Written Evidence submitted by Lockheed Martin UK

1. Lockheed Martin UK (LMUK) is a wholly-owned subsidiary of Lockheed Martin Corporation, and employs approximately 1,800 people. Lockheed Martin spends on average £1.6 billion each year in the UK, supporting over 1,000 British companies (80 per cent of which are SMEs), and 20,000 jobs.

2. Lockheed Martin is the world's largest space company. For the U.S. military, it provides capabilities for early warning, surveillance, and navigation. These include the Space-Based Infrared System (SBIRS) for surveillance, the Global Positioning System (GPS) for navigation, the Mobile User Objective System (MUOS) for narrowband satellite communications, and the Advanced Extremely High Frequency (AEHF) system for protected satellite communications. The UK Ministry of Defence (MoD) is involved in, and co-funded, AEHF.

3. In the UK, Lockheed Martin is part of Team Athena, the new national space team including CGI, Inmarsat, and Serco. Team Athena aims to grow and diversify the UK's space sector. Lockheed Martin is supporting the UK Space Agency's (UKSA) commercial spaceflight programme, LaunchUK, by leading a team to deliver the first vertical space launch from British soil in 2022. It is also exploring opportunities to invest, aligned to major programmes such as the Skynet 6 military satellite communications programme, and the Space-Based Position, Navigation and Timing Programme (SBPP).

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

4. Protecting services and operations in the space domain is a significant task, given the scale of the domain. Collaboration with allies can increase the reach and resilience of space systems and services, and at reduced cost.[1] Developing alliances in space may itself deter adversaries, as assets would be part of a collective capability. The U.S. Department of Defense's (DoD) Space Strategy recognises this, and includes cooperation with allies as a discrete Line of Effort.[2]

5. The UK already contributes personnel, and some data, to the U.S.-led Combined Space Operations Center (CSpOC) and Operation OLYMPIC DEFENDER. The UK has an opportunity to increase its contribution to Space Domain Awareness (SDA), by investing in more sovereign sensors that are interoperable with allies (see paragraph 8).

6. Furthermore, the Five Eyes and NATO allies are increasingly concerned about the resilience of their space systems and services.[3] Lockheed Martin's analysis shows that layered architectures, with different assets in different orbits, are most effective. The UK therefore has an opportunity to be 'international by design' in at least two areas:-

    a. <u>Military satellite communications.</u> The U.S. and Australia are recapitalising their satellite communications capabilities in similar timeframes to the UK, through the U.S.' Evolved Strategic SATCOM (ESS) and Protected Tactical Satellite (PTS) programmes, and Australia's JP9102 Defence Satellite Communications System. As each is likely to require different assets in different orbits, the MoD has an opportunity

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[1] Mark Chang, 'Protecting Next-Generation Military Satellite Communications with an Innovative Disaggregation Approach: Delivering Major Gains through Business Change', *Air and Space Power Review*, Vol 22, No 22, Summer 2019, pp. 16-31.
[2] U.S. Department of Defense, *Defense Space Strategy Summary*, June 2020, p. 6.
[3] For NATO's military satellite communications requirements, four Member States – the UK, France, Italy, and U.S. – provide spare capacity from their satellite communications programmes, under the NATO SATCOM Services 6th Generation (NSS6G) satellite services project. The Memorandum of Understanding for NSS6G operates from 2020 to 2034. It succeeds the NATO SATCOM Post-2000 project, under which the UK, France, and Italy delivered capacity to NATO. For PNT, NATO uses U.S. GPS, as it is the only available system that meets its military requirements.

to design an architecture for its Skynet 6 programme (see paragraphs 12 and 13) that complements and delivers services to allies; and

b. Position, Navigation and Timing. The U.S. Government is considering how to improve the resilience of its GPS constellation, which is in Medium Earth Orbit (MEO). The UK's SBPP could complement GPS, by providing assets in different orbits (see paragraphs 9 and 10). Other nations have already adopted this approach for their Global Navigation Satellite Systems (GNSS), including China's BeiDou system.

Collaboration of this type would increase the UK's international influence, by establishing it as critical contributing partner for the provision of resilient space capabilities.

7. In addition to collaborating on these strategic space missions, there is scope for greater collaboration with allies on space protection capabilities (see paragraph 19), Operationally Responsive Space (see paragraph 14), and skills development. The statement of intent between the MoD and DoD for '*Enhanced Cooperation on Carrier Operations and Maritime Power Projection*' could be a model for formalising collaboration on space capabilities.[4]

Where can the UK most effectively develop and deploy its own sovereign defence capabilities?

8. Space Domain Awareness. The UK currently has some SDA sensing capability through the Upgraded Early Warning Radar at RAF Fylingdales. It has plans to procure a ground-based missile defence radar, which will significantly enhance its SDA sensing.[5] In addition, the UK could consider investing in space-based sensors, including as part of programmes such as Skynet 6, and new forms of ground sensor. It will be important for the UK to adopt common Command and Control, Battle Management, and Communications (C2BMC) systems with allies, to ensure interoperability for SDA. Fusing SDA with other intelligence sources will be important to enable full attribution and understanding of intent.

9. Position, Navigation and Timing. Part of the rationale for UK involvement in the European Union's Galileo programme was to improve the resilience, accuracy, and performance of space-derived PNT, by developing another signal and allowing triangulation with that received from GPS. As a result of Brexit, the UK does not have full access to Galileo, and has explored options for developing its own GNSS.[6] This requirement has arguably increased, as the UK also no longer participates in the European Geostationary Navigation Overlay Service (EGNOS), which transmits information about the reliability and accuracy of GPS signals (but not its own signal).

10. The UK GNSS Programme originally considered adopting a similar approach to other GNSS systems – namely, a large constellation in MEO. However, it was replaced by SBPP, which is exploring more innovative approaches, including with allies.[7] Based on its experience of designing, developing, and operating PNT satellites, Lockheed Martin

[4] See *Statement of Intent by the Department of Defense of the United States of America and the Ministry of Defence of the United Kingdom of Great Britain and Northern Ireland regarding Enhanced Cooperation on Carrier Operations and Maritime Power Projection*, 5 January 2012, available at http://data.parliament.uk/DepositedPapers/Files/DEP2012-0189/DEP2012-0189.pdf.

[5] S-Band Solid State radar technologies have the inherent sensitivity, range and range resolution, and discrimination capabilities to perform SDA.

[6] On 1 December 2018, the then Prime Minister confirmed the UK would not use Galileo for defence or critical national infrastructure (CNI) and instead pursue options for a British system. See https://www.gov.uk/government/news/uk-to-tell-eu-it-will-no-longer-seek-access-to-secure-aspects-of-galileo.

[7] SBPP is also part of a broader National PNT Strategy.

recommends that the UK develop sovereign satellites for an alternative orbit, which are interoperable with and can complement the GNSS constellations of allies. Satellites in the Geostationary Orbit (GEO) are likely to be most effective, compared to hosted payloads on existing satellite systems or satellites in Low Earth Orbit (LEO):-

a. ‘Hosted payloads’ are modules attached to an existing satellite with communications circuitry, operating independently of the main spacecraft but sharing power supply and transponders. However, combining multiple missions onto a single spacecraft can create technical issues and challenges, when prioritising satellite position to favour different payload missions. This is further complicated if a commercially operated satellite hosts a military payload; and

b. LEO has characteristics that can offer some capability benefits but also make it more vulnerable than other orbits, and pose challenges for persistent coverage (see paragraph 20a). Specifically from a PNT perspective, LEO satellites would not have enough size, weight, and power to accommodate atomic clocks, so could only rebroadcast other GNSS signals to deliver position and timing services. In other words, LEO would be unlikely to provide the UK with a sovereign, independent PNT capability.

11. <u>Intelligence, Surveillance and Reconnaissance (ISR).</u> The UK procures commercial data, which has limitations in supporting operational and tactical decision-making. It largely relies on the ‘National Technical Means’ (NTMs) satellites operated by the U.S. Government for actionable ISR data. The Government could develop its own ISR constellation for defence, and wider purposes (for example, climate security).

12. <u>Communications.</u> The armed forces are increasingly dependent on data and communications. This includes the platforms they operate, which can require data to be passed and processed at the machine-to-machine level – a trend which will grow given the shift towards autonomous systems. The exponential increase in the scale of data, and bandwidth required, makes satellite communications systems more critical for military operations. Alternative options, such as non-space-based communications nodes (e.g. High Altitude Long Endurance (HALE) and High Altitude Pseudo Satellite (HAPS)), will not meet all requirements on their own.

13. The contract for the UK’s current Skynet 5 military satellite communications constellation is due to expire in 2022. The MoD plans to contract with a new service provider when the contract ends (the Skynet 6 ‘Service Delivery Wrap’, SDW), and also recapitalise the constellation (Skynet 6 ‘Enduring Capability’, EC). Skynet 6 EC will need to deliver a step change in capability to support future needs. It will likely require assets operating across multiple orbits to provide the best mix of capability. Resilience will be an essential requirement (see paragraphs 18 to 21).

14. <u>Launch and small satellites.</u> Thinking about the military use of small satellites is still nascent. The U.S. Air Force (USAF) is developing the concept of ‘Operationally Responsive Space’ (ORS), which is the rapid integration, launch and deployment of satellites in LEO in response to emerging operational needs.[8] It is the focus of early concept studies, such as the Blackjack Programme. The Royal Air Force has Project ARTEMIS as a concept demonstrator, but it is unclear if this will progress to a full programme. Potential applications include remote sensing, command and control, tactical communications, tracking Hypersonic Glide Vehicles and other hot bodies, and

[8] ORS is defined as ‘*an affordable capability to promptly, accurately and decisively position and operate national and military assets in and through space and near space. The ORS vision is to provide rapid, tailorable space power focused at the operational and tactical level of war*’.

over-the-horizon situational awareness to address intelligence, surveillance and reconnaissance gaps in Anti-Access Area Denial environments (for example, in support of Carrier Enabled Power Projection). The UKSA's LaunchUK programme could provide the foundation for a sovereign ORS. It could also support delivery of aspects of Skynet 6 and SBPP.

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)?

15. The Centre for the Protection of National Infrastructure (CPNI) designated space as part of the critical national infrastructure in February 2015, recognising that it underpins the delivery, availability, and integrity of essential services, and that disruption would have significant economic and social impacts. For example, a Blackett Review highlighted the dependencies of most critical sectors on satellite-derived PNT information (see Figure 1).[9] Loss of access would have a significant economic impact, with an estimated cost of £5.2 billion for a five-day disruption to GNSS.[10] At the moment, the UK relies on the capabilities provided by other nations for the provision of PNT services, including GPS.

Timing (T)

Commercial & civilian
Telecoms
Wireless communications networks
DAB & DTV synchronisation
Railway sensor timing
Financial transactions
Automated Teller Machines
Sub-atomic particle experiments
UTC time transfer
Earthquake seismology event timing
Power grid synchronisation & maintenance
Military
Radar time synchronisation
Communications synchronisation

Position (P)

Legal & enforcement
Fisheries protection & vessel tracking
Border disputes
Environmental protection
Prisoner tracking
Road tolls
Security & tracking
Asset & fleet tracking
Child protection
Theft prevention
Geo-fencing
Prisoner tagging
Tracking & control of hazardous substances
Transport services
Buses
Taxis & cabs
Car insurance pricing
Leisure & entertainment
Photo geocoding
Social networking
Gaming
Precision agriculture
Tractors & combine harvesters
Smart fertilisation
Marine
Hydrographic surveying
Cable laying
Collision avoidance (Suez, Panama canals)
Marine AIS (automatic identification systems)
GPS buoys
ECDIS (electronic chart display & information systems)
Harbour operations, port automation
Container tracking
Dredging
Trawler monitoring of net snagging
Vessel attitude & heading
Aviation
Emergency Locator Transmitters
Air traffic control
Military
Command & control
Battlespace management
Mine warfare
Target acquisition & tracking
Civil Engineering
Grading (earthworks)
Road & construction control
Deformation monitoring & subsidence
Bridges & dams
Surveying & mapping
Geographic information systems
Map production
Topographic survey & setting out
Scientific applications
Earthquake magnitude estimation
Plate tectonics
Meteorology
Space vehicle orbit determination
Space weather (derived ionosphere activity)
GNSS reflectometry & occultation

Navigation (N)

Leisure & entertainment
Geocaching, cycling, hiking
Fishing using GPS
Gaming
Space vehicles
Launch & orbit injection
Trajectory control
Rendezvous & docking
Space-based augmentation systems
Car & pedestrian navigation
SatNavs, smartphones
Smart watches
Aids for visually impaired
Road lane identification
Air
Take off, landing, taxiing
Flight path control, air space management & collision avoidance
Ground-based augmentation systems
Space-based augmentation systems
Drones
Marine
Harbour operations
Inland waterway & coastal navigation
Dredging
Emergency Services
Police, fire brigade, ambulance
Coastguard, lifeboats
Civilian search & rescue
Military
Precision ordnance
Command & control
Battlespace management
Night operations, reconnaissance
Parachute & equipment drops
Combat search & rescue
Aircraft approach & landing
Drone operations

Emerging Applications

New telecoms: 5G
Smart intersections
Internet of Things
Autonomous vehicles
Vehicle usage & taxation
CubeSats
Next generation air traffic control
Space traffic management
Commercial guaranteed service level
Next generation regional augmentation systems
Phased array satellite transmissions
Geostationary orbit positioning using GNSS side lobes
Signal integrity
Jamming & interference resilient PNT

Figure 1: Sectors that use satellite-derived PNT[11]

16. CPNI's designation also recognised that the loss of space capabilities would have a significant impact on national security, defence, foreign policy, and the functioning of government. Space systems provide strategic (national level) functions, including communications and ISR. They also underpin the operational and tactical deployment and application of military force; over 90 per cent of military capability is dependent on space.[12] Currently, the UK has its own military satellite communications constellation (Skynet 5), and has recently collaborated with industry to evaluate a limited Earth Observation capability. However, for many requirements, the UK is dependent on access to U.S. systems, such as GPS and NTMs.

[9] Government Office for Science, *Satellite-derived Time and Position: A Study of Critical Dependencies*, Blackett Review, January 2018, p. 23, Table 3.1 on p. 34, and Chapter 3.
[10] London Economics, *The economic impact to the UK of a disruption to GNSS*, June 2017.
[11] Government Office for Science, *Satellite-derived Time and Position*, p. 22.
[12] Captain Dave Moody RN, 'MoD Satellite Communications', presentation to Defence Space Conference, 21-22 May 2018.

17. The risks to space system architectures – which include launch, ground stations, satellites, orbital and data links – are diverse. They include natural hazards, space debris, and hostile activity. The critical dependency of the UK and allies on space systems, makes them an increasing target for potential adversaries. The Center for Strategic and International Studies (CSIS) publishes an annual open source threat assessment, including details of types of counterspace capabilities (see Figure 2).[13] Its assessments capture the counterspace efforts of China, Russia, Iran, North Korea, and others. In March 2020, CSIS concluded that '*threats to space systems are growing as more countries and non-state actors acquire counterspace capabilities and, in some cases, employ them in more ways*'.[14] It particularly highlighted the levels of investment being made in electronic counterspace weapons, cyber disruption, non-kinetic physical attacks, and co-orbital anti-satellite (ASAT) weapons.[15] CSIS' most recent assessment highlighted increasing efforts to integrate counterspace weapons into forces and operational plans (including irregular warfare and tactics), the growing risk of dual-use capabilities, and new capability development, including new direct ascent or co-orbital ASAT weapons, laser ASAT systems on additional airborne and ground-based platforms, and new cyber capabilities.[16]

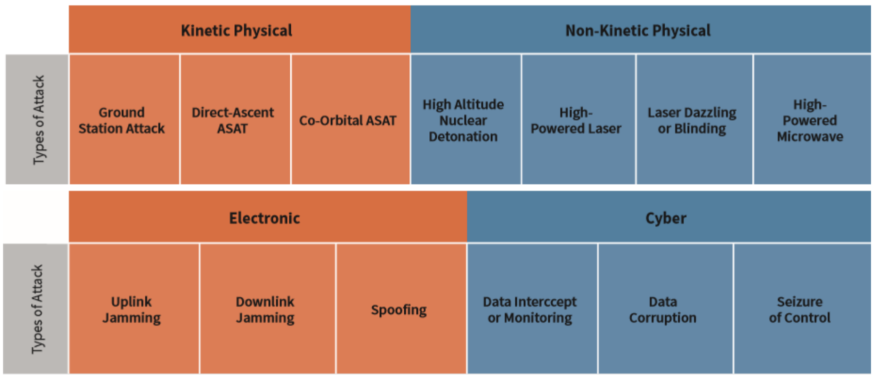

Figure 2: Types of counterspace weapons[17]

18. 'Space resilience' is therefore an increasing concern. A useful analogy is to think of satellites as aircraft carriers, operating outside the protection of their home bases, able to deliver significant military effect, but vulnerable and therefore needing dedicated protection either in proximity or from range.

19. Lockheed Martin has developed a methodology, and related tools, for assessing the mission assurance of space systems and services.[18] Analysis consistently shows that measures need to be put in place to address all types of counterspace capabilities, and across all aspects of a space system's architecture, as a system is only as strong as its weakest link. The following approaches need to be considered:-

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[13] See Todd Harrison *et al.*, *Space Threat Assessment 2021*, Center for Strategic & International Studies, April 2021, pp. 6-7 for more detail. It should also be noted that each orbital regime has advantages and disadvantages in relation to counterspace weapons.
[14] Todd Harrison *et al.*, *Space Threat Assessment 2020*, Center for Strategic & International Studies, March 2020, p. 54.
[15] *Ibid.*
[16] CSIS' most recent assessment noted China's efforts to integrate counterspace weapons into its forces and operational plans (including its irregular warfare and tactics) as well as develop dual-use capabilities, the likelihood of Russia conducting additional testing of new capabilities (including direct ascent or co-orbital ASAT capabilities, additional laser ASAT systems, and cyber capabilities), and the ongoing efforts by Iran and North Korea to use their electronic and cyber counterspace capabilities as well as progress space launch. See Todd Harrison *et al.*, *Space Threat Assessment 2021*, pp. 28-29.
[17] Adapted from CSIS' annual *Space Threat Assessment* reports.
[18] See Marc J. Berkowitz *et al.*, *Space Mission Resilience*, American Institute of Aeronautics and Astronautics (AIAA) SPACE 2013 Conference and Exposition, 10 September 2013, San Diego, CA (https://arc.aiaa.org/doi/pdf/10.2514/6.2013-5407). On tools, Lockheed Martin has developed the 'Global Communications Model', which is a communications analysis tool that quantifies requirements and performance of defence, intelligence and commercial communications, including cross-domain network and system performance.

a. Space protection/defensive operations, i.e. onboard monitoring, and onboard defensive systems and countermeasures against potential adversaries, including active and reactive measures (such as repositioning);

b. Resilience, i.e. features of a system designed to enhance its survivability and resist degradation. This includes factors such as nuclear hardening, forms of propulsion, improvements in anti-jam and low probability of intercept/low probability of detection performance, self-aware and self-healing networks, onboard signal and data processing,[19] and software defined satellites.[20] It also includes diversity in orbits (i.e. multiple assets in different orbits, so-called 'hybrid' or 'layered' architectures), diversity in frequency allocation, diversity in geography ('distributed' architectures), and putting in place cross-domain alternatives and layered defences;

c. Reconstitution, i.e. replenishing lost or diminished functions to an acceptable level; and

d. Recovery, i.e. plans for re-establishing full operational capability and capacity.

20. It should be noted that each orbital regime (LEO, MEO, and GEO) has advantages and disadvantages in relation to coverage, persistence, and vulnerabilities. In developing resilient architectures, the UK needs to bear this in mind:-

a. Satellites operating in LEO deliver reduced latency of transmissions due to the proximity of the terminals to the satellite. This is useful for some applications. LEO satellites are also cheaper to build and launch. However, they move rapidly in relation to the users on the ground, so cannot provide a persistent service or coverage – unless there are many of them in large constellations, which also requires increases in ground infrastructure and often drives the total cost beyond that of a GEO constellation doing the same role. LEO systems are also more vulnerable to certain threats. They are close to the earth, so easy to track and target by ASATs; they are susceptible to nuclear degradation; they have a distributed ground segment that is harder to defend; and the whole orbit can be rendered unusable for an extended period of time by exo-nuclear detonations;

b. GEO satellites are often larger, and can therefore provide greater capability, though at higher cost for build and launch. As the satellites rotate at the same speed as the earth, they provide persistent coverage and service for regions, although do not offer polar coverage. GEO satellites are harder to target by adversaries due to their distance, and they have the power to host defensive aids as well as being nuclear-hardened. This is why the most assured satellites systems are in GEO; and

c. Satellites operating in MEO are essentially a compromise between LEO and GEO satellites.

21. For the UK, the resilience of space assets can be improved through:-

a. Enhancing SDA (see paragraph 8);

[19] This would reduce the vulnerabilities introduced by ground segments, which are often the most vulnerable elements.

[20] Software defined satellites can self-diagnose security issues, implement defences autonomously, and support each other. They also allow satellites to be reprogramed/re-configured for multiple missions. Open standards allow the rapid insertion of new technologies, including from other suppliers.

b. Using specialist modelling tools to assess, and then specify in procurements, the resilience requirements for space systems such as Skynet 6 and SBPP. The MoD should develop a 'Theatre Entry Standard' for all UK systems deployed in space;

c. Developing layered architectures with allies (see paragraph 6); and

d. Utilising the capabilities and services provided through LaunchUK. Rapid launch of small satellites to LEO can provide resilience for space-based assets in other orbits; should an asset go offline, a rapidly launched small satellite could provide cover until that asset is reconstituted or recovered. In 2018, the then Chief of the Air Staff said: *'the prospect of cost-effective constellations of small satellites being built, launched and replaced quickly is hugely exciting, providing us with the resilience that we seek'*.[21]

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

22. The Defence and Security Industrial Strategy (DSIS) recognises that space industrial capability is vital to operational independence. However, the UK's space industrial base currently lacks diversity, particularly for onshore satellite manufacturing, including at prime level. This impacts operational independence, competition, and innovation.

23. As Skynet 6 is currently the only large-scale programme with confirmed funding, the MoD has a unique role in shaping the future of the UK's space sector. It should use the procurement to encourage inward investment to grow and diversify the sector, providing greater choice for upstream capabilities, increased export opportunities, and scaled-up Research & Development.

24. Space is an important area for international capability collaboration. Industry has a role to play in enabling collaborative capability development, and should be included in the delivery of government-to-government arrangements, such as the U.S.-UK Next Generation Capability Cooperation (NGCC) initiative.

Have recent machinery of government changes ensured a joined-up and coherent approach to defence space policy both across Whitehall and within the MoD? What further improvements could be made?

25. Space expertise within the Government is relatively limited. It will be important for the MoD and wider government impartially to access the expertise that exists within industry, as they develop policies, strategies, and requirements.

26. Currently, there are no substantive or formal mechanisms for the Government to engage with industry for this purpose, though the MoD's new Space Directorate has developed good relationships. The U.S. National Space Council has a Users' Advisory Group (NSpC UAG), which could be a model for UK's National Space Council.

13th July 2021

[21] Remarks during the *Defence Space 2018 Conference*, The Air & Space Power Association, 8 Northumberland Avenue, London, 21 – 22 May 2018.