ANNEX D

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

SUMMARY OF SURVEY RESPONSES

Note: the text below reflects the views of the respondents with no edits other than removing repetitive views and personal identity information. Not all respondents have provided a response to every question asked.

1. What are the strengths of the Scottish Space sector? How can these be consolidated and enhanced to maximise benefit to Scotland over the next two decades?

Scotland's strength in space is often characterised as an 'end-to-end capability' – from design to launch to data exploitation. This is a reasonable way of describing our unique selling point (USP) as we are not focused on one particular aspect, but due to history and geography we can address the entire chain. This could however lead to spreading ourselves too thinly, and thus not making a significant impact in any particular aspect, and also creates a difficulty in articulating our uniqueness (to external investors for example). The 'end-to-end capability' tagline does help with the latter, but to address the former we can show specific areas of particular strength in Scotland:

- NanoSats
- Components and subsystems for larger sats
- Launch vehicles and launch sites – this is a new but growing area for Scotland. With 5 potential launch sites in Scotland, and the only three vertical launch sites in the UK, we are well placed to win future launches from Scottish soil.
- SaxaVord became Europe's first licensed vertical launch site in December 2023 and hopes to start launch operations later in 2024. Being able to launch from Scotland is the last piece of the 'end-to-end capability' needed.
- Environmental considerations – one related aspect that should be kept in mind is Scotland's growing reputation for incorporating environmental considerations into the growth of commercial space activities.
- Science missions – The UK Astronomy Technology Centre in Edinburgh is the Science & Technology Facilities Council (part of UKRI) UK national centre for the design and build of astronomy instrumentation.
- Data exploitation (applications) – this is a major part of Scotland's space sector that is likely to generate the largest commercial revenues in the longer term.

As space eventually becomes another tool to deliver services to customers it is the applications that differentiate commercial offerings. There are academic research areas in data applications, and this ties strongly into the Edinburgh University aim to be the ‘space data capital of Europe’ but also the strong heritage in data analytics in Scotland.

Full value chain capability (a rare end-to-end ecosystem that will involve the addition of orbital launch services in the near future) covering:

- Satellite manufacturing (particularly cube / nanosatellites and below made by Spire, AAC Clyde and Alba Orbital although soon to grow with the arrival of Mangata to manufacture larger satellites)
- Orbital launch vehicle developers (launch companies employing hundreds of people and gaining significant private and public sector investment)
- Developing launch sites (the “missing piece of the jigsaw”)
- Thriving downstream data analysis segment with thirty-three earth observation companies commercialising space data and more looking at wider geospatial / IOT etc.
- World-class universities underpinning the sector.
- Proven heritage in space research and contributing to deep space missions, via the likes of STFC / ATC but also through private companies such as Star Dundee and WL Gore
- A collaborative environment, from Space Scotland acting as an enabler and platform for engagement / sectoral representation, closely aligned with ‘A Strategy for Space in Scotland’ and combined with the Space Scotland ‘spin out’, Scottish Space Academic Forum, to the likes of HIE, SE and SOSE sharing knowledge via the Scottish Government Space Group feeding directly into SG
- Developing wider USPs that include space sustainability, an organised movement in Scotland that culminated in ‘Space Sustainability - A Roadmap for Scotland,’ the world’s first sustainability strategy for a nation that has drawn engagement from space agencies around the world and led to engagement at UN level.

In order to merge and enhance, the strong level of collaboration between industry, academia and government must continue. This engagement is encouraged and helped by organisations such as Space Scotland and Scottish government agencies, all of whom have been valuable supporters and ambassadors for our fast growing (but still formative) commercial space industry. It is important to highlight Scotland’s space strengths and ambitions, as outlined above, in a uniform, considered manner that is amplified by industry ambassadors, MSPs and MPS, as well as Global Scots.

There are two parts of this question. Firstly, space deployed assets and secondly, products and services that can be enhanced with data derived from space e.g. GPS or earth observation. Academically we are stronger in the second area. Interestingly,

I see in the industrial landscape the reverse of this scenario with satellite manufacture and launch. My belief is that Government policy is more aligned to the second area. Strengthening could be achieved by closer linking of both of these areas.

Scotland has key strengths in the Space Sector:

- Satellite manufacturing
- Launch
- Ecosystem
- Governmental / Enterprise Agency support
- History and Heritage in innovation
- Academic prowess

Other areas have highly complementary sectors of great capability in Scotland from Fintech to Gaming but we need to actively strive strategy that collaborates where the output is greater than the sum of the parts.

Clyde Space Ltd was set up in 2005 in Glasgow, and whilst now owned by parent company AAC Clyde Space AB, headquartered in Sweden, still represents the group's largest site, employing one hundred people by the end of 2023. The company has been designing and building subsystems for small satellites for 20 years, with a range of academic, industrial, and institutional customers all over the globe. The company also built the UK's first CubeSat, UKube-1, launched in 2014, for the UK Space Agency

2. Where are the greatest opportunities for Scotland in the Space Sector in the next 10-20 years and where should we focus our priorities?

There are identified opportunities looking forward, where Scotland has a good or reasonable change of having some traction. In a very rough priority order (high to low) in terms of likelihood of Scottish success / impact. *Note - there are areas of overlap (e.g. laser-comms and quantum comms, or space mining and space robotics), however we have simply included these to avoid missing potential future opportunity areas:*

- Photonics, including laser-comms
- Quantum communication
- Science missions, particularly those using smaller satellites / spacecrafts
- Quantum sensing
- Space robotics, including autonomous systems
- ISRU (in-situ resource utilisation)
- Space mining
- RF spectrum utilisation / optimisation, including Software Defined Radio (SDR) & phased array antennas
- Space based solar power
- Debris removal / mitigation
- Nuclear power
- Space tourism

By building upon the industry-led space sustainability movement in Scotland, the country can cement its position as a world-leader in this increasingly key area. From supply chain sourcing, the development of green propulsion, environmentally conscious launch site developments and the ability of space data coming from Scottish satellites and being analysed by Scottish space data firms, Scotland can lead by example as part of the wider UK proposition around space sustainability in orbit (active debris removal/ space situational awareness).

Scotland can also use its reputation as being Europe's main producer of small satellites to encourage inward investment and further grow the skills pipeline/ new businesses in this area. If Scotland can offer a compelling, comprehensive launch proposition and remain internally collaborative, the opportunity is there to be the European home of spaceflight. In such a broad industrial market, one that plays a key role in every sector imaginable, it is difficult to say where we should focus priorities beyond the importance of continued knowledge-sharing, awareness-raising, and collaboration to build upon the impressive sectoral development to date.

Space data, however, feels like the area of the industry with the greatest level of growth opportunity. Scotland's expertise in this area, from university to the businesses commercialising satellite data from Scotland all over the world, is a huge opportunity due to the increasing need of information from space to support our environment, economy (insight for businesses in most sectors) and society in general (via the everyday space applications we all access, such as weather forecasting or logistical information).

I would be interested to see international benchmark data relating to the evolution of the satellite and launch capability here and this being used to define how we can be a global leader / significant player. This should consider how we can develop our capabilities e.g. satellites of higher payload. Consideration should be given to launch and maximisation of asset value. The applications area is still ripe for exploitation and how we can become a significant player in the development of space-based infrastructure and applications. This should consider broad benefits – economic, societal, and environmental. Building on the latter point, are there opportunities for us to apply our ability and reduce the impact of space utilisation and build this as a strong underpinning theme?

Scotland is recognised for its powerful reputation in the satellite market, and I believe that the obvious next step would be to provide leadership in developing cyber security resilience in this area. To achieve this, Scotland should adopt an initiative-taking and forward-thinking approach which goes beyond simply adapting existing frameworks, it should focus on building and implementing secure-by-design principles across the entire supply chain and ecosystem of the Scottish Space Sector and seeking new methods of cyber resilience. This will require innovative fresh ideas, and pressure testing across the ecosystem. But Scotland is still small and agile and as such this is the right moment rather than trying to retrospectively address issues later. Furthermore, I believe a focus on cyber security in the sector may also provide potential benefits for our young people. There is currently a global skills shortage in both the space and cyber domains, and this shortage is expected to continue. By positioning Scotland as a leading nation in both domains, we can

create opportunities for our young people to fill these gaps and become global leaders themselves. The intersection of space and cyber presents untapped entrepreneurial potential for Scotland as a nation but also our young people and entrepreneurs. Additionally in developing end to end capabilities with innovative cyber resilience building into the ecosystem, Scotland could develop enhanced national security measures and protect data sources used to inform decision making and commercial activity. One such example from public data is that that Chinese researchers have claimed that they can hack into Elon Musk's Star link network and change data and also change the positions of orbiting devices and disrupt data traffic. The veracity of these claims is unknown, but these risks are real and developing at a pace. There is an urgency in this field which cannot be overstated.

Areas of opportunity are outlined in the space strategy. Areas which align to / leverage distinctive Scottish University strengths / strategic activities are of real interest (e.g. downstream space data driven innovation activities, strategic net zero / sustainability initiatives) and should provide competitive advantage in a fast developing sector worldwide. Although the economic value to be extracted from earth observation data alone will diminish, as it becomes ubiquitous, value will come from combining these data with other sources of (proprietary) data that a customer owns.

Scotland as the employee gateway to the construction of New Space. The North East's Oil and Gas sector has developed great capability at sending workers offshore to hazardous environments, looking after them, having them conduct their job to exacting standards in dangerous environments, feeding them, caring for their health and wellbeing, and bringing them hope safely. This sector needs to pivot. Off-Earthing is the next step – as we start to build in space (labs, datacentres, hotels) or Lunar settlements on the moon or the mining of asteroids etc – Scotland can realign its ability from off shoring to off earthing. Rather than helicopters flying offshore, rockets will launch taking personnel off earth. The entire supply chain in this proposition from spaceship construction, to launch to health & safety and so much more is well within our reach and expertise. Come to Scotland – Go to space – do you job safely – come home.

Scotland has a long history of innovation and manufacturing, and it has an established space sector, delivering £180M of income in 2020/21 and employing 8,568 people in 183 space organisations, according to the Size and Health of the UK Space Industry 2022. Clyde Space Ltd e. in 2005 in Glasgow, and whilst now owned by parent company AAC Clyde Space AB, headquartered in Sweden, still represents the group's largest site, employing one hundred people by the end of 2023. The company has been designing and building subsystems for small satellites for 20 years, with a range of academic, industrial, and institutional customers all over the globe. The company also built the UK's first CubeSat, UKube-1, launched in 2014, for the UK Space Agency, pivoting the company from being a spacecraft subsystems supplier to providing full missions for its customers. The Glasgow site is now AAC Clyde Space's nucleus for satellite manufacture and is part of its satellite operations service.

Satellite manufacturers are now also set up in Glasgow, including Spire Global, and Alba Orbital as well as multiple other upstream companies such as Craft Prospect

and Bright Ascenion It has been well quoted that Glasgow builds more satellites than anywhere else in Europe. This strength is undisputed, and with the continued support of Scottish Development International to attract inward investment, and Scottish Enterprise to back growth of the sector, this trend should continue. There is also a large downstream sector in Scotland, and AAC Clyde Space is focussing its future on Space Data as a Service, delivering access to high-quality, prompt data from space to its customers, from weather forecasting to precision farming to environmental monitoring, essential to improving our quality of life on Earth. Again, we are not alone in this endeavour in Scotland. The central belt is fast becoming a 'space corridor' connecting the west to the east coasts and there is a wealth of companies analysing and delivering insights and services from space data to their customers, including Global Surface Intelligence, Astrosat, Trade in Space, Krucial and more. This is potentially where there is the biggest opportunity for Scotland as the global demand for communications, Earth observation, maritime services and even quantum services from space are set to increase.

With globally recognised Universities and Higher Education bodies in Scotland specialising in related disciplines including AI and ML, the country is poised to use the space applications opportunity. Finally, of course, the spaceport and launch offering has been tantalisingly close for some time, with funding having been invested into no less than 5 spaceports across the nation. There is no denying the opportunity is real, but the real market demand for such small satellite launchers and launch facilities is still to be realised. Aims of launching multiple times per year from multiple sites seem overestimated, while the rideshare market for small satellites is already well established, trusted, and dominated by SpaceX in the US. To maximise benefit for Scotland, we propose that the Scottish Government becomes an active user of space data derived from Scottish-built satellites, using skills from Scottish universities and Scottish data companies to process and analyse such data into services and insights. This requires dedicated focus, coherence, and funding within Scotland and with the wider UK.

Space is, by-default, a dual-use environment. The Ministry of Defence has made significant steps towards re-establishing a sovereign defence space capability. Much of this, by necessity as well as logic builds on prior UK civil investment, and, logically, future developments should pre-emptively seek out such civil-defence synergies. However, the Scottish sector is not well positioned to benefit from this investment trend as it is neither as intrinsically dual-use or as engaged with the defence and security industries as the sector elsewhere in the UK. Academia, in Scotland, should be supported to enable Scottish SME engagement in the space defence and security sector. Cyber security in the space sector is attracting significant international attention. The US recently launched a consultation on their proposed Hybrid Satellite Network framework. Germany has launched technical guidelines for satellite security, and the European Space Agency (ESA) has increased its focus on cyber security and resilience launching a 'Space Shield' tool to collect adversary tactics and techniques to develop an evidence base of attack types to enable ESA to strength it is security actions. This trend to build cybersecurity into the space ecosystem from a 'secure-by-design' perspective arises at a time when internationally there is a global shortage of skilled cyber security experts (currently estimated at, at least, 3.5 million).

The Scottish government has already found cyber security as a critical enabler of space sector growth; for example, working with ScotlandIS, a membership organisation for Scotland's digital technology industry, to begin identification of activities to enhance the cyber security stance of the Space sector. Given Scotland's global reputation in the satellite market, there is an opportunity for Scotland to lead in ‘secure-by-design’ cyber security resilience. This would, in-effect, create a competitive advantage for Scottish space businesses and, simultaneously, create a skilled workforce in the dual emerging domain of cyber: addressing skills shortages in both sectors.

Sustainability of the space environment will be a key sector-wide challenge, and opportunity, in the coming decade. Similar to the terrestrial environment, this is more than wealth creation and must be viewed in the context of losses incurred in an unsustainable space environment. Space has the potential to become a trillion-dollar sector in the 2030’s, with Scotland well positioned to secure a significant share of that if future investment is astutely targeted at ‘moving the dial’. Failure to preserve another natural environment from irresponsible human actions jeopardises this opportunity, alongside the vital contribution space makes in mitigating the impact of humans on the Earth’s ecosystem, and, to the NetZero transition.

The regulation of space is a reserved matter. Notwithstanding this, the ambition of the Scottish Government’s proposed Human Rights Bill to become one of the first common law jurisdictions to establish the human right to a healthy environment provides an opportunity for Scotland and the UK to provide further leadership through ambitious and strong legal protection and policy initiatives for environmental and sustainable protection by extending this human right into space. Enabling Scotland, and hence the UK, to provide global leadership and vision in the regulation of a sustainable space environment. It could be perceived that Earth observation continues to underdeliver on promised commercial potential. The new space Earth observation sector lags the rest of new space in Scotland. However, in Europe as a whole the new space Earth observation market is significantly outperforming the rest of the Earth observation sector. Scotland, and the UK, has proven a track-record of company creation but has failed to scale those companies, with market share significantly below pro-rata levels in comparison to leading ESA member states. Earth observation needs to look beyond its traditional core community, to engage with adjacent technology sectors where Scotland, and the UK, also has significant strengths, and to engage as a solution provider across the economy into challenge owner sectors such as FinTech and HealthTech.

Globally, the space sector is transitioning away from the concepts of ‘up’ and down’ stream. The sector is becoming more integrated, more ‘cross’ stream. This is clear in Scotland’s manufacturing (upstream) capability, with companies acting as service providers (downstream), who also build spacecraft, rather than as merely manufactures. This shift is not only higher margin, but it also enables the rapid deployment of novel capabilities that provide unique commercial advantage, often from within Scotland’s leading academic community which is itself a key attractor to inward investors in the sector. However, the lack of access to suitable finance, both private capital within Scotland and Scottish government investment into sector capability rather than singular companies that often merely drive staff movement

between companies rather than sector or economic growth, risks loss of potential as companies exits in pursuit of opportunities elsewhere.

There is already a bountiful photonics sector in the central belt of Scotland. That sector will be critical to future growth and capability in the near future for a range of applications (space situational awareness, earth observation, optical communications, amongst other things). In addition, that photonics sector is also breading a quantum technology sector, which itself will be critical to future directions of the space industry.

Edinburgh has a huge global network of collaborators and partners in the space sector. In order to continue to accelerate and maximise such initiatives, we would call upon both the Scottish and Westminster governments to find ways to ease the movement of international students and scientist, and to grow the opportunities for bilateral projects and novel space missions, such as GLAMIS. A key strategy for Scotland must also be to exploit the existing successful sectors. Beyond the technical and economic, we should not forget the social. Scotland's Inward Investment Plan sets out "our ambition for Scotland to be a leading destination for inward investment aligned with our values as a nation." Strengthening those values offers a further route to a USP. At Edinburgh we like to imagine a space nation that becomes the #1 choice for 50% of the population (i.e. women) because it provides a professional culture that allows them to succeed. Edinburgh University looks to do just that as a means to differentiate ourselves and unlock the transformation we aspire to achieve.

The Scottish space sector stands as a formidable force within the UK, yet its potential could be further realized by expanding its vision into sectors that are not only unique to Scotland but also overlooked within the broader framework of the UK Space Agency (UKSA). A particularly promising avenue lies in the domain of Space Sustainability, an area that has recently piqued the interest of UKSA, albeit with a limited focus on terrestrial debris and orbits. Crucially, there is a growing international interest, notably in the US, including NASA, about the utilisation of biotechnologies for sustainable space exploration and the potential benefits these could offer to Earth. This presents a unique opportunity for Scotland, given its vision toward sustainability and its remarkable ability in biotech and synthetic biology.

With significant funding predicted from the UK government over the next decade, Scotland has the potential to appear as a leader in the intersection of human space exploration and space sustainability. Edinburgh, in particular, stands out as a hub for this vision, hosting one of the only space biology research groups in the UK, spearheaded by myself as the principal investigator. The research group not only boasts a robust focus on space circular economy but also actively collaborates with esteemed entities such as NASA, ESA, and the Italian Space Agency (ASI). By using this expertise and fostering strategic collaborations, Scotland can position itself at the forefront of pioneering initiatives that redefine the landscape of human space exploration and contribute significantly to the overarching goals of space sustainability.

Looking at developing an ability in the use of robotics for space applications. These include opportunities in manufacturing of payloads, construction in orbit, debris

removal, in orbit maintenance, lunar habitat creation, lunar habitat sustainment and planetary (and other bodies) exploration.

The key opportunities for the Scottish space sector lie in the integration of university R&D, industrial satellite manufacture, satellite launch and downstream satellite data services with the advent of small satellite launch facilities.

3. What mechanisms and interventions are required to ensure Scotland maximises the benefits of the Space Sector for the Scottish economy?

Scotland's economic impact is dominated, particularly in the space sector, by SMEs – therefore we need to focus on how to improve creating and supporting the growth of SMEs. We have reasonable provision of support for spinouts and start-ups in the space sector (though more support would always be welcome), however where we noticeably fall down is the scale-up part of the journey – from say 10 FTE to 50 FTE. In particular the provision of mixed lab/office spaces for scale-ups. Access to labs (including cleanrooms, shared facilities, etc) collocated with offices is available for start-ups (e.g. via the ESA BIC UK), however there is limited availability for scale-ups – who obviously need more space but cannot (yet) afford their own dedicated facility. This is an area where intervention would support economic growth in Scotland. This should be geographically dispersed, not just in one location, as the need is spread across Scotland, albeit in concentrated hot spots. Another aspect is improving support for component and subsystem suppliers into the (world-wide) supply-chain for larger satellites / spacecraft. There are often complaints from the community that, for example, we do not get as much return to Scotland from ESA subscriptions as we should – which is dominated by where the primes are located (none being in Scotland). Therefore, the way to address this is to support the indigenous subsystem & component suppliers to join the wider European / world-wide supply chains and be part of consortium bids into ESA. This support could come from a combination of SDI, UKRI and UKSA:

- Skills mapping and development
- Support to space companies in order to guide more sustainable practices.
- Gov staying informed and engaging with the industry (due to the fast-changing priorities, challenges, and opportunities)
- Support with exporting products and services
- Support with UK gov and ESA procurement portals, which can be cumbersome and overly administrative, disadvantaging the SMEs that make up our sector and preventing access to government contracts
- A move from funding to government contracts at Scottish and UK level (particularly around earth orbit and geospatial insights)

I would explore further the potential divergence of industrial and academic capabilities and strengthen this through mechanisms to support new / sustain ongoing industrial / academic collaborations. Funding and delivery of collaborative R&D could be extremely beneficial here. I would also look at what translational assets we have to bridge the academic and industrial gap. Academic institutions income comes from teaching and research and quite rightly this will be their priority.

Industry is focused on delivering shareholder value through robust financial performance of their products and services. There is a gap here. Recently, a good game has been talked about the roles of universities in delivering innovation. I do not see this, and we should consider a translational asset supported by public-private partnership.

The interventions needed to ensure Scotland maximises the benefits of the Space Sector are:

- Cyber security skills development: Currently there are skills gaps in cyber security c. 3.5 million. When considering acceleration in technology and new markets such as space, this figure is likely to increase.
- Sector market positioning. I realise that the UK campaign 'Space for All' is developing the narrative that space is not just for scientists and engineers. However, I teach and supervise students in business schools on space entrepreneurship, and consistently these young people claim that space was not for them as they did not take a traditional (science and engineering) route. But when they are presented with the opportunity to explore space, they relish the opportunity and enjoy the experience. It would be beneficial to have funding to develop HE and Executive courses in Space Entrepreneurship, cyber security, and technology. There also needs to be more people working across Space Educations with a non-STEM background. I have analysed job adverts in the 'Space' sector and they by default include technical skills for jobs that do not necessarily require technical ability. One such example a job advert for education outreach in January 2023, specifically sought high level technical skills.
- Funding support for young entrepreneurs and women looking to run a business in the sector.
- Developing ambitious plans for manufacturing with end-to-end capability across the space ecosystem to be prioritised at speed to realise the potential of the sector.

Place based impact acceleration activities built around and using Scotland's ecosystem strengths and civic partnerships (e.g. in the central belt) would be highly UK competitive and timely in developing cluster activities to impact. The Scottish sector is based around SMEs, whose cluster development requires more support and can contribute overall less leverage. Training and capacity building (an effective multidisciplinary skills development pipeline across all relevant disciplines, from early career to leadership) is needed to deliver the stated strategic growth. Continuity of support is crucial at a time of the funding cycle when government funding is tight, and commitments are in danger of being short term. Unclear – Company creation and job creation are the obvious go to's but keen to understand and develop more. Investment and academic leadership and direction.

Scotland is a unique global jewel from geographical. environmental and technological leadership perspective. As a country we should pioneer the technology to capture data, analyse and show to the rest of the world how we can improve our life here on earth.

Linked to above either government as a customer or the direct introducer to larger global corporates who will co/fund the development for the likes of cyclops etc. Scotland offers its space companies an ideal ‘sandbox’ to develop and demonstrate services, from urban areas to remote settlements, from oil & gas to renewable, from protecting our fish stocks to our water. These services can both directly help our people and environment but also be exported globally to the multiple other countries that share similar challenges.

It is proposed that the Scottish Government would develop a national programme through which public and private entities could explore what space can offer and similarly allow space companies to understand the challenges faced. This would be further catalysed through a government-as-a-customer programme designed to make available data to the market for development, obtained from our very own Scottish space-based assets. This approach would bring coherency and stability to the ecosystem resulting in significant inward investment.

The space sector is R&D intensive: the UK’s space industry’s R&D investment is more than five-times the UK business average. However, both government stagey and the commercial nature of the sector distorts the nature of R&D investment towards the mid- to high-Technology Readiness Levels (TRL). Consequently, the sector is under-represented and under-active in the lower TRL range. This predisposition is repeated throughout the sector, in its representations and its governmental support with, for example, a tendency to focus on the commercially valuable outputs of the innovation pipeline rather than the inputs. This has created a disconnect within the sector. The Scottish government includes experienced users of satellite data, including agencies such as Marine Scotland, Nature Scot, and Scottish Environment Protection Agency (SEPA). These users should be supported to work with academia to inform and co-create future research programmes to address user needs with, for example, development of new sensors or data processing techniques to ensure enhanced impact and social value from publicly funded research.

Academia needs to be viewed as a key enabler and core part of the sector that is integral to future growth. Further recognition should be given to the value of basic research as the pipeline of future commercial innovations, and that engineering science underpins the technical innovations of the future. To this end, steps should be taken to encourage an increase in sector engagement in low-TRL research and consideration given to how academia might better support government with the identification of longer-term opportunities. This could include, for example, secondment into the civil service.

Training - Specific STEM national action/activity to push people towards the technological area of the space sector. There is an abundance of focus on astronauts and astronomy, but in reality, there are limited jobs. We need more of a focus on the technological side of space to promote those career routes. There is a critical lack of technical level workers for to support and grow the sector. There needs to be an intervention to bring more technical apprentices into the sectors. There used to be a technical graduate programme in the central belt that supplied technical graduates to aerospace companies in the past. The government could initiate a new joint programme bringing together the sector stakeholders.

Collaboration - Accessing space can be heavy on capital/infrastructure costs that spin-out, start-ups, and small-to-medium enterprises simply cannot afford. Many of those capital/infrastructure needs can be common and only needed intermittently. The creation of a “Scottish hub” that gives those unpractised players access to facilities will give them a significant boost over international competitors. Such a “Scottish Hub” would provide essential facilities such as space qualification machines, but also look to support the future sector such as optical test and measurement facilities (including an optical ground station). While the facility could also support the growing need of current “big industry” who themselves require more facilities for test and measurement.

Building space heritage – bringing together teams who want to space-qualify components and create space heritage through a series of funded (or co-funded) CubeSat missions.

Growth - Infrastructure to grow – currently a lack of places attracting the space-sector where manufacturing can take place at scale. National support for those looking to provide that infrastructure/real-estate.

One major challenge that University of Edinburgh staff are addressing is “the congestion in the RF spectrum with ever increasing demand for greater capacity, [which] is leading a drive to develop technologies that operate at higher and optical frequencies, including inter-satellite links.” Scotland has a concentration of expertise in photonics and optical communication system development at both academia and industry, which can be exploited to target future opportunities in developing high-speed satellite communications with less impact on the EM Spectrum. Scotland has to ensure we engage in UK-level bandwidth allocation and proactively lobby to ensure that protections are implemented, but simultaneously we support research in areas related to maximising the use of available EM Spectrum. Another key challenge in Scotland is that investment capital is expensive – investors take a higher share for the same capital as compared to London, and especially North America. Startups and spinouts therefore at once start with a disadvantage in global markets. Furthermore, growth capital is very scarce in Scotland. We must find ways to support our successful companies to become larger and even more successful. We consider it a priority for both the Scottish and Westminster governments to find ways to support such companies to scale and grow internationally. It is also vital that such support recognises the impact on the universities when staff members start a company. By way of example, we fully support the Royal Society of Edinburgh Enterprise Fellowship scheme (currently on hold), as that recognises the need to provide financial support for HEIs to host such endeavours. We need more initiatives like this.

The strategic priorities for the Scottish government in advancing the space sector are well-outlined and encompass a comprehensive approach. The Scottish government should focus on a) Invest in research and development to foster innovation and maintain a skilled workforce, this include provide appropriate and consistent funding for research, b) Establish partnerships with global space agencies for joint projects and knowledge exchange, c) Implement supportive policies and incentives for space-related businesses and research, particularly from the human exploration and the space sustainability perspective, d) Strengthen collaboration between academia and

industry to facilitate knowledge transfer, e) Foster education and training programs tailored to the evolving needs of the space industry.
There needs to be a coherent space sector industrial strategy that ensure time, money and effort is used to best impact:

- A Scottish CubeSat programme would support STEM outreach to deliver a pipeline of talent for the future. The provision of training by Scottish universities could be integrated to transition new graduates into the space sector, both for upstream and downstream activities.
- Bespoke funding opportunities for training and education related to the space sector will help support and keep a strong workforce. A critical pathway for skilled researchers would be through Centres for Doctoral Training (CDTs) in all aspects of the Space Sector.

4. **Which countries are going to be the most important international collaboration partners for Scotland and what is required to enable these partnerships and to ensure that Scotland is at the forefront of the sustainable space agenda?**

Space is inherently an international business; however, Scotland's closest collaborators will continue to be (in priority order): the rest of the UK; Europe; USA. There are individual projects/areas where specific international partners are important, whether that be Australia, or Singapore, or Japan, or elsewhere – but it is not clear we can really focus this down further. We need to keep our focus international, but also collaborate with our closest neighbours – particularly across the UK – to enable efficient delivery.

Aligning with other ambitious, fast developing nations make strong partners as there are emerging areas of constructive collaboration for knowledge sharing (e.g. skills development/ sustainability) but also mutual gaps that can be found. Switzerland, Portugal, Australia, Gulf nations, Malaysia, Singapore, etc. Despite improved cluster engagement across the UK, more could be done with wider UK nations.

For space data, Astro Agency's work on the UKSA funded International Bilateral Fund programme demonstrated the opportunities to export our capabilities to countries that need our support in local challenges (in this case the Gulf nations, but identifying other government departments around the world that have challenges that are suited to the capabilities of Scotland's EO companies would work well – Astro Agency completed a report for SDI on this very topic).

The US will always remain a clear partner for collaboration, enhanced by the TAA between the UK and USA, but again on the EO side I would suggest widening that to North America due to the huge EO segment in Canada.

There are huge opportunities in transferring skills from adjacent sectors right across the supply chain, from part manufacture to data scientists. The key is to build awareness in Scotland's space sector as not only an exciting place to work, but an industry that offers job security. The challenge around skills again comes back to the "challenge" of Scotland's strengths being so broad. It is difficult to say at this time whether launch vehicle manufacturers will be needed more than other areas of the

sector until the launch proposition has not only been developed but can deliver long-term security and results. Whereas more assured areas, such as satellite manufacture and data analysis are less of a risk, but again broad and diverse kinds of skillsets.

UK, Nordic, and smaller, technically strong EU counties such as the Netherlands. It is also worth noting that the competitor/collaborator/partnership space includes USA and Europe; in the latter case exploiting strategic partnerships post-Horizon association could present further opportunity and there has been a huge commercial shift in the nature of the US space industry which presents both a competitive challenge and a potential opportunity.

America, Middle East. Continual and persistent high level relationship building and strategic commercial development – Incentivised where possible.

Scotland should continue to work with the rest of the UK to use the relationships across industry and academia, cohered by UK Space Agency and other funding institutions. ESA is still one of the key partners to Scottish organisations too. In terms of specific countries, we expect that collaborations with Portugal, USA, Netherlands, South Africa, Sweden, New Zealand, Australia, and Canada will be valuable.

Given the heavily integrated nature of the sector across Europe, the European sector will remain vital. Moreover, the growth and investment of the sector in Ireland and their desire to work closely with and learn from the Scottish sector offers a unique ‘Celtic’ opportunity.

The “Five Eyes” – UK, Canada, America, Australia, and New Zealand will be critical for cybersecurity and telecommunications (inc. optical / quantum communications). Japan/Korea – scientific and components supply. America – big science and optical communications, EU – access to ESA funding for R&D.

Finland has a highly active tech ecosystem that has a good record of feeding into the space sector globally (e.g. Iceye). Within Europe, Finland is the most similar country to Scotland in terms of space activities and ecosystems. India has proven that they are a space nation at the forefront on the new space race. We should ensure we integrated with their progression. Australia, given its size and low population density, will soon rely even more heavily on satellite Earth observation: for agriculture, insurance, mining, Environmental, Social, and Governance (ESG), environmental impact, and early warning. There are clear synergies and alignments with Scotland and Australia’s space ambitions, and it make sense to build on that.

Cultivating collaborations with key international players is crucial for the growth and success of the Scottish space sector. Regarding the EU, Scotland should a) Establish and strengthen partnerships with EU space agencies, institutions, and industry players, b) Advocate for Scotland's participation in EU space programs and projects, c) Actively engage in Horizon Europe and other EU funding programs to enhance research and development opportunities, d) Work towards regulatory alignment to facilitate smoother collaboration post-Brexit.

Italy is becoming particularly active in the space sector, and collaborations are encouraged. I recommend strengthen ties with the Italian Space Agency (ASI) through joint projects and initiatives, collaborate with Italian space industry players like Kayser Italia, both in Italy and its twin branch in England, explore opportunities for knowledge transfer and joint research ventures.

Collaborations with India and China India should explore joint ventures and collaborative projects with local space agencies, leverage on each other's ability for mutual benefit, participate in bilateral space cooperation agreements to help knowledge exchange, identify areas of mutual interest such as satellite technology, long-term human space exploration, and Earth observation.

By strategically positioning Scotland as an active participant in international collaborations with the EU, India, China, and Italy, the Scottish space sector can use diverse ability, resources, and opportunities, contributing to its global standing and fostering innovation and growth.

5. **Does Scotland have the skills needed to support the space sector in the next two decades? Are there sectors with transferable skills that can be retrained? How do we promote a steady conduit of graduates with the necessary skills?**

We do not have enough STEM skills in Scotland. However, focusing on trying to poach skilled people from parallel sectors is entirely the wrong approach – but is one that people across sectors seem to keep promoting – this approach will fail as there are few parallel STEM-heavy sectors in actual decline where skilled people will be made available. Even the often reference oil & gas sector is in a bit of a revival and not shedding skilled people. The correct approach is to focus on building the general STEM skills base, not focusing on a particular sector – however we can use space as one of the 'poster child' sectors to attract more people into STEM education. This is a slow-burn activity as it needs to go all the way back to schools to encourage more children to study STEM skills at school to be able to study STEM courses at university/further-education. And we need to have a broad view of skills to include not just graduates but also for example technicians. This also crosses over into inclusion – particularly gender inclusion – as we can help alleviate the STEM skills shortages by encouraging more girls at school (including primary) to see STEM subjects as something they should seriously consider, as STEM subjects (and jobs) are not just for boys!

There are huge opportunities in transferring skills from adjacent sectors right across the supply chain, from part manufacture to data scientists. The key is to build awareness in Scotland's space sector as not only an exciting place to work, but an industry that offers job security. The challenge around skills again comes back to the "challenge" of Scotland's strengths being so broad. It is difficult to say at this time whether launch vehicle manufacturers will be needed more than other areas of the sector until the launch proposition has not only been developed but can deliver long-term security and results. Whereas more assured areas, such as satellite manufacture and data analysis are less of a risk, but again extremely broad and various kinds of skillsets.

Graduate skills yes. From recent experience undergraduates may have challenges in connecting with the Scottish space business base. If showed to be valid we should look at how we can bridge this gap and build a deeper mutual understanding. One approach could be to create a jointly sponsored academic competition – something like formula student. Manufacturing skills I doubt this given the competitive pressure in the employment sector from areas such as Scot Wind, Hydrogen etc. Again, I would like to see data here and seek the views of entities such as Scottish Engineering. Transferrable skills are an interesting area. Space is a regulated industry. I would start here and look at adjacent areas where we have a regulated sector. Oil and gas could be a useful start.

Skills Needed: Scotland currently has gaps in the skills pipelines needed to support the space sector's growth potential and ambition over the next two decades. The skills focus should include the following areas - AI and Data analysis, Cyber Security and risk management, Business, Innovation, and problem solving and Regulatory and Legal Knowledge.

Steady Flow of Graduates: The sector needs to continue to focus on young people from primary school through their education journey. In terms of FE and HE students, a wider offering of opportunities to study space across non-traditional routes, disciplines such as entrepreneurship and cyber security and a Space Summer Leadership programme. I have a podcast: 'Space: No Rocket Required' to try to open up the conversation about alternative careers opportunities are available in space.

The potential is there for a skills pipeline, building on Scotland HE (and FE) sectors. Iain has articulated potential existing activities/disciplines that could be used to produce the required multidisciplinary skills mix. A challenge is that the disciplines needed (e.g. robotics, systems engineering, computer science/informatics, sustainability) are extremely attractive to high growth sectors. The attraction to train/retrain to go into the Space sector is clear, and the Scottish strategy and signature activities in widening participation/early career development provide a useful signpost to opportunity. Sustained commitment to the development and support of the capacity building needed for space as a sector is needed; support needs to factor in the reduced leverage capacity/increased complexity in SME cluster development (see iii), as recognised by e.g. UK research councils for doctoral training.

Oil and Gas sector, video game development. We need to do a better job at promoting and educating about the sector and the opportunities. It needs to be a bold country wide endeavour – 'Your Country needs you' type of thing, Scotland's 'Moonshot' made by someone with credibility… We need to inspire primary school children to reach for the stars and S1 and S2 student to choose more STEM subject – especially girls. Organisations like the International Space School Education Trust should be signed up wholesale to deliver this in Scotland and significant investment made without forgetting underrepresented or socially economically deprived regions. We will also need space apprenticeships with a focus on vocational, practical capability.

Scottish Universities are world renowned, and certainly generate high calibre graduates with skills suited to the space sector, including mechanical engineering, aerospace/aeronautical engineering, systems engineering, software engineering electronics and electrical engineering, and various data disciplines such as data engineering, data analytics, Artificial Intelligence and Geographical Information Science.

Clyde Space Ltd certainly hires graduates from the University of Strathclyde and the University of Glasgow, we have excellent pipeline of talent and skills available in Scotland, however the current challenges of investing and developing skills for the Scottish space industry limits our talent prospects and opportunities. We could promote our skills capability by providing more specific space-focussed courses such as Space Science or Space Engineering, or even entire space departments at universities, the value of this would be to attract more talent into the country and internally develop our own skills pipeline for the sector. In England, the University of Leicester, UCL and the Open University all have dedicated space science courses, feeding the sector locally. The International Space University puts France in a helpful position with regards to space sector skills, and there are countless others in Europe such as TU Munich and TU Delft who feed the space sector in their countries. In the US, dozens of universities such as Caltech, Embry-Riddle, University of Colorado Boulder offer space science and engineering courses. Scotland pales in comparison. In addition to this, we could receive help from tailored Modern Apprenticeships, Graduate Apprenticeships, and advanced courses for qualified professionals to continue to develop skills development for the sector. It would support our local talent eco-system with strengthening the skills capability, especially for more niche skillsets. It is, however, important to acknowledge that there is a greater demand for experienced, skilled resources in Scotland at the moment, rather than graduates. With the current challenges around skills shortage within the UK, 20% of our workforce are educated, non-UK nationals. The talent pools from Europe and Asia provide experience and skills that are currently not available in the UK, or scarcely available given the competition for skills in our established Scottish Space industry. By developing a Scottish ecosystem for talent, the industry would be better placed to deal with future challenges. There are certainly other sectors with transferable skills – there is of course a large dependency on engineering skills, the space sector needs financial, HR, administrative and marketing skills like any other sector. Any manufacturing industry will have personnel suitable for satellite design, assembly, integration, and testing – especially from tightly regulated industries such as defence or pharmaceutical. Data engineering is the most transferrable – whether data comes from satellites or from other sources is immaterial. There may be opportunities to upskill or retrain from other sectors which has not been considered or aware of at this time. Members of the team at Clyde Space Ltd transferred from sectors as diverse as engineering, IT, nuclear, and oil and gas. Scotland has the foundation of skills to support the space sector with the capability to provide the skills for the future, with the right support and investment at a national level. Space is an inter-disciplinary sector that draws on a broad range of skills and capabilities, all of whom correctly identify as part.

6. **How can Scotland's space sector align with and contribute to broader national and international goals in areas such as climate change, AI, technology innovation, and education?**

There are huge opportunities around supporting net zero as mentioned already, but just to reiterate, this is both on the upstream manufacturing side but also in the ‘space data for our environment’ side. Scottish universities offer a wide range of space related courses, and this looks to be further improving. Whereas key enabling technologies like AI, quantum and areas like photonics have enormous potential to enhance Scotland’s space sector for years to come. There are significant opportunities here for space derived applications.

Areas which align to/leverage distinctive Scottish University strengths/strategic activities, including our recently published Research & innovation strategy, include climate change/net zero and AI and data.

Space needs to have a seat at the table to lead. Initiatives like TechScaler need to be more openminded, inclusive and collaborative. Industry and international partners need to evangelise about the importance. Barriers need to be removed. The sector needs representation in policy and strategy like NSET and we need vocal supporters akin to Mark Logan for Tech in the space sector.

Clyde Space Ltd specializes in small satellite technologies and services that enable businesses, governments, and educational organizations to access high-quality, prompt data from space. This ‘space data’ has a vast range of applications, from weather forecasting to precision farming and environmental monitoring. It is essential for improving our quality of life on Earth. Small satellites are critical for understanding our planet better and addressing pressing global challenges such as climate change. Small satellites can detect trends in key climate change indicators, such as ocean health or the size of the polar ice caps. With that data, we can make better decisions for our future. The combination of more cost-effective technology, ever-improving capability (e.g. Moore’s Law) and innovative commercial models such as Space Data as a Service, it has become practical for companies to use space without needing to invest large Capex or time.

For space to deliver its promised potential it needs to transition to an outward looking, underpinning sector of the economy that is ubiquitous across a vast range sector in a similar fashion to things like artificial intelligence, communications, and data analytics. Strategy and policy must accelerate this transition.

Involvement in Earth Observation missions through UKSA and ESA to allow more engagement in climate change and AI. Technology innovation is about collaboration. Creating stronger networks between industry and academic institutions will help the capability to apply for funding to conduct innovative R&D. At the end of the day, money is the key to all of this. More investment is needed to align and grow the sector. Industry needs to feed into university education to set the skills needed by students. Offering high school industrial placement options – something like the “Year in Industry.”

Scotland's commitment to addressing climate change through space technology can be further strengthened by expanding its focus on space sustainability and the circular economy. This strategic shift not only aligns with the United Nations' Sustainable Development Goals but also positions Scotland as a pioneering force in using space activities for the benefit of Earth. Initiatives such as the Bio-based

manufacturing in space group exemplify existing efforts that can be built upon. Exploring innovative approaches to reduce space debris and promote sustainable resource use will contribute to the region's leadership in these areas. Emphasizing the role of space activities in achieving UN SDGs (quoting the UN: “space activities are essential tools for realizing the achievement of the Sustainable Development Goals”), including environmental protection, poverty alleviation, and technological innovation, will highlight the broader societal impact of Scotland's advancements in the space sector. Integrating artificial intelligence and innovative technologies into satellite systems and data analytics will enhance efficiency and accuracy, fostering research and development in AI applications for space sustainability. Educationally, Scotland's commitment to providing high-quality programs, such as the recently established MSc in Astrobiology and Planetary Sciences in Edinburgh, ensures the continual development of skilled professionals in space-related disciplines. Public outreach initiatives, engaging schools, communities, and the general public, will further raise awareness about the societal benefits of space activities, emphasizing the link between space technology, sustainability, and environmental protection. This approach aligns with global priorities and underscores Scotland's dedication to using space technology for the betterment of Earth and the international community.

Work in harmony with the existing UK agencies (Catapults, Harwell etc) who are already pursuing activities aligned to these goals.

7. **What role do you see for public-private partnerships in advancing Scotland's space sector, and what models or examples could we look to for successful collaboration.**

Science missions are a good example of public-private activities that can work well – when strong project management and systems engineering drive the overall activity. The reason for Scotland’s space industry success to date is down to collaboration between public bodies (whether research or enterprise agencies) and industry stakeholders (established local on inward investment firms). The more collaboration the better and PPPs have proven to work in many nations. I would add that it is not all about money, there are ways that the public sector can support industry growth.

The preponderance of SMEs and the timescale and nature of the development opportunity requires public-private partnership and co-funding (see iii). The alignment of academia, industry government strategies, government, and relevant development agencies and the now combined National Space Strategy provides the driver for such integrated partnership programmes; the challenge is ensuring this connectivity by addressing the barriers which hinder such long-term support. UKRI Harmonised Impact Acceleration and Place Based Investments

Would need to consider more but Public 100% needs to be pump priming this sector and making it easy (especially on the investment side) for Private to get involved. The Scottish Space Network is regularly active in its plans to create a space investment marketplace leading to the creation of an investment fund. Players like SNIB and Seraphim are already expressing interest to SSN. Gov needs to de-risk. Furthermore – The government needs to start buying, as a customer, services from the sector – from upstream to downstream.

As with any Public Private Partnership (PPP) model, the main benefit is risk sharing. Risk sharing leads to a host of other benefits including the promotion of innovation and creativity, local supply chain development, alignment between academia and industry, more efficient delivery of public initiatives, diversity and equality, and increased exports. Space infrastructure programmes are inherently more risk laden than an average large scale terrestrial programme owing to the environment and lack of access to the assets once in place. Often considered to be working at the bleeding edge of technical development, it has become increasingly difficult to secure the necessary funding to realise plans with investors wishing to see proof of concept (or indeed, market). These are areas that the PPP model directly addresses and can be an effective way to mitigate these challenges. The UK Space industry, including Scottish companies, are running under this model with ESA and the UKSA. The perfect example of this success is xSPANCION, where AAC Clyde Space lead a trio of businesses in collaboration with ESA.

Within Europe, sub-national governments are supporting local space economies by acting as a contracted customer for space services deployed by new satellites. The Scottish & UK government both commission vehicles in other domains to support government business. Consideration should be given to acting as a contracted customer for novel space services, in support of core government business, developed and launched from Scotland. This must not be a ‘space for the sake of space’ approach and must ensure a focus on value for money in delivery of government business. As such, developed services would deliver significant export value. Government users of satellite services should be supported to work with the academic sector to inform and co-create future research programmes to address user needs and drive value for money in tax-payer services. On the commercial side, the tendency for government to issue grants rather than contracts hinders company growth. Government should look to function as a customer, supporting both the creation and delivery of new services for the government customer within a single contract. This will support the development of commercially practical, scale-able products, and investable companies. Increasing the offering of Graduate apprenticeships, Doctoral training programmes, and MSc – industry placements. Specialised MSc programmes within the space sector could be subsidised if a student were employed or to be employed by a space sector company on completion of the MSc.

A key area of potential improvement lies within the procurement processes within the space sector. A considerable proportion of Scotland’s current space industry is driven by Earth observation data – much of the hardware companies in Scotland are building satellites to collect data about the Earth. It is therefore prudent of the Scottish government to find ways to provide long-term (5+ years) anchor contracts to data suppliers who can then secure investment on the back of this committed contracts. Good examples of this model include TerraSAR-X, a public-private venture from the German government (via DLR) and EADS Astrium.

Enhancing collaboration among government agencies, academia, and private companies is pivotal for elevating the ability, impact, and transferable skills within the Scottish space sector. To achieve this goal, Scotland can draw valuable insights from successful international models of public-private partnerships in the space sector, learning from their effective strategies and implementation approaches. By adopting

best practices and tailoring them to the local context, Scotland can foster a dynamic ecosystem that maximizes the collective potential of all stakeholders involved in space-related endeavours.

Scotland's public finances will never justify such a partnership for Scotland to flourish in this sector it is all about private investment.

8. **In which areas of the Scottish technology industry and research community is the Space Sector already an important customer and what are the key relevant technologies.**

The main area that comes to mind is environmental testing, with the Higgs Centre in Edinburgh offering space companies shared resources to support SMEs at a crucial stage of their development. Similarly, the incubators and accelerators are hugely important for the space sector.

Cube satellite development. Emergent environmental monitoring applications. Increasingly, delivery of public services (such as social care) into highly remote locations.

Includes access to talent, relevant equipment/infrastructure, research/innovation, consultancy to support (predominantly) SME creation/development. Innovative technology developments and testing designed to meet the challenges of extreme conditions and e.g. payload, sustainability, data science technologies.

Would need to know more personally – a platform for understanding this and a spotlight shone on this nationally would be helpful.

As a cornerstone of the Scottish Space Sector, our organization has been instrumental in the development and manufacturing of micro satellites. We have had the privilege of seeing firsthand the remarkable growth and evolution of this industry. The success of the sector within our community can be attributed to the existing skills in the area. The Space Sector has given an opportunity to those with experience in 'Silicon Glen' to repurpose their world-leading manufacturing skills for space-related applications, thereby laying a robust foundation for the sector's development. Furthermore, the supply chain in Scotland that supports the industry is experiencing growth, a testament to the success and contracts being secured within the country. This growth is not only strengthening the entire supply chain within the country but also providing a plethora of technological partners for SMEs like AAC Clyde Space to collaborate with on countless opportunities.

These partnership opportunities enable us to support our collaborations with academic and research institutions. For instance, we have enjoyed a productive relationship with Strathclyde University for over three decades, with a project or program in progress every day since our first collaboration. While this is a specific task, we also engage with Glasgow University, keeping a functional relationship centred on product testing. This allows us to see both early technology development and final product testing. Research institutions play a crucial role in the space sector and continue to contribute to and support the growth of this industry in Scotland.

Those involved in Earth Observation, astronomical work, or creating their own CubeSat missions for in-orbit demonstrations.

Crucial components within the space sector encompass data analytics, remote sensing, materials science, and engineering, all of which are fundamental for satellite construction and launch vehicle development. Additionally, satellite communication technologies play an essential role, contributing significantly to the overall infrastructure and capabilities of the space sector. These key areas collectively form the backbone of advancements and innovations within the space industry, underscoring their integral nature in shaping the present and future landscape of space exploration and technology.