UK SPACE IN-ORBIT SERVICING AND MANUFACTURING PRIORITIES PAPER

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IN-ORBIT SERVICING & MANUFACTURING PRIORITIES

EXECUTIVE SUMMARY

FLAGSHIP NATIONAL INVESTMENTS THAT UNLOCK NEW MARKETS

GOVERNMENT SHOULD EVIDENCE COMMITMENT TO SUSTAINABLE SPACE VIA FLAGSHIP NATIONAL PROGRAMMES

ACTIVE DEBRIS REMOVAL

UK Government continues to fund the national ADR mission for the removal of 2 defunct UK spacecraft

REFUELLING

UK Government extends the UK ADR mission via procurement of refuelling service for the ADR spacecraft to remove additional defunct spacecraft

REPAIR/UPGRADE

UK Government mandates serviceability into other space missions it invests in. For example, a communications satellite lifetime could be extended by maintenance of components or upgrading the payload.

Opportunity for UK to be a Global Leader in Sustainable Space

£2.7 Billion

UK Market Share Opportunity achievable by 2031

BENEFITS

- UK is attractive Global Partner
- Protection of UK's Space Critical National Infrastructure
- Sustainability of Space Environment
- Growth
- Export & Inward Investment
- High Value Employment
- UK owned Strategic Capabilities

VITAL NEW TECHNOLOGY DEVELOPMENT RECOMMENDATIONS

GOVERNMENT SHOULD LEAD PIONEERING TECHNOLOGICAL INNOVATIONS THROUGH FUNDING CRITICAL TECHNOLOGY DE-RISKING

- DESIGN FOR SERVICING
- CLOSED LOOP AUTONOMY FOR SERVICING OPERATIONS
- REFUELLING
- ENHANCED SSA & STM
- NATIONAL IOSM TEST FACILITIES

ENABLERS OF FAVOURABLE BUSINESS ENVIRONMENT IN UK

GOVERNMENT SHOULD CREATE A FAVOURABLE BUSINESS ENVIRONMENT TO ATTRACT AND RETAIN COMPANIES

- CLEAR VISION
- INTERNATIONAL PARTNERSHIPS
- SKILLS
- ACCESS TO FINANCE
- REGULATION, LICENCING, STANDARDS AND AGREEMENTS

1 The Big Picture

The space economy is changing at a rapid pace. The Low Earth Orbit (LEO) environment is congested and unstable with a high risk of collisions between objects with resultant impact on societal services and applications dependent on space. International pressure to establish sustainable behaviour norms is rising. Changes in the launch industry has seen cost of launch, or access to space, fall rapidly. There is increasing demand for high performance materials such as defect free semi-conductors that can be manufactured on orbit. Large space structures, assembled on orbit, will be made feasible by the significantly reduced launch costs and much larger launchers coming on line such as Starship.

The demand for services provided from space is increasing for both commercial and scientific applications, such as direct to mobile communications, robotic spacecraft, space based energy generation and next generation scientific telescopes. Return to the Moon initiatives are in development across space agencies and commercial companies globally. These factors are driving the need for next generation space systems that disrupt the status quo and open up significant new markets.

Satellites of the *near*-future will…

- Track, monitor and inspect each other
- Supply and upgrade each other
- Assemble and maintain each other
- Protect, repair and clean-up after each other

In-Orbit Service & Manufacture (IOSM) is the new logistics sector of the 21st century space economy. It will **provide the foundations for sustainable space infrastructures** that underpin the developing on-orbit industrial revolution.

Being at the forefront of the new In-Orbit Service & Manufacture (IOSM) generation is imperative. It will enable and expand the sustainable and beneficial use of the space environment – and it will strategically defend our critical national infrastructure – both in and from space. The UK will not be the only nation seeking these capabilities and they can be put to other uses – potentially threatening, undermining and subverting the UK's use of space if not adequately prepared for.

The UK is one of a small number of nations that are well-placed to lead this emerging new market. We are recognised leaders in advanced systems R&D, innovative finance, international collaboration and entrepreneurial creativity. We can capitalise on our strengths to work globally, and to shaping and leading the in-orbit economy of the 21st century.

The benefits to the UK are well-aligned to the government's priorities[i]:

- Sustainability and Net Zero
- Promoting the values of Global Britain
- Levelling up via Skills development and creation of highly skilled jobs
- Exportable services and technologies
- Protect and defend national interests in and through space
- Growing the UK as a science and technology superpower

IOSM will underpin the future of space:

- **An active in-orbit economy** – providing logistics for everything we currently do in space, and more
- **Sustainable constellations** – ensuring that space junk is cleaned up, not left for the next generation
- **Super space sensors and observatories** – with capabilities beyond anything seen to date for observing our planet and the universe
- **Micro-gravity factories** – creating things that are unmakeable on Earth
- **Space-based Solar Power systems** – providing clean predictable energy

2 The In-Orbit Servicing Opportunity

2.1 Active Debris Removal (ADR) protects our access to space

The UK is leading Europe in the development of Active Debris Removal (ADR) missions. ADR is a critical capability to address the rapidly growing threat of debris and potential collisions in orbit which could disable vital services provided from space to society. These include past UK-led missions such as RemoveDebris, ELSA-d and future missions such as ELSA-M, and international missions with UK involvement such as ClearSpace-1 (ADRIOS-1) and the Astroscale ADRAS-J mission. Presently the UK is at a Phase B development level for "UK ADR", a refuellable mission to remove and de-orbit two defunct UK-owned and registered spacecraft.

ADR missions address key elements that underpin the future IOSM sector:

- **Technology** - Develop technology and flight heritage in Rendezvous and Proximity Operations (RPO) – a key enabling technology.
- **Licensing and Liabilities** - Progress global leadership in complex space mission regulation & licensing, and leadership from insurance industries in London.
- **Delivery Capability** - Drive growth of both mission production (manufacturing) and operations.
- **Sustainability** - Position the UK as a global leader in space sustainability.

2.2 Life Extension and Refuelling will change the way 'space' is done

Whenever a satellite launches into space, propellant typically makes up half of the launch mass. It limits the mission in both endurance and capability. Propellant running out is often the first reason satellites are retired.

In-Orbit Life Extension and Refuelling changes that. It allows:

- To extend mission lifetimes.
- To increase mobility and manoeuvrability.
- To use more mass for the payload – either in Earth orbit or in deep space exploration
- Or to reduce launch mass and fill up in space.

These advantages translate into increased revenues, reduced operating costs, new capabilities and greater flexibility.

Life Extension and refuelling are exportable services for the future global space sector.

The NSR's In-Orbit Servicing Markets, 4th Edition (IoSM4) report forecasts $6.2 billion in cumulative revenues from in-orbit services by 2030, dominated by GEO life extension services making up to 72% of total revenues.

The UK space industry is actively participating in the ADRIOS-2 mission which will lead up the first European-led GEO life extension mission and enable the development of one or more servicers which will be the main stepping-stone towards the more advanced IOSM services such as refuelling, repairing, assembling and manufacturing.

Refuelling infrastructure and services can be used to support sustainment, and also satellite End-of-Life (EOL) de-orbiting, including ADR. The ability to refuel enables unlimited manoeuvring and repositioning. Refuelling is, therefore, a key capability that underpins other space markets, allowing missions to go much farther, expanding the envelope of possible commercial use cases for spacecraft, and significantly improves the business case for other IOSM activities such as EOL, ADR.

The spacecraft being developed under the UK ADR mission will be refuellable and will put UK based companies in the driving seat for IOSM.

2.3 Transportation & Logistics Infrastructure

Tens of thousands of new satellites are planned to be launched in the next decade. These satellite constellations will deliver innovative and disruptive services to almost all the traditional industrial sectors on our planet. Just as terrestrial industry is supported by road, rail, air and water transport infrastructure such as ports, service stations and highways, the on-orbit economy will be supported by similar on orbit transportation and logistics infrastructure – effectively creating a circular space economy. Launch is one element of the puzzle and should be supported by on-orbit depos, hubs and inter-orbital transportation to make the on-orbit economy more efficient and sustainable.

The lack of logistics infrastructure in space is a key opportunity that the UK is committed to pursue. Additionally, any foray into large scale infrastructure in space will need to be supported by a strong space transportation industry, effectively building the 'roads' that will enable the growth of the new space economy.

The UK's commitment to building this capability is reflected in its participation to "Boost! - ESA's Commercial Space Transportation Services and Support Programme", which should be maintained to consolidate UK's access to these services. This will need to include international partnerships to make the most of the available European heritage in space transportation.

2.4 Repair, Assembly & Manufacturing enables a circular space economy

In-Space Assembly and Manufacturing has two broad applications: Manufacturing and Assembly for use in space, and manufacturing for use on earth. When Life Extension and Refuelling is available, satellite lifetimes will be limited by other factors such as degradation of solar panels. These life limiting items will need to be maintained or upgraded in order to meaningfully extend the life of the satellite – thus further opening up the market opportunity for refuelling as well.

Satellites repairable & reusable by design

Design for on - orbit assembly and maintenance enables repairable and upgradable satellites. Currently, satellites are single use by design and have to work perfectly first time, often adding years and millions to the project cost, as they cannot be touched after launch. Soon satellites will be able to be maintained, repaired and upgraded on orbit, rather than launching an entirely new satellite to replace it. This will increase efficiencies, extend lifetimes and allow capability upgrades. It sets the foundations for large scale on orbit infrastructures and sustainable lifecycle management such as re-use and recycling.

Building Large Space Structures by assembly on orbit will enable new, large-scale infrastructure such as space-based solar power, commercial space stations and the next generation of science and exploration such as interplanetary missions and the successor of JWST. These missions were previously impossible to fit on a launcher or were reliant on highly complex, and fundamentally limited deployment mechanisms.

Large structures no longer constrained by launch

New Materials for use on Earth

Manufacturing for Earth: Space is a unique environment. It can be used to create materials that are environmentally dangerous, difficult or impossible to manufacture on Earth, successfully demonstrated in experiments from Skylab to the ISS over the last 50 years. Using the natural vacuum and microgravity environment, it is possible to create materials and structures for use in a variety of applications, including defect-free semi-conductors, pharmaceuticals and super-alloys. Scaling up from research to manufacturing levels requires new technologies to automate fabrication processes on a spacecraft and to reduce the cost of return from space, which has not yet seen falls in price comparable to launch cost trends.

3 The Ask of Government

Moving forward, UK Government should continue to:

1. **Evidence commitment to sustainable space infrastructure** via flagship national programmes to unlock new markets.

2. **Lead pioneering technological innovations** - Through funding large scale demonstrations, developing national facilities (for and in space) and underpinning critical technology enablers for future IOSM services.

3. Create a favourable business environment to attract and retain commercial in-orbit servicing companies to do business in the UK.

UK IOSM capabilities will drive export, attract inward investment, create strategic national capabilities, and secure global influence. **This is a new sector and significant new market estimated to be worth $14.3bn**[ii] globally by 2031.

3.1 Flagship National Investments to Unlock New Markets

Government should continue to **invest in servicing** missions to **evidence commitment to sustainable space infrastructure**. By procuring services and acting as a first customer, this will create momentum needed to move towards sustainable space infrastructure instead of disposable satellite missions. Like investing in charging infrastructure to make buying an electric car attractive, investing in servicing such as refuelling will unlock sustainable space.

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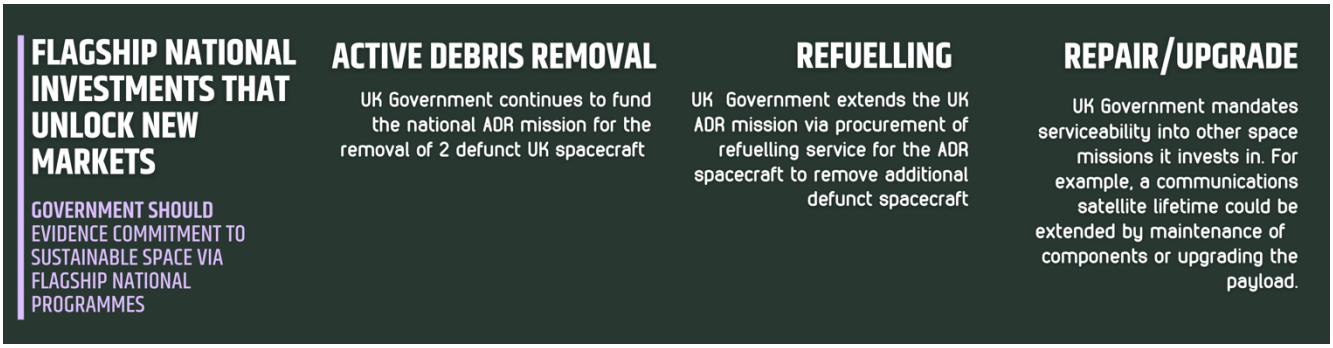
UK Government should

- **Continue the national ADR mission** to remove at least 2 UK owned spacecraft
- **Extend** the ADR program **via a refuelling** service
- **Mandate design for servicing and sustainability** in other government space investments, e.g repair/upgrade of Earth Observation or communications satellites



Without flagship national investments, the UK risks being left behind. UK ADR is the only mission where UK companies are leading. Other international missions the UK is part of are heavily influenced by countries willing to take larger risks, such as ESA's ADRIOS-2 being dominated by large contributions from Luxembourg and Italy. In addition, Italy recently awarded $265M for a national in-orbit servicing demo in 2026[iii]. The UK Government needs to put a certain amount of funding behind to evidence commitment to the ambition as stated in the National Space Strategy, but also harnessing national strengths in business and innovation.

For details of the proposed investments, see Appendix A.

Action 1 – Continuation of the UK ADR Mission

UKSA SHOULD FULLY FUND THE UK ADR MISSION AND COMMIT TO ITS FOLLOW-ON REFUELLING MISSION.

The next steps need to encompass funding the UK ADR mission to remove two or more objects, ensuring a follow-on refuelling mission is conducted and advances our space sustainability by allowing for the removal of additional defunct objects using the same UK ADR removal spacecraft.

Why?

- The National Space Strategy commits to "lead the global effort to make space more sustainable" – a national ADR mission and resultant capability is key to realise this ambition
- The UK has an opportunity to capture a significant market in ADR and satellite End-of-Life (EoL) servicing that ADR capability will help to enable
- The UKSA is transforming into a delivery agency and national missions like UK ADR are key to help develop the necessary space mission delivery capability inside Government

Action 2 – Define refuelling mission extension and design for servicing

UKSA SHOULD INITIATE SYSTEM STUDIES INTO REFUELLING MISSION EXTENSION.

It is recommended that a refuelling study is initiated within 2023 to define market driven mission scenarios and trade-off system architectures for refuelling servicers.

UKSA SHOULD INITIATE STUDIES FOR DESIGN FOR ASSEMBLY, MAINTENANCE & UPGRADE AND EXPLORE HOW AND WHERE SERVICEABILITY CAN BE MANDATED INTO OTHER GOVERNMENT FUNDED SPACE MISSIONS.

Design requirements and best practice guidelines to design for assembly, maintenance & upgrade should be established in parallel with advancing robotic maintenance technologies, so they can be implemented in new spacecraft design by 2025. Government should explore how and where design for servicing might be appropriate to be mandated into future space investments (such as ESA's Zero Debris Policy).

For both of these studies, interoperability between different solutions needs to be a priority for an open market place, therefore modularity and standardisation should be considered.

Why?

- Refuelling engineering requirements needs to be understood as it impacts the ADR mission spacecraft design (and can provide significant cost savings in part selection)
- Government investment in space needs to demonstrate sustainable best practices, else risking loss of access to space
- Mission studies unblock critical technology developments (such as GNC) that are heavily driven by the system design
- Refuelling is not enough alone to continually extend the lifetime, as component degradation will cause failures and reduced performance. The risk is that refuelled satellites fail catastrophically and then rely on emergency ADR rather than planned maintenance and eventually disposal. The ability to upgrade hardware based on technology improvements or to increase performance rather than launching an entirely new spacecraft increases longevity and flexibility while reducing CAPEX.
- Spacecraft cannot be assembled, maintained or upgraded commercially unless they are designed for this in the first place. The sooner the design principles can be established and validated, the sooner they will be adopted, this is the key to fully unlocking the servicing market and increasing adoption.

3.2 De-Risk Critical Technology Enablers that underpin the market

Government should focus technology grant funding into areas which need de-risking in order to prepare for the next stages after the national ADR mission – focussing on enabling refuelling and repair service development. Investment in these cutting edge developments allows capability to be built within the UK, not only allowing UK companies to gain first mover advantage, but also to be able to use in order to protect and sustain critical national space infrastructures.

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This group have identified 5 short-term priorities that should be de-risked within the 2023-24 timeframe, that leads to a ground-based demonstration of inter-operable capability:

- **Closed-Loop Autonomy for Servicing Operations** (GNC+Propulsion, Vision based Navigation & Sensing, on-board processing, autonomous approach for refuelling)
- **Design for Servicing** (Robotic Assembly and maintenance, spacecraft design for serviceability)
- **Refuelling** (Commercial/Open Refuelling Interface, Mechatronics & Fluidic Transfer System)
- **National IOSM Test Facilities** (Digital and Simulation Environment, Physical Test Facilities e.g at Westcott, On-Orbit validation facilities)
- **Space Traffic Management (STM) and Enhanced Space Situational Awareness (SSA)** (Support this adjacent sector for IOSM needs)

Capabilities identified here are critical enablers of establishing refuelling and servicing technology expertise. These areas should be funded and rapidly prototyped/tested, with the goal to bring together individual demonstrations in one or several interoperability tests at the IOSM test facilities. This is an ambitious goal and will allow important lessons to be learnt for future developments at an early stage, while encouraging open standards and de-risking mission critical processes early on.

Proposals and examples within each of the technology areas are expanded on within Appendix B.

Action 3 – De-Risk Critical Technology Enablers

UKSA SHOULD CO-FUND EARLY STAGE TRL RAISING ACTIVITIES IN THE TOP 3 CATEGORIES WITHIN 2023-24 TIMEFRAME.

De-risking Refuelling, Design for Servicing, Closed-Loop Autonomy for Servicing Operations technology can be done to encourage rapid development and prototyping of these enabling capabilities.

While this report has managed to gather a small snapshot of UK capabilities and short term wins it is also recommended that a more detailed technical study is initiated to assess in depth the critical technical capabilities and plan for beyond 2024. UK Government should establish a multi-year technical capability building strategy, including implementation and monitoring.

Why?

- Enables UK to become Sustainability Technology Superpower with world leading capabilities and innovation
- De-Risks and rapidly develops the technology needed for the ADR follow on missions, so that refuelling and maintenance is ready on time
- UK will make much bigger strides by having focussed and ambitious objectives with clear export potential
- Independent technical assessment and evidence gathering allows for targeted capability building based on market drivers, alongside early stage interoperability tests allows creation of a competitive marketplace and prevent monopolies
- To provide needs and drivers that support the business environment to be developed effectively – e.g requirements on Licencing, Standards, Insurance and Skills development activities

Action 4 – IOSM Development & Test Facilities

USKA SHOULD PROVIDE FUNDING TO ESTABLISH WORLD-LEADING IOSM DEVELOPMENT & TEST FACILITIES IN THE UK.

Doing so will make the UK the destination of choice for innovation, where start-ups and primes can collaborate and de-risk their business plans (‘fail fast and cheap’, then succeed). Hardware-in-the-loop, robotics and RCPO physical tests facilities, RCPO software development & test facilities, as well as simulation centres and prototyping support are all key facilities required.

Why?

- Attract companies to the UK for access to key skills and unique facilities
- Facility locations can support job creation and levelling up
- Reduces barriers for start-ups by reducing cost and impact of the learning curve on the ground before major investments in-orbit
- Support companies to secure investment by demonstrating derisking activities at lower cost
- Provides simulation and training facilities to operators prior to mission operations
- Provide the UK with strategic advantage in terms of regulatory reform

See Appendix D for further details.

3.3 Create a favourable business environment for IOSM in the UK

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UK government must create a favourable environment in order to achieve any of the possibilities outlined in this document. This can be achieved by government via:

a) **Presenting a clear vision for UK as global leaders** in in-orbit servicing and space sustainability.

b) **Develop best practice & international leadership in modern space regulation** - in sustainability, regulation, standardisation and insurance to promote sustainable growth of the IOSM market without stifling progress.

c) **Develop international partnerships** by pursuing bi-/multi-lateral missions in IOSM to foster international partnerships and demonstrate feasibility across jurisdictions, in-line with the UN Outer Space Agreement.

d) **Facilitating access to private financing** for innovative commercial in-orbit servicing business, in particular to allow businesses to scale-up in the UK.

e) **Build the skilled workforce** of the future by investing in skills foresighting and development programmes that allow the workforce to scale at pace with the market growth.

The UK must **prioritise these key areas** to attract and retain companies to establish in the UK. These are the fundamental enablers and actions that must be taken by government to facilitate IOSM. These areas are of fundamental importance to any activity and are critical to establishing the UK as a serious global player.

The following actions are recommended to support the development of a favourable business environment in the short term. More details about each of the possibilities can be found in Appendix C - Vital Enablers of favourable business environment.

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Action 5 – Bilateral Mission

UKSA SHOULD SEEK TO EXTEND AN EXISTING BI/MULTI-LATERAL MISSION TO BE ENABLED FOR IOSM WITH INTERNATIONAL PARTNERS.

Such a mission is a way to break down barriers between regulatory regimes and aligning licensing practices and liability handling between nations.

Why?

- Explore and align regulatory and licensing practices across international lines
- Demonstrate the technical, operational and political elements of a multi-lateral IOSM mission
- Build economic ties for growth
- Explore dual-use activities, for example around CPO, inc. 'red flag' exercises

Action 6 – ESA REACH Objectives

UKSA SHOULD LOBBY WITHIN ESA FOR "REACH" OBJECTIVES TO BE BUILT INTO FUTURE ESA MISSIONS.

UKSA can influence ESA's wider programmes to both benefit from, and bring about, the future of IOSM. Missions with Reach Objectives can then benefit from and stimulate IOSM logistics services – e.g. for life extension and/or in-orbit upgrade. ESA have developed a Zero Debris strategy but does this go far enough towards in-orbit servicing?

Why?

- Gain IOSM-enabled advantages for core ESA missions, increasing return on investment and re-use of assets
- Seed a sustained demand for IOSM investment and services, supporting finance and investment
- Ease critical pressure on ESA mission mass budgets by taking advantage of post-launch IOSM corrective activities
- Normalise ESA-member state regulatory and licensing practice for CPO

Action 7 – IOSM "X-Prize"

UKSA CAN HELP CREATE AN 'X-PRIZE FOR IOSM'

Such a prize will stimulate a much larger private investment in pursuit of the prize.

Why?

- Modest government investment (insurance policy) enables a much larger prize fund, which stimulates even larger private investment into the UK, in pursuit of the prize
- Engages and takes advantage of UK financial markets
- Attracts risk-taking companies to establish offices in the UK
- Drives technological development

Action 8 – Skills Development

UKSA TO USE IOSM AS A "BEST IN CLASS" EXAMPLE OF HOW TO DEVELOP SKILLS.

A multi-approach action to developing skills:

- Use IOSM as a case study to pilot a space sector workforce foresighting skills activity
- Use IOSM as an inspirational example for the general public and young people
- Develop training activities, in the short term by investing in training and bootcamps for cross-skilling from other sectors, and in the longer term, programmes that directly address the skills gaps identified in the foresighting process
- Establish tools, courses, and training opportunities to upskill and expand the IOSM workforce in the UK

Why?

- To better support the growing sector with SQEP
- Reduced overall costs / greater effectiveness for businesses through higher skills levels

Action 9 – Technology Grant Funding for Skills

TECHNOLOGY GRANT FUNDING SHOULD ALSO FUND PEOPLE.

Encourage industry buy-in by mandating that 5% of every TRL raising grant fund should be spent on skills development initiatives: e.g. salary of interns, apprenticeships, graduates or career changers in order to develop the workforce at the same pace as the technology and give more opportunities to new entrants to the sector.

Why?

- Creates a scheme where skills development is embedded into company culture
- Better support the growing sector with SQEP
- Reduced overall costs / greater effectiveness for businesses through higher skills levels

Action 10 – Space-Based Testbed

Establish a space-based testbed for RCPO technology validation, operational skills development, and regulatory evolution. The testbed would enable repeat trials and promote sector wide skills development beyond single missions where only select companies benefit.

UKSA should create a space cluster that acts as the in-orbit focal point for regulatory evolution and large scale skills development in RCPO, both within the UK and internationally. The mission is to launch a constellation of assets including sensors, RCPO validation hardware, and a fuel depot/refuelling servicer that would serve as the anchor elements of the in-orbit IOSM testbed.

Why?

- Permits RCPO and logistics to be practiced in a safe and controllable way
- Ensures sector wide access beyond single missions where only select companies benefit
- The operating model serves to reduce space junk and natively re-uses hardware for multiple demonstrations including ADR and refuelling.
- Serves as a testbed for regulatory evolution, enabling a paradigm shift towards a ‘rules of the road’ approach to licensing
- Supports international collaboration development for partner nations

The central element of an in-orbit testbed is achievable with a modest budget comparable to other national missions and can operate on a commercial model.

4 Benefits

The UK government supporting the IOSM sector in the above asks will deliver benefits not only to the sector, but to the nation.

- **Market Leaders** in sustainable space infrastructure with an opportunity of capturing a market share of £2.7bn[iv] by 2031
- **Protection** of the UK's space CNI
- **Growth** of the UK's economy, underpinned by space capabilities
- **Sustainability** of the space environment
- **Export & Inward Investment** in an area where UK has many strengths, selling the picks and shovels to benefit from the international space "gold rush"
- **Global Partnering**, making the UK a high-value partner for other nations ("science and technology superpower")
- **High Value Employment** attracting international talent and young professionals into STEM
- **UK Strategic Capabilities** supporting the UK's freedom of action to pursue and protect its own interests (e.g. dual use applications, remote sensing, big science, space power)

In recent years, interest in pursuing an In-Orbit Servicing and Manufacturing (IOSM) based Space economy has gained substantial traction and is on track towards reaching critical mass. As Space has been recognised as a vital component upon which the UK's Critical National Infrastructure is based, the challenges associated with Space sustainability, and in particular, the mitigation of existing Space debris objects, is of critical importance to maintaining national resilience and security. With this need, the UK is perfectly positioned, and with the technical capability, to take a leading role in addressing Space sustainability, leading to the maturation of a wider UK-based IOSM market with longer-term opportunities. It is well established that the demonstration of capability for Rendezvous and Proximity Operations (RPO) and Active Debris Removal (ADR) will unlock bigger, more strategic, and lucrative In-Orbit Assembly, Servicing, Manufacturing opportunities. This leads to the enabling of initiatives such as: Space Based Solar Power (SBSP), Robotic Space Stations and Orbital Depos, all as the In-orbit economy matures.

The benefits to prioritise from UK industry should be in development of the fundamental capabilities to cement the UK as an IOSM centre of excellence given its end-to-end supply chain competence from spacecraft hardware and software design and development, assembly integration and test through to verification and validation of applications, mission concept development and launch. The market size will be at least £1bn[v] for the UK in 2030 and being part of this market can unlock tens of billions more in future via the expansion of sustainable space infrastructure. UK industry must be prepared to capture the opportunities that this nascent market offers. By supporting the development of IOSM related technologies, adjacent and complimentary capabilities will also be advanced, further enhancing the competencies of the UK Space supply chain.

5 Summary of Actions

Action #	Action	Do What?	Why?
1	Continuation of the UK ADR Mission	UKSA should fully fund the UK ADR mission and ensure its follow-on refuelling mission	• The National Space Strategy commits to "lead the global effort to make space more sustainable" – a national ADR mission and resultant capability is key to realise this ambition • The UK has an opportunity to capture a significant market in ADR and satellite End-of-Life (EoL) servicing that ADR capability will enable • The UKSA is transforming into a delivery agency and national missions like UK ADR are key to help developed the necessary space mission delivery capability in Government
2	Define refuelling mission extension and design for servicing	UKSA should initiate system studies into refuelling mission extension. UKSA should initiate studies for design for assembly, maintenance & upgrade and explore how and where serviceability can be mandated into other government funded space missions	• Refuelling engineering requirements needs to be understood as it impacts the ADR mission spacecraft design (and can provide significant cost savings in part selection) • Government investment in space needs to demonstrate sustainable best practices, else risking loss of access to space • Mission studies unblock critical technology developments (such as GNC) that are heavily driven by the system design • Refuelling is not enough alone to continually extend the lifetime, as component degradation will cause failures and reduced performance. The risk is that refuelled satellites fail catastrophically and then rely on emergency ADR rather than planned maintenance and eventually disposal. The ability to upgrade hardware based on technology improvements or to increase performance rather than launching an entirely new spacecraft increases longevity and flexibility while reducing CAPEX. • Spacecraft cannot be assembled, maintained or upgraded commercially unless they are designed for this in the first place. The sooner the design principles can be established and validated, the sooner they will be adopted, this is the key to fully unlocking the servicing market and increasing adoption.

Action #	Action	Do What?	Why?
3	De-Risk Critical Technology Enablers	UKSA should co-fund early stage TRL raising activities in the top 3 categories within 2023-24 timeframe: Refuelling, Design for Servicing, Closed-Loop Autonomy for Servicing Operations	• Enables UK to become Sustainability Technology Superpower with world leading capabilities and innovation • De-Risks and rapidly develops the technology needed for the ADR follow on missions, so that refuelling and maintenance is ready on time • UK will make much bigger strides by having focussed and ambitious objectives with clear export potential • Independent technical assessment and evidence gathering allows for targeted capability building based on market drivers, alongside early stage interoperability tests allows creation of a competitive marketplace and prevent monopolies • To provide needs and drivers that support the business environment to be developed effectively – e.g requirements on Licencing, Standards, Insurance and Skills development activities
4	IOSM Development & Test Facilities	USKA should provide funding to establish world-leading IOSM development & test facilities in the UK	• Attract companies to the UK for access to key skills and unique facilities • Facility locations can support job creation and levelling up • Reduces barriers for start-ups by reducing cost and impact of the learning curve on the ground before major investments in-orbit • Support companies to secure investment by demonstrating derisking activities at lower cost • Provides simulation and training facilities to operators prior to mission operations • Provide the UK with strategic advantage in terms of regulatory reform
5	Bilateral Mission	UKSA should seek to conduct a bi-/multi-lateral IOSM mission with international partners	• Explore and align regulatory and licensing practices across international lines • Demonstrate the technical, operational and political elements of a multi-lateral IOSM mission • Build economic ties for growth • Explore dual-use activities, for example around CPO, inc. ‘red flag’ exercises

Action #	Action	Do What?	Why?
6	ESA REACH Objectives	UKSA should lobby within ESA for "Reach" objectives to be built into future ESA missions.	• Gain IOSM-enabled advantages for core ESA missions, increasing return on investment and re-use of assets • Seed a sustained demand for IOSM investment and services, supporting finance and investment • Ease critical pressure on ESA mission mass budgets by taking advantage of post-launch IOSM corrective activities • Normalise ESA-member state regulatory and licensing practice for CPO
7	IOSM "X-Prize"	UKSA can help create an 'X-Prize for IOSM'	• Modest government investment (insurance policy) enables a much larger prize fund, which stimulates even larger private investment into the UK, in pursuit of the prize • Engages and takes advantage of UK financial markets • Attracts companies to establish offices in the UK • Drives technological development
8	Skills Development	UKSA to use IOSM as a "best in class" example of how to develop skills.	• To better support the growing sector with SQEP • Reduced overall costs / greater effectiveness for businesses through higher skills levels
9	Technology Grant Funding for Skills	Technology Grant Funding should also fund people.	• Creates a scheme where skills development is embedded into company culture • Better support the growing sector with SQEP • Reduced overall costs / greater effectiveness for businesses through higher skills levels
10	Space-Based Testbed		• Permits RCPO and logistics to be practiced in a safe and controllable way • Ensures sector wide access beyond single missions where only select companies benefit • The operating model serves to reduce space junk and natively re-uses hardware for multiple demonstrations including ADR and refuelling. • Serves as a testbed for regulatory evolution, enabling a paradigm shift towards a 'rules of the road' approach to licensing • Supports international collaboration development for partner nations

6 Appendix A – Flagship National Investments that Unlock New Markets

The following are the proposed flagship national missions:

UK ADR Mission

Two parallel consortia are currently working on mission developments towards a novel UK national debris removal mission, aiming to remove two existing failed UK-owned assets from space. Many of these assets are smaller (tens to a hundred kilogram) satellites which were launched in the 1980s and have now failed in high orbits that would take a very long time to de-orbit from. The servicer being produced in this mission is designed to be refuellable.

It is proposed that UKSA continues to fund this mission due to the following:

- The mission demonstrates the UK's commitment to sustainable space in an era where other governments and agencies (including Japan/JAXA, ESA and US) are embarking on similar sustainability drives.
- The mission pushes forward the National Space Strategy commitments to "lead the global effort to make space more sustainable".
- The mission from a technology perspective unlocks the capability of unprepared small asset rendezvous and capture, which differentiates it from services that are designed for prepared clients.
- The rendezvous and proximity operations (RPO) capabilities developed are transferrable to other domains.
- The mission will highlight the strong UK supply chain (international non-dependence), UK manufacturing, UK operations and UK leadership in the entire IOS domain.

Refuelling Extension Mission

The servicer from the UK ADR mission is designed to be refuellable. One key mission recommended for development is a UK mission to mature refuelling technologies. A servicer could be developed which would rendezvous and dock with the servicer from the UK ADR mission (now the client).

It is proposed that UKSA continues to fund this mission due to the following:

- The mission helps mature refuelling technology, a key technology in future sustainable space operations. Just as cars are not single use and are refuellable (or rechargeable), future satellites can be designed for refuelling operations.
- The mission has minimised cost due to already having a client in orbit ready to be refuelled (which could potentially extend the first mission). This means a separate refuellable client does not need to be launched into space.

Repair/Upgrade Satellite Mission Extension

Refuelling is limited in market size without also being able to repair, maintain and upgrade satellite subsystems and components, as these also limit the life of satellites. It is recommended that the UK begins to mandate design for servicing into other programs it invests in – for example, via a communications satellite or earth observation mission. This could be done with an international partnership, via ESA or bi-laterals, to achieve maximum market access for UK PLC.

It its proposed that UKSA funds this due to the following

- Demonstrates that the UK is committed to Space Sustainability and can lead by example, by looking to the future of how to prevent debris being created in the first place.
- Creates initial incentive to encourage satellite manufacturers to change the way they design, unlocking future on-orbit servicing supply chains and reducing waste.

- If done internationally this mission will help develop the regulation, licencing and agreements needed for UK PLC to be able to export services in the future.
- Demonstrates key technology maturation in design for servicing, including robotics and automation.
- Costs are kept low, design for servicing is a small fraction of the cost of developing an entire mission

Mission Developments

It is proposed some type of initial low-phase mission development is funded for the refuelling mission for at least 2 consortia, which could progress down to 1 in later stages. A similar approach should be taken for the repair/upgrade mission extension, where an additional feasibility study should also look into the impacts of imposing design for servicing in future space investments.

It is key that all missions proposed here are designed in a lean, commercial and cost-effective manner. This is a key differentiator from other institutional missions which are very expensive and large scale developments, mostly good for developing technology, but unusable for future commercial servicing.

7 Appendix B - Vital Technology Development Recommendations

This section describes the highest priority technology de-risking activities that are fundamental enablers of IOSM capabilities and have applications to all of the market segments.

There are 5 main categories of development that have been prioritised:

- **Refuelling** (Commercial Refuelling Interface, Mechatronics & Fluidic Transfer System)
- **Design for Servicing** (Robotic Assembly and Maintenance, spacecraft design for serviceability)
- **Closed-Loop Autonomy for Servicing Operations** (GNC+Propulsion, Vision based Navigation & Sensing, on-board processing, autonomous approach for refuelling)
- **National IOSM Test Facilities** (Digital and Simulation Environment, Physical Test Facilities e.g at Westcott, On-Orbit validation facilities)
- **Space Traffic Management and Enhanced Space Situational Awareness** (Support this adjacent sector for IOSM needs)

The 5 developments enable a **ground-based interoperability demonstration** to happen that is stronger than the sum of its parts, to show an end-to-end test. The innovation that the demo addresses is combining the technology together at system level and determining the inter-operability of systems which is fundamental to IOSM.

While stronger as a whole, the demonstration can happen with any combination of the technology development steps in order to de-couple the developments with the exception of the IOSM ground facility development which is fundamental to any demonstration.

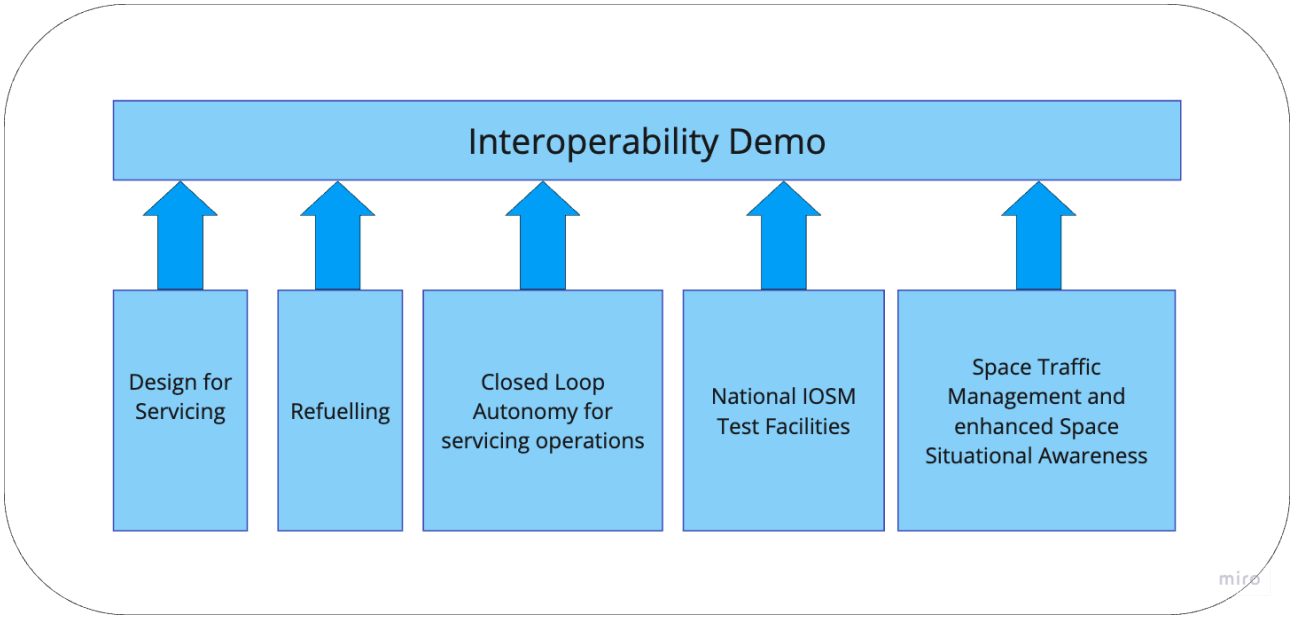


Figure 1 - Technology De-Risking Steps leading to Ground Based Demo

The UKspace IOSM WG has identified these as near-term shared priorities that underpin future success. A further study is recommended to address longer-term priorities.

8 Appendix C - Vital Enablers of favourable business environment

8.1 Clear Vision

The UK must establish and communicate a clear vision towards sustainable space infrastructure and in-orbit servicing and manufacturing. While some initial steps and context is presented here, this report focusses primarily on technology development steps and short term investments prior to 2025 that can be undertaken immediately by UKSA. It is recommended that a further study is commissioned by D-SIT in order to develop the ideas further and envisage scenarios for the future of in-orbit servicing. UK should prioritise sustainability in space and assess how in-orbit servicing will change other areas of space. A “Kennedy Moment” should be outlined and public engagement programmes established.

8.2 Regulation, Licencing, Standards and Agreements

The development of national and international space regulations is a key enabler to the growth of the IOSM sector. The UK can take a leadership role for space sustainability and use that as a platform for wider IOSM growth. Without regulations, there will be little incentive for operators to follow safe and sustainable space practices.

The UK has a world-leading and highly regarded policy and regulatory capability – the UK has already licensing innovative IOS missions such as RemoveDebris and ELSA-d, already providing global leadership in this domain.

A number of recommendations can be made to UK government:

1. **Global ESG Standard** – Support the development of the Earth and Environment Sustainability Initiative (ESSI) as a global ESG standard that can be brought into IOS licensing frameworks.
2. **Future Licensing Recommendations** – For IOSM to be successful and for an in-orbit economy to develop, we need to move beyond licensing missions to perform specific identified actions and toward a system similar to maritime operations. Ships (satellites) can be launched subject to quality/safety and then move around freely but need to act in certain ways when near other ships/objects or ports.
3. **Sustainability Best Practice** – The UK space sector need partners to protect UK interests in by developing international best practice. By acting as thought leaders, the UK can establish internationally accepted common standards & operating models leading to a good regulatory environment for UK space organisations. The UK government should continue its work within international forums such as IADC, UNCOPUOS, ISO to lead discussion on the implementation measures for space sustainability and to ensure their widespread application by operators in other jurisdictions. In addition, evaluating sustainability and IOSM guidance from bodies such as the IOSM WG (part of UKspace), CONFERS, SWF (Secure World Foundation), and Paris Peace Forum.
4. **Transparency in Licensing** – Ensure transparent licensing conditions which do not change during the licensing process and to engage effectively with other government departments to ensure this – this is important for companies wishing to develop a space service or set up business the UK and need to compare regulatory regimes with other host countries. It is important there is a defined end point for licensing where discussions are closed
5. **Closer International Collaboration and Trust Building Measures** – it is important that regulators, which include UKSA, CAA and Ofcom as well as MOD co-ordinate their national and international activities with regard to development of regulations with international parties. The UK space community should also consider how the application of regulatory frameworks differ between commercial, military and dual-use operations. CAA’s international department should be engaged with CAA’s space teams to speed up the international collaboration.
6. **Space-Based Regulatory Testing-** Existing regulations were born of a time of limited government missions and when assets were launched to avoid each other. The paradigms are changing to be much more commercial and to see economic interaction of assets in space. We need to design from scratch the regulations and norms around regular close proximity operations beyond single missions.

The UK needs to create a robust but enabling regulatory environment for innovative IOS missions. Leadership in regulation for space sustainability and debris removal, and rendezvous and proximity operations (RPO) is a strong market development lever for the UK. A visible, fast moving UK programme, including regulatory innovation where the UK has clear strengths, will help to raise the profile of the UK as the country that can enable these advances to happen and attract investment and economic growth.

8.3 International Partnerships and Engagement

The UK's domestic market for IOSM will not be enough to secure success. If it is to succeed, IOSM must be a global logistics sector, serving the needs of space missions from around the world. The UK's leadership and influence is thus vital. An **open and interoperable** international market is in the UK's interests.

The UK, including through UKSA, must engage positively with European initiatives, and seek to engage with and influence partner nations beyond Europe such as the "5-Eyes" and Japan. A profusion of incompatible systems and regulations will serve no one well.

"Quantity has a quality of its own" – Greater demand for IOSM in these early stages will drive capability and reduce costs, in turn creating more demand. A virtuous circle - but it needs pump-priming.

8.4 Bilateral Mission

IOSM aims can be achieved by 'extending' bilateral missions in other domains (E.g. EO or communications). The primary high level objectives for IOSM in a bilateral mission would be:

- **Regulatory** – Developing norms of collaboration between bi/multilateral licensing regimes. This is a key enabler for the sector. IOSM services *must* be able to operate across national boundaries to be viable.
- **Technical** – Proving specific technical capabilities - e.g. upgrading or re-supplying a spacecraft, leveraging international innovations to hasten the development of UK programmes
- **Financial** – Encourage inward investment into the UK and collaborate with partners to achieve goals outside of the scope achievable alone
- **Operational** – Extend the useful life of the EO/Comms satellite, upgrade based on advances in technologies and have a responsible disposal/circularisation strategy.

As an example – A UK spacecraft could deliver additional hardware such as additional solar arrays or batteries to a partner nation's EO spacecraft on orbit, increasing its operational capability. The bilateral extension would impose "design for servicing" requirements on the spacecraft, and the serving could be done as a mission extension.

The following countries have been identified as particularly interesting priorities for which to seek a bilateral: Australia, Japan and Canada. Saudi Arabia is identified as an interesting "high risk high reward" option to consider. Details can be found in Appendix G – Bilateral Mission.

There is strong overlap between regulations and international collaboration so are brought together with the following actions.

8.5 Access to Finance

One of the UK's key objectives is to catalyse investment in the UK. To fully realise this ambition, the UK must make itself more attractive to investment. There is substantial availability of funding for companies at the seed and pre-seed stage. The bottleneck for growth in the UK remains at the Series A and beyond stages (scale up). Ensuring UK-based companies have access to support financing of highly capital-intensive projects with long time horizons will prove crucial towards accelerating the growth of the sector.

This model, based on exploiting the UK's insurance markets, can achieve significant gearing between funding to create the prize and the benefit gained. Past examples of this approach include the Orteig prize for transatlantic flight, and the X-Prize for sub-orbital flight. Prize funded typically have low but achievable odds of success. E.g. 10:1 ratio on pay-out to policy cost.

An explanation of how it could work, and example technology challenges is given in ***Appendix E – "X-Prize" Model for IOSM Technology stimulus***.

Candidate technology challenges include:

- Boosting power capacity in customer satellites
- Close inspection and 3D scanning
- TT&C link boosting

8.6 Skills

The development of a highly skilled workforce is crucial to enable new business opportunities and for the UK to maintain its position as a science and technology superpower. The IOSM sector requires a broad range of skills across many disciplines including:

- STEM
- Regulatory, Policy and Law
- Politics & International Relations
- Finance & Insurance
- Risk Management
- Business & Entrepreneurship
- Sustainability
- Logistics & Supply Chain

Many of these areas are common across other sectors and other elements of space. IOSM is attractive to the general public as it can capture imaginations covering space, sustainability, engineering, international collaboration and exploration.

It is important to **identify the skills needed for the next 10+ years** as the sector grows. Innovate UK and the High Value Manufacturing Catapult have developed the concept of Workforce Foresighting which is being piloted across a number of Catapults and will be applied to the IOSM sector.

Some of the problems the sector faces include lack of opportunities for young people to gain experience (evidenced by tens of applications for one internship position), but massive skills shortages for roles requiring 5+ years experience. This can be tackled by:

- Cross-skilling activities e.g bootcamps and training programmes
- Encourage industry to invest in retention and early careers at the same time as technology development so skilled graduates are not lost to other sectors.

Ensure that new and appropriate vocational qualifications are available (e.g. new L4-6 Apprenticeships and HNCs/HNDs) and accessible to industry with training opportunities in their regions. The Foresighting work is expected to ensure the acceleration and evolution of new and existing standards and qualifications.

9 Appendix D - IOSM Test Facilities

The UK has already created a world-leading IOSM facility at Westcott Venture Park. The facility has been established to support hardware testing of IOSM activities based on close proximity operations. Examples of operations and equipment that the facility is targeted to address include:

- Physical coupling mechanisms
- Materials transfer
- Visual guidance systems
- Proximity sensing systems
- Attitude control processing

It may be the largest of its kind in an openly accessible facility. Nevertheless, the facility will require further investment to reach its full potential and meet the growing needs of the IOSM community.

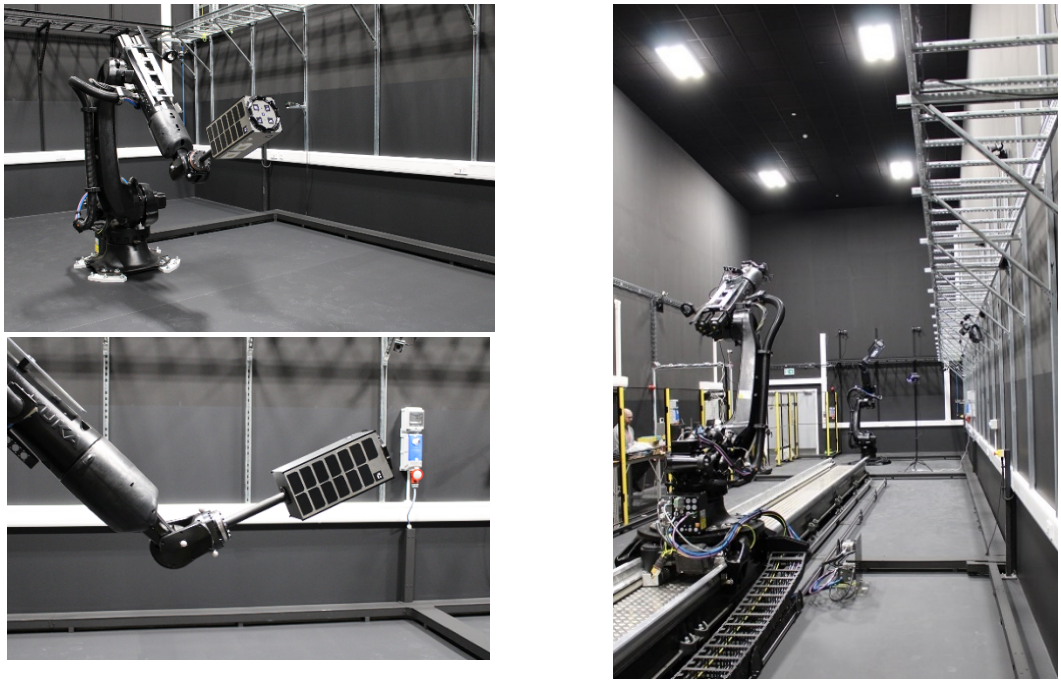


Figure 2 – National IOSM test facilities, Credit to Satellite Applications Catapult & Lunasa

9.1 Development of ground testing facilities for Close Proximity Operations (CPO)

These facilities will support innovators to **de-risk their flight technology and to build a safety case for operator licensing** of CPO activities.

Scenarios to support at the IOSM Ground Test Facilities include:

- Target ‘posture’ determination and tracking (visual and other sensor feeds)
- Physical interface approach and closure
- Robotic tele handling in-orbit

Technology requirements include:

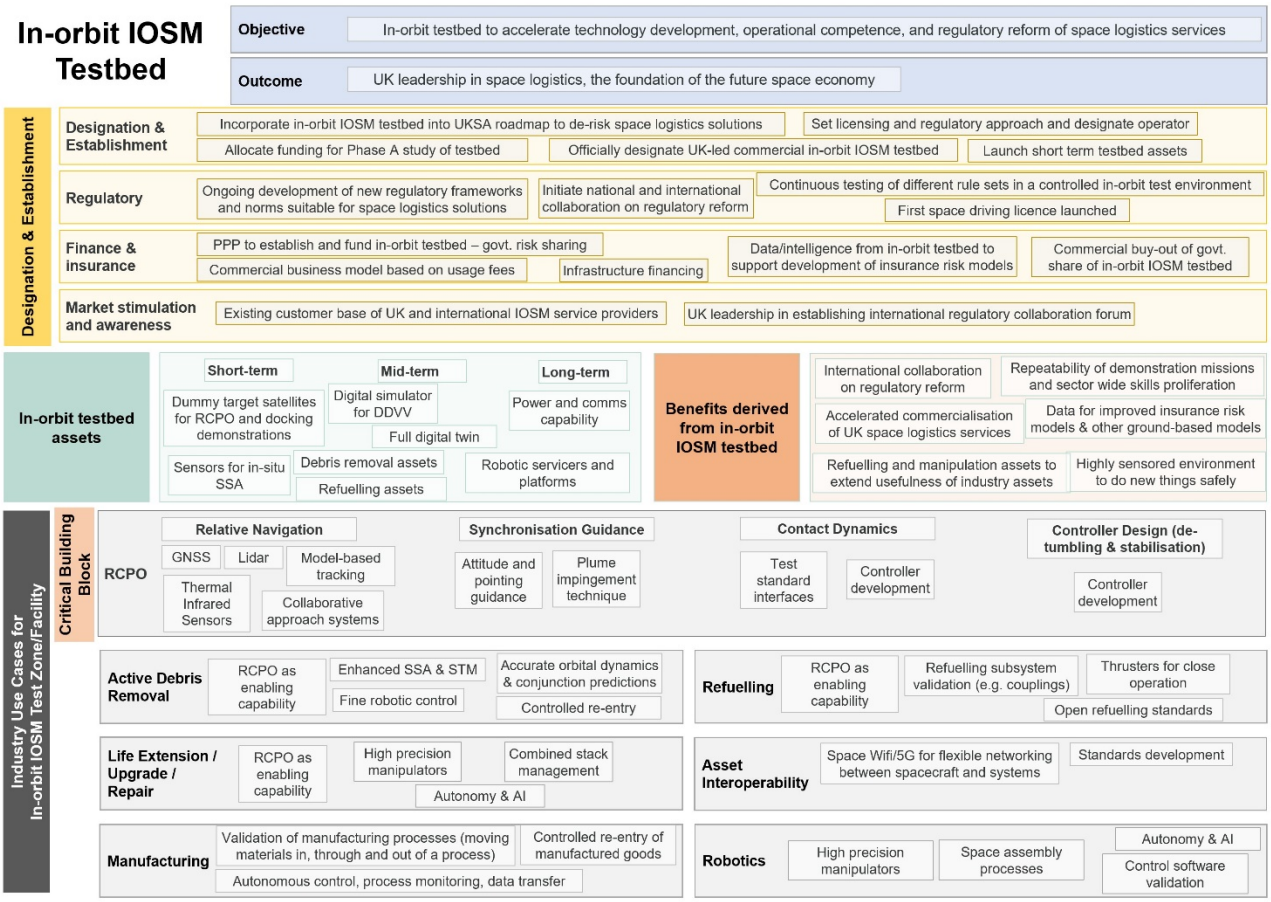
- **Orbital environment simulation** (e.g., moving Sun, Earth / Moon background clutter, 'frictionless' motion conditions) including:
    - Automated movement of solar/moon/etc light sources and 'clutter' (implies additional robotic devices that can be programmed and moved simultaneously) *
    - Large screen (whole wall) back projection of images (other space craft, planetary bodies) *
    - Flat/smooth floor (low friction) & True dark room conditions
    - Representative satellite models (improvements to current & full-scale space station models *
- **Data interfaces for open/closed loop** response to satellite Attitude and Orbit Control System (AOCS) behaviour including:
    - Hardware and software in the loop generic ACOS and GNC controllers and/or API interfaces into client systems.
    - Robot operating system (ROS) integration API with outputs to various data streams incld MatLab/Simulink.
    - Increased capability on motion capture system (more cameras & less background noise); dynamic tracking and position updating of programmed robot motion.
    - Data interfacing and logging across multiple in-house systems (virtual environments, robotics, lighting environment, projections systems, motion tracking, etc.
    - Connection between virtual/simulation environments and real world (digital twin).
    - Data link time delay modelling (link latency).
- **Upgraded robotics** hardware and software (integrated, with safety features):
    - Tele-operation for large robotic devices (both physical and mixed reality controlled)
    - Mobile robotics (replacing track with automated vehicle to give 360 deg approach vectors to target) *
    - Increased payload capacity and range for robots (to accommodate larger payloads)
    - Tumbling gimbal to simulate uncooperative/tumbling satellites.
    - Positioning of target without the need for a robot (i.e., suspended from overhead or floor mounted fixture)

*Items marked with * assume that a facility is big enough to accommodate (which the current Yard is not).*

Facility upgrade is proposed over a 2-year period, with development performed by UK industry under SAC's management. Individual programme elements may be undertaken in parallel.

The Facility reduces friction in the innovation process. It reduces the cost/time burden of high-risk orbital testing. Innovator's investment is focussed on the specific high-risk technology areas, while still on the ground. *"Fail fast"* on the ground, for success in orbit.

9.2 Development of In-Orbit IOSM test bed



10 Appendix E – "X-Prize" Model for IOSM Technology stimulus

10.1 The model

Use of insurance processes to enable prizes is a well-established practice. An insurance policy is taken out for a specified event. The policy pays out if the event occurs. In the case of a prize fund, the shaping of the insurance (prize) policy must balance the competing interests of the funder, the insurer and the prize competitors.

If well-designed, the prize policy will have the following benefits:

- **Enduring Legacy -** Be aligned with business interests of the competing companies towards a goal that they continue to exploit long after the prize has been awarded
- **Inward Private Investment -** Increase motivation for private sector investment across many organisations, at a combined scale substantially larger than either the policy cost or the prize
- **Targeted Technology Jump -** Help propel a rapid technology development cycle
- **Spin-out Technologies -** Generate valuable, exploitable spin-out IP in the competing organisations, whether or not they win the prize
- **Anchor in the UK –** Encourage innovative companies to establish and invest in the UK

10.2 Example Prize Challenges

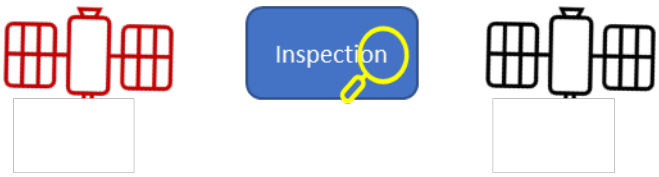
The following are candidates technology demonstrations for a prize fund:

- **Power Boost**

Many satellites are power-limited as a result of constraints on launch mass, dimensions or other factors. An IOSM capability to boost available power, permanently or temporarily could be provided as a service. This could be achieved either through reflecting additional sunlight onto the satellite's arrays at close range, though short-range wireless power transfer – or by delivering and connecting supplementary equipment (batteries for storge or arrays for generation).

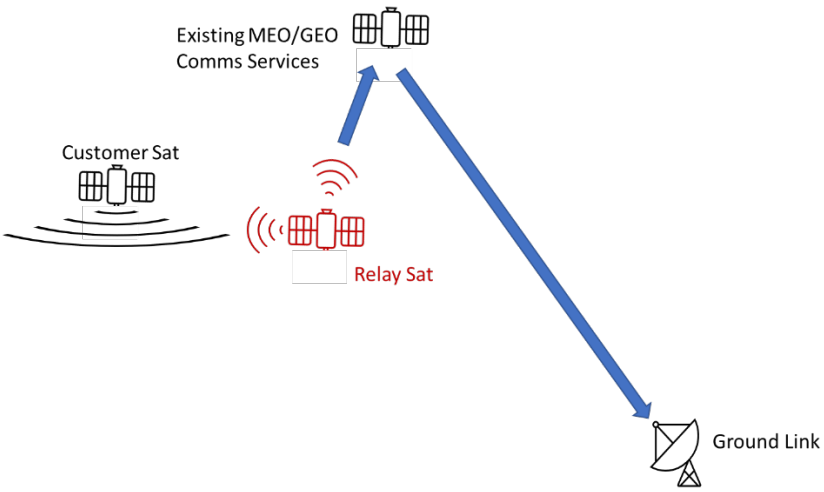
- **3D Scan & Health Check**

Assessing the state of damaged or malfunctioning satellites can be difficult through TT&C links. Visual inspection capabilities will become increasingly valuable as larger and more complex structures develop in orbit. A prize challenge could involve creating the first ever '3D laser scan" of an orbiting satellite for structural inspection.



- **TT&C Boost (“Relay services”)**

Most LEO satellites currently are able to communicate only when over a ground station, for short periods. They typically use wide-beam antennas. A nearby satellite, able to operate on the same frequencies, could act as a relay capability through GEO/MEO satcomms – providing extended TT&C links as a service. This service could be provided to satellites that had not been explicitly designed to support it.



10.3 Exploration of the Model

Designing an effective prize scheme, and securing the ‘best price for the insurance policy’, means balancing a range of stakeholder factors. E.g.

- Insurers competing to provide the policy
- Achieving a prize challenge that is 'not too hard' and 'not too easy‘
- Securing a gearing from policy cost to prize value that is appealing to competitors

The IOSM WG recommends that UKSA fund an initial piece of work to:

- Identify candidate technology challenges for the prize
- Consult a range of insurance providers, to confirm a ‘supply’ market for providing the prize policy
- Provide economic assessment of the stimulus that would be achieved into the IOSM sector

11 Appendix G – Bilateral Mission

The following countries have been identified as particularly interesting priorities for which to seek a bilateral: Australia, Japan and Canada. Saudi Arabia is identified as an interesting "high risk high reward" option to consider.

The US – being a leader in IOSM – should not be ignored, but has been left out here as a priority as the UK already has good existing relationships, the impact that that UK can make here is small and it is important to avoid developing ITAR restricted solutions.

11.1 Priority Partners

1. Australia

Precedent: The UK-Australia Space Bridge is a strategic partnership established in 2020 between the UK Space Agency and the Australian Space Agency to promote collaboration and growth in the space sector. The UK and Australia have collaborated on a number of projects related to satellite communication as well as projects related to space situational awareness. The UK and Australia have collaborated on a project called the Space Environment Management Cooperative Research Centre (SEMCRC), which aims to improve space situational awareness and address challenges related to space debris.

+ Good candidate to establish an IOSM related bilateral
+ Existing relationship with the UK
+ Impression that there is a high concentration of start-ups focussing on in-orbit servicing and space situational awareness technologies in Australia
– Relatively immature space industry, less potential to spin in technologies but:
+ Strong Export potential - by working with the UK to develop and lock in IOSM standards and practices for foundations of the future space economy

2. Japan

Precedent: The UK and Japan have signed a Memorandum of Understanding on sustainability and have conducted joint studies between JAXA and DSTL into space debris. JAXA have provided an MOU for interest in refuelling under ESA In-Orbit Servicing programme under prime Astroscale, who already worked cross-nationally to deliver the ELSA-d mission to demonstrate removal technology. Fujitsu established a £22million investment into the UK for the Centre for Cognitive and Advanced technologies that will import technology from Japan, focusing on AI and Quantum computing both of which can be leveraged to strengthen IOSM.

+ Strong precedent for UK-Japan collaborations, particularly around space sustainability and advanced computing
+ Further collaborations would improve strategic partnerships with an important G7 partner
+ Recent signing of the Hiroshima Accord between both UK and JP prime ministers pushing towards joint space ambitions
+ Leveraging joint Japanese-UK missions (such as ADRAS-J) for development of operational in-orbit servicing best practice,

3. Canada

Precedent: The UK and Canada have collaborated on a number of space robotics missions and have a long history of missions including the Canadarm developed by MDA, a company that has a footprint in both UK and Canada. In 2019 the UK and Canada signed an agreement to explore areas of collaboration on the Lunar Gateway project.

+ Strong in the area of space robotics particular for large ESA and NASA missions
+ UK could benefit from partnerships in this area to access technologies and the US market
– UK has extensive heritage in robotics in extreme environments (Nuclear, Oil and Gas) and may want to focus on this strength in the future which could be seen as competitive with Canada's strengths

11.2 Wild Card: Saudi Arabia

Precedent: The UK and Saudi Arabia have signed an MOU to work together on space exploration, which includes the potential for joint missions to explore the Moon and Mars.

A partnership with Saudi Arabia would not be an easy relationship to develop and there are concerns about human rights issues, however it is included as a high risk high reward option. Primarily the benefits would be access to large amounts of capital for UK companies and to create a long-term strategic partnership with a potential competitor.

11.3 Next Steps

Work needs to be done to coordinate on existing bi-lateral discussions in order to add an "IOSM Enabled" element. The exact IOSM scope would depend on the satellite mission, country and relationship. An example mission is outlined in Appendix C - 8.4 Bilateral Mission

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