Space Academic Network (SPAN) Whitepaper: Academic View on the Future of Space Policy and Funding

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Introduction

This whitepaper is a summary of views from the Space Academic Network (SPAN) on UK Space policy and funding covering issues such as potential gaps in funding and their consequences, the role of ESA, bilateral and multilateral missions and the National programme along with links to industry and some general points. It is a view from the SPAN chairs, office and the chairs of Space Science and Exploration, Space Engineering and Technology, Earth Observation and Data Analysis Working Groups, along with those of other SPAN members listed above, and also tries to capture views expressed by the membership of SPAN gathered from other various working groups, Town Halls, and other meetings over the past year where discussions have been held and views discussed and aired.

Updated version 1.5 adds important points raised as a result of the European Low Gravity Association UK Space Agency microgravity workshop (6th September 2024), Space Partnership Board (10th September 2024) and the UK Earth Observation Conference (10-12th September 2024) and some comments (from a number of SPAN members) resulting from version 1.4. It should be noted that all versions from 1.4 onwards also attempt to address replies from the SPAN DSIT Delivery Review survey. A thank you to all these contributions and contributors.

These changes are indicated by side bars to the text.

Executive Summary

Space influences and impacts society through economic, cultural, education, knowledge, innovation and policy related activities.

The Space Academic Network (SPAN) believes the UK should:

- **Use Space to implement and ensure civic/societal policies**
- **Use Space as an innovation and science engine**
- **Use Space as a gateway for national and international business**
- **Use Space for resilience and security (public, defence, and environment)**

Academia is a key part of the sector alongside Government and Industry. Space is an industry which is important both economically and in generating knowledge, and hence needs to be a key part of Government industrial policy. Space is part of our critical national infrastructure, and will enable and help to power the economy in the future - indeed it is already doing so to a significant and growing extent.

To enable maximum return on Government investment in Space, a UK programme should consist a strong national programme, which in turn provides increased impact for the UK's significant investment in ESA, which must remain its prime focus. This coupled with bilateral and multi-lateral programmes, will enable the UK to lead the development of significant space missions from concept through to launch, operations and exploitation.

The UK spend through MoD on space is now significant: opportunities to develop dual-use technologies should be exploited to maximise benefit to UK tax payers.

Maintaining long-term commitments in all planning and funding is key for the UK to remain a reliable and trusted partner for collaboration on ESA, bi-lateral and multi-lateral projects.

As with industry, academia believes that, given the long-term nature of Space missions and research, a 10-year flexible funding cycle along with a 15-year outlook is appropriate (this

ideally aligned with the decadal planning for NASA Science Missions). This cycle should have a corresponding 10-year matching Research and Development (R&D) plan and strategy.

Gaps in funding to academia increase project risk, are highly likely to result in the loss of critical staff, and increase reputational risk for the UK. UK Universities are increasingly unable to cover funding gaps due to the financial problems facing higher education.

From an academic perspective, ESA involvement is an essential element of UK Strategy and Science and provides the UK with large science returns, ability to take part in world class missions, helps enable the UK's knowledge economy position and status, enables fundamental development towards demonstrators and operational type missions, and enables building of international partnerships and training of staff.

A strong national programme is required and needs to cover the ESA contributions. However, it also needs to cover national interests such as technology development, relevant infrastructure build, and supply chain development, along with value-added programmes such as bilaterals, nationally-led, and sovereign missions. Academia has an active interest in all of these aspects. A strong national programme is essential for growth in the Space economy and for maintaining the UK's knowledge economy position.

From an academic and SPAN perspective, bilateral and multilateral missions are highly valuable because they:

- increase science return to the UK
- help train the next generation of engineers and scientists
- allow the UK to adopt a first mover, demonstrator, innovator, or opportunist position
- allow joint UK industry-academia development
- satisfy a desired science return for gaps in the ESA programme
- build the Knowledge Economy
- allow the UK to be seen as a good partner and build partnerships helping the UK to exercise soft power

We also note the link to UK Launch and UK small satellite capability in bilaterals/multilaterals, and the need for potential Government procurement of missions both the scientific and demonstrator application variety. These at a minimum will demonstrate UK capability, including the industry supply chain, noting the opportunity to strongly promote the UK sector and its capability in small satellites and missions. Government-procured missions will enable the UK to potentially demonstrate capabilities in areas as diverse as marine security and pollution control, atmospheric pollution and health, monitoring climate change, Space Situational Awareness and Space security. Demonstrator missions could enable the UK to adopt a first mover position or at least possess a sovereign capability and may lead to operational and commercially based missions. We stress the need for data exploitation plans to be in place to maximise the return on the investment.

It is disappointing to see that recent Government strategies in areas such as AI, materials and others fail to mention Space either in terms of output areas or inputs driving need in these sectors.

Two areas should be addressed: (a) funding for early concept studies and (b) the need for funding very early technology development jointly between academia and industry. SPAN notes and applauds the EO data hub initiative but sees the need to continue to add to data sets to maximise economic and scientific growth in EO. The above initiatives would enable the UK to develop concepts and enable more rapid growth of the sector.

We highlight the opportunities and importance of UK rejoining the Horizon Europe programme and the Copernicus programme, these providing excellent opportunities for academia in terms of general Space technology, and for industry in terms of Earth Observation and Space Science.

The academic community and SPAN are increasingly coordinating views and holding discussions with industry via UKspace, the industry trade body.

> Academia and the sector aim to build on previous work and consultations about key strategy decisions resulting from DSIT and other Government commissions on roadmaps etc. enabling decisions and strategic plans to be an inclusive sector wide view.

There is rapidly growing interest across the sector especially in academia concerning the "Soft Sciences" aspects of the space sector: law and regulation, and the societal impacts of space, by policy and business-related studies. Given the strategic importance of Space to the UK, this should be funded in academia via UKRI or other suitable means. A first step could be to support centres or virtual clusters of such expertise. A significant UK strength, and opportunity for the UK space sector, is our combination of world-class expertise in science, technology, law / regulation, and finance.

It is clear that if the UK wants to maximise growth of the sector and attract and cultivate investment, then the funding for space needs to grow, noting this might be via a more co-ordinated use and repurposing of various funding sources currently "siloed" across Government including contributions to the "space infrastructure" from users.

> Flat cash settlements or cost reduction funding settlements will only unfortunately result in a degradation in UK capability, reputation (including global view as a reliable partner), growth and the knowledge economy and a reduction in future opportunities for future generations.

The key we believe is making space a key component of industrial and R&D strategy.

Funding Gap Implications to Academia and the UK

Academia is a key component of the UK Space Sector alongside Industry and Government, and contributes significantly to the UK economy. Academia underpins UK R&D, much of which is jointly with industry, as well as contributing trained people and innovation to the knowledge economy. Academia provides the Principal and Co-investigators for space missions across the sector, from space science and exploration to Earth Observation, and develops next generation instrumentation, technologies and data analysis methods, including applications of Artificial Intelligence (AI) and Machine Learning (ML). A growing number of groups within the UK also design, build, integrate and test instruments and subsystems for space missions, and even implement and operate small missions (mainly CubeSats to date). Spinouts from academia also contribute to the Space Economy and academia plays a vital role in training for the sector.

Academic contributions to the sector are delivered via a variety of mechanisms and funding sources. This funding (including grants and contracts from agencies, UKRI, industry and others) not only funds the R&D, mission implementation and exploitation, but also the organisations that attempt to co-ordinate academic views i.e., the Space Academic Network (SPAN) and Space Universities Network (SUN). SPAN enables the discussion of issues and co-ordinates views from academia from an R&D perspective, whilst SUN covers the teaching and training aspects.

The funding to academia is short-term; either limited to the duration of the project or by Government funding constraints such as the Comprehensive Spending Review (CSR) cycle, which has varied from yearly to 3 years. Given the long-term nature of Space missions and research, academia (along with industry) believes that a 10-year cycle along with a 15-year outlook would be more appropriate.

> This cycle should have a corresponding 10-year matching Research and Development (R&D) plan and strategy.

Some flexibility is needed within such a cycle, noting flat cash will only result in a degradation of UK capability. We note the use of decadal type planning for NASA Science Missions and the possibility of aligning UK planning with this cycle. Because of constraints like the CSR cycle, changes in policy, and delayed approval of budgets, gaps in funding to university space projects can and do arise, with important negative consequences.

The funding received is vital for the delivery of academic contributions, and any funding gaps have severe consequences.

> This is particularly because many staff, especially technical and engineering staff, are employed on "soft money", with internal university procedures requiring staff to be notified 6 months <u>before</u> possible end of funding in terms of possible risk of redundancy and for them to enter redundancy proceedings 3 months <u>before</u> the end of funding. As much of the detailed technical and project expertise is held by such staff and critical to the success of projects, such a loss of capability can prove extremely damaging. It is hence recommended that processes such as affordability reviews etc. are concluded at least 6 months before a CSR boundary.
>
> For many Universities funding in tranches is also not that practical when many, if not all of their project staff are on "soft money" given the redundancy issues mentioned above.

Although the funding gap scenario is not new, what is new is the fact that the Universities are struggling so much now financially that it may well be simply impossible to bridge such gaps. There simply is not the available cash flow. So, although academia used to tolerate this issue it is unlikely that universities collectively can continue to do so. This is because many universities are struggling to remain solvent due to the non-increase of student tuition fees (since 2017), recent inflation, and decreases in international student recruitment (due to visa changes and reducing demand). University costs have hence risen considerably but have not been matched by income increases. Universities are close to entering a "financial death spiral" with enormous implications to local economies (£100's millions if not £billions) as well as UK R&D if they fail.

Gaps in funding will result in:

- Loss of key and experienced staff
- Increased risk, potentially fatal to projects
- Reputational damage to UK if the UK fails to deliver on international projects e.g., bilateral/multilateral projects where the UK is a key player
- Significant delays and the need to restart UK based work and services. This applies to all hardware and analysis projects and supporting services, and organisations such as SPAN and SUN which provide services to the academic community and summarise and provide key inputs to the sector. Loss of such services to the sector from SPAN and SUN would lead to an inability to contribute to initiatives like the Space Partnership. Advice to decision makers would either be lost or become fragmented or highly specialised.

If the loss or gaps in funding are not overcome, then considerable to severe damage to the sector will happen, affecting growth, economy, and the knowledge economy, with the UK rapidly falling in ranking in terms of space powers.

It should be noted that academics contribute to many national committees, workshops, etc. using internal funding, this being unpaid work on top of normal responsibilities. For the reasons stated above, this is becoming increasingly difficult for universities to support.

We note the high growth rate and potential of the sector and the critical nature of the space infrastructure and assets in terms of underwriting the economy (~16% non-financial GDP Size and Health report) and as evidenced below its contributions to the knowledge economy. In terms of funding in general it is clear that if the UK wants to maximise growth, investment and return from academia then the funding for space needs to grow, noting this might be via a more co-ordinated approach and repurposing of various funding sources currently "siloed" across Government including contributions to the "space infrastructure" from users.

> Flat cash or cost reduction funding settlements will only unfortunately result in a degradation in UK capability, reputation (including global view as a reliable partner), growth and the knowledge economy and a reduction in future opportunities for future generations.

In the following sections potential areas for investment are highlighted.

Need for continued involvement in ESA

The Space Industrial Plan states "our membership of the European Space Agency is critical if we are to achieve our ambitions for Space". The 2022 review of UK investment in ESA demonstrated an economic return of £10 for every £1 invested in ESA. It is essential that the UK builds on this success.

The plan presents six actions to obtain maximum benefit from ESA, strengthen the UK's position, and provide confidence for the sector (quoting from the plan).

Academia endorses these actions to:

- Create a more coherent UK cross-government framework that enables the UK to prioritise its own programme investment decisions clearly and robustly at future Councils of Ministers.
- Influence the programmes that are developed by ESA to align with UK competitive advantage, capability requirement and space science goals.
- Provide a clear strategic timeline of priority areas of investment, linked closely to the Capabilities Plan, spanning multiple Spending Review periods.
- Assess the skills and facilities that the UK benefits from through ESA membership, to better evidence and inform policy decisions.
- Maximise the benefit of the European Centre for Space Applications and Telecommunications (ECSAT) based in Harwell, working closely with ESA as they explore possible future areas of focus for the site.
- Facilitate greater collaboration with wider international partners beyond ESA member states.

From an academic perspective, ESA involvement is an essential element of UK Strategy and Science and enables:

- Large science returns. An example here is the ESA Gaia mission which has resulted in a crucial database which is the largest and most precise 3D space catalogue ever made, totalling approximately 1 billion astronomical objects, affecting all areas of astronomy from the solar system (mapping asteroids) to galactic dynamics. See below.
- Technology development for world class missions beyond current UK budgets, for example the LISA gravitational wave mission planned for the 2030's and UK's involvement in JWST via the MIRI Instrument (an instrument consortium led by the UK).

- UK academic science strength across all areas for science exploitation. The UK's science strength and leadership (see below) has arisen from the UK's involvement across all areas of space exploration, including traditional Space Science (astronomy, planetary science, magnetospheric physics), Earth Observation, and Exploration.
- The UK's current knowledge economy position. UK academia undertakes technical R&D development in conjunction with industry, science analysis and operations support, as well as producing science output, see above and below.
- Building of international partnerships e.g., science and technology, and also industry, both domestic and international, with an economic return, see below.
- Some Earth Observation missions, as well as those delivering science (for example the ESA TRUTHS mission for climate measurements) lead, in the medium to longer term, to subsequent demonstration and operational missions e.g., Aeolus which resulted from the ESA Earth Explorer programme. It is notable that such missions enable science as well as societal return. Similar developments are starting to occur from magnetospheric missions e.g., the Vigil mission, and similar developments may be expected from Space Situational Awareness missions for example in planetary defence.
- Training of staff; although this tends to be more experienced staff as a minimum level of experience is required to undertake a role in an ESA programme. See national and bilateral programmes along with general points section below for the overall picture of training.

Failure to continue to invest in ESA would result in the UK suffering severe reputational damage. Alongside UK academia, the majority of this impact would be on UK industry, and it would impact both current projects and future opportunities.

> Academia is very willing to engage with the UK Space Agency ESA team to discuss issues associated with the various ESA programmes and support production of inputs to and the Council of Ministers (CMIN) meeting itself as needed.

To enable maximum return on Government investment in Space, a UK programme should consist of a tightly coordinated involvement in ESA, a strong national and bilateral/multilateral programme, along with nationally led missions (see above and sections below).

Academia recognises that, for industry, ESA missions may not be that profitable, with recent moves by ESA to place increasing amounts of risk on the contractors, threatening profitability and consequently willingness to bid. Equally, academia recognise that ESA has invested heavily in developing costly technologies for some of its planned missions, when national funding has been insufficient. The National Programmes of ESA member states (see below) provide the funding for the instruments for the Space Science and Exploration Missions.

ESA and Space Science

Regarding space science, in late 2020, SPAN commissioned a report from know.space on the space science research community and its benefits. We also note that the Space Partnership commissioned three independent reports in 2024 on UK Leadership; space science was ranked top in all three reports. These and the SPAN report highlight the science impact from what to date has mainly supported by the ESA programme and hence its importance to academia. The SPAN report was commissioned via the previous chair of SPAN, Prof. Andrew Holland. This report is available for download from the SPAN website (https://span.ac.uk/wp-content/uploads/2021/04/SPAN-UK-space-science-nature-benefits-FINAL-REPORT-060421.pdf). The term space science in the report includes lunar and planetary science and solar physics, space weather and space plasma physics. As highlighted for example in the know.space report, (paraphrasing) "although the UK has true global leadership in only a few small areas in Space, Space Science[1] being one, it sits amongst the leading nations in a wide variety of significant areas".

At the time of the SPAN report (April 2021) "53 universities were active space science researchers with over 2000 researchers at post-doctoral level and above engaged in the scope within the report". In particular the report noted "that a wide range of non-university organisations and networks played a role from public organisations such as UKRI-STFC through to companies such as Airbus DS, Thales Alenia Space, Teledyne e2v and others – employing many more researchers". All these "other actors" contribute to astronomy, its impact and return as well as the wider topic of space science. The report also looks beyond the economic and scientific benefits. The report has not been updated due to lack of available funding. The majority of UK academic involvement is currently via the ESA programme. SPAN notes in passing the decision from Thales Alenia Space UK to close its Bristol base which provided science-based systems work and their move to concentrate on defence and propulsion in the UK, we believe this is a real loss to the UK in terms of academic collaboration as well as the UK industrial base.

Figure 2 within the SPAN report showed 40 universities involved in astronomy. The in-depth case study within the report covers the **Gaia** space astronomy mission (see also above and below), as an example of UK involvement which has a major impact and is continuing to do so. Figure 8 of the report shows the field-weighted citation impact for space science publications, showing the world-leading position of the UK in citations resulting from publications. Figure 9 of the report shows the OECD analysis of UK share of space publications, with the UK ranked 4th in the world and 2nd globally in terms of share of the top 10% highly cited publications (at the time of the report). Both illustrate the UK as a "science superpower". This position has come about due to ESA membership and an active role in its programmes.

The success and impact of the ESA Gaia mission, which is providing a unique map of the Milky Way, providing precise positions and astrophysical characterization of over 2 billion stars in our Milky Way, is demonstrated by the vast numbers of peer reviewed papers generated using Gaia data. Gaia is the most scientifically productive space science mission ever flown by ESA. The recent 2023 report by know.space, commissioned by the UK Space Agency, demonstrated the significant impact and return to the UK of the UK Space Agency investment in the UK participation in the Gaia project. The report concluded that "The mission has clearly had a positive impact in terms of enhancing the reach and reputation of the UK space sector. The picture presented in this report is one of clear benefit both for the UK's reputation, and its competitiveness in the space science domain. There are numerous examples of where nationally-funded Gaia roles have led or is expected lead to UK involvement in other missions, such as PLATO, Euclid and – if it is taken forward – GaiaNIR."

Exemplar ESA science missions include:

- An example of a large science mission outside the boundaries of UK-only funding is involvement in the NASA/ESA **James Webb Space Telescope** (JWST) mission. Scientists and engineers in the UK were crucial to the development and launch of the Mid-Infrared Instrument (MIRI), which can see the faint light from the most distant stars, effectively looking further back in time than ever before, and can peer through dust and gas to spot stars being born. MIRI was designed, built, and tested by a European Consortium of 10 member countries led by the UK, in partnership with the US. The European contribution is led by Professor Gillian Wright MBE of

[1] The term Space Science can be confusing because its scope is interpreted differently by different users: the alternative term Space Research and Innovation has been proposed at a recent SPAN Earth Observation Working Group (SEOWG) meeting.

STFC's UK Astronomy Technology Centre (UKATC), and includes STFC RAL Space, University of Leicester, and Airbus UK. The UK's lead role in the MIRI instrument involved (and continues to involve during flight operation) taking responsibility for the overall design, science performance, and the mechanical, thermal and optical design, along with the assembly, integration, testing and calibration software. The UK (UK Space Agency since 2011 and STFC) has invested almost £20 million in the development phase of MIRI.

- **Ariel** is an example of a future ESA mission that illustrates all the key points from the academic point of view, namely UK leading science and mission, world class science, working internationally, with ESA and industry. The size and cost of the mission would be unlikely to happen under a national or bilateral mission scenario. Due to launch in 2029, Ariel's mission is to understand the links between a planet's chemistry, its evolution and its host star, by characterising the atmospheres of 1,000 known planets outside our solar system. Ariel, which was proposed by an international consortium led by University College London (UCL), was selected by the European Space Agency (ESA) from 26 proposals put forward to be the next 'medium class mission' in its science programme. The UK will lead the overall science of the mission and head up a consortium of 17 countries building the mission's payload module. This investment is the first major long-term commitment that the UK has made to space science since the publication of the National Space Strategy and the leadership role will provide an unprecedented opportunity for the UK space sector's academic base. The £30 million is provided through the UK Space Agency's National Space Science Programme and is *in addition* to more than £6 million the Agency has already provided to support UK teams during Ariel's study phase up to March 2022. This investment will secure the UK's scientific leadership of the mission and will incorporate the delivery of Ariel's payload module, cryogenic cooler and optical ground support equipment, as well as science operations and data processing.

  UK organisations contributing expertise to the UK's role as Ariel mission consortium Principal Investigator and payload lead include University College London (UCL), Cardiff University, University of Oxford and the Science and Technology Facilities Council's (STFC) RAL Space at the Harwell Space Cluster in Oxfordshire. Teams at RAL Space will build and test the Ariel payload module, managing hardware contributions from other consortium nations, while the STFC Technology department is developing the £5.5 million cryogenic active cooler system. Scientists at UCL and University of Cardiff will lead performance analysis, testing and fine-tuning the complex algorithms that will process the data returned from Ariel. The University of Oxford team will deliver the equipment to test Ariel's payload telescope and optical elements.

- **Euclid** is a recent ESA mission which is already producing ground-breaking science, see https://www.esa.int/Science_Exploration/Space_Science/Euclid/ESA_s_Euclid_celebrates_first_science_with_sparkling_cosmic_views#:~:text=The%20early%20findings%20showcase%20Euclid's,galaxies%20have%20evolved%20over%20time for early science results. The UK has played a leading role in the conception and development of Euclid. The UK Space Agency has invested £37 million in the mission, supporting world-class UK science and funding research teams in 7 different institutions across the UK to contribute to the mission.

  The production and operation of Euclid's imager for visible light, VIS, is led by University College London's Mullard Space Science Laboratory (MSSL), and researchers across the country have developed data processing pipelines to analyse the data, including the gravitational lensing analysis that will create maps of dark matter from the VIS images. The VIS Principal Investigator is Prof Mark Cropper at MSSL. The MSSL team has responsibility for managing the instrument consortium that has designed and built the various subsystems for VIS. MSSL is also directly responsible for the development of the detector chain of the instrument (the readout electronics receiving data from the sensors and their associated power supplies).

The charge-coupled device (CCD) detectors were provided by Teledyne e2v in Chelmsford, under contract to ESA. In addition to the lead role on VIS, the UK also has a strong role in the development of the Ground Segment for Euclid. This includes a Science Data Centre in Edinburgh and the lead role on cosmic shear measurements and analysis, a critical element of Euclid science. Professor Andy Taylor of the University of Edinburgh leads the development of the UK ground segment, with contributions from research teams at Oxford University, Cambridge University, University of Portsmouth, University College London, MSSL, the Open University and Durham University.

Other ESA Missions where the UK has a significant role and a large academic interest include the launched and on route ESA-Jaxa **BepiColombo** mission to Mercury, the **JUICE** mission to Jupiter and its icy moons; the **Athena next generation** X-ray telescope mission; and **PLATO** (due for launch in 2026) which will seek to identify and characterise 'Earth analogue' exoplanets, which in turn will be key targets for follow-up studies by Ariel and Webb.

ESA and Earth Observation

On the Earth Observation (EO) side, the ESA Earth Explorer (EE) missions provide a vital input to global EO science, with the UK taking science and study leadership and science management roles; instrument builds are carried out by industry. Scientists in UK universities have played leading roles in several recent EE missions, covering a broad range of geoscience topics:

- **Cryosat** (1st EE mission) for ice studies,
- **Aeolus,** observations of the global wind field, with significant impacts in meteorology,
- **SWARM**, for Earth's magnetic fields,
- **Biomass**, due for launch in 2025 and intended to provide a global inventory of carbon stored in Earth's forests,
- **FORUM**, due for launch in 2027 to study the thermal balance of the Earth.

Specialist missions such as **TRUTHS** complement this programme along with the Sentinel programme of satellites funded by ESA and the EU. The UK has a high interest in and leads TRUTHS which will set a "gold standard" reference for climate measurements based around UK (led by NPL and others) based technology. Future missions in the Earth Explorer class have high UK academic interest e.g., Wivern (EE 11) and Hydroterra+ (EE 12). Eumetsat "first mission demonstrators" are delivered via ESA involvement, with Eumetsat paying for subsequent missions, data from these missions will support the EO science community as well as government and industry users.

Other opportunities for EO include ESA Scout missions with their €35m cost cap and UK bilateral missions, see below regarding the latter. We note the value-added products resulting from EO missions for application areas such as insurance, agriculture and decarbonisation.

We also note the opportunities and importance of UK re-joining the Horizon Europe programme and the Copernicus programme, which is providing excellent opportunities for academia in terms of general Space technology, and for industry and academia in terms of EO.

The initiative to form an EO Data Hub to demonstrate data analysis for development of applications and science was welcomed by the academic community. Continuing to add (and procure where necessary) data for this facility enables users to investigate ideas at low cost, addressing the "low TRL" side of software and data analysis development. Data procured via sovereign (see below) or other missions to demonstrate the full range of EO data and types of applications, is encouraged to enable all types of users. We note the need for data exploitation plans and mechanisms to be in place for missions to maximise the return to the UK, initiatives like EO Data Hub being an example. Regrettably only now are discussions underway we believe on UK sovereign missions like NovaSAR.

We note the UK initiatives in large scale exabyte computing and high-performance computing are needed from a science point of view and for example modelling of new materials and technologies for use in the sector. SPAN notes however the "silo" problem with many facilities not joining the dots across different areas of application. The SPAN Data Analysis Working Group (SDAWG) will produce a white paper in 2025 addressing the need and ideas to consolidate Space Science data analysis, to enable access to all the different and complementary data sets available today and thereby increasing knowledge return. Past initiatives and facilities for EO are noted.

Scientists trained on data-intensive science projects such as EO data analytics or Gaia, often go on to work in commercial data-intensive industries with benefits to the UK.

ESA and Space Exploration

On the Exploration side there is high UK academic interest, with many objectives for both lunar and Martian science, including the **ExoMars Rosalind Franklin rover** which will provide the first look at geochemistry and possible signs of life at depths below the surface, and **Mars Sample Return** where the full range of laboratory based diagnostic techniques could be used on returned samples. The £377 million UK total investment in the ExoMars rover, associated technology and instruments is noted. Lunar science in terms of its geochemistry and In-Situ Resource Utilisation (ISRU) are also key interests for UK academia. The ESA Exploration Programme also provides a "home" to academia interested in microgravity from understanding the physics and chemistry of materials, through to astronaut health, with the latter being a model for aging processes in humans here on Earth. A recent example has been the interest shown in the possible Axiom UK mission. Microgravity science provides key inputs and understanding for some aspects of In-Orbit Space Manufacturing (IOSM) a key area of interest for the UK.

> We note however the issue of multiple "siloed" funding sources for this science as well as Space related technology development (the latter in general), and the need to link this to the National Space Strategy.

ESA enables both strong science but also the first steps towards areas such as the low earth orbit, cis-lunar and deep space economies. An example are the ESA plans to investigate In-situ Resource Utilisation (ISRU) on the moon, which requires a combination of planetary geochemistry, instrument, and technology development.

Space exploration is also a test-bed for the technologies of space robotics and autonomy which will underpin future industries of the in-orbit space economy expected to develop over the next decades.

ESA and Space Technology

ESA is a major sponsor of European space technology development. UK universities are involved at early-stage (low Technology Readiness Level, TRL) development, and then often work with UK industry to mature the technologies either for direct commercial exploitation, or for further maturing through the ESA process.

> The community hence welcome national GSTP funding and see this as a crucial step in developing technologies and applications.

The UK's national funding is a key enabler of access to the ESA programmes such as ARTES (satellite communications) and NAVISP (Positioning, Navigation and Timing, PNT, technologies). These two programmes support UK space industry to pioneer new space services and often involve UK universities because of the expertise of their staff.

Much of the future growth of the UK space sector will build on the technologies of communication and PNT, and continued UK support for these areas in universities is critical to enabling innovation and for training the people who will make it all happen.

Need for a strong national programme and bilateral missions

The UK national Programme funds instruments and technology for ESA and other missions. As a minimum the programme should cover the ESA contributions, however it also needs to cover national interests such as technology development, relevant infrastructure build, and supply chain development, along with value-added programmes such as bilateral/multilaterals and nationally-led missions. Academia has an active interest in all of these aspects. A strong national programme is essential for growth in the Space economy and maintaining the UK's knowledge economy position.

The UK now has both civil and military defence space strategies and has committed to investing to realise both. There is therefore a significant opportunity to leverage the many dual-use technologies in which UK universities have expertise (e.g., large space structures, propulsion, communications, radar) to benefit both the nation's security and its space sector. There are clear benefits in using the UK's total "space spend" wisely, to avoid unnecessary duplication and to leverage civil / commercial technologies for the defence sector. See also National Space Programme section below.

Space safety, including the functions of space situational awareness and elements of space traffic management for collision avoidance, have clear benefits to both civil and military space operators. This is another area in which universities have relevant expertise (e.g., satellite dynamics and control, space sustainability, space weather, autonomous systems) which can be used to benefit both society and commerce, and to position the UK for international leadership.

Bilateral Missions

Starting back in the 1960's and through to the 1990's the UK ran a series of nationally led missions as well as co-operating with important partners in bilateral or multi-lateral missions. Examples of these past missions include the very successful X-ray astronomy **Ariel** series (1962 to 1979), the NASA/DLR/UK **ROSAT** mission (1990-1999) which conducted the first all-sky survey of XUV sources (60-300 angstroms), and the NASA/UK **Swift** mission that has been investigating gamma-ray bursts since its launch in 2004 and is still operational and producing excellent science today, in particular in conjunction with the ground-based LIGO gravitational wave observatory. This kind of mission funding came to a halt due to funding limitations before the formation of the UK Space Agency. Recently, bilateral missions have been reinstated, following lobbying by SPAN and others, and discussions with, and business cases prepared by, the UK Space Agency.

Bilateral missions have been implemented in two forms: (1) A Science and Exploration programme; and (2) an International Bilateral Fund (IBF), this latter fund focussed on industry based and/or strategic partners e.g., NASA, Five Eyes, etc. We note that EO missions currently only have one route via the IBF. We also note how national or bilateral/multilateral missions in other countries outside the UK have led to either ESA contributions to those missions or an ESA mission itself e.g., the Cheops (CHaracterising ExOPlanet) mission in 2019 originating out of Switzerland.

From an academic and SPAN perspective, bilateral/multilateral missions:

- Increase science return to the UK
- Help training, in particular of the next generation of engineers and scientists
- Allow the UK to adopt a first mover, demonstrator, innovator, or opportunist position
- Can link to UK Launch and UK small satellite capability
- Allow joint UK Industry academic development
- Satisfy a desired science return for gaps in the ESA programme
- Further build the Knowledge Economy
- Allow the UK to be seen as a good partner
- Build potential partnerships, allowing the UK to exercise soft power

We note that the (recent) bilateral funding has improved other agencies' views on collaborating with the UK, as it is now seen as a potentially reliable partner, whilst prior to this the UK was seen as a centre of excellence but without funding to support collaborations.

A variety of mission study concepts, instrument developments and contributions to major missions have been funded by the recent bilateral programmes. On the science side, this spans Cosmology (via a contribution to JAXA's LiteBIRD mission) through Solar Physics (NASA's HelioSwarm mission) to lunar science (LEAP, a Canadian/NASA Mission) and UV observing (CASTOR, a Canadian lead mission). Studies include contributions to the Canadian Space Agency and JAXA's Mars Ice Mapper mission, through radio spectroscopy via CosmoCube (NASA/ University of Arizona) to the Enceladus Thermal Mapper for a NASA Saturn mission. This funding is also reasonably well-distributed across the UK's groups, primarily associated with recognised space hardware institutions and some based on past and existing collaborations.

The IBF fund has also addressed a cross section of opportunities ranging from Space Nuclear power solutions (two studies by Rolls Royce and the University of Leicester) through to AI for Space operations (Strathclyde) to Planetary Protection (Open University), alongside more industry-led mission focussed studies such as Aquawatch (SSTL) looking at water monitoring, to a programme with Inmarsat with Japan's Mitsuibishi Heavy Industries.

An excellent example of a bilateral EO project is the **MicroCarb** mission with the French Space Agency (CNES) for which the UK is the minor partner. The objective of MicroCarb is to collect precise atmospheric column CO_2 data that can be translated into regional estimates of carbon emission and uptake. This will improve our ability to monitor changes in the natural carbon cycle and emissions from human activity and help track international progress towards meeting the goals of the Paris Agreement. MicroCarb is due to launch in the first half of 2025.

MicroCarb is the first European mission that has been built to study the carbon cycle. It will become part of a virtual constellation of satellites, some of which are way beyond their intended lifetime. As such, the launch of MicroCarb ensures continuity in the satellite data record of atmospheric CO_2.

UK scientists and engineers have a range of roles from assembling and testing the satellite, ground segment algorithms to translating the data into new policy-relevant scientific knowledge about the carbon cycle.

The UK Space Agency has invested £15 million in the mission, securing UK expertise involved with the assembly, integration and testing of the satellite, design and build of key parts, data collection, algorithm development and scientific mission preparation. Project partners include the National Physical Laboratory, Thales Alenia Space UK, STFC RAL Space, GMV UK, and the Universities of

Edinburgh and Leicester. The UK PI of the MicroCarb project is Professor Paul Palmer from the University of Edinburgh whose work helped to motivate the business case for this bilateral.

Recent technology development funding from (UKRI) STFC and UKSA for space missions is welcomed and supports the ESA and bilateral programmes, however, it is heavily oversubscribed. A particular issue is funding for early development of mission concepts that will dictate the medium to long term ESA or medium term bilateral (or national) missions, so that the UK can be leading space science (and other space) missions rather than being just a partner. Such funding existed in the past (15-20 years ago) but has been "squeezed" out due to budgetary pressures. Current funding focuses on short to medium timeframe opportunities, with some development already achieved rather than more "speculative" ones. This issue is true across all elements of Space in the UK from EO to astronomy, and is true for ESA, bilateral and (possible) national missions. Noting missions (of all varieties) may turn into demonstrators and operational missions or at least heavily inform them.

The need for timely concept studies is exemplified by significant UK academic interest in the proposed NASA Habitable World Observatory where the UK would like a significant role (as per MIRI for JWST) and where US-based industrial studies are already underway. There is a significant danger that the UK will be "too late to the party".

National Space Programme

Recent funding from the UK Space Agency (UKSA) for bilateral and multilateral missions outside of ESA, as described above, has been welcomed by the community and has increased the number of astronomy (and other) missions the UK may take part in. However, there are many more missions, opportunities and ideas than can be funded, so an increase in programme budget along with a dedicated parallel and linked UK small satellite programme would be welcome in the future. Such an expanded programme could utilise UK launch capability and stimulate the use of "home grown" missions, contributing to building the UK supply chain as well as providing training and inspiration for uptake of STEM subjects (Science, Technology, Engineering, and Mathematics) and general public scientific literacy. It would also form a set of case studies to inform the public as to how Space affects their daily life via EO and other missions, and what science missions can deliver. Such a programme would support needs across the sector and Government, and greatly increase outreach possibilities.

Furthermore, we note the need for potential Government procurement of missions of the demonstrator application variety, which could enable the UK to demonstrate capabilities in areas as diverse as marine security and pollution control, atmospheric pollution and health, and Space Situational Awareness (SSA). Demonstrator missions could enable the UK to adopt a first mover position or at least have a sovereign capability which in turn may lead to operational and commercial missions. We note the recent launch of the Tyche Space Command (visible imager) mission as the first part of a sovereign Intelligence, Surveillance and Reconnaissance (ISR) system and reports that data will be available to other government users. Degraded or selected data from such a system could be useful to academic users as well as outlined in the SPAN Dual Use report from the workshop in November 2022.

These types of mission contribute to other UK capabilities, including research and the manufacture of small satellites. Potential Government procurement of such types of mission at a minimum would demonstrate UK capability including the quality and resilience of the industry supply chain.

In terms of training the Bilateral programmes offers junior staff and Early Career Researchers (ECRs) the opportunity to build experience and capabilities that may be harnessed later under the ESA programmes.

The issue of existing commitments in all planning and funding is key, as is the need to deliver on them for the UK to remain a reliable and trusted partner for collaboration at both ESA and bi-lateral and multi-lateral levels.

The bilateral approach may also enable use of soft power to eventually build export opportunities for the UK via initial science or demonstrator type collaborations with various countries. Collaboration with the Global South being an economic area worth targeting alongside current collaborations.

Links to industry

UK academia is increasingly working with industry on projects and technology development for Space. There is a common interest linked to economic return and a need for an integrated financial and knowledge economy, with academia transferring knowledge, IP (Intellectual Property), and skills to industry, and academia benefiting via funding and impact (as well as publications), impact being an increasing important key deliverable for universities given current assessment/performance criteria.

Academia can also provide a means to link industry to different sectors, industries and knowledge bases based on their multi-disciplinary nature, for example, AI, advanced materials, etc. These collaborations form the basis of many of the various Space Clusters around the UK (see General Points, below).

Industry and academia work together via a variety of methods including sponsored and contract research, projects of mutual interest, for example ESA, UKSA, via academic spinouts, training, and outreach projects. One of the keys for the future of the sector is very early (proof of concept) joint development of technologies and techniques, prior to (any substantial) commercial investment and return. This is to enable ideas to be explored before harnessing other methods of funding for more advanced and proven concepts. To date, such funding tends to support only one partner, where an integrated approach is required and where academia is paid for its time, and industry costs are covered (at least partially). This 'SuperSprint' approach is based around the Sprint programme funded previously by Research England (where only academic time was paid for). Such a scheme would allow early development prior to applying for higher TRL (Technology Readiness Level) development funds via UKRI or UKSA or other funding streams. This would be similar to the early mission concept funding, described above, enable growth and capability within the sector as well as eliminating unfeasible and uneconomical concepts at an early stage, giving a "Fail Fast" approach.

Academia forms the bedrock of training for the sector. This is achieved via degrees, postgraduate training (MSc and PhD), and, increasingly, via Continuous Professional Development (CPD), micro-credentials and degree level apprenticeships. Academics lead much outreach to both children and the public. Examples include supporting and working with the National Space Academy based at the National Space Centre in Leicester, the national STEM centre in York, and academics (and industry professionals) giving talks to schools, local societies, and organisations. Much of this emphasises widening participation and reaching underserved and underrepresented communities as a priority, in order to help the UK space sector to address the issues of diversity and inclusion.

Academia is now working closely via organisations like the Space Academic Network with UKspace on areas of mutual interest such as Space Policy, funding etc. Academia can now directly contribute to Space Policy via the Space Partnership and has direct contact with UKRI (UK Research and Innovation), DSIT (Department for Science, Innovation and Technology), DBT (Department of Business and Trade) and UKSA (UK Space Agency) alongside workshops and discussion meetings (including those in professional bodies e.g., the Royal Astronomical Society - RAS). This enables academia to provide guidance and advice to decision makers; this ability should continue and be strengthened.

General Points

Space services society in three main ways, growing knowledge, growing the economy through space-based services and infrastructure, and providing security for the public and environment. All three parts of the sector are required to deliver these objectives: Government, Industry and Academia. Space can address issues such as tracking and investigating societal challenges such as climate change and pollution of the environment, and aspects of societal interest such as our place in the Universe and the possibility of Life elsewhere. Space as critical infrastructure underpins society and can help protect the planet from Space Weather and eventually asteroid impacts via Planetary Defence, and in the longer term enable use of off-planet resources.

R&D underpins all of Space and the economy, it should be noted that, given the wide ranging and interdisciplinary nature of Space, there is important cross-talk between adjacent technologies and sectors. *It is disappointing to see that recent Government strategies in areas such as AI, materials and others fail to mention Space either in terms of an output area or provision of inputs driving need in that sector.* We note the potential spinouts, spin-ins, and spin-alongs with these other areas. A more joined-up approach is required to inform UK industrial and research policy. R&D by academia deals with fundamental knowledge but increasingly applications and technology developments, many jointly with industry, see sections above. We hence, like industry, would like to see Government take a co-ordinated and integrated approach to enable the most in terms of the sector, in particular as a key and growth industry for the future and to ensure efficient use of Government funding.

There is rapidly growing interest in academia concerning the “Soft Sciences” aspects of the space sector: law and regulation, and the societal impacts of space, by policy and business-related studies. Given the strategic importance of Space to the UK, this should be funded via UKRI or other suitable means. A first step could be to support centres or virtual clusters of such expertise. A significant UK strength, and opportunity for the UK space sector, is our combination of world-class expertise in science, technology, law / regulation, and finance.

The Space sector is an enabler of new technology, with highly skilled people advancing national capability in Earth Observation, Space instrumentation design, planetary science, telecommunications and data science. The sector hence underpins responses to climate change and other global environmental challenges, where the UK has world-leading scientific strength and strategic interest. Economic growth of the UK’s Space sector is anticipated to be largest in the downstream services (EO, connectivity, etc. – including the broad field of drone technologies). Nurturing talent and enhancing support for the development of skills at the interface between EO and applications alongside Space technology and instrumentation will address the brain drain and signal to the international Space sector that the UK supports long term capability and capacity. Investment in skills will also enhance porosity and collaboration between academia, industry, and the public sector, enhancing the UK's ability to grow the sector and the knowledge economy and develop and use EO for societal, economic, and environmental benefit.

> Additionally, such an approach will create diverse career pathways across academia, industry and the public sector where skills are transferred across different domains. ‘Loosing’ an early career scientist to industry, creates a new opportunity in academia (assuming available funding) and equally boosts the growth of a startup, SME or Prime with novel technology or applications, the

net effect being that “all the boats rise together” – collectively growing the sector and the opportunities for all, particularly if there are funding streams to encourage collaboration between academia and industry, see other text.

The 2021 UKSA Space skills survey showed that growth of the UK Space sector is currently limited by a severe skills shortage which risks missed scientific insights, slow adoption of emerging technology and an inability to scale up companies. 42 companies stated that “...we are struggling to recruit the skilled people we need... [we are] limited by a severe skills shortage, which if not addressed risks slowing our ability to scale up and grow our companies in the UK.”

The lack of PhD graduates is a problem for these industries now, however, the problem will worsen in coming years as the UK government’s vision and societal need is for the sector to expand rapidly. Organisations are already struggling to recruit skilled people and this will worsen as priorities such as Nature Based Solutions, net zero, extreme event prediction and climate change mitigation grow in economic importance. At a time when the Government’s National Space Strategy (NSS) and the Defence Space Strategy promote development of the Space Economy for the benefit of the UK, and the rate of global change increasingly needs skilled people to provide amongst others geospatial insights, a lack of suitably trained people will be limiting for the economy and the environment. To maximise Space sector benefits for the UK it is crucial that research institutions, government bodies and industry work together to deliver the strong pipeline of talent identified in the National Space Strategy through excellent post-graduate training provision. This again pointing to a co-ordinated and integrated approach across Government.

Sustainability is a key interest in the UK, with the UK aiming to become a world and in particular a thought leader, and the sector also has a role to play in terms of maintaining and not degrading the Space environment as well as using less resources to function in Space. R&D in these areas is needed jointly with industry, whilst the Government tackles the national and international politics around these issues.

Many academics have commented on the timescales and differing application processes for UKSA and other Government funding. In particular the relatively short notice and the need for long applications (10’s of pages in general) given other pressures on academics (teaching etc.). Academia hence recommends, where possible, a two-stage process with a short initial Expression of Interest (EOI) type followed by a detailed application after initial sifting of the EOIs. We also note the possibility of a database of key organisations, individuals and their capabilities rather than having to generate such documentation for each application as CVs and organisation capabilities do not tend to change on a short timescale. A special points of interest section in any application would address special points of note relevant to that application.

Some space research groups emerging from non-engineering-based disciplines e.g., biology have raised the issue of linkage to expert academic groups who may advise or even help them with respect to engineering of their concept. A list of academic and industrial organisations with appropriate expertise could be held via UKSA or SPAN (with funding) and made available on a web site.

Academia and the sector aim to build on previous work and consultations about key strategy decisions resulting from DSIT and other Government commissions on roadmaps etc. enabling decisions and strategic plans to be an inclusive sector wide view.

We note EU ambitions expressed recently by Ursula Von der Leyen including:

- **Boosting productivity with digital tech diffusion:** She has committed to stepping up the investment in the next wave of frontier technologies, in particular space technology, super computing (AI Factories initiative, European AI Research Council), semiconductors, the Internet of Things.
- **Putting research and innovation at the heart of EU economy:** She has pledged to expand the European Research Council and the European Innovation Council, focussing on strategic priorities including green and digital transformation and high value technologies and establishing new research infrastructure and laboratories. This will include strengthening the collaboration between research departments of universities and business, and investing in University Alliances.
- She has committed to putting forward a **new European Competitiveness Fund** which will invest in strategic technologies – from AI to space, clean tech to biotech.

Space can and should be used for good in terms of solving the climate crisis and addressing (e.g.) many of the UN Sustainability Goals. Space enables many things and improves society and is criticality important to the UK with academia providing a vital role and input. UK Investment in Space is critical to the future development of the UK, its economy, society and the World. The sector in the longer term is building the foundations for humankind to establish itself off planet as well on the Earth.

References

Space Industrial Plan, Department of Science, Innovation & Technology, March 2024

Size and Health of the UK Space Industry 2022, Know Space on Behalf of UK Space Agency, March 2023

National Space Strategy, HM Government, September 2021

National Space Strategy in Action, HM Government, July 2023

Plan for Space Sustainability, HM Government Summit Meeting, June 2022

Evidencing UK Leadership in the Global Space Sector. A report for the Space Partnership. Know.space February 2024

Report from Space Academic Network Dual Use Workshop University of Leeds 5th December 2022, Version 2 14th March 2023, available on request from SPAN

UKSats: The UK Satellite Programme Leading Global Space & Partnerships, White Paper from Space Academic Network March 2024

Impact evaluation of UK investment in ESA, UK Space Agency, Nov 2022 (https://www.gov.uk/government/publications/impact-evaluation-of-uk-investment-in-esa/impact-evaluation-of-uk-investment-in-esa-executive-summary)

Gaia Interim Impact Evaluation: Interim Impact Report for the UK Space Agency, know.space, March 2023, https://www.gov.uk/government/news/report-highlights-impact-of-uk-contribution-to-the-gaia-mission

Bilateral Mission Information Courtesy Matt Crosby and Caroline Harper UK Space Agency

Website References

https://www.gov.uk/government/news/james-webb-space-telescope-launch-celebrated-by-uk#:~:text=The%20mission%20is%20led%20by,with%20partners%20in%20the%20US.

https://www.gov.uk/government/case-studies/euclid

https://www.gov.uk/government/news/mission-to-explore-life-on-mars-one-step-closer-as-uk-team-to-replace-russian-components-for-mars-rover November 2023