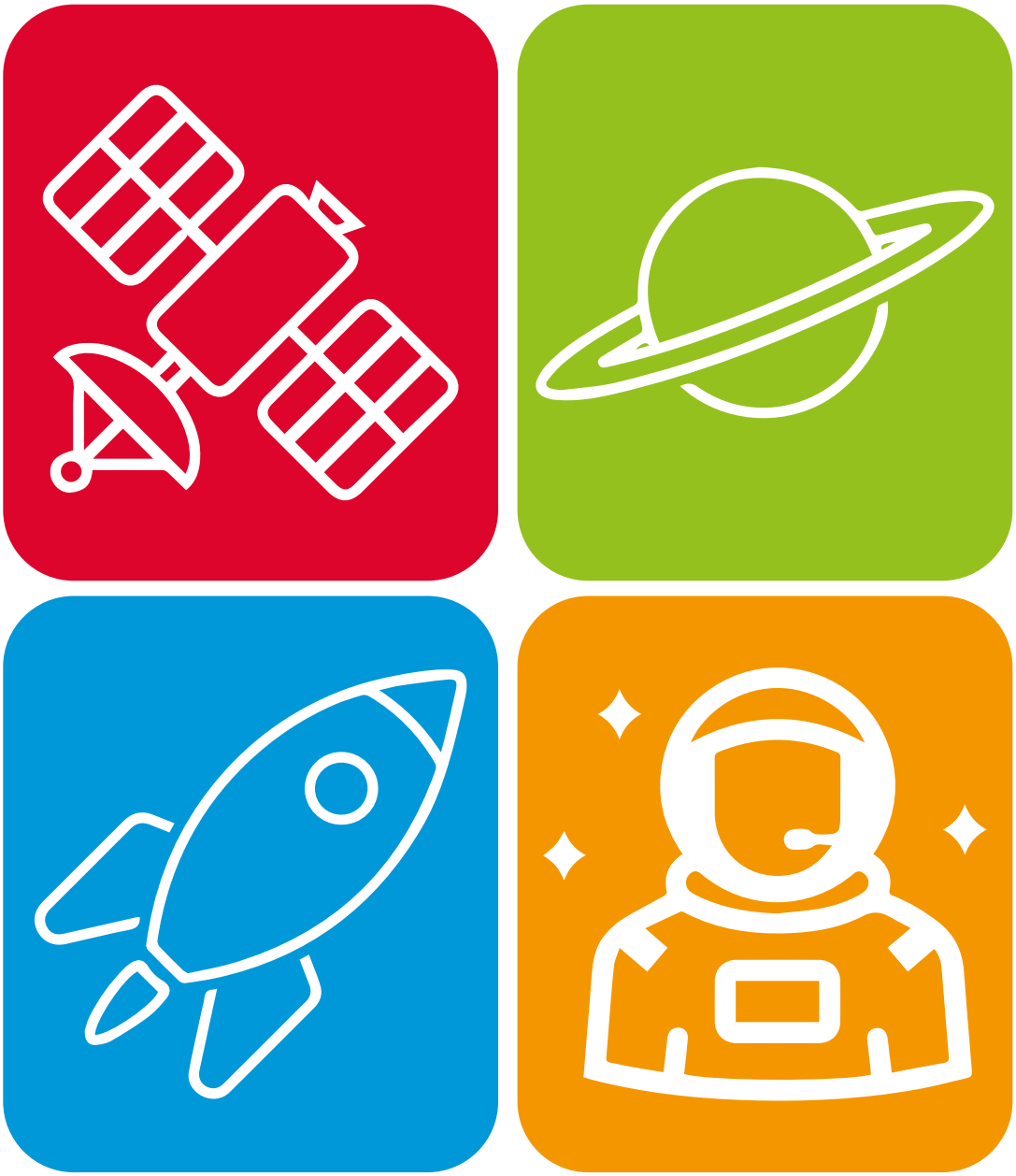
Scottish Science Advisory Council

Scotland's Space Sector: Exploring potential future opportunites



Contents

Executive Summary

The Scottish and UK governments have identified the Space Sector as a significant opportunity to develop a thriving and innovative national space economy. The global space economy is projected to grow from an estimated £270 billion in 2019 to £490 billion by 2030.[1] This report is in response to a request to the Scottish Science Advisory Council, from the "New Market Clusters Team" of the Scottish Government, to help identify future opportunities (commercial and societal) for the sector in the next 10-20 years, aligned with Scotland's research and industrial strengths.

The report begins with a summary of the Scottish space ecosystem, noting that there are aspects reserved to the UK government and others devolved to the Scottish Government. We note the dual-use aspects of the sector in civil and defence, and we outline the current routes to funding for space projects and programmes.

An examination of Scotland's strengths and weaknesses reflects on heritage in contributions to space science missions and highlights the development of the "new space" sector in Scotland with its strong focus and expertise in small satellite manufacturing, data analytics, and its emerging strengths in the launch sector, potentially providing an "end-to-end" capability. Supporting the sector is an increasing number of infrastructure assets and the diverse strengths of the academic community. With an SME-dominated economy (small and medium enterprises), weaknesses noted include the difficulties in scaling our space-related businesses, the lack of a Scottish prime contractor and difficulties in accessing larger programmes.

An examination of future opportunities and challenges starts by considering areas for consolidating and stabilising the new space sector including satellite manufacture and launch. It explores areas where Scotland can provide leadership, such as in sustainable space, while acknowledging commercial constraints and how these can be alleviated. It recommends building on our expertise in data science and analytics and suggests exploring the use of satellite networking for opportunities to introduce new public and private services.

Leveraging our academic strengths is seen as a key driver of the Scottish sector, and making use of our breadth and depth in Enabling Technologies is seen as an important differentiator. Skills are seen as an area of focus with greater promotion of the sector in schools and increasing the talent pool through transferrable skills and apprenticeships. Looking longer-term, we examine opportunities in emerging themes such as in-orbit services and space resource utilisation.

Consideration of competition and collaboration looks at threats and opportunities from comparable nations such as the Nordic countries, and areas where we can learn from the use of legal frameworks in countries such as Luxembourg.

The recommendations are:

1. **National Contracts:** The Scottish Government should explore the use of national contracts to support and enable the growing Scottish space sector and associated supply chain.
2. **Co-created Research Programmes:** The Scottish Government should act to support co-created research programmes between academia and industry targeting innovation in satellite manufacture and operation, and work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.

1 https://www.gov.uk/government/publications/national-space-strategy

3. **Nordic Collaborations and Legal Frameworks:** The Scottish Government should explore collaborative opportunities with the Nordic nations in those areas devolved to it, and examine space legal frameworks, including Luxembourg's, with a view to influencing UK's own space legislation.
4. **Infrastructure and Educational Strategy:** The Scottish Government should commission Space Scotland and the Scottish Space Academic Forum to undertake an exercise covering the following areas:

    a. A mapping of the supporting infrastructure available to the space sector, examining opportunities for shared access to capital assets;

    b. A review of Scottish research activity in space "emerging themes" with a view to informing future strategic collaborative programmes; and

    c. The development of a strategy for promotion of the space sector across primary and secondary education.

5. **Entrepreneurial Programme for Space Data:** The Scottish Government should introduce a focussed entrepreneurial programme for space data start-ups linked to the existing Entrepreneurial Campus[2] and Techscaler[3] programmes. This should be promoted using Scottish space data start-ups as exemplar case studies and engaging SDI (Scottish Development International) with assistance to route-to-market.
6. **Economic Development Interventions:** The Scottish Economic Development agencies should look at using existing intervention mechanisms to help pump-prime the application sector for the use of satellite communications networks as an enabler of new innovations in service solutions for public and private services, to reduce cost and improve the quality-of-service provision for economic and societal benefit.
7. **Legislative Examination and Standards Engagement:** The Scottish Government should examine legislation already under development by Scottish and UK legislatures to explore opportunities to include the space environment, and encourage greater engagement, across the sector, with relevant standards bodies.

2 https://www.gov.scot/publications/entrepreneurial-campus-higher-education-sector-driving-force-entrepreneurial-ecosystem/
3 https://www.techscaler.co.uk/

1. Introduction

The Scottish Government has identified the Space sector as a key economic opportunity for the future through the National Strategy for Economic Transformation, the Inward Investment Plan and the recently published National Innovation Strategy.

The Scottish Space Strategy was launched in November 2021. It shares an ambition to deliver an annual contribution to the Scottish economy in excess of £4bn by 2030, with year-on-year sector growth of 26%, and a five-fold increase in the workforce. These targets reflect an evolution from the 2017/2018 figures, where Scotland's space industry contributed £245M total income (14% of UK space industry contribution), generated £880M in Gross Value Added (GVA), employed 8,500 individuals and saw a sustained annual growth rate of 12% since 2016.[4] The Scottish space workforce is approximately one fifth of all UK space jobs with 85% working in space applications, with the remaining 15% spread across space manufacturing, space operations and ancillary services. Key features of the Scottish strategy include developing space infrastructure and the research environment, consolidating Scotland as a leading UK location for space technology development, supporting the launch sector, growing the customer base for end-to-end solutions, increasing national and international collaboration, and aligning the sector with Scotland's Net Zero ambitions.

The approach adopted in preparing this report included: a) a literature review and desk research to examine the academic and industrial ecosystem in Scotland, together with a short study of comparable international markets; b) a set of survey questions informed by the desk research and completed by sector stakeholders; and c) an online roundtable of key stakeholders from industry, academia, and the wider public sector. This report draws on each of these sources of evidence and knowledge from within the SSAC to arrive at the key findings and conclusions.

4 https://spacescotland.org/wp-content/uploads/2023/11/a_strategy_for_space_in_scotland.pdf

2. The Scottish Space Ecosystem

The UK's national space strategy, published in September 2021, is jointly owned by the UK Space Agency (UKSA), the UK Government Department for Science, Industry and Technology (DSIT) and the Ministry of Defence (MoD). Areas related to national security, defence, and international relations, including regulation of satellite launches, spaceports, and membership of the European Space Agency (ESA), are typically reserved matters for the UK Government. Aspects of space policy and regulation that concern economic development, education, innovation and regional planning are devolved to the Scottish Government, although there may be some cross-over. Collaboration and co-ordination between the two governments on matters of mutual interest are accepted in areas such as space exploration, satellite technology, and the promotion of the UK space industry as a whole.

The UK Space Agency was established in 2010 and is responsible for coordinating the UK's civil space programme, overseeing strategic investments, and promoting the sector. The agency collaborates with industry, academia and international partners to advance scientific research, technology development, and space exploration. In March 2024, the agency announced that its new headquarters would be based in Harwell, Oxfordshire, with regional offices in Scotland, Wales and the Midlands. The Scottish office of UKSA will be located at Queen Elizabeth House in Edinburgh.[5]

The Scottish Space Strategy was formulated with input from the Scottish Government Space Group, Space Scotland[6] and the Scottish Space Academic Forum. Within the Scottish Parliament there is an active cross-party working group of MSPs. Enterprise agencies, including Scottish Enterprise (SE), Highlands & Islands Enterprise (HIE), and South of Scotland Enterprise (SOSE), have all assigned policy leads for space.

With over 133 Scottish space organisations, the Scottish ecosystem is diverse and expanding. A brief overview of the industrial landscape is detailed in Annex E, and a similar snapshot of the Scottish Space academic network is outlined in Annex F.

Space is a dual-use environment. With a view to having a sovereign defence space capability, the Ministry of Defence established UK Space Command (UKSC) in 2021.[7] The UKSC has three functions: space operations, space workforce generation, and space capability. It was noted that much of this is built on prior UK civil investment, and the sector would benefit from civil-defence partnerships. However, the Scottish sector is not inherently dual-use nor actively engaged with the defence and security industries as seen elsewhere in the UK. Progress in this area would amplify Scotland's contributions to national security and defence. For the most part, this report concentrates on civil space sector opportunities.

Funding routes for space-related innovation development can come from a variety of routes: government grants and funding programmes from UK Space Agency (UKSA), Innovate UK as well as the enterprise agencies; research council grants for academic institutions and researchers (UKRI, including STFC, NERC, EPSRC); European Space Agency (ESA) contracts and collaborations; EU Horizon Europe programme; private investment and venture capital; and industry partnerships and collaborations. Defence-related funding can also come from the Defence and Security Accelerator (DASA), Defence Science and Technology Laboratory (Dstl) and through collaborative funding from MoD; the Advanced Research & Invention Agency (ARIA) has funding aimed at supporting high-risk, high-reward research and innovation projects.

5 https://www.gov.uk/government/news/uk-space-agency-announces-new-headquarters-and-regional-offices
6 https://spacescotland.org/
7 https://www.gov.uk/guidance/uk-space-command

3. Scotland's current and emerging sector strengths and some weaknesses

Scotland has heritage and contributions to space missions which continue to the present day, including supplying components for lunar and deep space exploration. These come from research organisations such as the UK Astronomy Technology Centre based at the STFC's Royal Observatory Edinburgh site, and industrial companies such as WL Gore and Star Dundee, through to the optical bench system for the LISA gravitational space interferometer developed by the University of Glasgow,[8] and the HABIT ExoMars Mission instrument developed by the University of Aberdeen.[9] However, the growth in the "new space" sector can be linked to the formation of Clyde Space in 2005 and the development of small satellite manufacturing and associated supply chain, which attracted other manufacturers and start-ups in this area. Indeed, an often-quoted statistic is that Glasgow builds more small satellites than any other city in Europe.

The sector in Scotland today is still dominated by small satellite manufacture but this is being augmented and diversified by the creation of an end-to-end ecosystem including the development of five dedicated launch sites and the emergence of launch vehicle manufacturers such as Orbex and Skyrora. These elements, together with the strength of the Scottish Data Analytics academic and industrial community, centred around Edinburgh, provide the connected elements of a national end-to-end space offering. Strengths exist in specialist component design and manufacture although the relationships with systems engineering companies is an area for improvement.

In the downstream sector, there is an established cluster of companies, public and private organisations including NGOs (Non-Governmental Organisations), working in Earth Observation, many of which are targeting services in natural capital data for forestry, agriculture, land use, biodiversity monitoring and climate change monitoring and mitigation. This feeds into elements of the "sustainable space" agenda, where Scotland is acknowledged to be a leader having introduced one of the first roadmaps in this area, "The Space Scotland Sustainability Roadmap", published in 2022.[10]

Scotland's strengths in the space sector are underpinned by a significant depth and breadth in "Enabling Technologies". This catch-all term is often used to describe technologies which can be applied across multiple sectors, and which are used to derive complementary innovations in an industry, much of which is driven by outputs from university research. Examples include Photonics, Quantum Technologies,[11] Robotics and Automation, Communications Technologies, Sensing and Imaging Systems, Cybersecurity, Advanced Manufacturing, Engineering Biology and many others. For example, more than 75% of Scottish companies working in photonics are active in more than one operational sector.[12]

While the above indicates areas of the ecosystem where Scotland has strength, it is acknowledged that the "new space" sector is still nascent, and support will be required to consolidate and deliver on its potential.

8 https://www.physics.gla.ac.uk/igr/index.php?L1=detectors&L2=lisa
9 https://www.abdn.ac.uk/geosciences/departments/planetary-sciences/habit-1567.php
10 https://spacescotland.org/wp-content/uploads/2023/11/Space-Sustainability-A-Roadmap-for-Scotland-Compressed-Version.pdf
11 https://scottishscience.org.uk/publications/ssac-report-quantum-technology-opportunities-scotland
12 https://technologyscotland.scot/wp-content/uploads/2022/10/Photonics-Survey-2022-final-version.pdf

The small satellite market is maturing, and steps need to be taken to avoid Scottish manufacturers being outcompeted by larger international players who can ramp-up mass manufacture. Differentiation can be maintained by improvements to product design and specification and/or improvements in infrastructure for manufacture. Scale-up is a significant challenge for companies and current mechanisms should be examined, and if necessary evolved, to support this. Diversification will help the sector and there are promising signs of development in larger sized medium earth orbit (MEO) and highly elliptical earth orbit (HEO) satellites for satellite-enabled communications networks and cloud services by Mangata, an inward investment with a proposed space engineering R&D Centre (Research and Development) and operations hub based at Prestwick.[13]

In the space sector, Scotland is dominated by SMEs with a lack of an established prime contractor. This is in contrast to other regulated industries such as Defence or Oil and Gas, where a cascading subcontract culture is more obviously beneficial to SMEs. As such, it is difficult for these SMEs to gain access to larger programmes from ESA and elsewhere. There is also a lack of specialist venture capital, including patient capital, as compared to the "Golden Triangle" in the southeast of England. It is not yet possible to raise required finance wholly in Scotland. This is considered a risk that has led some SMEs to locate their headquarters outside Scotland. Also, with UKRI's increased emphasis on "challenge led" R&D funding, the proportion of funding coming to Scotland has seen a reduction in recent years.[14]

To counter these challenges, fostering a more supportive ecosystem for SMEs and start-ups is seen as being key. Initiatives could include the development of a Scottish space sector investment fund, tailored financial instruments for space enterprises, and enhanced mechanisms for participation in larger international space projects. Strengthening connections with global space industry networks and encouraging the establishment of prime contractors within Scotland could significantly elevate the sector's international standing and capabilities.

A more detailed review of Scotland's strengths in research and industry can be found in Annexes E and F.

13 https://www.mangatanetworks.com/
14 https://researchbriefings.files.parliament.uk/documents/SN04223/SN04223.pdf

4. Future Opportunities and Challenges

Future opportunities often rely on consolidating and building on existing strengths. There is no doubt that Scotland has built up an enviable position in the manufacturing of small satellites. Many respondents in this area have reported on the challenges associated with scaling up their businesses. Competition is growing in the small satellite sector and there are some concerns that market saturation and arrival of lower cost competitors may threaten future commercial opportunities. With that in mind, it is important that Scotland maintains differentiation through innovation and optimised manufacturing infrastructure. Co-creation of targeted research programmes between industry and academia will support the former and it is suggested that the use of shared infrastructure together with closer integration of national assets in the sector, such as the National Manufacturing Institute of Scotland (NMIS) and the National Robotarium, will help support the latter.

There is desire from stakeholders for a coherent investment strategy in Scotland to support sector growth, perhaps including a space investment marketplace, set up to create a sector-specific investment fund involving Scottish National Investment Bank and others, plus support for exporters through strategies such as "Scotland: A Trading Nation".[15]

Several respondents indicated that a move away from government support in the form of grant funding to government contracts involving the satellite end-to-end ecosystem would be highly beneficial. In this case, the Scottish Government would be a procurer of space data (Earth Observation) from Scottish companies, supplied from Scottish satellites, launched from Scottish Spaceports. This would help maintain Scottish competitiveness and provide opportunities to validate existing and emerging developments. Indeed "Advance Market Commitments (AMC)" are being promoted by Innovate UK as potential valuable mechanisms for scaling innovation in Net Zero and other areas.[16] Application areas include examples such as environmental monitoring and forestry. Long-term anchor contracts of 5 years or more to data suppliers would help attract further investment. One example of this type of model is Terra SAR-X, a public-private venture from the German Government and EADS Astrium.[17]

> **Recommendation:** The Scottish Government should act to support co-created research programmes between academia and industry targeting innovation in satellite manufacture and operation, and work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.
>
> **Recommendation:** Space Scotland should be commissioned, alongside the Scottish Space Academic Forum, to undertake a mapping exercise of supporting infrastructure available to the space sector with an examination of opportunities for shared access to capital assets such as manufacturing and test facilities.
>
> **Recommendation:** The Scottish Government should explore the use of national contracts to support and enable the growing Scottish space sector and associated supply chain.

Space sustainability is an area, raised by many respondents, where Scotland is seen to be a leader. The World Economic Forum notes that "in the near future, space debris will become a critical challenge for the global community, endangering access to space and the benefits this access brings".[18] With the orbital environment being a globally shared resource, current standards are both insufficient and unenforceable failing to prevent a significant build-up of debris and an increasing collision risk.

15 https://www.gov.scot/publications/scotland-a-trading-nation/
16 https://www.ukri.org/blog/the-innovation-demand-paradox/
17 https://earth.esa.int/eogateway/missions/terrasar-x-and-tandem-x
18 https://www.weforum.org/projects/space-sustainability-rating/

Opportunities exist to provide solutions based on multi-stakeholder public-private collaborations. Space sustainability is also seen as a mechanism to help with the delivery of the United Nations Sustainable Development Goals (SDG).[19]

The Scottish space sector's sustainable space roadmap, published in November 2022, is the first initiative of its type, addressing issues from the environmental implications of the space industry to the growing need for businesses to deploy satellite data for environmental monitoring and climate analytics. This has garnered interest from UKSA and elsewhere. Respondents referenced several points including the development of green propellants by the launch sector (Orbex is actively engaged in this area), space debris removal and mitigation, reducing the impact of space resource utilisation, and the use of Earth Observation data for climate health monitoring, where Scotland has a track record of company creation, although again the point was made about failures in scaling these companies.

Innovating in space traffic management and actively participating in international dialogues on space law and governance could further Scotland's leadership in sustainable space. Developing technologies and frameworks that enable responsible use of space resources and ensuring the long-term sustainability of outer space activities are areas where Scotland can contribute at a global level.

There is a growing international interest, notably in the US, including NASA, regarding the utilisation of biotechnologies for sustainable space exploration and the potential benefits these could offer. Scotland has significant expertise in synthetic and engineering biology and the potential to emerge as a leader in the intersection of human space exploration and space sustainability with several research groups focusing such biotechnologies to enable the circular economy, including the UK Centre for Astrobiology at the University of Edinburgh.

Having leadership in sustainable space is one thing; being able to exploit the outputs of that leadership is quite another. The challenge is that sustainable practices may be in tension with commercial exploitation if those practices are not implemented everywhere. The solution may be found in international collaboration and legislation. International legislation is not yet in place and therefore future development will be essential.

The Artemis Accords[20] are a series of non-binding bilateral arrangements between the United States Government and other world governments that sets out the norms expected to be followed in outer space, particularly with lunar development. These could be expanded upon and could act as a template for other multi-country legislation on space sustainability.

Some respondents pointed to the Scottish Government's proposed Human Rights Bill, one of the first common law jurisdictions to establish a human right to a healthy environment, and whether this could be extended to cover space, through working with the UK Government to include legal protection and a policy framework for regulation of the sustainable space environment. Wherever and whenever new regulations are formed, it was recognised that it is important that Scotland strives for increased representation on standards committees and having a "voice in the conversation". This is reinforced from experiences in other sectors such as Oil and Gas, where those who set the standards are often best placed to benefit from them (cf. Rocket Lab,[21] a California-based space system company, who have been proactive in helping to develop space standards).

19 https://sdgs.un.org/goals
20 https://www.nasa.gov/artemis-accords/
21 https://www.rocketlabusa.com/

> **Recommendation:** The Scottish Government should examine legislation already under development by Scottish and UK legislatures to explore opportunities to include the space environment, and encourage greater engagement, across the sector, with relevant standards bodies such as the National Physical Laboratory (NPL), the British Standards Institution (BSI) and others.

The use of satellite-derived space data and the use of satellite-enabled communications networks are both areas that can provide new opportunities for key application and service providers.

As an SME-dominated country, data-based solutions offer low cost of entry for start-ups and SMEs. Scotland's industrial and academic strengths in data processing and analytics suggests that this could be a significant area to develop.

There are a number of providers of free, or low cost, satellite data such as the Sentinel-3 Copernicus Online Data Access (CODA) service. SMEs already take advantage of these data, including (for example) Trade in Space Ltd, who use satellite data and distributed ledger technology (asset tokenisation) to provide micro-financial services applications globally in the agriculture sector.

Expanding the utilisation of satellite data for advanced analytics and AI-driven insights could open new frontiers for Scotland's space sector, particularly in agriculture, forestry, maritime surveillance, and urban planning. Enhancing capabilities in satellite data analytics and fostering start-ups in these domains could enhance Scotland's position in the space data economy.

By encouraging and promoting greater entrepreneurship in space data applications, Scotland can grow this part of the commercial space sector significantly.

Alongside this, the introduction of satellite communications networks (e.g. Starlink) for secure, high-bandwidth, low latency, cloud services, has opened opportunities to deliver service-based applications across a variety of sectors including maritime, aerospace, transport, healthcare, fintech, agriculture, including "Internet of Things" (IoT) services in areas not covered by terrestrial cellular networks. Prestwick-based Mangata is an emerging entrant to this market, with satellites being developed for MEO and HEO orbits, together with Edge data servers for data processing closer to the application. Respondents noted that Scotland is an ideal "sandbox" for a diverse range of space related applications having an established ecosystem alongside a varied metropolitan/rural/maritime environment.

> **Recommendation:** The Scottish Government should introduce a focussed entrepreneurial programme for space data start-ups linked to the existing Entrepreneurial Campus[22] and Techscaler[23] programmes. This should be promoted using Scottish space data start-ups as exemplar case studies (for example Trade in Space Ltd) and engaging SDI (Scottish Development International) with assistance to route-to-market.

> **Recommendation:** The Scottish Economic Development agencies should look at using existing intervention mechanisms to help pump-prime the application space for the use of satellite communications networks as an enabler of new innovations in service solutions for public and private services, to reduce cost and improve the quality-of-service provision for economic and societal benefit.

22 https://www.gov.scot/publications/entrepreneurial-campus-higher-education-sector-driving-force-entrepreneurial-ecosystem/

23 https://www.techscaler.co.uk/

The section on Scotland's sector strengths above highlighted "Enabling Technologies" as being one of our key strengths in the space ecosystem. While this has been acknowledged, to some extent, via support through the cluster organisation Technology Scotland and translational assets such as Fraunhofer CAP and CENSIS, many respondents felt that there was a lack of connectivity across the individual technologies that could benefit from greater co-ordination and sector-specific focus. This has started to be recognised at both Scotland and UK level with the proposal of a Scottish "super-cluster" of critical technologies comprising quantum technologies, photonics, semiconductors and wireless communications, and at UK level with DSIT defining five critical technologies: AI, engineering biology, future telecommunications, semiconductors, and quantum technologies.[24]

The Scottish supercluster comprises over 140 companies, generating more than £3.6 billion in turnover, £1.2 billion GVA and supporting over 10,000 jobs. This cluster is understood to be the largest in the UK, outside the East and Southeast of England. Some other adjacent technologies, which are cited as being particularly relevant to the space sector, include cybersecurity, with a focus on secure-by-design aspects across the supply chain, and technology related to the gaming sector. Cybersecurity particularly has been identified by the Scottish Government as a key enabler of the space sector with Scottish expertise in a number of areas including quantum key distribution for satellite communications.[11] Several national agencies are developing frameworks and guidelines related to cybersecurity including the USA and Germany, who have initiated the development of technical guidelines for satellite security.

While some informal cross-technology alliances are already in formation, such as "Photonics for Space"[25] special interest groups within Technology Scotland and UKRI's Knowledge Transfer Network (KTN), there is perceived to be a lack of project-related cooperation with defined outcomes, designed to secure technological advantages for the Scottish and UK space sector. Examples of such activity could include alleviation of congestion of the RF spectrum by development of secure AI-enabled photonics for ground-to-satellite or satellite-to-satellite communications, the use of compound semiconductors for novel satellite imaging components, or the use of engineering biology for space-based pharmaceutical manufacturing.

> **Recommendation:** The Scottish Government should work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.

Running through all the above narrative is the subject of skills. Representatives of the industrial space sector have observed that hiring staff with five or more years' experience in the space sector is difficult due to the limited talent pool, while sector growth is making retention challenging. It was also noted by respondents that access to experienced talent from Asia and Europe is not currently available to companies in the UK and that much of the R&D funding available (UKSA) is short duration, feeding into the overall skills shortage. Many respondents also remarked on the lack of diversity and highlighted that more could be done to encourage women and girls into the sector. Other, more established, sectors can address some of these challenges through co-investment with skills providers to develop tailored programmes matched to industry demand, which are not yet available in the Scottish space sector. While recognising that the skills required are competed for by other sectors, there exist opportunities for workers with transferable skills from other sectors to move into space, especially from regulated industries such as Oil and Gas, Subsea engineering, Nuclear and Defence. Indeed, it was pointed out that some engineering companies in these sectors could diversify into space if they had the vision and ambition to do so.

24 https://www.gov.uk/government/publications/uk-science-and-technology-framework/the-uk-science-and-technology-framework

25 https://photonicsscotland.com/photonics-for-space/

Although there was a desire to see more space-focused courses in higher education (cf. the International Space University in France) and further education (tailored Modern Apprenticeships), increasing the talent pool over the long term will require more focused effort on promotion of the sector as an available and attractive career choice from primary and secondary school age. It was also stressed that as manufacturing companies scale, the numbers of technicians significantly outweigh the numbers of HE graduates required. The use of space as a flagship sector for attracting more students into STEM education was raised as a significant opportunity. In addition to promoting space as a career choice, integrating space-related projects and competitions into the educational curriculum could inspire the next generation of space professionals. Collaborations with industry to provide hands-on experiences and internships would bridge the gap between education and employment, ensuring a steady pipeline of skilled individuals ready to contribute to Scotland's growing space sector.

> **Recommendation:** The Scottish Government should commission Space Scotland and the Scottish Space Academic Forum to develop a comprehensive strategy for promotion of the space sector in schools and the development of relevant education and training at all levels. This should be developed in partnership with relevant organisations such as Primary Engineer,[26] Stemettes,[27] and others to stimulate and inform young people about career opportunities in the sector and the skills required. This scope could be expanded to higher education levels if capacity allows.

The newly formed launch sector in Scotland is seen as being a key part of the end-to-end capability in Scotland, and support for the launch sector is a central pillar of the current Scottish Space Strategy. Success in this will depend on keeping the launch pipeline filled, with a move towards fast-track or on-demand launch services and streamlining the licencing process. Also, fundamental to this will be the establishment of supporting infrastructure to the more remote space ports such as transport, logistics and accommodation.

Looking further forward, respondents were keen to emphasise opportunities for Scotland arising in the following areas, many of which appear under "emerging sectors" in the UK National Space Strategy:

In-orbit servicing. There were of the order of 10,000 satellites launched in the last 70 years. It is expected that anywhere between 30,000 and 60,000 will be launched in the next decade. Part of space logistics, in-orbit servicing involves orbit transfer of satellites, satellite servicing, life extension and remediation, and de-commissioning. These services will rely heavily of specialist areas of robotics and automation. There are already companies operating in this field such as Italian start-up D-Orbit.[28] National assets in Scotland (e.g. NMIS, UKATC at the Royal Observatory, and the National Robotarium) could make a significant contribution here.

Active debris removal (ADR). Simulations run by ESA and NASA show that, even with the current density of objects in space, the number of debris objects would continue to grow with a forecast collision rate of once every 5-9 years. ESA's "CleanSpace"[29] initiative is looking at the required technology developments for ADR, including advanced image processing, complex guidance, navigation and control and innovative robotics to capture debris.

26 https://www.primaryengineer.com/
27 https://stemettes.org/
28 https://www.dorbit.space/
29 https://www.esa.int/Space_Safety/Clean_Space/Clean_Space2

In-space manufacturing. Environmental factors such microgravity and vacuum allow for production of materials that are otherwise difficult to produce on Earth. These may include exotic material such as superalloys, certain optical crystals, carbon nanotubes, crystallisation of protein-based pharmaceuticals, and others.[30] Production processes for these will require the use of autonomous or semi-autonomous robotics, or a human crew. In-orbit fabrication involves direct printing of materials to manufacture space structures. In-space modular assembly of assets, such as observatories and science platforms, allows for the modular construction of assets unconstrained by the specifications of a single launch vehicle.

Space travel, habitation and tourism. Programmes involving human spaceflight are increasing including NASA's Artemis missions[31] to develop a sustainable staffed base and lunar economy on the Moon. These will require innovations in areas such as engineering, energy generation, in-situ-manufacturing, life sciences, human health, and robotics. Scotland has an opportunity to contribute to these programmes given our strengths in many of these areas and our transferrable expertise from other sectors. With the prospect of future industrial activity in Earth orbit, a mix of human and robotic activity can be envisaged, with strong parallels to the remote working of North Sea oil and gas exploration. Collaboration between government agencies, industry partners, and academic institutions will be essential to drive these innovations forward.

Space resource utilisation. This includes extraction and use of resources beyond Earth. In-situ utilisation can support programmes such as Artemis, mentioned above, using resources such as water ice and mined material from the Moon (regolith) or asteroids. Water in particular can be electrolysed into hydrogen and oxygen to manufacture propellant in space. This offers the possibility of commercial propellant re-supply services to spacecraft in orbit at a lower cost than lifting propellant from the bottom of the Earth's deep gravity well. There are a number of opportunities to examine here including what may be required in terms of infrastructure and support. We also acknowledge that space resource utilisation can be a contentious area, given the Scottish Government's focus on environmental sustainability and the circular economy.

Space-based energy. There are numerous concepts for this including Solar Power Satellites (SPS) and larger orbital solar farm arrays, collecting solar energy in orbit and wirelessly transmitting that energy to Earth using microwave transmitters or lasers to ground stations for conversion to electricity. These have advantages of being free from the influence of weather patterns and nightfall and can be directed to locations not covered by terrestrial grids. There are a number of Scottish universities with research that is directly relevant to this application including the Universities of Glasgow and Strathclyde.

> **Recommendation:** Scotland has research activity in all six of the above mentioned "emerging themes". The Scottish Government Space Group should engage the Scottish Space Academic Forum and Space Scotland to undertake a mapping exercise to highlight these areas as a collective, with a view to informing future strategic programmes and collaborations.

30 https://www.nasa.gov/international-space-station/space-station-research-and-technology/in-space-production-applications/

31 https://www.nasa.gov/feature/artemis/

5. Competition and Collaboration

A brief review of competition risks and collaboration opportunities is outlined in Annex G. The key points are summarised below:

With more than 70 countries investing in space, our closest collaborations are expected to be in our relations with our UK partners and aligned with the UK Space Strategy being delivered by UKSA, and in Europe with the related association with ESA. That view was reflected by a majority of our respondents. Other opportunities may lie with participation in large lunar and Martian programmes from NASA. For security collaboration, the "five eyes" of UK, USA, Canada, Australia and New Zealand are seen as being especially important.[32] That said, there are strategic objectives and considerations from a purely Scottish national perspective that make an assessment of "comparable countries" worthwhile, including countries in Europe and elsewhere, which have economies and populations comparable to Scotland. Such countries also have comparable space ambition, timing, programs, progress, space relevant geography, and national strategies. Some of those considered include Sweden, Luxembourg, Lithuania, Belgium, Norway, Denmark, Finland, and Israel. Many of these may emerge as potential competitors or collaborators, or both.

Most of these nations showed documented ambition and commitments in the space sector, including commercial space activities, particularly in the past half-decade (2016-2022), and have declared space strategies either for the first time or published a revised version to include their current capabilities and forecasts.

The "small satellites segment" is expanding in multiple comparable countries, emerging as a high priority in their strategies with ambitions to build and promote a relevant supply chain within the nation or via collaboration. Sweden appears as a likely main competitor although also a potential source of inward investment (in 2019, AAC Clyde Space was formed following acquisition of Clyde Space by AAC Microtec). In addition, Sweden has had an ongoing focus on the launch sector in recent years (cf. Esrange Space Centre[33]) backed by its well-established aerospace and defence industry (Saab, OHB), and expanding capabilities to include satellite tracking, telemetry, and command services, as well as hosting ground stations for satellite communication and Earth observation. Sweden therefore presents strong competition to Scotland in the space sector overall. With a geographical and economic proximity, one important aspect of this competition could be in attracting relevant funding from EU programmes or private investment, which could have a significant impact on the overall growth of the sector in either country. Among other comparable countries, Luxembourg (with Société Européenne des Satellites), Israel (with Israel Aerospace Industries) and Belgium (with Thales Alenia Space) are also seen to have strong positional focus on satellite manufacturing and data services.

Beyond satellite manufacturing and launch services, Luxembourg's space activities, including its very recent legal framework for space resource exploration, may present potential competition to Scotland's space sector. Luxembourg has established an efficient legal and regulatory framework with a dedicated space law for the exploration and utilisation of space resources making it the first European country to offer such regulations in the space sector.[34] These regulations provide clarity and stability for space ventures, which can help attract international operators and investors. The legal framework in Luxembourg supports commercial space projects and space mining ventures. Scotland may gain from learnings in space law, and in technical or commercial collaborations with small countries like Luxembourg and Lichtenstein. This is relevant considering their success in the early setup and implementation of a legal and regulatory framework, which has proven useful in attracting business and investment in the space sector despite their small size.

32 https://www.cigionline.org/articles/the-five-eyes-and-space-a-new-frontier-for-an-old-intelligence-alliance/
33 https://sscspace.com/esrange/
34 https://space-agency.public.lu/en/agency/legal-framework.html

While Scotland has no immediate strategic roadmaps for space resource utilisation, energy from space or space tourism, these have started to appear in the strategies of some comparable countries, notably Sweden and Denmark. Strategic collaboration with other small countries, especially the Nordic nations, may lead to partnership opportunities in these and other areas. With limited budgets, collaborations will become more important, avoiding independent developments in areas requiring heavy investment. Engaging in joint ventures and projects with these countries could leverage Scotland's strengths and mitigate competition risks by fostering a collaborative rather than competitive environment in the niche segments of the space industry.

> **Recommendation:** The Scottish Government should explore collaborative opportunities with the Nordic nations in those areas devolved to Scottish Government, and examine space legal frameworks, including Luxembourg's, with a view to influencing UK's own space legislation.

6. Conclusion and Recommendations

The "New Space" sector in Scotland is still in the formative stage. Action taken now will have significant consequences for the stability and growth of the sector. By leveraging the strengths of our academic and industrial communities in support of the sector, Scotland can derive significant economic and societal benefits for its citizens. As a small country, collaboration will be key to ensuring that we maximise the opportunities that the space sector offers, including collaboration with the rest of the UK and Europe, collaboration in translating our academic research into industrial impact, and the formation of successful partnerships across our industrial base and with external partners.

Our recommendations cover the following areas:

1. The use of intervention mechanisms at their disposal by the Scottish Government and the enterprise agencies to support the sector;
2. The introduction of focussed academic and collaborative research programmes to benefit the space sector;
3. Promotion of space in schools and in entrepreneurship to help secure the sector's long-term future;
4. The use of sector mapping to establish opportunities for use of collaborative infrastructure and expertise; and
5. The role of legislation and standards in supporting the sector.

We recommend:

1. **National Contracts:** The Scottish Government should explore the use of national contracts to support and enable the growing Scottish space sector and associated supply chain.
2. **Co-created Research Programmes:** The Scottish Government should act to support co-created research programmes between academia and industry targeting innovation in satellite manufacture and operation, and work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.
3. **Nordic Collaborations and Legal Frameworks:** The Scottish Government should explore collaborative opportunities with the Nordic nations in those areas devolved to it, and examine space legal frameworks, including Luxembourg's, with a view to influencing the UK's own space legislation.
4. **Infrastructure and Educational Strategy:** The Scottish Government should commission Space Scotland and the Scottish Space Academic Forum to undertake an exercise covering the following areas:

    a. A mapping of the supporting infrastructure available to the space sector, examining opportunities for shared access to capital assets;

    b. A review of Scottish research activity in space "emerging themes" with a view to informing future strategic collaborative programmes; and

    c. The development of a strategy for promotion of the space sector across primary and secondary education.

5. **Entrepreneurial Programme for Space Data:** The Scottish Government should introduce a focussed entrepreneurial programme for space data start-ups linked to the existing Entrepreneurial Campus[35] and Techscaler[36] programmes. This should be promoted using Scottish space data start-ups as exemplar case studies and engaging SDI (Scottish Development International) with assistance to route-to-market.
6. **Economic Development Interventions:** The Scottish Economic Development agencies should look at using existing intervention mechanisms to help pump-prime the application space for the use of satellite communications networks as an enabler of new innovations in service solutions for public and private services, to reduce cost and improve the quality-of-service provision for economic and societal benefit.
7. **Legislative Examination and Standards Engagement:** The Scottish Government should examine legislation already under development by Scottish and UK legislatures to explore opportunities to include the space environment, and encourage greater engagement, across the sector, with relevant standards bodies.

35 https://www.gov.scot/publications/entrepreneurial-campus-higher-education-sector-driving-force-entrepreneurial-ecosystem/
36 https://www.techscaler.co.uk/

Acknowledgments

The authors acknowledge with gratitude the contributions made by the survey respondents and roundtable participants, an essential element in developing this report. We thank the SSAC Secretariat and Scottish Government New Market Clusters Team for their support in the practical arrangements for the roundtable. We are grateful to Professor Colin McInnes of the University of Glasgow, and Professor Javier Martin-Torres of the University of Aberdeen, for their participation in the working group. We are also grateful for the participation and support of SSAC project volunteer, Dr Anton Dubenko of the University of Edinburgh, and Dr Shrawan Jha of CENSIS, for their contributions to the literature review and desk research, many of which form Annexes to this report. The recommendations are the responsibility solely of the SSAC and have been agreed by the Council as a whole.

Annexes

Produced for Scottish Science Advisory Council by APS Group Scotland, 21 Tennant Street, Edinburgh EH6 5NA
(May 2024)

scottishscience@gov.scot