquisition could keep up with rapid innovation in the space sector, bringing benefits to the UK in terms of security, influence, and prosperity.

4. How can the Ministry of Defence ensure that it attracts, develops and retains high calibre space specialists in both policy and operational roles?

In recent years, space has been recognised as an operational domain, marking a shift from a technological domain requiring niche and specialised knowledge to one also requiring much broader skillsets to fulfil various operational and 'back office' roles. The MOD finds itself in the early stages of this transition, reflected in the presence of highly qualified and niche technical expertise in some areas (e.g., SATCOM, space weather monitoring) but an overall lack of suitably qualified and experienced personnel (SQEP) to meet the demands of a growing range of space-related roles.

Addressing the SQEP challenge will be fundamental to enabling the UK Government achieves its ambition of becoming a 'meaningful player in space'. The MOD should consider good practices and cautionary tales in terms of personnel strategy in other domains, industries and among allies and partners. There is no shortage of past initiatives designed to grow and sustain technical and soft skills relevant to defence; however, many have proven a partial success at best, and some lessons may not be transferrable to the context of the UK MOD given the low baseline from which it is developing its space workforce.

Past RAND research shows that effective ways of identifying and addressing skills gaps require a strategic, national-level approach. This should make use of all levers available to the MOD (e.g., training, education, recruitment and retention initiatives) but also be underpinned by cooperation across government, industry and the education sector. This collaborative approach to the development of the skills base for space should be enhanced by concrete interventions to foster specialised training and knowledge exchange (e.g., industry placements, mid-career development programmes). These should be further fostered through strategic workforce planning in individual space organisations and institutions and clearly identified career pathways.

1. How should the UK Government seek to further develop its strategic relationships and interoperability with allies?

1.1. Though starting from a low base in most areas, the UK should capitalise on its strengths when approaching potential partners

1.1.1. Building on an approach already firmly rooted in collaboration

Traditionally, the UK has relied significantly on collaborative partnerships in space and has been able to access valuable space capabilities and services as well as provide important technical expertise into collaborative programmes with allies and partners. This effort has primarily been directed through its participation in the European Space Agency (ESA) for civil programmes and through close collaboration with the United States (e.g., on Operation Olympic Defender) and the wider Five Eyes intelligence alliance on military programmes.[5] The UK MOD also works on space-related issues with and through multinational organisations such as the North Atlantic Treaty Organisation (NATO), as well as providing support to allies and partners via use of sovereign UK assets such as its Skynet satellite communications (SATCOM) system.

1.1.2. Making use of all resources and levers of influence

Over the past two years, the UK has also been successful at exercising its political and diplomatic influence in leading the preparation of a UN General Assembly resolution on responsible behaviours in space and the subsequent global discussion on the key principles and norms of such behaviour.[6] The UK is similarly engaged in other multilateral efforts to shape space governance and promote space safety and sustainability, including through the Outer Space Treaty or most recently its signature of the NASA Artemis Accords.[7]

For smaller space powers, like the UK, that lack the resources to develop a comprehensive suite of space capabilities in a fully sovereign way, collaboration is critical for successful access to and exploitation of the space domain. Arguably, even large space powers like the United States increasingly recognise the benefits of collaboration for enhancing the resilience of their military capabilities, sharing costs, enabling access to innovation and different perspectives, promoting interoperability between allies, and driving development of international rules and norms on topics such as responsible space behaviours and governance.

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[5] In addition to the UK and US, this includes Australia, Canada, and New Zealand.

[6] Bruce McClintock, Katie Feistel, Douglas C. Ligor and Kathryn O'Connor. 2021. *Responsible Space Behaviour for the New Space Era: Preserving the Province of Humanity*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/perspectives/PEA887-2.html

[7] UK Space Agency. 2020. 'International Treaty: The Artemis Accords'. Gov.uk. As of 1 July 2021: https://www.gov.uk/government/publications/the-artemis-accords

1.1.3. Increasing the UK's level of ambition

The UK Government will soon begin implementing a new *National Space Strategy* supported by a specific *Defence Space Strategy* and the cross-government activities of the new National Space Council. These are intended to deliver on the ambition set out in March 2021 in the *Integrated Review of Security, Defence, Development and Foreign Policy* for the UK to become a 'meaningful player in space'.[8]

Implementing the *Defence Space Strategy* over the coming decade will start from a relatively low baseline of existing UK defence space capability. This consists primarily of the Skynet SATCOM system and ground-based assets such as the radar installation at RAF Fylingdales, which forms an important node in the United States Space Surveillance Network, and the UK Space Operations Centre (UK SpOC) at RAF High Wycombe, with its role in understanding, monitoring, and operating in the space domain. Looking beyond defence, public investment in space nationally lags behind similar-sized economies such as France, Germany and Japan, with France alone spending more than four times as much on space as the UK.[9]

1.1.4. Adopting a Team UK approach in close cooperation with industry

Despite the UK's relatively low level of public investment and capability in space, the UK commercial space sector has seen significant innovation and growth over the last two decades, with the number of employees in the sector increasing threefold since 2000.[10,11] The UK benefits from strong niche industrial capabilities in many areas typically associated with so-called NewSpace activities – including in market segments such as small satellites, antennae, or novel propulsion systems – and is aiming to become the first space launch site in Europe, with launches of small payloads aiming to start in 2022.

The UK is also actively innovating and investing in 'downstream' applications to bring space-enabled services to end users across a broad range of markets, as reflected for example in the work on the Satellite Applications Catapult on everything from agriculture to climate change, health, or transport. These again provide opportunities for international collaboration, as well as beneficial spillovers between defence space and civil or commercial space technologies.

As the UK looks towards articulating what its 'meaningful player in space' ambition means in practice, therefore, it starts from a low, but solid base in terms of the value it can offer to collaborative partnerships.

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[8] HM Government. 2021. 'Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy.' Gov.uk, 16 March 2021. As of 16 June 2021: https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy

[9] Euroconsult. 2020. "Government Space Programs: Benchmarks, Profiles & Forecasts to 2029",

[10] Know.space. 2021. 'Size & Health of the UK Space Industry 2020. Summary Report for the UK Space Agency.' Gov.uk, May 2021. As of 16 June 2021: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/987497/know.space-Size_Health2020-SummaryReport-FINAL_May21.pdf

[11] LE (London Economics). 2019. *Size & Health of the UK Space Industry 2018: A Report to the UK Space Agency*. London: London Economics. As of 16 June 2021: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774450/LE-SHUKSI_2018-SUMMARY_REPORT-FINAL-Issue4-S2C250119.pdf

1.2. The UK Government should seek to fill in gaps in allies and partners' strengths, to yield effective collaborative programmes

Alongside understanding the UK's own strengths and limitations, effective partnerships are also predicated upon understanding the capabilities of potential partners as well as the gaps which the UK might be able to 'fill' through industrial, scientific, technological, military, political or financial contributions. In this way, the UK Government can strike a bargain that is mutually beneficial and use all available levers to help shape how that partnership evolves in line with UK policy objectives (e.g., securing industrial workshare for UK firms to help promote prosperity benefits, or ensuring UK military requirements are suitably prioritised).

Several considerations that affect the prospects for collaboration include:

- **Geographic location:** The ability to access launch sites in different parts of the world presents opportunities to access orbits that the UK may not be able to otherwise access in a timely and cost-efficient manner (given differences in launch windows or the amount of fuel needed to achieve certain orbits from different points on the Earth). Other benefits of geographical location may come in terms of hosting radars, telescopes and other sensors for space surveillance and tracking (SST) – a key component of the space situational awareness (SSA) capability which the UK MOD wishes to develop in the near future. Here, countries like Australia and New Zealand could present valuable opportunities for partnerships given their location, as well as some existing capabilities.

- **Resources and space policy:** Space is important not only to defence and national security but also presents commercial opportunities with potential benefits for prosperity, innovation and enhanced international standing. This presents potential common ground (but also a source of occasional competition and friction) between UK ambitions and those of other space powers. Alignment or divergence in policy, ambitions, resources and planning cycles is an important factor in the success or failure of multinational partnerships. Beyond defence or commercial aspects, there are also wider areas of common interest to explore, such as environmental monitoring and climate resilience and disaster relief, where the UK might find shared goals and objectives with countries like France, India and the United Arab Emirates (UAE), or organisations such as ESA. The 'dual-use' nature of space technologies means that they can often be harnessed for both military and civil applications.

- **Gaps in capability:** Effective collaborations often arise when actors are able to identify the niche contributions that they could each bring into the partnership in a way that makes it mutually beneficial while also underwriting longer term commitment through mutual dependency. As such, it is important to consider not just similarities between prospective partners but also the differences, particularly in terms of capability gaps. France and Germany, for example, have strong space sectors; indeed, they are the biggest contributors to ESA programmes and derive significant benefits from them. The UK, in contrast, has more limited capability and heritage in some of the more 'traditional' space missions (e.g., it lacks any sovereign heavy launch capabilities) but has seen a significant growth over the last two decades in its NewSpace sector. As such, it is well positioned to bring 'added value' in these areas of skills, expertise, technology, and industrial capability. Similarly, other countries possess particular strengths which could fill in specific capability gaps facing Defence or the UK space sector more broadly – for example, Canada and Japan have strong heritage in space

robotics, while Germany has an excellent scientific R&D base in energy, propulsion and alternative power generation systems for space. The MOD should continue to work with the Department for Business, Energy and Industrial Strategy (BEIS), the UKSA and others to map the UK's areas of comparative advantage, as well as to identify those capability areas that should remain sovereign and those where the UK should be proactively seeking to collaborate with others or access certain technologies and services from the market (see Section 3 for more discussion of the 'own-collaborate-access' framework introduced in the *Integrated Review*).

- **Acquisition cycles and processes:** While commonalities in space policy and the presence of capability gaps are important factors in creating an effective partnership, the practical reality of needing to align funding and acquisition cycles across multiple defence establishments can sometimes be overlooked. This is nonetheless a critical factor for successful collaboration and, conversely, it is a critical barrier if acquisition cycles and processes cannot be aligned effectively, necessitating that these be considered from the outset to minimise programme risk.

- **Building on existing collaborative efforts:** One of the principal enablers for collaboration is the ability to build on past successful collaborative efforts. These efforts would normally build trust between recurring partners, establishing working relationships that can help iron out differences in approaches over the duration of the programme. In the case of the UK, the long-standing close collaboration with the United States creates a strong incentive to explore where and how further space collaboration may be beneficial to both sides. Similarly, the UK's existing relationships with France and Germany, through ESA, as well as bilateral partnerships, present opportunities to build further. This could include initiatives that integrate space into multinational programmes in other operational domains or encourage multi-domain integration and interoperability with allies.

- **Learning from good practice:** Some of the challenges ahead for UK Defence specifically – and the UK more generally – include the need to build up space-related skills, nurture nascent collaborative partnerships and find new and more timely ways to access, and where necessary protect, sensitive cutting-edge technologies. Given these challenges, international collaborations can be used as part of a learning process to identify good practice and drive subsequent improvement. For example, the UAE presents a unique case where the combination of high ambitions for space, significant financial resources and a reliance on international collaboration that explicitly involved building up skills and expertise locally, resulted in the successful delivery of complex space missions – especially the launch of spacecraft to orbit around Mars – from a baseline of little or no capability in a period of only 12 years. The UK's ambitions to boost its defence space capabilities, promote its commercial sector and bring prosperity benefits to different parts of the country are also shared with countries like Australia, whose national space agency's sole focus is to boost its commercial space sector and significantly grow jobs. Equally, larger nations such as the United States may start from a much higher level of domestic space capability and expertise but may, in some areas, be less agile than emerging players such as the UK given the scale and complexity of their institutions.

2. How vulnerable are our space assets to deliberate attack, both physical and otherwise, and what steps can be taken to improve their resilience (with regard both to defence capabilities and other critical national infrastructure)?

2.1. Space assets are inherently vulnerable in many respects, though this may not be sufficiently appreciated by government and the public

Space is commonly described as becoming more 'congested, contested and competitive'. This entails threats to space security and safety, affecting satellites themselves as well as data and communication links.

2.1.1. Challenges in defending against deliberate attack and other threats

Though it depends on a given satellite or spacecraft's size and design, it can be hard to conceal objects once they are placed in orbit or other points in space. They can be tracked by the various actors (state and non-state) involved in space surveillance and tracked more easily than many military assets in other domains, such as land, maritime and air. This reflects the lack of concealment in space (an armoured vehicle can be hidden in a wooded area or behind a hill, but a satellite cannot), the predictable nature of orbital mechanics, and the operational constraints imposed by the time and fuel costs of manoeuvring, given delta-v budgets.[12]

It can also be difficult or at least costly to harden space objects against attack. Enhanced protective measures imply trade-offs in terms of space, weight, and power during the satellite design phase, as well as increased production and launch costs. Furthermore, older or 'legacy' satellites still in orbit may not reflect the latest technology or adequately consider aspects such as cybersecurity. At the same time, the growing reliance of modern militaries, economies and societies on space infrastructure also increases the incentives for state and even non-state actors to seek advantage by threatening satellites, networks, and related infrastructure.

2.1.2. Increasing dependencies across government, the economy and society

Loss of access to space-enabled services, such as SATCOM, positioning, navigation and timing or Earth observation, could not only directly affect military operations by the UK and its allies, but also have cascading effects across the economy, society and critical national infrastructure.[13] This includes

[12] Delta-v is a measure of the change in velocity required to move between different orbits, locations, or objects in space, and space missions all have a finite delta-v budget, limiting the scope for high delta-v manoeuvres.

[13] Government Office for Science. 2018. *Satellite-Derived Time and Position: Blackett Review*. London: Government Office for Science. As of 16 June 2021: https://www.gov.uk/government/publications/satellite-

the risk of disruption to financial systems, telecommunications, energy grids, water systems, transportation, emergency services and global supply chains for UK companies and consumers.[14] Space is also an important enabler for nuclear deterrence in terms of command, control and communications systems and early warning, as well as the national technical means of verification to monitor arms control treaties. Disruption of access to or use of space may therefore have knock-on effects for strategic stability and escalation in any future crisis.

Despite these apparent vulnerabilities and dependencies, the UK's space assets (notably Skynet) do not have entire fleets of other platforms and systems tasked to protect them, unlike in other defence domains, as for example the Carrier Support Group protects the Queen Elizabeth-class aircraft carriers. Indeed, the 2021 Integrated Review acknowledges that the UK's sovereign capability to deliver the 'protect and defend' mission in space is currently limited, with the MOD heavily reliant on support from the United States (though it aims to reduce this by investing in new capabilities out to 2030).

2.2. Threats to the UK's space assets include both deliberate attack and accidental damage or natural hazards, requiring tailored responses

A range of threats, hazards and risks are present in space, requiring mitigation and resilience. There is a growing unclassified literature in the public domain providing detail on such threats, though it should be emphasised that some of the potential threat vectors (e.g., most theorised space-based weapons) remain hypothetical, have not yet been implemented in the real world and may be subject to a degree of 'hype'.

In broad terms, the main dangers to UK space assets can be categorised as follows:

- **Environmental hazards** e.g., space debris, radiation, space weather. As regards debris, the risk of cascading collisions in space is increasing as the number of objects in orbit rapidly grows, driven by the falling cost of launch, the rise of mega-constellations and the commercialisation of the sector. Perhaps the worst case scenario is a phenomenon known as the 'Kessler syndrome' – a situation whereby all activity in a given orbit is affected by cascading collisions that lead to the unchecked generation of space debris, eventually rendering entire portions of space unsafe to traverse or use.
- **Threats and risks to space-based assets** i.e., kinetic and non-kinetic effects either originating from Earth or from co-orbital threats within space. Examples include anti-satellite missiles, jamming, spoofing, dazzling and other electronic or cyber-attack, as well as close proximity missions in space.

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derived-time-and-position-blackett-review

[14] James Black. 2018. 'Our Reliance on Space Tech Means We Should Prepare for the Worst'. Rand.org. As of 1 July 2021: https://www.rand.org/blog/2018/03/our-reliance-on-space-tech-means-we-should-prepare.html

- **Threats and risks to ground-based segments** including launch sites, ground stations and space industry supply chains. Examples include cyber-attacks, espionage, kidnapping or kinetic strikes.
- **Threats both above and below the threshold of open armed conflict** including covert, ambiguous, or overt activities in the 'grey zone' in the context of persistent great power competition.

The vulnerabilities owing to natural and man-made threats are exacerbated by the aforementioned interdependencies with other defence domains, critical national infrastructure and cross-government or civilian end users. As a result, space systems have many stakeholders, some of whom may not understand the technical details of space systems or the threats they face, but nonetheless rely on their capabilities.

2.3. Mission assurance and resilience are key for effective use of space

Threats to space assets should be considered from the outset of any UK defence space programme, from the earliest definition of the UK's military requirements through to the eventual design, development, and acquisition and support phases. This places mission assurance and resilience at the core of thinking about space strategy, policy, force and capability development, and operations.

Importantly, mission assurance and resilience can be achieved in a variety of ways. A tailored response to threats is required, depending on the capability and intent of the potential attacker (assuming the threat is man-made), the vulnerability and importance of the UK space asset in question, and the resources and levers of influence available to the MOD to mitigate the effects of any damage or disruption.

2.3.1. Learning from other domains and countries

Relevant thinking exists in other areas beyond space. For example, the UK MOD's Missile Defence Centre conceptualises the response to air and missile threats in terms of five pillars, describing measures that come into play both before and after the onset of an attempted attack by a hostile actor:

1. Counter-proliferation: denying or limiting the adversary's access to capability.
2. Deterrence: deterring the adversary from employing that capability against the UK and its allies.
3. Counter force: preventing or limiting the launch of hostile attacks (e.g., through military action).
4. Active defence: seeking to intercept a hostile attack or otherwise minimise its impact.
5. Passive defence: seeking to mitigate the effects of any hostile attack to minimise disruption.

There are also potential lessons to be learned from theory and practice in other space-faring nations. The United States' joint doctrine, for example, defines space mission assurance in terms of three main categories of measures: defensive operations, reconstitution, and resilience.[15] This includes not only protecting space assets but also being agile enough to be able to produce, acquire and launch new

[15] U.S. Joint Chiefs of Staff. 2020. *Joint Publication 3-14: Space Operations.* Washington, D.C. As of 1 July 2021: http://www.jcs.mil/Doctrine/Joint-Doctrine-Pubs/3-0-Operations-Series/

satellites to replace them in a crisis, and implementing technical and non-technical measures to reduce the impact of any attack on space infrastructure that should occur. These efforts, in turn, contribute to overall deterrence and reduce the incentive for hostile actors to try to attack space assets in the first place.

2.3.2. Moving beyond materiel solutions to ensure a holistic approach

Recent RAND research for the U.S. Air Force has sought to improve methods for assessing and enhancing space mission assurance, given enduring shortfalls for even well-resourced and established spacefaring actors such as the U.S. Department of Defense.[16] It has similarly emphasised the need for non-materiel solutions, conscious that making changes to space systems themselves can be difficult and costly.[17] Enhancing resilience also requires activity in terms of policy, doctrine, organisation, training, leadership and education, personnel, facilities and infrastructure – much of which may fall across other areas of responsibility beyond, in the UK context, the MOD Space Directorate or joint Space Command. This necessitates a collaborative approach within Defence that encourages multi-domain integration, as well as working closely with partners across the rest of UK Government, for instance through the National Space Council. A coherent and integrated approach across Government departments and agencies is especially important if the UK is to manage the growing dependencies between space and critical national infrastructure.

2.3.3. Ensuring redundancy and a portfolio of different capability solutions

Resilience also stems from striking a balance between use of space and non-space alternatives. When considering different options for achieving a desired military effect, space may be essential in some cases but is not always the answer. Space can offer the valuable enhancement of capabilities on Earth, particularly via networks and data, but should not be regarded as a universal panacea for all requirements or scenarios. Defence must consider whether a given capability can only be delivered through the space domain and what other solutions (e.g., airbreathing systems or other terrestrial alternatives) might be available to supplement it, or if the space capability were to be denied or destroyed, to replace it altogether.

There is similarly a need to consider reversionary modes (including Tactics, Techniques and Procedures) for when access to and use of space is contested or denied. On the other hand, for capabilities that can only be delivered through space, mission assurance and resilience should be prioritised and enhanced, for example, by robust protect and defend procedures, physical and cybersecurity measures, increased redundancy of systems (e.g., by deploying constellations of satellites) and partnering with international allies to increase deterrent effect or provide access to other nations' capabilities.[18]

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[16] Brien Alkire et al. 2020. *Enhancing Assessments of Space Mission Assurance*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR2948.html

[17] Gary McLeod et al. 2016. *Enhancing Space Resilience Through Non-Materiel Means*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR1067.html

[18] For more on the complex dynamics of deterrence in the space domain, see Forrest Morgan et al. 2018. *Gaming Space: A Game-Theoretic Methodology for Assessing the Deterrent Value of Space Control Options*. Santa Monica, Calif: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR694.html And Bonnie Triezenberg. 2017. *Deterring Space War*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/rgs_dissertations/RGSD400.html

2.3.4. Leveraging the industry's capabilities and capacity to boost resilience

Given the dominance of commercial players in the space market today, there is also an opportunity for the UK Government to tap into a wide range of mature solutions, avoiding long lead times and reducing costs. This faster and potentially cheaper set of options may also help enhance resilience by redundancy. This is rather different from other operational domains (with the possible exception of cyber and electromagnetic), where industry has a less prominent role and where military requirements are likely to be very different from civilian users.[19] The dual-use nature of many space technologies and the enhanced opportunity to work closely with industry also means that UK Defence can potentially develop from its low-level capabilities (outside of Skynet) relatively quickly, rather than needing to duplicate the learning, innovation and iterative product development that has already occurred in other countries or commercial settings.

At the same time, integrating industry into the UK's defence space operations poses a number of policy, legal, cultural and practical challenges, which may undermine rather than reinforce resilience if not handled carefully. To address the barriers to more effective collaboration, Defence has already taken steps to establish a Commercial Integration Cell at the UK SpOC, similar to one operated by the U.S. Space Force at the Combined Space Operations Centre in Vandenburg, CA.

[19] For example, there are both military and commercial markets for PNT, EO or SATCOM, but this is often not the case for defence equipment in other domains (e.g., missiles, attack submarines, or main battle tanks).

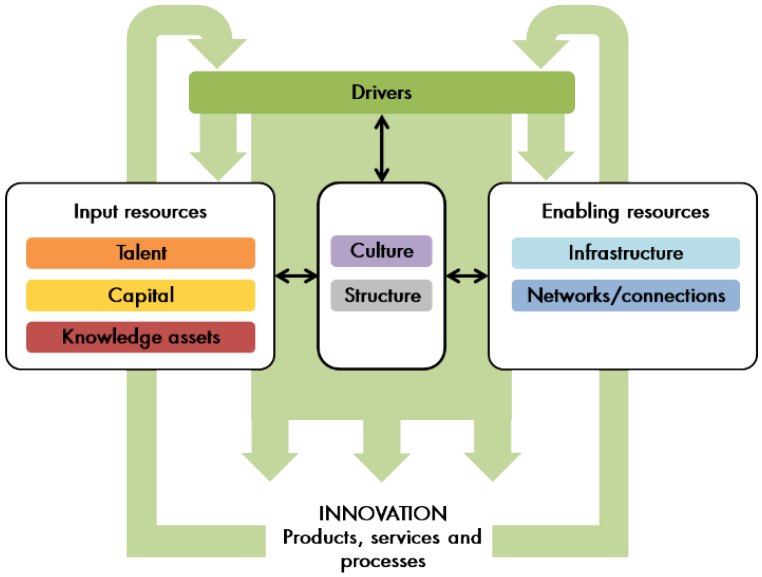
3. How can defence industrial policy ensure that investment and innovation in the private space sector is harnessed to align with the UK's defence requirements?

3.1. Industrial policy forms part of the space innovation ecosystem and needs to be considered in a wider context for innovation to succeed

Innovation is a complex phenomenon that is influenced, shaped and ultimately succeeds within a wider environment that extends beyond the individual, organisation or company undertaking innovation activities. Similar to other sectors of the UK economy, innovation takes place across various actors within the space ecosystem, including industry (both large primes and small and medium enterprises), academia and government departments and agencies, particularly the MOD (incl. Dstl), BEIS and the UKSA.

RAND has previously helped MOD and Dstl develop a simplified model of how innovation occurs, as shown in Figure 3.1. This captures the interaction between drivers of innovation (motivations such as social benefits; sustainability; profit drive, etc); inputs and resources (talent, capital and knowledge) and enablers (infrastructure, networks) and factors that shape how/how well innovation can take place, including culture and organisational structure.

Figure 3.1 RAND Europe framework for innovation



Source: Freeman et al (2015).

All of these factors need to be understood and adapted to foster and harness innovation, with government-industry relationships – and the related industrial strategy outlining how these are managed – forming only one piece of the overall innovation puzzle.[20] This is true in the space domain as in other parts of Defence, though as has been mentioned the relative balance between military and civil markets as drivers of research and development (R&D), investment and innovation activities differs from that in other capability areas.

3.2. Implementing the principles outlined in DSIS would provide a starting point for a constructive relationship to enable innovation

To achieve its ambitions for rapid innovation in the space domain, the MOD is guided by the overarching principles of its *Science and Technology Strategy*,[21] as well as the *Defence and Security Industrial Strategy* (DSIS) released in March 2021.[22] The DSIS provides a renewed impetus for greater collaborative working between the MOD and industry and academia, particularly when developing indigenous capability or sovereign components of capability.

The principles outlined in the DSIS resonate with RAND's own research on good practices in the acquisition of military capability and fostering innovation in defence markets, particularly noting:

- **The importance of an early and regular dialogue between government and industry** to a) provide a strategic view of defence capability requirements which helps give greater confidence to industry when making decisions on future resource planning and investment, such as R&D, skills, and infrastructure investment, and b) to understand and access the latest innovation and explore alternative approaches to effective delivery.
- **The importance of engaging with suppliers from across the wider supply chain,** including less traditional suppliers and small and mid-sized enterprises who may offer innovative solutions, for example through competitions, hackathons, innovation grants, technology challenges, etc.
- **The need to work with industry in the areas where critical skills need to be sustained and grown** to ensure resilience of defence capabilities and the long-term performance and sustainability of the underpinning industrial base in areas of particular importance. The DSIS frames the question of which areas of skills and industrial capability should be national priorities in terms of the concept of 'strategic imperatives' and 'operational independence'.[23] Notably too, the new National Security and Investment Act given Royal Assent on 29 April 2021 identifies space and satellite technologies as an area requiring special attention and protection, requiring

[20] Jon Freeman et al. 2015. *Innovation Models: Enabling new defence solutions and enhanced benefits from science and technology*. RAND, Santa Monica, Calif. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR840.html

[21] Ministry of Defence. 2020. *MOD Science and Technology Strategy 2020*. As of 1 July 2021: https://www.gov.uk/government/publications/mod-science-and-technology-strategy-2020

[22] Ministry of Defence. 2021. *Defence and Security Industrial Strategy*. As of 1 July 2021: https://www.gov.uk/government/publications/defence-and-security-industrial-strategy

[23] These concepts build upon and replace the previous focus on Technological Advantage, a function of Operational Advantage (OA) and Freedom of Action (FOA), as set out in Ministry of Defence. 2012. *National Security Through Technology*. As of 1 July 2021: https://www.gov.uk/government/publications/national-security-through-technology-technology-equipment-and-support-for-uk-defence-and-security-cm-8278--2

mandatory notification of foreign investments in relevant UK firms to help secure supply chains and UK intellectual property.[24]

- **The importance of fostering collaboration with actors within the wider space ecosystem**, including industry, academia and across Whitehall, such as through the creation of 'co-creation spaces' or targeted engagement with fora such as the Defence Suppliers Forum or Defence and Aerospace Growth Partnerships, with the aim to accelerate development of innovative solutions.

3.3. Successful adoption of innovation will require a balanced approach to capability management and cultural adjustment

3.3.1. Striking the balance between sovereignty, collaboration, and competition

Implementing the ambitions set out in the DSIS (or the upcoming *National Space Strategy)* in relation to both public and private sector activities in the UK space sector would help set the foundations for a nascent, healthy space ecosystem from which MOD Space Command can draw for acquisition of space capabilities. On any given space programme this could be approached in several different ways; broadly broken down into indigenous design ('own'), developing a UK contribution to a multinational programme ('collaborate') or accessing existing capability from the market ('access'), in line with the new 'own-collaborate-access' approach to capability management set out in the *Integrated Review*.[25]

RAND research for the MOD has outlined key principles and a decision support tool for navigating these choices about how to determine when to 'own', when to 'collaborate' and when to 'access', given the UK's evolving policy ambitions and requirements in the space domain.[26]

3.3.2. Recognising the shift in the locus of innovation towards the commercial sector

The fast growth of commercial space activity in the last decade, including into areas traditionally monopolised by governments and militaries, has shaped the global space market and technology landscape in ways that make any one national government likely to be a 'market taker', rather than 'market maker', for many elements of space capability it may wish to access or acquire. This is increasingly true even for the largest players (e.g., the United States) but certainly a major consideration for small and medium players such as the UK, with their comparatively limited resources and influence over the innovation ecosystem.

While being a 'market taker' in many capability areas may sound like a constraint and risk – and certainly an experience rather unlike the MOD's more predominant role in other, more established defence markets such as for complex weapons or naval shipbuilding – there are also substantial potential benefits. The MOD has an opportunity to tap into innovation occurring in 'dual use' technologies and business models related to space activity; leveraging private sector investment,

[24] HM Government. 2021. 'National security bolstered as Bill to protect against malicious investment granted Royal Assent'. Gov.uk. As of 1 July 2021: https://www.gov.uk/government/news/national-security-bolstered-as-bill-to-protect-against-malicious-investment-granted-royal-assent

[25] HM Government. 2021. *Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy*. As of 28 June 2021: https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy

[26] Retter, Lucia, James Black, Theodora Ogden. 2021. *Realising the Ambitions of the UK's Defence Space Strategy: Factors Shaping Implementation to 2030*. Santa Monica, Calif: RAND.

benefitting from economies of scale not often encountered in other defence domains, and gaining rapid access to new products and services.

3.3.3. Ensuring MOD's ability to be an intelligent customer and cultivate innovation

To achieve these leapfrog advancements, however, the MOD will need sound market intelligence and horizon scanning capabilities to identify, understand and monitor developments in global commercial space markets and the latest S&T developments and innovations of relevance to defence. It will also require a culture of innovation that focuses on risk management rather than risk aversion, and which empowers decision makers while also providing appropriate 'off ramps' so that high-risk programmes can 'fail fast and fail early'. This culture of innovation must also be reflected at the organisational level, for example through structures, processes and contracting mechanisms that enable the MOD to engage effectively with space industry, SMEs, and academia, so as to translate good ideas into real-world capability in a timely manner.

3.4. The MOD has an opportunity to build a more agile model of space capability development if it adopts innovative approaches

3.4.1. Embracing the chance for a fresh approach in the 'new' space domain

Compared to most other domains (besides cyber and electromagnetic), Defence has an opportunity to pursue fresh approaches to innovation and to capability development that are unencumbered by legacy ways of doing things. Though the UK MOD is not starting from a 'blank sheet of paper' in the space domain, especially given its considerable expertise and equities around Skynet, the relatively low level of extant capability in many areas (e.g., protect and defend, space domain awareness), coupled with the establishment of a new MOD Space Directorate and Space Command offers a chance to do things differently and learn lessons from other countries or domains without the constraints of legacy structures and systems.

Similarly, Defence stands to benefit from ongoing cross-government efforts, such as through BEIS and the UKSA, aimed at engaging a broader range of private sector and academic organisations and nurturing existing and new space innovation ecosystems, such as the Harwell space cluster.

3.4.2. Adapting the MOD's processes to keep up with rapid innovation

Promoting innovation across this national space enterprise should also include a strong focus on ensuring that the MOD's approach to acquisition of defence space capability is able to keep up with the rapid pace of change in space-related technologies, threats, and markets. Taking a decade or two to deliver a new ship, armoured vehicle or combat aircraft is increasingly deemed unacceptable in other domains, but such a rate of programme delivery would certainly be wholly inadequate in many areas of space capability, given sweeping changes underway in the sector.

Against this, there are some well-documented and persistent policy, organisational and cultural barriers to rapid delivery of new capability through the current structures and processes of the MOD (Defence Equipment & Support).[27] These domain-agnostic challenges are exacerbated by space-

[27] Lucia Retter, Julia Muravska, Ben Williams and James Black. 2021. *Persistent Challenges in UK Defence Equipment Acquisition*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RRA1174-1.html And National Audit Office. 2021. *Improving the Performance of Major Equipment Contracts*. As of 1 July 2021: https://www.nao.org.uk/report/improving-the-

specific factors, such as the limited pool of suitably qualified and experienced personnel (SQEP) within the UK defence space enterprise (see Section 4 for further discussion of the shortfall in skills and expertise). More established space actors such as the U.S. military have similarly struggled to deliver space programmes on budget and schedule in the past,[28] and are undertaking corrective reforms to speed up this process.[29]

Given these challenges, recent RAND research on more agile models of space acquisition suggests several approaches that may be suitable for the fast-paced nature of space capability development and market dynamics. These include, but are not limited to[30]:

- Spiral development, which emphasises incremental development and quick reactions to changes in capability needs based on end user feedback.
- Creation of 'digital twins' and use of digital engineering (as is a priority for the U.S. Space Force).[31]
- Rapid prototyping, which is a set of design and development activities conducted in the early stages of acquisition to reduce technical uncertainty and to inform subsequent acquisition decision making, towards fielding capabilities faster than traditional acquisition programmes.
- Modular open systems architecture, which makes use of a modular design philosophy with plug-and-play system modules connected via consensus-based interface standards, which allow for interoperability and technology reuse across the organisation.
- DevSecOps and iterative models of software development, which focus on optimising workflow to generate faster times to market, improved overall productivity, while prioritising security throughout all stages of development.[32]

When deciding which agile acquisition approach to select for a given programme, Defence should also build on the lessons provided by other domains, previous MOD successes (e.g., Skynet, Carbonite-2), and the experiences of allies, partners, and commercial organisations in this increasingly competitive domain.

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performance-of-major-equipment-contracts/

[28] Yool Kim et al. 2015. *Acquisition of Space Systems: Past Problems and Future Challenges*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/monographs/MG1171z7.html

[29] Nathan Strout. 2020. 'Space Force lays out acquisitions reforms in new report'. C4ISRnet.com. As of 1 July 2021: https://www.c4isrnet.com/battlefield-tech/space/2020/05/21/space-force-lays-out-acquisitions-reforms-in-new-report/ Government Accountability Office. 2021. *Space Acquisitions: DOD Faces Challenges and Opportunities with Acquiring Space Systems in a Changing Environment*. As of 1 July 2021: https://www.gao.gov/assets/gao-21-520t.pdf

[30] Yool Kim et al. 2020. *Improving Acquisition to Support the Space Enterprise Vision*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR2626.html

[31] United States Space Force. 2021. *U.S. Space Force Vision for a Digital Service*. May. As of 1 July 2021: https://media.defense.gov/2021/May/06/2002635623/-1/-1/1/USSF%20VISION%20FOR%20A%20DIGITAL%20SERVICE%202021%20(2).PDF

[32] Plutora. 2021. *DevSecOps: A Complete Guide to What, Why, and How*. Available: https://www.plutora.com/blog/devsecops-guide .

4. How can the Ministry of Defence ensure that it attracts, develops, and retains high calibre space specialists in both policy and operational roles?

4.1. Though space is a technology-intensive domain, people and skills remain the most important assets for any space enterprise

Defence policy and strategy documents are replete with references to the importance of people to the UK's advantage over competitors and adversaries. Having people with a qualitative edge is especially important for a relatively small population such as the UK, which cannot hope to compete in terms of quantity (mass) without a significant uplift in defence spending or a return to conscription.[33]

This stated focus on attracting and developing talent encompasses not only regular military personnel, but also reservists, civil servants and contracted support from across industry and academia – i.e., taking what the MOD calls a Whole Force approach.[34] Personnel are similarly recognised as an essential component of capability in the Defence Lines of Development (DLODs), along with the training and education required to cultivate the knowledge, skills and experience (KSE) needed in a productive defence workforce.[35]

Despite this heavy reliance on access to KSE, Defence faces enduring and well-documented challenges in accessing, recruiting, retaining, and developing the necessary quality and volume of suitably qualified and experienced personnel (SQEP). This is true not only in the UK but also across NATO and beyond.[36] Similar challenges also exist within the defence and aerospace industry, which have been well-documented in RAND research and other sectoral reviews.[37] Past RAND studies for the MOD and allied governments have repeatedly shown that a lack of industrial skills can have a

[33] For example, see the 2021 Integrated Review or Defence Command Paper, the Integrated Operating Concept (IOpC 2025) or Strategic Defence and Security Reviews (SDSRs) and other policy documents back to 2015 or 2010.

[34] John Gearson et al. 2020. 'The Whole Force by Design: Optimising Defence to Meet Future Challenges'. Serco Institute and KCL. October. As of 1 July 2021: https://www.kcl.ac.uk/news/the-whole-force-by-design-optimising-defence-to-meet-future-challenges

[35] Ministry of Defence. 2020. 'How Defence Works: The Defence Operating Model'. Gov.uk. As of 1 July 2021: https://www.gov.uk/government/publications/how-defence-works-the-defence-operating-model

[36] Katerina Galai et al. 2020. *Understanding Skills Gaps in the European Defence Sector*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_briefs/RB10094.html

[37] Katerina Galai et al. 2020. *Vision of Defence-Related Skills for Europe Today and Tomorrow*. European Commission. As of 1 July 2021: https://www.rand.org/pubs/external_publications/EP67991.html And Lucia Retter, Louise Taggart and Jon Freeman. 2015. *Key Skills and Competences for Defence*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR1226.html

direct impact on defence capability development and acquisition – posing substantial risks to programme performance, costs and timelines, as well as increasing long-term costs when critical skills need to be re-grown after atrophying to a low base.[38]

Within the space industry specifically, surveys commissioned by the UKSA have revealed skill gaps at both the national and firm level and various recruitment, retention, and workforce development challenges. Observed consequences include 'constraint on innovation, failure to exploit business opportunities or to win contracts, and reduced productivity'.[39] These have knock-on effects not only for UK prosperity, but also for the ability of Defence to leverage the industrial base to promote national security and influence.

4.2. UK Defence starts from a low level of SQEP in space, requiring investment in space literacy, education, and workforce development

With space being a capital- and technology-intensive domain, it is essential that the MOD and wider national space enterprise prioritise the development of a pipeline of space-related SQEP as an indispensable enabler of future policy, capability, and operations. This is especially important if the UK wishes to increase its operational independence in the space domain and reduce its reliance on international allies and partners, most notably the United States, who have access to larger pools of SQEP.

To this end, the MOD is already taking action to establish a new Space Academy. Though there is limited information in the public domain about what this will entail in practical terms – such as the level of funding and expected numbers of personnel completing courses each year – it is hoped that this will help to provide enhanced training and professional military education on space-related topics.[40]

4.2.1. Learning from good practice interventions to build and sustain skills

In developing a sustainable pool of space SQEP, the MOD should build on steps taken in other defence domains, and identify transferrable lessons from how allies, partners and industry are developing their own space skills. The UK's approach must of course be tailored to its unique context. How the MOD designs and implements personnel strategy to address emerging requirements in the space domain will look different to structures and processes in other countries. Nonetheless, relevant principles can be derived from theory and practice in other settings. For example, previous RAND research has identified several prerequisites for effectively growing and sustaining skills needed for the defence industrial base.[41] Examples include:

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[38] Lucia Retter et al. 2021. *Persistent Challenges in UK Defence Acquisition*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RRA1174-1.html And Lucia Retter et al. 2017. *Response Strategies to the Cost Escalation of Defence Equipment*. European Defence Agency. As of 1 July 2021: https://www.rand.org/pubs/external_publications/EP67014.html

[39] UK Space Agency. 2021. 'Space Sector Skills Survey 2020: Research Report'. Gov.uk. As of 1 July 2021: https://www.gov.uk/government/publications/space-sector-skills-survey-2020-research-report

[40] HM Government. 2021. 'Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy.' Gov.uk, 16 March 2021. As of 16 June 2021: https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy

[41] Katerina Galai et al. 2020. *Vision of Defence-Related Skills for Europe Today and Tomorrow*. European Commission. As of 1 July 2021: https://www.rand.org/pubs/external_publications/EP67991.html And Lucia

- The need for a strategic approach (e.g., articulated through strategy documentation) which centres around aligning interests and ambitions to grow and sustain a pipeline of skills nationally.[42]
- Setting up effective collaborations between government, industry, and the education sector both to identify skills gaps and develop initiatives to build a pipeline of new talent to address them.[43]
- Specialised industry-led interventions to provide on the job training that adapts to novel skills requirements that arise alongside new technologies and to capability development programmes.[44]
- Addressing not only specialist skills in any given area, but also investing in education and awareness-raising activities for those working in other parts of the organisation. This also helps ensure that senior leadership has a sound understanding of how activities in that area impact the wider business.

4.2.2. Identifying key principles for effective workforce management in space

In addition to the broader set of initiatives and interventions, previous RAND research has also identified specific lessons in relation to key principles and strategies for space workforce management, while noting that these may manifest differently in the UK MOD compared to other national or organisational settings.

For example, RAND work to inform creation of the United States Space Force emphasised in particular[45]:

- Strong leadership to build and sustain momentum for the implementation of initiatives to address barriers to building a healthy pool of SQEP at different ranks and levels of experience and a set of viable career pathways, especially at a time of broader organisational change.

Retter, Louise Taggart and Jon Freeman. 2015. *Key Skills and Competences for Defence*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR1226.html

[42] This can be realised through various policy and practical interventions, for example setting up training academies or centres of excellence, or by fostering knowledge spill-overs from the defence sector to civil industries and vice versa.

[43] For example, this could include creation of dual degree programmes that combine academic education with on-the-job training, staff exchanges and industry/government placements.

[44] These include, for example mid-career development programmes and specialised training focused on updating and tailoring the required skillsets as skills requirements evolve.

[45] Michael Spirtas et al. 2020a. *A Separate Space: Creating a Military Service for Space*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_reports/RR4263.html And Michael Spirtas et al. 2020b. *Creating a Separate Space Force: Challenges and Opportunities for an Effective, Efficient, Independent Space Service*. Santa Monica, Calif.: RAND. As of 1 July 2021: https://www.rand.org/pubs/research_briefs/RB10103.html

- A tailored approach that recognises the challenges inherent in the relatively small size of the space workforce, in terms not only of a lack of resilience, but also the potential mismatches between personnel policies designed for the joint force or armed services and the needs of this niche area.
- A realistic awareness of the limited leverage that this small workforce may have across the wider defence community (e.g., reflected in the small number of senior officers promoted into leadership positions where they can advocate for space-related priorities and influence policy decisions), and efforts to mitigate this by enhancing awareness of space among stakeholders in other domains/areas.
- The need to develop a positive culture in this emerging domain, including a distinctive identity for the space workforce. Difficulties reflect not only the workforce's limited size, but also its primary focus on being a force enabler (i.e., supporting and enabling operations across all defence domains) in ways that are often not well understood and appreciated by those outside the space enterprise.
- The importance of considering not only the defence space workforce and future skills requirements in terms of operational or technical roles, but also 'back office' functions such as space-related policy and strategy; intelligence; operational concepts and doctrine development; requirements-setting; planning, programming, cost estimation, and delivery of space acquisition programmes; modelling and simulation; and legislative liaison and public affairs.
- The need to minimise seams between services and organisations that undermine the development of a coherent and holistic approach to space workforce development across the joint force.

There is consequently a need to think creatively about how to design space-related career pathways, retention incentives, learning and development offers, and collaboration with industry (e.g., via contracted support, or use of secondments, sponsored reserves, and other means of accessing the talent pool beyond the public sector) and with partners across UK Government (most notably the UKSA) and internationally. Space-related games and exercises can also help both to build space-related expertise, as well as better identify skills gaps and stress-test assumptions about the workforce needed.

Strategic workforce planning is also essential to ensure any nascent pipeline of space-related SQEP is sustainable and resilient to shocks (e.g., changes in operational requirements, new technology, or labour markets). This should be supported by relevant taxonomies, data, tools for tracking critical skills and modelling of both supply and demand over time to anticipate possible future skills gaps or mismatches. It is vital to take account of the time lag between any intervention, such as implementing new training or a recruitment drive, and its impact on the workforce years later. Monitoring and evaluation should similarly be undertaken to ensure initiatives, such as the Space Academy, achieve their objectives and deliver high quality (in terms of course content, delivery and access) and overall value-for-money.

RAND research suggests that UK Defence could also benefit from a concerted effort to enhance 'space literacy' (i.e., awareness of key trends in the space domain and their impact on military operations, government, the economy and wider society).[46] This would engage target audiences across

the MOD and Armed Forces, other Government departments, Parliament, media, industry, and the public. This awareness-raising activity is likely to be a long-term task not just for the MOD Space Directorate and new Space Command, but also for BEIS, the UKSA and others across UK Government, including ministers.

July 2021

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[46] Retter, Lucia, James Black, Theodora Ogden. 2021. *Realising the Ambitions of the UK's Defence Space Strategy: Factors Shaping Implementation to 2030*. Santa Monica, Calif: RAND.