Evaluating the benefits of the UK's investments in the European Space Agency

Impact and value for money report

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Preface

The UK Space Agency (UKSA) commissioned RAND Europe and Ipsos UK in November 2023 to conduct monitoring, evaluation, and benefits management for the United Kingdom's (UK's) investments in the European Space Agency (ESA). This study aims to assess the impact, delivery, and value for money (VfM) of the UK's investments, underpinned by comprehensive benefits management. Its objective is to inform the accountability of UKSA's ESA programme spending and provide learning for programme teams, analysts and policymakers, focused particularly on exploring the uncertainty around monetised benefits and the relative scale and uncertainty surrounding non-monetisable (quantified or otherwise) benefits.

This study began with an interim report scoping out the study's initial phase, followed by a comprehensive monitoring and evaluation (M&E) framework to assess the benefits of the UK's investment in ESA. This impact report is the final output of this study. It is accompanied by a separate executive summary and a non-public process evaluation report, of which the headline findings are incorporated here. It also includes a methodological annex that details our approach and additional detailed findings. These products were quality assured by Dr Susan Guthrie and James Black at RAND Europe, Chris Hale at Ipsos UK, and our expert advisory panel (see below).

RAND Europe is the European arm of RAND, a non-profit research organisation that aims to help improve public policy and decision-making through objective research and analysis. This study is undertaken through the RAND Europe Space Hub (RESH), which brings together RAND's civil and defence space expertise to deliver space-related research for governments in the UK, Europe, the United States (US), Australia and Japan.

The **expert advisory panel** for this study comprises space technology and policy experts: Dr Bonnie Triezenberg and Dr Peter Whitehead from RAND US, and Amanda Regan (independent, ex-ESA).

Ipsos UK is the British arm of the global market research organisation Ipsos, with extensive experience in theory-based and complex economic evaluations. Ipsos UK has expertise in multi-stranded programmes and policies, particularly in the innovation, net zero and environmental sectors, involving long-term process and impact/economic evaluations, plus advisory work on science and innovation policy.

For more information about the study, RAND, or Ipsos UK, contact the project lead:

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Executive Summary

The United Kingdom (UK) has been a member of the European Space Agency (ESA) since its inception in 1975 and has played a significant role in its programmes and initiatives. The UK Space Agency (UKSA) is responsible for managing the UK's involvement in ESA, which provides access to European space infrastructure and collaboration opportunities with other member states. This partnership has been crucial in supporting the delivery of the National Space Strategy (NSS), with approximately 70–75% of UKSA's annual budget dedicated to ESA activities.[1]

This evaluation finds that the UK's investments in ESA continue to deliver significant value to the UK economy, scientific and technical advancements, commercial success and a boost to the UK's reputation as a key player in space, more so than could have been achieved without the UK's ESA membership.

The UK is a leading nation in ESA, securing important contracts and mission leadership, yielding cutting-edge scientific and technical achievements via missions such as space telescopes and heliophysics. UK entities have developed world-leading technologies and capabilities, including facilities, instruments and mission leadership. The UK can also exploit the results of that Research and Development (R&D), with UK firms commercialising and leveraging the products of their ESA engagements.

The benefits of ESA are wide-ranging. Entities not involved in ESA contracts may still benefit from spillover effects, spin-offs and spin-ins from working closely with firms that are. Key capabilities in producing solutions for non-space applications in the medical and climate fields demonstrate that the UK's ESA membership benefits society as a whole despite long lead times on such innovations.

UKSA plays a major role in helping UK entities participate in ESA programmes. UKSA has also made a concerted and successful effort to increase the industrial return figures, resulting in more UK contracts and a lower deficit than overall spending.

Overall, every £1 public investment in ESA programmes leads to £7.49 directly benefiting the UK economy. The local and wider UK economies benefit significantly from ESA membership, with lasting increases in growth, employment, productivity and private investment for UK firms involved in delivering ESA contracts over the last decade. Thanks partly to efforts from teams within UKSA and efforts from organisations bidding for ESA contracts, the UK has achieved near parity in the UK's geo-return figure, a measure of how many contracts UK firms win relative to overall spending.

[1]Environment Agency (2021).

The UK's engagement with the ESA contracting ecosystem presents both opportunities for growth and significant challenges. UKSA's intermediary role is crucial in bridging the gap between policy and industry. However, more operational capacity is needed within the agency to provide direct support for UK bidders. Work is also needed to map capabilities in the UK vis-à-vis ESA using ESA's Reporting, Oversight and Coordination System (EROC), sub-contracting data and strategic studies to better understand the strengths and gaps ahead of the ESA Council at Ministerial Level 2025 (CM25).

Despite the UK's strengths in early-stage technology and instrumentation development, the national capacity to manufacture, test and integrate a full mission is limited. The number of industrial primes in the UK essentially constrains the UK's ability to capitalise on these contracts as and when they arrive, representing a key opportunity for the UK. It also underscores the importance of funding space sector investments throughout the development pipeline to enable UK stakeholder benefits at all levels.

To better realise the benefits of ESA membership, UKSA and the wider government could set out a better long-term national strategy/mission for the UK space sector and its investment in ESA that is well known and subscribed to by industry, academia and other organisations. It could also boost its national programme to complement ESA and better exploit downstream products.

Stronger cross-government alignment is needed to maximise the benefits of the UK's ESA membership. Despite various initiatives to promote alignment, such as via a National Space Council, space policy, decision making, procurement and R&D functions are still fragmented and spread across different government departments and agencies, as well as the military UK Space Command. Better alignment on space capability development and strategy is needed to streamline resources and focus on a whole-government approach to achieving domestic goals via ESA. Clarifying UKSA's role and enhancing its technical capabilities could support efforts to proactively align UK national space interests, work across government departments and agencies, leverage the UK's strengths and address capability gaps.

Despite its strong overarching strategy, the UK must bring industry along in delivering a long-term national and ESA strategy. The UK does well in securing leadership in high-profile missions but must focus on exploiting those missions' benefits and downstream opportunities.

On the industrial side, national funding has been crucial in driving the commercialisation of space technologies and supporting the growth of small and medium-sized enterprises (SMEs). There is a growing call for increased national funding and an expanded UK national space programme to further strengthen the UK's position within ESA and globally.

Ultimately, very few of the benefits described here would be achievable outside of ESA, which gives the UK access to collaboration opportunities with leading European companies and technologies and a pooled resource from which to draw.

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Abbreviations

ADRIOS	Active Debris Removal/In-Orbit Servicing
ARIEL	Atmospheric Remote-sensing Infrared Exoplanet Large-survey
ARTES	Advanced Research in Telecommunications Systems
BASS	Business Applications Space Solutions
BCR	Benefit-Cost Ratio
BERD	Business Expenditure on Research and Development
BIC	Business Incubation Centres
BSD	Business Structure Database
CA	Contribution Analysis
CAGR	Compound Annual Growth Rate
CCI	Climate Change Initiative
CCI SST	Climate Change Initiative Sea Surface Temperature
CM	ESA Council at Ministerial Level
CMUG	Climate Monitoring User Group
CNI	Critical National Infrastructure
CTP	Core Technology Programme
DiD	Difference-in-differences
DSIT	Department for Science, Innovation and Technology
ECV	Essential Climate Variable
EGNOS	European Geostationary Navigation Overlay Service
ENDURE	European Devices Using Radioisotope Energy
EO	Earth Observation
EROC	ESA Reporting, Oversight and Coordination
ESA	European Space Agency

EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FBC	Full Business Case
GHG	Greenhouse Gases
GNP	Gross National Product
GNSS	Global Navigation Satellite Systems
GSCIP	Global Supply Chains Intelligence Pilot
GSTP	General Support Technology Programme
GVA	Gross Value Added
HMT	HM Treasury
HRE	Human and Robotic Exploration
IPTF	Industrial Policy Task Force
ISS	International Space Station
ITT	Invitation To Tender
JAXA	Japan Aerospace Exploration Agency
Juice	Jupiter Icy Moons Explorer
JWST	James Webb Space Telescope
M&E	Monitoring and evaluation
MANTIS	Mission and Agile Nanosatellite for Terrestrial Imagery Services
MIRI	Mid-Infrared Instrument
MoD	Ministry of Defence
MOSWOC	Met Office Space Weather Operations Centre
NAO	National Audit Office
NASA	US National Aeronautics and Space Administration
NAVISP	Navigation Innovation and Support Programme
NOAA	US National Oceanographic and Atmospheric Administration
NPL	National Physical Laboratory
NSS	National Space Strategy
NSSIF	National Security Strategic Investment Fund
NSSP	National Space Science Programme
OA	Output Area
ODP	Open Data Portal

ONS	Office for National Statistics
PLA	Plasma Analyser
PNT	Position, Navigation and Timing
RAL	Rutherford Appleton Laboratory
RC	Return Coefficient
ROI	Return On Investment
SDiD	Staggered Difference-in-Differences
SEBP	Space Science and Exploration Bilateral Programme
SME	Small and medium-sized enterprises
SRS	Secure Research Service
SSTL	Surrey Satellite Technology Ltd
STEM	Science, Technology, Engineering and Mathematics
STFC	Science and Technology Facilities Council
SWA	Solar Wind Analysis
SWIMMR	Space Weather Instrumentation, Measurement, Modelling and Risk
ToC	Theory of Change
TRL	Technology Readiness Level
TRUTHS	Traceable Radiometry Underpinning Terrestrial-and-Helio Studies
UCL MSSL	University College London Mullard Space Science Laboratory
UKSA	United Kingdom Space Agency
UNFCCC	United Nations Framework Convention on Climate Change
VfM	Value for Money

1. Introduction

This chapter presents the policy context in which the evaluation of the UK Space Agency's (UKSA's) investment in the European Space Agency (ESA) operates and introduces this study's objectives and approach.

1.1. Policy context

1.1.1. The UK's history with and investments in ESA

The UK has been a member of ESA since its inception and has significantly contributed to ESA programmes and initiatives. The UK's involvement in ESA is delivered via the USKA, providing access to wider European space infrastructure and collaboration opportunities with other member states. It has been critical in supporting the delivery of the **National Space Strategy (NSS)**.[2] The NSS goals include growing and levelling up the UK's space economy, leading pioneering scientific discoveries and using space to benefit UK citizens and the world. The UK's participation in ESA programmes also supports broader policy objectives, aiming to harness the UK's strengths in science, technology, research and innovation. These include the 2021 **UK Innovation Strategy,**[3] which states the UK government's intention to become a global science superpower by 2030, and the 2023 **UK Science and Technology Framework.**[4] Innovation and economic growth of the UK space sector are key in supporting the government objectives outlined in these policies.

ESA member state ministers approved a record budget of €16.9bn for 2022–2027 at the ESA Council of Ministers 2022 (CM22),[5] representing a 17% increase from CM19 (2019–2024). This funding is divided across nine thematic programme areas (seven ESA domains):

[2] Environment Agency (2021).

[3] Department for Business, Energy and Industrial Strategy (2021).

[4] Department for Science, Innovation and Technology (2023).

[5] European Space Agency (2022a).

- Space Science and Basic Activities.
- Telecommunications.
- Earth Observation (EO).
- Human and Robotic Exploration (HRE).
- Space Safety.
- Technology.
- Navigation.
- Launch.
- Commercial.

Participation in the Space Science and Basic Activities programme is mandatory for all ESA member states. Participation in the other eight programme areas is optional, and individual member states are free to decide how to allocate national funding to each area and its component projects. Effectively monitoring and evaluating different ESA programmes requires varying monitoring and evaluation (M&E) intensities due to the variability in investment size and programme area design.

ESA receives approximately 70–75% of the UKSA annual budget, and the UK has committed £1.84bn between 2022 and 2027.[6] This commitment included £615m for the mandatory core science budget and a notable £315m for EO and climate programmes, representing a 45% budget increase (primarily due to investment into Traceable Radiometry Underpinning Terrestrial-and-Helio Studies [TRUTHS])[7] supporting priorities highlighted in the **UKSA Corporate Plan 2022-25**.[8] The UK's commitment to ESA secured several projects, including launching the UK-built Rosalind Franklin Mars Rover, the Vigil space weather mission and the TRUTHS climate laboratory. Additionally, the UK committed to sending three new UK astronauts into space.

The UK is the fourth largest contributor to ESA across the mandatory and optional programmes, a position it has maintained in multiple successive ministerial periods, behind Germany, France and Italy, as shown in Figure 1. At CM22, the UK contributed €1.89bn to ESA across all programme areas, making up 11.2% of ESA's overall €16.92bn funding portfolio as defined at the CM22 meeting. While the UK's absolute contribution at CM22 increased by €237m, the proportion of overall funding provided by the UK decreased from 11.4% to 11.2%, primarily due to increases by smaller nations.

Figure 1 shows the UK's commitments to ESA compared to other countries at CM19 and CM22. Again, it is important to emphasise that payments to ESA do not directly reflect where and when ESA allocates its funds; therefore, it is important not to overanalyse these figures. More comprehensive insights are available from geo-return and contract-based information; however, long-term trends across CM periods can still be discussed.

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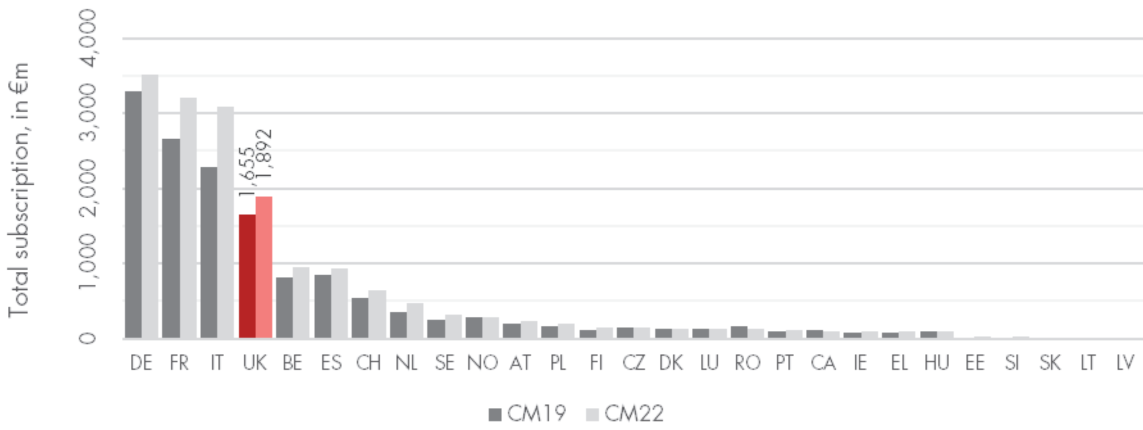
[6] As subscriptions to ESA programmes are made in euros, Gross Domestic Product (GDP) figures are subject to foreign exchange rates. This figure includes £378m to mitigate the volatility of foreign exchange rates and inflationary impacts.

[7] Department for Business, Energy & Industrial Strategy (2022).

[8] UK Space Agency (2024a).

Figure 1: ESA subscription by country at CM19 and CM22 in euros (millions)



Source: RAND Europe analysis of ESA documentation. The UK is highlighted in red.

The UK's funding of these optional programmes is decided at a national level for each ministerial period based on national priorities. Table 1 shows the UK's high-level contributions to each programme area between CM19 and CM22. While most funding over the statistical period has been dedicated to mandatory programmes and activities, it is important to note that investment in these programmes is calculated based on participating countries' gross national product (GNP). This ensures a proportional contribution from each nation, aligning their financial support with their economic capacity. Such a funding structure underpins the sustained investment in essential research and development (R&D) activities. In addition to mandatory elements, a significant proportion of funding was allocated to EO activities. This was particularly relevant in the UK's withdrawal from the European Union (EU) (Brexit) and the resulting uncertainty regarding access to EU-led EO programmes, such as Copernicus, when these commitments were made. This allocation aligns well with the NSS's emphasis on the importance of EO for monitoring and managing environmental change.

Table 1: UK investments at CM19 and CM22 by programme area

Programme area	Investment at CM19, £m (€m)	Investment at CM22, £m (€m)
Space Science and Basic Activities (Mandatory)	606 (708)	631 (722)
The only programme element that involves required spending within the portfolio allows ESA to invest in purely scientific missions exploring our solar system and deep space. Recently launched missions include Jupiter Icy Moons Explorer (Juice), Euclid and the James Webb Space Telescope (JWST).		
Earth Observation (EO)	228 (266)	321 (367)
Covers a wide range of programmes that support both upstream satellite development and downstream applications for EO data. With an estimated launch in 2030, TRUTHS has been a key investment in this area.		
Human and Robotic Exploration (HRE)	180 (210)	222 (254)
Supports both human space flight missions and the development of robotic capabilities for planetary exploration within the solar system. This programme funds UK astronauts and supports the Rosalind Franklin Mars Rover, which has had its launch rescheduled.		
Telecommunications	259 (302)	212 (242)
Seeks to drive advances in the development of satellite communication technology, including advances in quantum and other advanced wireless communication.		

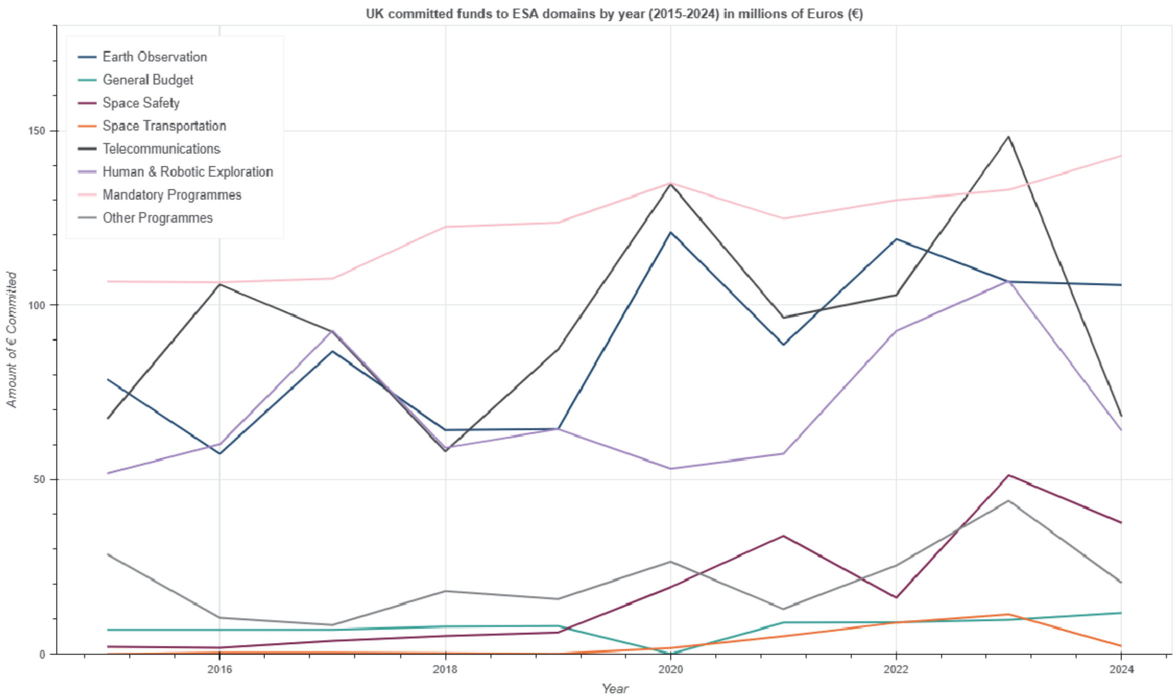
Programme area	Investment at CM19, £m (€m)	Investment at CM22, £m (€m)
Space Safety	87 (102)	114 (130)
Mission-driven, to ensure the safe use of space and the protection of critical infrastructure in situ. Vigil, a spacecraft in development that would enable near-real-time monitoring of solar activity and facilitate improved space weather forecasting, has been a key priority for UKSA.		
Technology	37 (43)	73 (83)
The General Support Technology Programme (GSTP) allows the UK to direct ESA funding to technology being developed by UK companies. This programme aims to support innovation that will be flown on future missions or lead to commercial applications.		
Navigation	26 (30)	32 (37)
Largely invested in the Navigation Innovation and Support Programme (NAVISP), the domain seeks new solutions derived from positioning, navigation and timing (PNT) data.		
Launch	13 (15)	13 (15)
Boost! seeks to drive a commercial launch capability, with the UK supporting firms that can develop cube and small satellite launches.		
Commercial	N/A	4.1 (4.7)
ScaleUp is a new programme created at CM22, designed to enable and accelerate space commercialisation.		

Source: RAND Europe analysis of CM19/22 Full Business Cases (FBCs). The CM22 FBC was conducted post-ministerially (confirmation of the investments made), whereas the CM19 FBC was conducted pre-ministerially (may not align with actual investments). Currency conversion at contemporaneous rates, rounded to the nearest million GBP. As of 15 November 2019, 1 EUR = 0.8566 GBP. As of 15 November 2022, 1 EUR = 0.87455 GBP. Rates sourced from the European Central Bank.[9]

Figure 2 and 3Figure 3 illustrate where UKSA funds are allocated within thematic programme areas and then against an average (second figure, black dashed lines) based on the same for the other top five contributing ESA member states (France, Germany, Italy, Belgium and Spain). The UK and other major contributors to ESA follow broadly similar funding trends, suggesting the top contributors follow cohesive strategies in some areas. It also highlights the UK's strong national priorities in funding telecommunications and space safety.

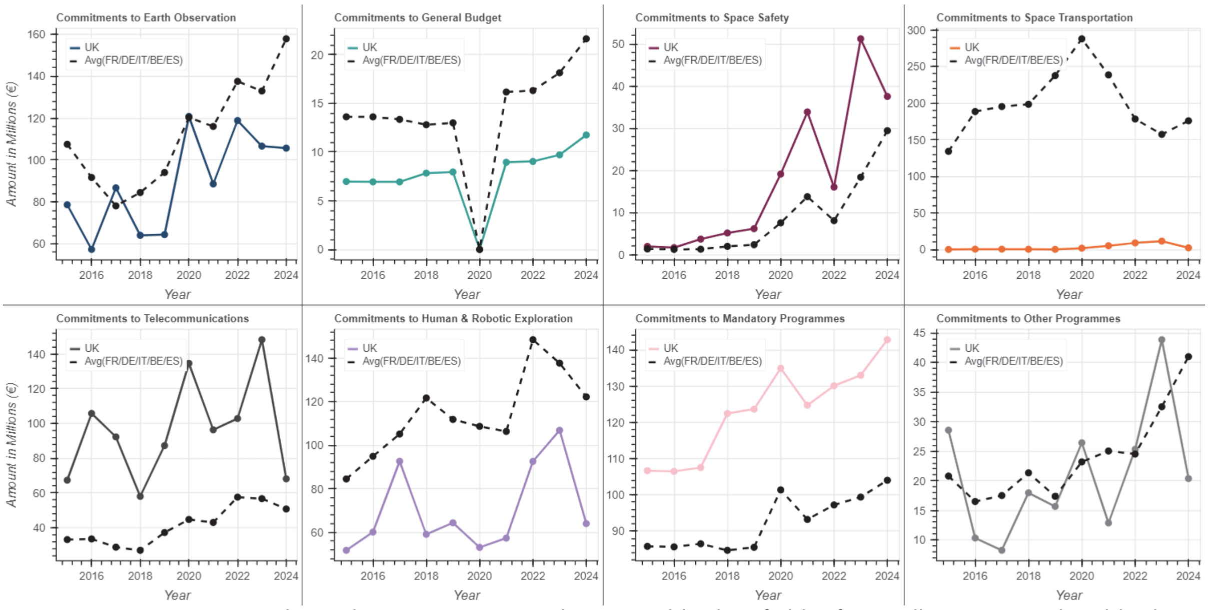
[9] European Central Bank (2025).

Figure 2: The UK's ESA commitments between 2015 and 2024 by domain in euros (millions)



Source: EROC. RAND analysis.

Figure 3: The UK's ESA commitments (solid line) compared to the other top five ESA contributors' average commitments (dashed line) between 2015 and 2024 by domain



Source: EROC. RAND analysis. The commitments to the general budget field refer to all corporate-related budgets, covering essential activities required for the Agency's operation and ensuring its fundamental existence.

Telecommunications, EO, HRE, Artificial Intelligence (AI) and Launch are all key priorities in the NSS that are related to unlocking growth, developing resilient space capabilities and building the UK into a science and technology superpower. The UK's substantial investment in telecommunications reflects these priorities, even surpassing mandatory investments at certain points. Two examples include the UK's investments in 5G/6G communications and space-based telecommunications infrastructure. Through its

5G Innovation Centre, the University of Surrey leads in next-generation telecommunications research, collaborating with national and global industry players and participating in international standard-setting bodies. At the same time, the UK's investment in the Moonlight programme aims to establish a lunar communications and navigation network, positioning the UK for a leading role in future lunar exploration by covering almost 40% of the programme's envelope. Similarly, the UK's substantial investment in HRE reflects NSS priorities related to returning samples from Mars. The UK has been the third-largest investor in this area for the last two CM periods. HRE is key for societal engagement with space, serving as a powerful tool for education and inspiration.

Historically, funding for space safety has been significantly lower in absolute terms than other programmes. This difference could initially be considered a misalignment with the NSS's emphasis on ensuring space activities' safety and sustainability. However, this perspective changes when considering the relative investment. In relative terms, the UK invests heavily in space safety compared to the total available programme spending, demonstrating leadership in this area. ESA's financial envelope for space safety increased from €600m to €910m between CM19 and CM22, with the UK being one of the leading investors – covering around 25% of the envelope at CM22 and around 60% of Vigil's overall budget.[10]

Other programmes and activities (including NAVISP, GSTP and Scale Up) received an investment uplift at CM22. However, it is unclear whether the current investment levels are sufficient to support the NSS goal to foster innovation and growth in the space sector. The UK has historically invested most heavily in GSTP Element 1 'Develop' rather than Elements 2 'Make' and 3 'Fly', covering approximately 27% and 3.5% of the envelope at CM22, respectively. At CM22, the UK invested relatively heavily in the new Electrical, Electronic and Electro-mechanical and European Devices Using Radioisotope Energy (ENDURE), focused on developing radioisotope heat and power systems for future missions and covering almost 90% of the ENDURE.

The UK's involvement in ESA programmes has had further domestic benefits beyond mission participation, knowledge generation and maintaining national security, as highlighted by the most recent (2022) evaluation of the UK's investment in ESA.[11] That report highlighted the economic benefits of UK-ESA activities, with an estimated 11.8:1 return on investment (ROI) in terms of Gross Value Added (GVA) and a projected net revenue increase of £5.75bn between 2020 and 2036. However, the vast majority of the '11.8' figure comes from spillover effects without a specified timeframe for realisation, only approximately 2.5 of which is within the 2020–2036 period.

1.1.2. Political uncertainties

As outlined above, there are clear benefits associated with the UK's investment in ESA. However, significant events in the political landscape, such as Brexit, highlight risks and uncertainties around the impact and the future of the UK's investment in ESA. A government inquiry into UK space strategy and

[10] European Space Agency (2022b).

[11] Technopolis Group (2022).

satellite infrastructure highlighted the need to link participation in ESA programmes more firmly to the aims of the UK's NSS.[12]

A recent report by the National Audit Office (NAO)[13] highlighted that the NSS might be too broad in scope, lacking more ruthless prioritisation to focus both government and industry investment. It also suggested that the Department for Science, Innovation and Technology (DSIT) has encountered challenges translating the high-level targets outlined in the NSS into actionable plans. Despite this, UKSA has endeavoured to align its vision with the NSS. Regardless of scope, the report states that budget constraints will likely hinder the UK's ability to achieve the ambitious objectives outlined in the NSS.

Despite evidence supporting the UK's investment in ESA, stakeholders consulted by the NAO emphasised the need to develop a stronger national programme. There is also a need to build an evidence base to articulate the benefits of space more coherently. The report also called for re-balancing funding for ESA programmes (i.e. less) and domestic space programmes (i.e. more). These concerns are concurrent with the (limited) progress the UK space sector has made in developing launch capabilities. The government's response to the report emphasised the importance of delivering on the UK's objectives against the NSS through national programmes, stating that this will be a key consideration in shaping future investment decisions.[14]

In a political environment marked by changes in government, an imminent spending review and a possible refocusing of the UK's ambitions in space, robust M&E efforts will be key in allowing the UKSA to understand the broader impacts of their investments in a time where the UK's investments in ESA and the associated industrial return are under scrutiny.

1.2. This evaluation

Rigorous evaluation of UKSA's spending into ESA is imperative to provide accountability and learning for programme teams, analysts and policymakers. This study's objectives are to:

1. Develop a robust, long-term plan for the ongoing evaluation of the UK's investments in ESA.
2. Gather a broad evidence base to understand the impacts and value for money (VfM) of the UK's investments in ESA to fill evidence gaps and support the development of work towards the next Spending Review, the CM25 investment round and beyond.
3. Build a framework to allow UKSA to better support and manage the realisation of benefits, improving long-term outcomes for the space sector and the wider UK economy.

1.2.1. Purpose of the report

This report synthesises all study findings into one public document. It is accompanied by a suite of separate products that have informed and are supplementary to it, including:

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[12] House of Commons Science and Technology Committee (2022).

[13] National Audit Office (2024).

[14] House of Commons Science, Innovation and Technology Committee (2023).

- **An executive summary:** Provides a brief summary for senior policymakers, the public and other interested stakeholders.
- **A process evaluation report:** Addresses all portfolio process evaluation questions on the governance, contracting, strategy and UKSA roles in ESA, with recommendations for the future (for UKSA's internal use only).
- **A benefits management framework:** Aims to support the long-term M&E and outcome realisation of the UK's ESA portfolio. For internal use by UKSA only.
- **A methodological annex:** Includes full descriptions of the methods applied, VfM report, scientometrics approach, interview details, expert review returns and supplementary data.
- **Evaluation frameworks (portfolio and programme-level):** Detail the blueprint for our approach for UKSA's internal use to inform future M&E.

1.2.2. Structure of this report

The remaining chapters of this report are structured as follows:

- **Chapter 2** examines the immediate financial returns of the UK's ESA membership, including impacts on growth, employment, productivity and private R&D investment.
- **Chapter 3** reviews the scientific and technological benefits, including developed capabilities and expanded capacities such as the attraction and retention of the UK space science workforce and the benefits of international scientific collaboration.
- **Chapter 4** considers the industrial capabilities and commercialisation efforts, including stimulating private investment into the UK space sector.
- **Chapter 5** examines the socio-economic benefits of ESA membership, including economic estimates of cost reduction from mitigating threats posed by climate change, space debris and others.
- **Chapter 6** assesses the socioeconomic returns of the UK's investments in ESA alongside a consolidated consideration of broader benefits important to recognise as part of the overall VfM picture.
- **Chapter 7** presents conclusions and recommendations.

1.2.3. Methods used

The evaluation team conducted the following activities to inform this report, all detailed comprehensively in the methodological annex:

- **A documentation review:** The team reviewed various documents, including UKSA business cases for ESA spending, contracts data, online research and previous UKSA evaluations of ESA investment.
- **A conceptual framework workshop and VfM workshop:** The project team facilitated a workshop with UKSA and DSIT to present our conceptual framework and gather feedback. We

split the workshop to cover a validation and discussion exercise for both our proportionality assessment and the development of evaluation questions. We also used this to present preliminary adaptations to the Theory of Change (ToC) and seek feedback. The VfM workshop aimed to refine and discuss the proposed VfM methods led by Ipsos and to understand UKSA's desired metrics and outputs.

- **Regular meetings with UKSA and DSIT:** The project team held regular meetings with UKSA and DSIT to provide updates on the project's progression and early findings and seek feedback.
- **Data collection interviews:** The project team conducted 94 interviews with 102 individual stakeholders, including ESA contractors and downstream users – 6 related to Technology, 18 to Space Safety, 33 to EO, 5 to Commercial, 5 to HRE, 7 to Navigation, 7 to Telecommunications and 13 to Science domain. These interviews collected evidence for the evaluation questions. In addition, we conducted 17 scoping interviews with stakeholders at UKSA, DSIT and ESA, including six related to EO, one related to commercial, one related to HRE, one related to Navigation, two related to Space Safety, three related to Technology and three related to Telecommunications. The scoping interviews helped the project team understand the programmes and design an individual evaluation framework for each domain. To maintain anonymity, we identify interviewees in this report using the format 'Int_XX_YY', where XX is an identification number for each interviewee, and YY is the domain/programme analysis area. For example, INT_10_SCI indicates the tenth stakeholder interviewed within the Science programme.
- **Expert reviews:** We engaged four experts in space science and technology to review three programmes evaluated at high/medium intensity: the Climate Change Initiative (CCI),[15] NAVISP and Vigil. We based the programme selection on the availability of programme outcomes and the technological expertise required to assess the impact, agreeing upon the selection with UKSA. For the review process, the RAND team put together programme 'fact sheets' with accompanying sources for optional review, e.g. resulting journal articles. The experts assigned to each programme then scored it on assessment criteria and provided an analysis.
- **Review of scientometric data**: Analysis of scientometric indicators for ESA-funded papers, focusing on the UK's scientific leadership and position relative to other ESA countries.

1.2.4. Impact and process evaluation approaches

The Magenta Book guidance issued by His Majesty's Treasury (HMT) advises utilising theory-based approaches to assess the contribution of complex interventions to observed results. UKSA's investment in ESA is itself a complex intervention (as per the Magenta Book's supplementary guide). This is because it funds many different programmes, with multiple types of programme intervention (mandatory and optional, basic vs applied science), long causal chains (e.g. time taken to get to launch) and a changing context (e.g. the UK rejoining Copernicus).

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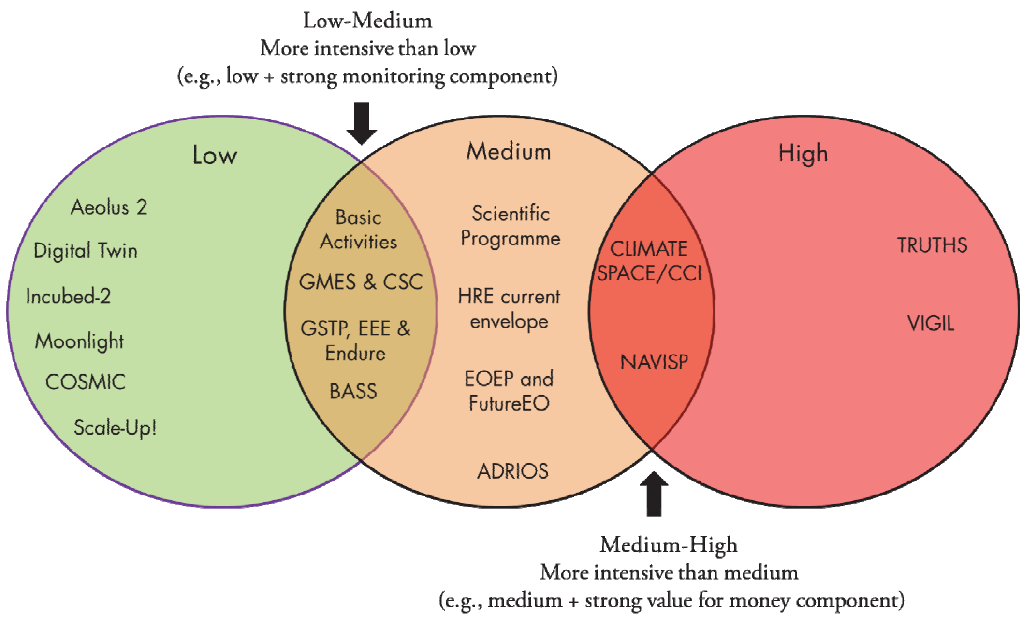
[15] European Space Agency Climate Change Initiative (2025).

As a first step, we conducted a **proportionality assessment**. As different M&E intensities are required due to UKSA's broad investment in ESA, covering some 98 programme lines across nine technology areas, it was neither feasible nor an effective use of resources to assess each programme with the highest possible intensity. Therefore, we developed three intensities of M&E: high, medium and low, each with a different methodological approach. 'High' represented the most intensive M&E, employing all methodological approaches, whereas 'low' was the least intensive, comprising a selection of methodological approaches suited to examining programmes in less detail. Our full approach is available in the technical annex, but we present a summary figure here to illustrate where programmes fell across the intensities (Figure 4). However, we did not design this exercise to assess the relative 'importance' of programmes; instead, we based it on practical criteria such as data availability, whether existing M&E was ongoing, and how long the UK had been contributing.

Figure 4: Venn diagram of the M&E level assigned to each programme



Source: RAND Europe analysis.

Our approach to the **impact evaluation** primarily centred around contribution analysis (CA) to assess the UK's investments towards each ESA domain of interest. By employing CA, we aimed to develop a framework for understanding how these investments have contributed to observed outcomes and align with the broader ToC. To build a strong basis for the evaluation, we implemented an impact indicator framework to guide the creation of indicators at a portfolio level. From this, we synthesised programme-level indicators and evaluation questions to underpin specific interview questions, data analysis and scientometric analysis. Sticking to our proportionate evaluation strategy for each domain/ programme area enabled us to synthesise findings from various programmes and aggregate insights at the ESA investment portfolio level.

For the **process evaluation**, we adhered to best practices articulated in the Medical Research Council's (MRC's) guidance. We used this because it is a topic-agnostic framework that emphasises taking context into account when making process judgments, aligning with our theory-based approach. Our focus was primarily on assessing the design, implementation and contextual factors affecting the delivery of ESA programmes. Like our approach to impact evaluation, we utilised a detailed process indicator framework to base indicators and metrics on overarching areas of interest and evaluation questions at the portfolio level. From this, we synthesised separate, more specific indicators and questions for each domain or programme of investigation. Our team could then aggregate evidence from each programme area of interest to the ESA investment portfolio level to capture detailed insights on overarching governance and management processes.

1.2.5. Limitations of this study and future studies

In designing and delivering this study, we received significant support from our UKSA client team and their colleagues in the programme teams in sourcing data, documents and external stakeholders. We also consulted a wide range of data sources and employed multiple methods to tackle each evaluation question. However, we encountered some difficulties for this study's next iteration, as outlined below:

- **The complexities of evaluating an intervention as multifaceted as the UK's ESA contributions**: The Magenta and Green books do not provide guidance for portfolio-level evaluations of this scale and complexity. The key challenge is generating a useful portfolio-level assessment from highly diverse discrete programmes and initiatives (a 'signal-to-noise-ratio' problem). Although our approach used and built on Magenta Book and Green Book principles, a lack of best practice and HMT guidance for evaluating interventions as complex as the UK's ESA contributions remain.
- **Challenges in measuring economic impact**:
    - To ensure methodological rigour in the economic evaluation, we adopted a conservative approach, prioritising measurable economic impacts aligned with HMT Green Book principles and acknowledging the methodological challenges in capturing broader, less tangible impacts. Thus, the economic evaluation focuses on 1) direct economic impacts on UK firms awarded ESA contracts and 2) indirect spatial agglomeration effects. While ESA investments are also expected to generate other economic spillover benefits (e.g. knowledge diffusion unrelated to spatial agglomeration), these are difficult to quantify and monetise. As a result, they are not included in the monetised estimates of economic impact. While not part of the economic evaluation, this report presents additional qualitative evidence on spillover economic benefits.
    - The space sector operates on long development cycles, meaning that the full economic impacts of ESA-funded activities often materialise over extended timeframes. Given that our dataset primarily covers contracts awarded between 2012 and 2022, some long-term economic effects may not yet be fully observable, particularly for contracts awarded later in this period.
    - Relatedly, the econometric analysis of medium-to-long-term impacts is constrained by the limited sample size of contracts with ten or more years to generate economic impact. Given the staggered nature of ESA contract awards, there are fewer firms in the dataset with contracts dating back far enough to provide medium-to-long-term economic impact estimates

with high statistical confidence. Thus, estimates of impacts beyond 10–15 years are characterised by higher statistical uncertainty due to reduced sample size.

- **Access to existing/ongoing M&E:** Separate studies have been conducted specifically for GSTP, NAVISP and ARTES, to which we did not have access. However, our portfolio-level data collection covered all domains and programmes in differing detail (decided via a proportionality assessment) to ensure sufficient evidence to reach portfolio-level conclusions. Future M&E should ideally have access to any specific programme-level studies to enhance this process.
- **Difficulties in reaching participants**: This evaluation reached over 100 contractors, end-users, policymakers, academics, companies and international partners. It also combined many more data sources to cover blind spots via triangulation. However, we experienced difficulty reaching a wide range of stakeholders due to respondent burden, whereby the space industry, particularly companies, are heavily consulted as part of other evaluations and national surveys. There was also little monitoring data available on ESA contracts. ESA holds this data and, due to GDPR protections, does not fully share it with UKSA. As a result, the contact list for this evaluation had to be compiled from multiple sources, presenting challenges in identifying and verifying relevant stakeholders.
- **ESA contract data**: We identified several issues in analysing this data, including data completeness and structure, geographical and contractual complexities, multi-domain contracts, and headquarters and prime name issues. We explain these challenges and their implications in full in the process report. These issues affected our ability to reliably identify where ESA work occurs (as only a contracted company's headquarters location is listed) and attribute contract values to domains and specific companies. We worked closely with UKSA to ensure the data presented here are as accurate as possible and suitably caveated. We also made recommendations in the process evaluation on how these data could be improved to allow for more robust analysis.
- **Lack of a prior unified M&E approach across the portfolio**: There was also some duplication since other evaluation activities were occurring in parallel with this one, with no formal knowledge-sharing mechanisms. This duplication also caused issues where other evaluations had already approached the same stakeholders, which may have deterred them from engaging with ours. Our recommendation for a unified approach across the portfolio in the future may help mitigate this issue and better consolidate the outcomes from ESA spending more consistently over time.

2. Immediate returns of the UK's ESA membership

This chapter presents findings on the immediate financial returns from the UK's investments in ESA. First, we analyse UK contract receipt data to assess the direct financial return to the UK from ESA, including by domain and region. We then assess the benefits derived from those financial returns through contracts, including the effects on economic growth, employment, productivity and private R&D investment for companies receiving ESA funding. We also discuss the UK's geo-return ratio and the results of efforts undertaken by the UK to reduce its geo-return deficit.

Key findings on the immediate returns of the UK's ESA membership:

- **UK contract returns:** UKSA contributes the majority of its budget to ESA and, in turn, receives contracts for key projects, missions and programmes. The UK registered 3,306 unique contract numbers from ESA, totalling €3.4bn. Over 20% were small and medium-sized enterprises (SMEs), representing the largest proportion of all ESA member states.
- **Geographic spread:** UK contracts overwhelmingly flow to England (92%), with 82% focused on three regions: the East of England (47%), the South East of England (26%) and London (10%). Different regions show different relative strengths across domains.
- **Domain strengths:** UK contracts are spread across all ESA domains, reflecting the UK's wide-ranging competitiveness and strengths. Large mission prime contracts in space science and exploration highlight the interplay between scientific and industrial expertise.
- **Benefits for the UK on growth, employment, productivity and private R&D investment:** There is strong evidence that ESA contracts deliver a significant positive impact on turnover and employment for UK firms, both for total employment and specifically for R&D employment, and that contracts have a lasting positive impact on productivity (in terms of turnover per worker and GVA per worker) and R&D expenditure among UK beneficiaries.
- **Geo-return and reducing the deficit:** As of Q4 2024, the UK's Return Coefficient (RC) with ESA stood at 0.99, improved thanks partly to the UKSA-ESA Industrial Policy Taskforce (IPTF) established to address the historical deficit.

2.1. UK contributions to and returns from ESA

In addition to being responsible for coordinating space exploration and satellite missions, ESA also serves as the **primary 'customer'** for many companies within the space industry, making success in the ESA contracting ecosystem crucial for some companies' financial success. This is particularly true for large system integrators, whose business viability often hinges on securing large ESA contracts.

It is important to understand the scale and distribution of ESA activities carried out by UK entities. Our analysis examined contracts awarded to the UK, whether directly by ESA or subcontracted to UK-based companies by overseas entities. Unlike prior assessments that focused exclusively on contracts during the CM19 period, our approach considers all available contracts, offering a more comprehensive understanding of the accrued benefits, especially as many missions and activities extend across multiple CM periods.

2.1.1. Contracts won by UK entities

There were 3,306 unique contract numbers and 134,667 unique commitments associated with UK entities as of Q4 2024, amounting to €3,402,561,567 (£2,846,685,084).[16] Analysis of the contract data provides insights into the UK's contract portfolio. Table 2 shows the total contract value delivered to the UK for each domain and the date range that that value covers, while Table 3 Source: RAND Europe analysis of ESA contracts received by the UK (EROC data and exchange rate accurate as of 19 March 2025).

shows the highest value contract under each domain and the duration of that contract. By far, the largest contracts are with UK industrial primes for the overall design, manufacture and delivery of a mission or satellite. Across Space Science and Space Safety, the most significant contracts are for the implementation phase of Solar Orbiter and the development of Vigil, respectively, both awarded to Airbus UK and totalling €178m.

Solar Orbiter and Vigil are both solar physics missions, building on significant UK scientific expertise and instrument development heritage in magnetometers and other instruments designed to measure the solar wind. Similarly, the UK has an established heritage in rover development and has received a €90m contract to develop the Rosalind Franklin Mars Rover. These suggest that the UK's strengths in specific domains of science and instrumentation development may play a role in the provision of prime contracts to UK industry, especially when combined with strategic investments in missions aligned with existing national strengths.

Of the 1,020 UK entities participating in ESA contracts, 20.2% had claimed SME status with ESA – the highest proportion across the ESA member states, according to ESA-STAR.[17] However, this is likely to be a lower bound due to whether companies declare this information.

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[16] EROC (weighted values). The currency conversion was accurate as of 20 March 2025.

[17] European Space Agency STAR (2025).

Table 2: Total value of all contracts by domain

Domain	Date range	Sum of weighted amount in £m (€m)	Proportion of total contract value received by the UK (%)
Telecommunications	2012 – 2024	744 (885)	26
Earth Observation (EO)	2013 – 2024	713 (848)	24.9
Space Science and Basic Activities (Mandatory)	2013 – 2024	629 (749)	22
Human and Robotic Exploration	2000 – 2024	456 (543)	15.9
Other Programmes and Activities	2013 – 2024	163 (193)	5.7
Space Safety	2015 – 2024	102 (121)	3.6
Launch (Space Transportation)	2013 – 2024	54 (64)	1.9

Source: RAND Europe analysis of ESA contracts received by the UK (EROC data and exchange rate accurate as of 19 March 2025).

Table 3: Highest value contract by domain

Domain	Contract Title	Total contract value in £m (€)	Contract Start	Contract End
Space Science and Basic Activities (Mandatory)	Implementation Phase of the Solar Orbiter Mission	110 (131)	2015	2021
Human and Robotic Exploration	Rover Vehicle Lead	76 (90)	2015	2024*
Telecommunications	Phase B/C/D/E – ARTES 33.3 Quantum Satellite	55 (66)	2015	2021
Earth Observation (EO)	Biomass	55 (65)	2016	2024*
Space Safety	Vigil Satellite Development	40 (47)	2024	2024*
Other Programmes and Activities	Sabre Development Programme	9 (11)	2016	2023
Launch (Space Transportation)	Maintaining of the Guiana Space Centre	7 (8)	2017	2024*
*Note: Based on contract data provided up until 2024. A contract end date of 2024 can reference a contract that ended in 2024 or an ongoing contract extending beyond the cut-off for this data set.				

Source: RAND Europe analysis of ESA contracts received by the UK. Since missions often have several contracts, these values will not reflect the full contract value for any given mission.

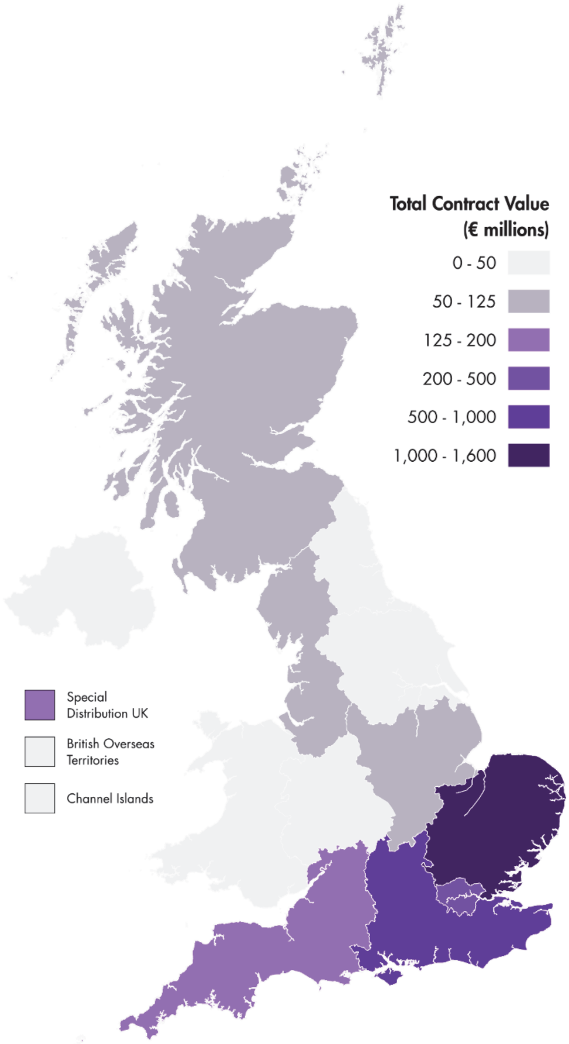
Contracts received through ESA were not equally distributed across the UK. Instead, contracts focused on regions with key primes and space industry clusters, with the East of England, the South East of England and London receiving a combined 82% of the total contract value.

Figure 6 shows the contract value by domain returned to each constituent nation in the UK. Among the constituent nations of the UK, England received 91.9% of all contract value, with Scotland receiving 3.2% and Wales and Northern Ireland receiving 0.5% and 0.4%, respectively. Some 4% of contracts were allocated to 'Special Distribution UK'. Figure 5 represents these figures geographically. **The geographic**

spread of contract value also varies by domain, with certain regions showing successes in particular domains. For example, despite accounting for only 3.2% of all contract value returned, Scotland received 6.5% of all contract value in Telecommunications.

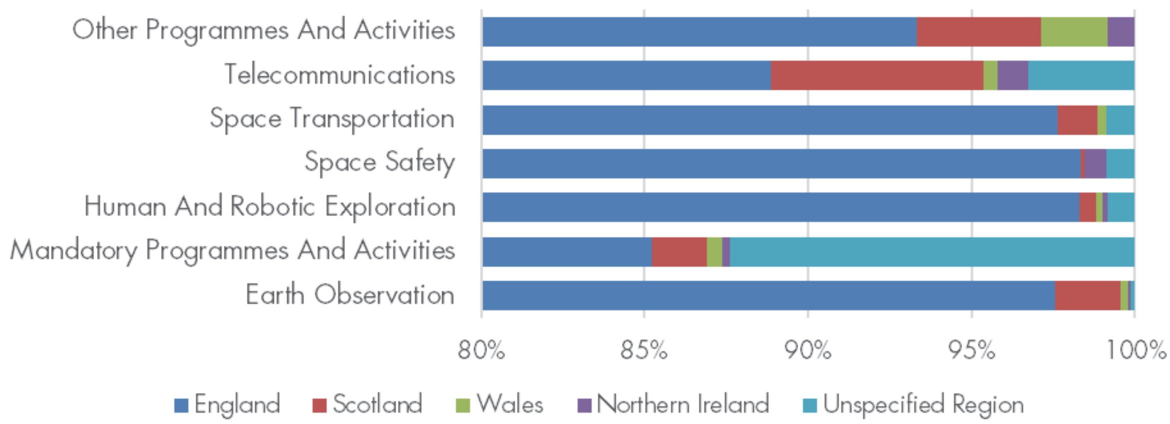
Promoting a greater geographical spread of contract returns aligns with the growth goal outlined in the National Space Strategy. While analysis of contract spread is skewed because large prime contracts are granted to a small number of companies mostly located in the East, South East or London, greater attention could be paid to recognising and cultivating strengths amongst other regional hubs to ensure that contracts are received more broadly across the UK. UKSA – specifically the IPTF – has worked to address these imbalances, which have seen increased contract numbers across all regions since 2022. One limitation of the data below is that location data is based on company headquarters, which may or may not be where the actual work occurs, and is a broader limitation of the data ESA collects.

Figure 5: Total value of contracts received per region



Source: RAND Europe analysis of ESA contracts received by the UK. The EROC data is accurate as of 19 March 2025.

Figure 6: Contract value by domain, according to the constituent UK nation



Source: RAND Europe analysis of ESA contracts received by the UK. The EROC data is accurate as of 19 March 2025. 'Other programmes and activities' include Navigation programmes, GSTP and ScaleUp.

2.1.2. UK geographical return

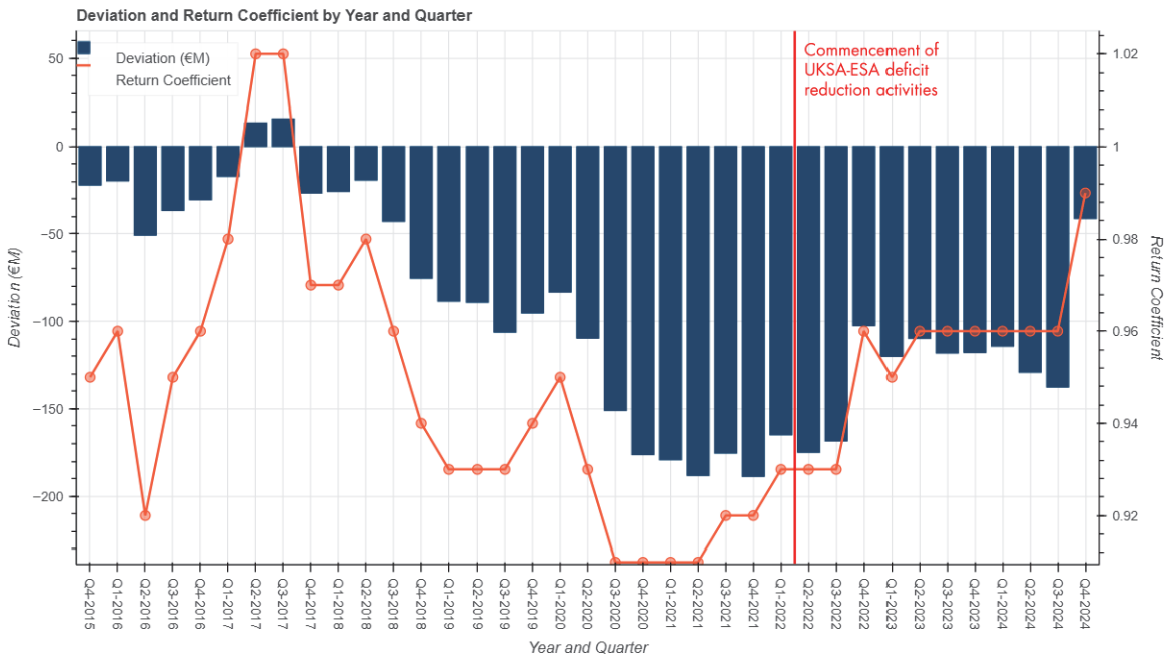
The ESA convention mandates equitable participation among its member states, reflecting their financial contributions. This principle involves awarding contracts to industries or academic institutions within a member state in proportion to that state's financial investment in ESA after deducting overhead costs – a process known as geographical return or, more commonly, geo-return. Geo-return is presented as a return coefficient, which should be 1.0 if parity is reached, and as a financial deficit or surplus as applicable. It is a cumulative metric covering the entire period from Q4 2015 to Q4 2029 across all mandatory and optional programmes a member state invests in.

Geo-return does not account for the broader economic, social, scientific or technological advantages a member state might derive from its investment in ESA. Therefore, geo-return should be viewed with an understanding of such contextual factors and considered alongside impact, process and VfM evaluations of the UK's investments in ESA. This evaluation aims to showcase these wider benefits. However, **geo-return has been used as a primary indicator of the UK's benefits within ESA. Understanding the UK's current geo-return position allows for a more nuanced analysis of how financial contributions and industrial returns are balanced.** This understanding helps us discuss how these factors, whether justifiable or not, influence strategic priorities and policy decisions within the ESA framework.

Geo-return – addressing the deficit

The UK's geo-return RC now stands at 0.99 with a deficit of €41.18m, meaning that for every €1 invested, the UK received €0.99 back in contract value (Figure 7).

Figure 7: Geo-return for the UK by quarter, showing € deficit value in columns and RC in dots



Source: EROC. UKSA - ESA Data & Insights Team (2025) ESA Operations ESA Research Questions – February 2025. Red line denotes the commencement of UKSA-ESA deficit reduction activities.

Due to below-target geo-return, a joint UKSA-ESA IPTF was established to work towards reducing the deficit. The IPTF worked to secure additional contracts with UK industry and academia and encourage new bidders in the market through educational and training programmes.

Specific measures implemented by the IPTF to address the deficit included[18]:

1. **ESA Business Incubation Centres (BIC) Funding Extension**: UKSA invested €3.4m to extend funding for the UK ESA Business Incubation Centre (ESA BIC) for four years to support SMEs seeking ESA contracts.
2. **ESA Φ-lab Funding**: €2m has been made to establish the first-ever Φ-lab (Phi-lab) in the UK, dedicated to advancing research initiatives on space exploration. The Phi Lab comprises two offices: the Explore Office (exploration/innovation) and the Invest Office (commercial pre-development/development via the InCubed Programme). The Φ-lab acts as a hub between industry, academia and investors.
3. **Reintroduction of the ESA Technology Broker**: The ESA Technology Broker has been reintroduced to facilitate connections between technology providers and product developers.
4. **Integrated Data System**: New data infrastructure now provides a comprehensive overview of the entire ESA portfolio, helping identify geo-return patterns to aid in deficit reduction activities.
5. **Bid Writing Workshops**: ESA gives UK industry and academia advance notice of upcoming Invitations to Tender (ITTs), supplemented by free ESA Bid Writing Workshops.

[18] Bate (2023).

The reduction in the geo-return deficit is positive news for the UK overall, though it is important to note that the coefficient changes regularly, with differing values per domain. As such, we do not dwell on these geo-return figures beyond the headline number; instead, we move on to the first element of our VfM analysis.

2.2. Direct economic benefits

This section of the report considers a timeline-based analysis of the direct economic impact of UK firms' participation in ESA programmes.[19] As such, it contains a useful stand-alone assessment of the overall timeline for how these economic impacts emerge and behave. The analysis also provides a key component for the public benefit-cost ratio (BCR) analysis subsequently presented in Chapter 6.

Our analysis provides **strong evidence that ESA contracts generate significant and sustained economic benefits for UK firms**, driving growth in turnover, employment, productivity and private R&D investment. The following sections present detailed results of the econometric analyses quantifying these economic benefits to UK companies awarded ESA contracts.

Figure 8: Summary of direct economic impact findings

Firms awarded ESA contracts experience a significant and sustained increase in firm growth. On average, £1m of ESA contract funding led to firms experiencing an annual 8.2% increase in turnover and an annual 6.7% increase in GVA over the time period of the analysis.

Employment impacts are also positive. On average, £1m of ESA contract funding led to an annual increase of 3.3% in total employment among beneficiary firms and an annual increase of 6.1% for R&D employment over the time period of the analysis, suggesting that ESA funding particularly supports the creation of highly skilled jobs.

Firms awarded ESA contracts experience a significant and sustained increase in productivity. On average, £1m of ESA contract funding led to firms experiencing an annual 4.9% increase in turnover per worker and an annual 3.9% increase in GVA per worker over the time period of the analysis.

Additionally, ESA funding leads to an increase in private R&D investment. On average, £1m of ESA contract funding led to an average annual increase of 6.6% in R&D expenditure over the time period of the analysis.

The above impacts have different timeline trajectories, with R&D-related impacts peaking earlier and broader firm-level growth and productivity impacts peaking later and being sustained for longer. This suggests that ESA participation is associated with a temporary boost to R&D activity that generates broader knock-on economic effects.

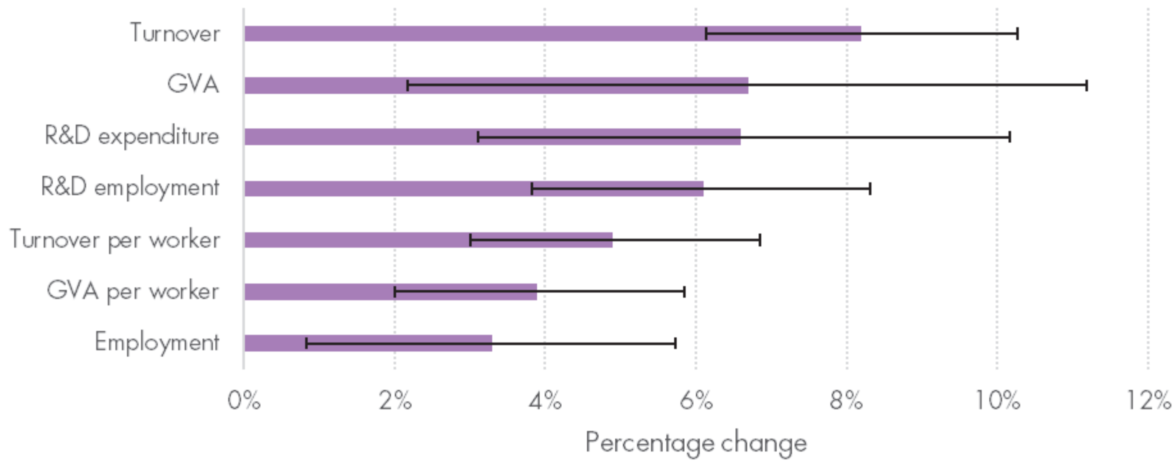
Figure 9 (below) presents the estimated average annual percentage change in key economic indicators associated with receiving £1m in ESA contract funding over the time period of the analysis. It should be noted that these estimates reflect the average annual treatment effect across all years within the

[19] 'Timeline-based analysis' refers to the examination of how economic impacts unfold over time following firm participation in ESA programmes. This includes identifying the lag between participation and impact realisation, the duration of impact and how impacts are patterned over time.

observation window. While these overall averages are statistically significant at the $p<0.05$ level, it is important to note that individual year-specific effects within the observation window vary in their magnitude and statistical significance. This is detailed in the disaggregated annual treatment effects presented in sections Effects on private R&D investment2.2.1-2.2.4 below.

The largest average annual estimated effects are observed for turnover and GVA. In terms of productivity, £1m in ESA contract funding is associated with an average annual 4.9% increase in turnover per worker and an average annual 3.9% increase in GVA per worker over the time period of the analysis. Total employment also increases, albeit more modestly.[20] The error bars in Figure 9 represent 95% confidence intervals, illustrating the range within which we can be 95% confident that the true impact likely sits.

Figure 9: Average annual effects for £1m of ESA contract funding



Source: Ipsos UK calculations, based on ESA contract data, ONS Annual Business Survey data, ONS Business Structure Database data and ONS Business Enterprise R&D Survey data. Note: Error bars represent 95% confidence intervals.

To establish the causal impact of ESA funding on UK firms, we employed a **staggered difference-in-differences (DiD) approach**. This quasi-experimental method is widely used in policy evaluation and aligned with Green Book principles. A standard DiD framework compares economic indicators between firms awarded ESA contracts and a control group of similar companies not awarded contracts. However, identifying a suitable control group is challenging in this highly specialised space sector, where comparable firms are limited. To address this, we designed our analysis to leverage the staggered nature of ESA contract awards. Rather than using a separate control group of firms that do not receive funding, we only compared firms awarded ESA contracts, distinguishing between those that have already received funding

[20] These estimates reflect the total observed effect across all contract recipients in the dataset, with the post-award observation period varying by firm depending on the year of contract award. In the SDiD framework used in these analyses, the estimated coefficient represents a weighted average of cohort-specific treatment effects, where weights are determined by post-treatment data availability and the distribution of treatment timing across cohorts.

and those that have not yet received it.[21] This approach enables us to estimate the impact of ESA contracts, capturing the effects of funding as firms enter the programme at different time points. The technical annex presents further methodological details.

Several important points should be noted regarding the data used in this analysis. The analyses below utilised **all available electronic historical data on ESA contracts awarded to UK firms**. Although additional historical contract data exists in the ESA archives, it is only available in hardcopy rather than digital form, so we could not use it. For most ESA programme domains, the dataset covers 2012–2024. This large sample allowed for a robust quasi-experimental analysis, ensuring statistically reliable impact estimates. However, a longer time series was available for the HRE programme domain, covering 2000–2024. We incorporated this data to increase sample size and capture longer-term effects, which are particularly relevant in the space sector given many space-related projects' extended development cycles. However, this earlier data represents only a subset of ESA contracts awarded during that period, and the sample size for these earlier years is relatively small and specific to this domain. As a result, impact estimates from 14 years onwards are based on a smaller and less representative sample and should be interpreted cautiously. Importantly, the reduced sample size in these later periods lowers the statistical power of the analysis, increasing the statistical uncertainty around long-run impact estimates.

The firm-level contract data was linked to Office for National Statistics (ONS) firm-level datasets through the ONS' Secure Research Service (SRS). This service allowed us to incorporate detailed economic indicators covering growth, employment, productivity and R&D investment into the dataset. Specifically, we drew data on firm-level economic outcomes from three key ONS datasets: the **Business Structure Database (BSD)**, the **Annual Business Survey (ABS)** and the **Business Enterprise R&D (BERD) Survey**. We only used ESA contract data up to 2022 for the analysis, as the ABS and BERD data are only available until this year. While the BSD is available up to 2023, we restricted the dataset to 2022 for consistency.

2.2.1. Effects on economic growth

Our analysis provides strong evidence that ESA contracts deliver a significant and lasting positive impact on UK firms' growth in turnover and GVA.

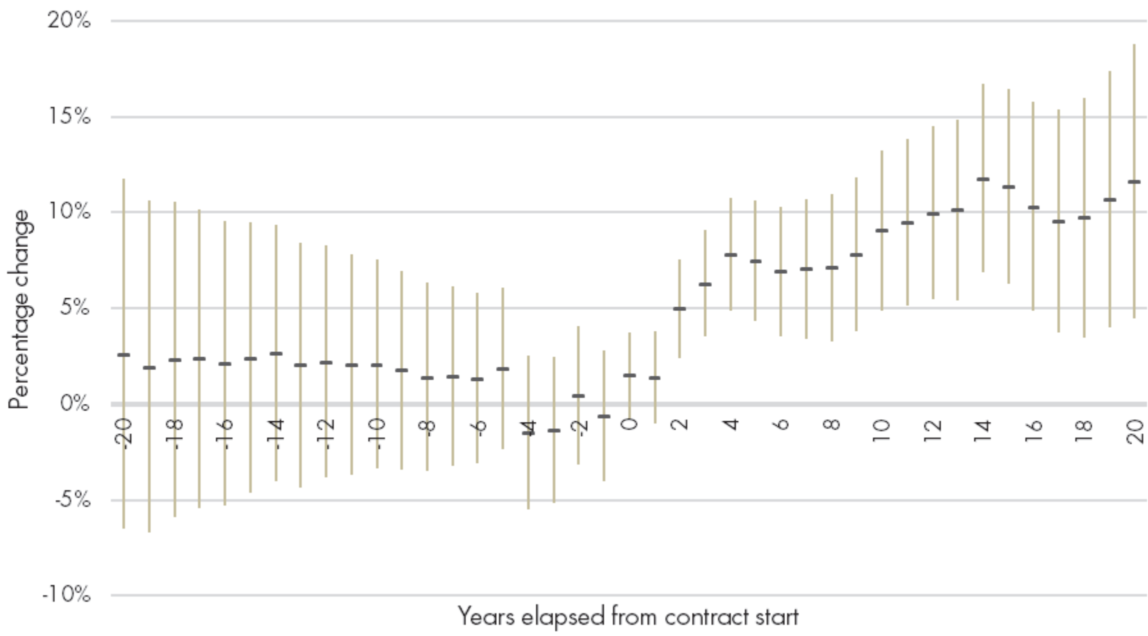
Regarding company turnover, our analysis found that being awarded an ESA contract leads to a sustained increase in turnover, with effects persisting 20 years after the contract start year (see Figure 10 below). Figure 10 shows the average treatment effect (ATE) on turnover for each year after a firm receives an ESA contract. The vertical axis shows the estimated percentage difference in turnover between firms that have been awarded ESA contracts and those not yet awarded an ESA contract (but due to become ESA contractors later within the analysis period). The horizontal axis shows the number of years since the contract was awarded. For example, suppose a firm was awarded an ESA contract in 2010, and the chart shows a statistically significant 5% effect in Year 2. This means that in 2012, the firm's turnover was, on

[21] To ensure robustness in the absence of a pure control, we conducted parallel trends tests to assess the validity of the identifying assumption and implemented the Callaway & Sant'Anna (2021) estimator, which accounts for potential bias in staggered treatment adoption.

average, 5% higher than it would have been in that year had the firm not been awarded a contract. Therefore, the chart shows how the impact size evolves, helping to assess the persistence of growth of effects over the long term.

On average, £1m of ESA contract funding led to an annual 8.2% increase in firms' turnover over the time period of the analysis. However, this estimate carries some uncertainty. The 95% confidence interval for the estimated impact ranges from 6.1–10.3%, meaning we can be 95% confident that the actual annual effect of receiving £1m in ESA contract funding on turnover was between 6.1% and 10.3%.

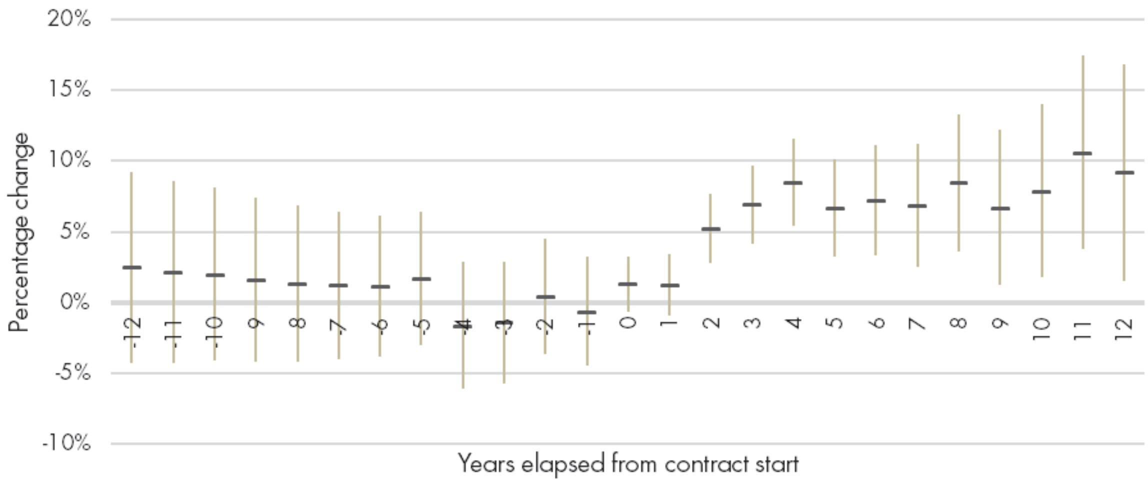
Figure 10: Effects of ESA contracts on company turnover among UK beneficiaries



Source: Ipsos UK calculations based on ESA contract and ONS BSD data.

In addition to company turnover, ESA contracts led to a measurable increase in GVA (see Figure 11 below). GVA captures the value generated by businesses after accounting for input costs, making it a more precise measure of economic impact than turnover alone. The increase in GVA suggests that ESA-funded firms are generating more revenue *and* creating higher-value outputs. This increase is sustained over time, with effects persisting for 12 years after the contract starts (it is worth noting that the available time series for company GVA data is shorter than that for company turnover). On average, £1m of ESA contract funding led to firms experiencing an annual 6.7% increase in GVA over the time period of the analysis. The 95% confidence interval for the estimated impact ranges from 2.2–11.2%.

Figure 11: Effects of ESA contracts on GVA among UK beneficiary companies



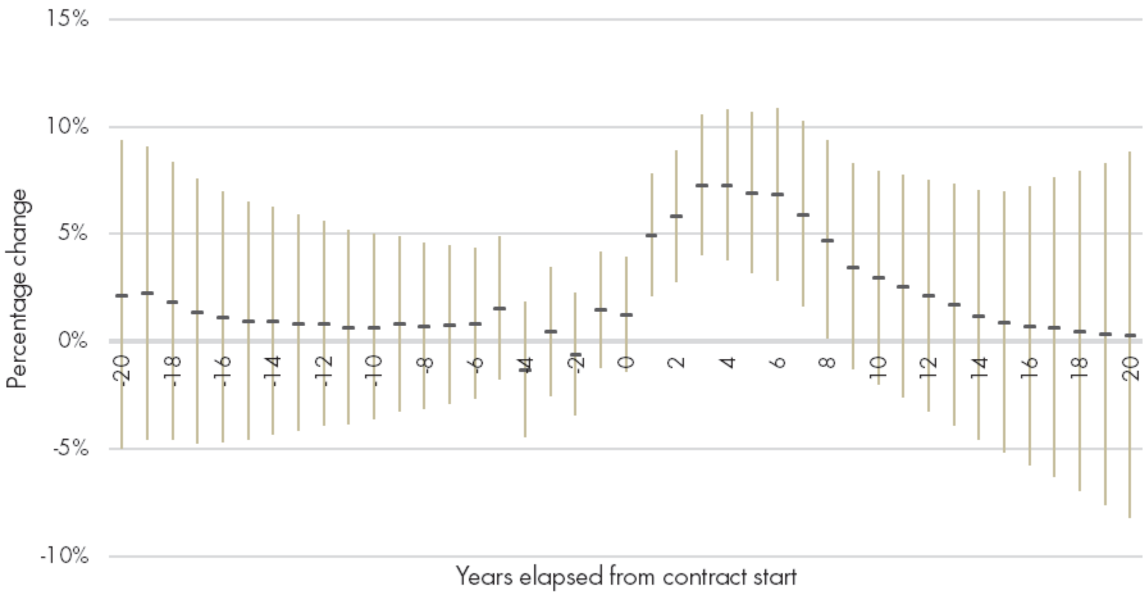
Source: Ipsos UK calculations based on ESA contract data and ONS ABS data.

2.2.2. Effects on employment

Our analysis provides strong evidence that ESA contracts significantly positively impact employment for UK firms, both for total employment and R&D-specific employment.

We found that £1m of ESA contract funding led to an average annual increase of 3.3% in total employment among beneficiary firms (see Figure 12 below) over the time period of the analysis, with a 95% confidence interval of 0.8–5.7%. The impact on employment persists for several years, peaking around 3–4 years after the contract award. Beyond this point, the effect begins to decline and is no longer statistically significant after nine years. However, this loss of statistical significance is partly due to a reduction in sample size over time. As fewer firms with contracts awarded more than 10–20 years ago remain in the dataset, the ability to detect statistically significant effects diminishes, not necessarily indicating that the employment impact disappears. Nevertheless, the estimated effect size after roughly 15 years post-contract award is small, suggesting that any long-term employment impact is limited, regardless of sample size constraints in the analysis.

Figure 12: Effects of ESA contracts on employment among UK beneficiary companies

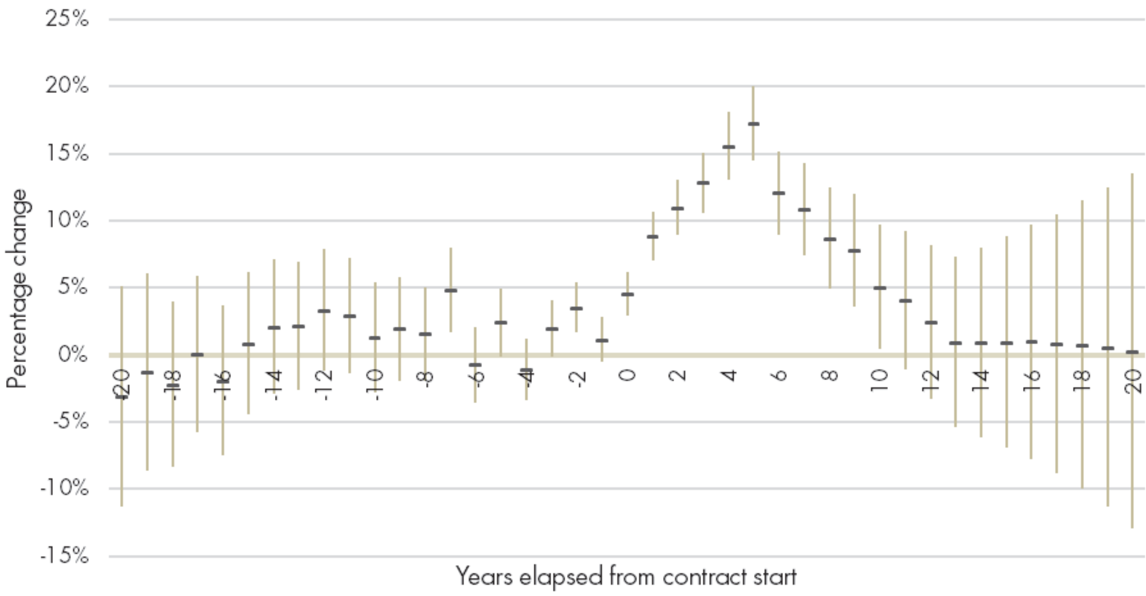


Source: Ipsos UK calculations based on ESA contract and ONS BSD data.

Our analysis of R&D employment found that impacts on this type of employment are even more pronounced,[22] suggesting that ESA funding particularly supports the creation of highly skilled jobs within beneficiary firms. Every £1m of ESA contract funding led to an average annual increase of 6.1% in R&D employment among beneficiary firms (see Figure 13 below) over the time period of the analysis, with a 95% confidence interval ranging from 3.8–8.3%. This effect peaks five years after the contract start date, indicating a strong initial boost to R&D-intensive roles. Beyond this point, the impact gradually declines and is no longer statistically significant after 11 years. As with total employment, part of this decline in statistical significance is due to a reduction in sample size over time. However, the estimated effect size is small after 12 years, suggesting that any sustained impact on R&D employment beyond this period is limited.

[22] The ONS BERD survey defines this as employees working on in-house R&D, where R&D is conceptually defined as creative and systematic work undertaken to increase the stock of knowledge (including knowledge of humankind, culture and society) and devise new applications of available knowledge. This definition is operationalised by the ONS BERD survey following the guidelines set out in the OECD's Frascati Manual 2015 for collecting and reporting data research and experimental development data.

Figure 13: Effects of ESA contracts on R&D employment among UK beneficiary companies



Source: Ipsos UK calculations based on ESA contract and ONS BERD Survey data.

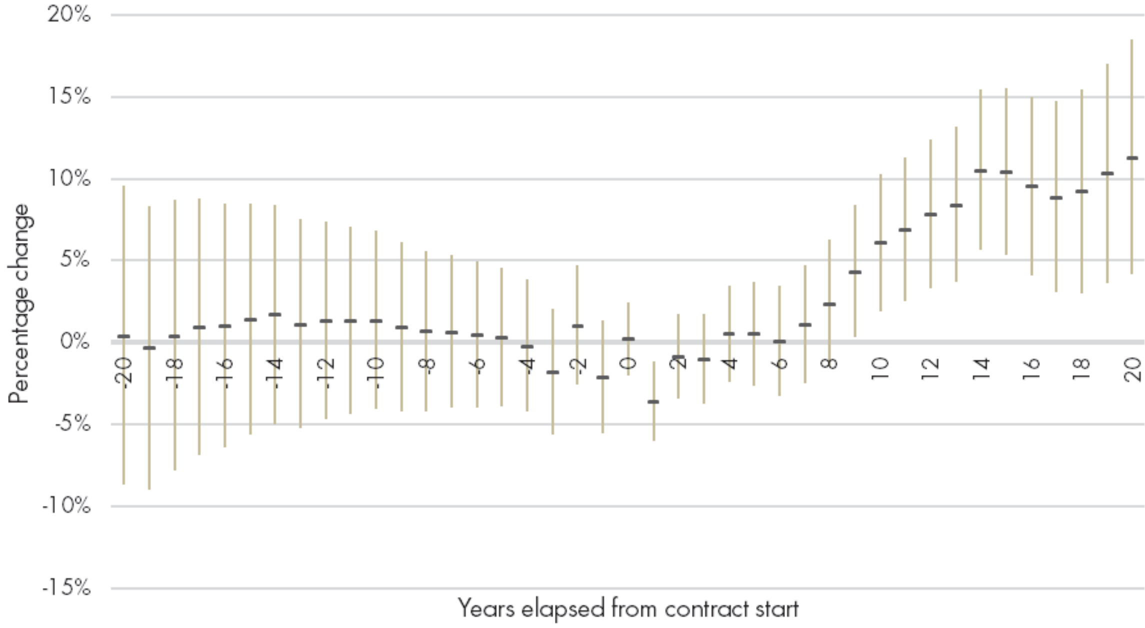
2.2.3. Effects on productivity

Our analysis provides strong evidence that ESA contracts deliver a significant and lasting positive impact on productivity for UK firms, both in turnover and GVA per worker. These findings indicate that ESA funding supports not only firms' growth but also improvements in efficiency and higher value creation per employee.

We found that £1m of ESA contract funding led to an average annual increase of 4.9% in turnover per worker among beneficiary firms over the time period of the analysis (see Figure 14 below), with a 95% confidence interval of 3.0–6.9%. Our analysis found that this increase was sustained over time, with effects persisting 20 years after the contract start year.

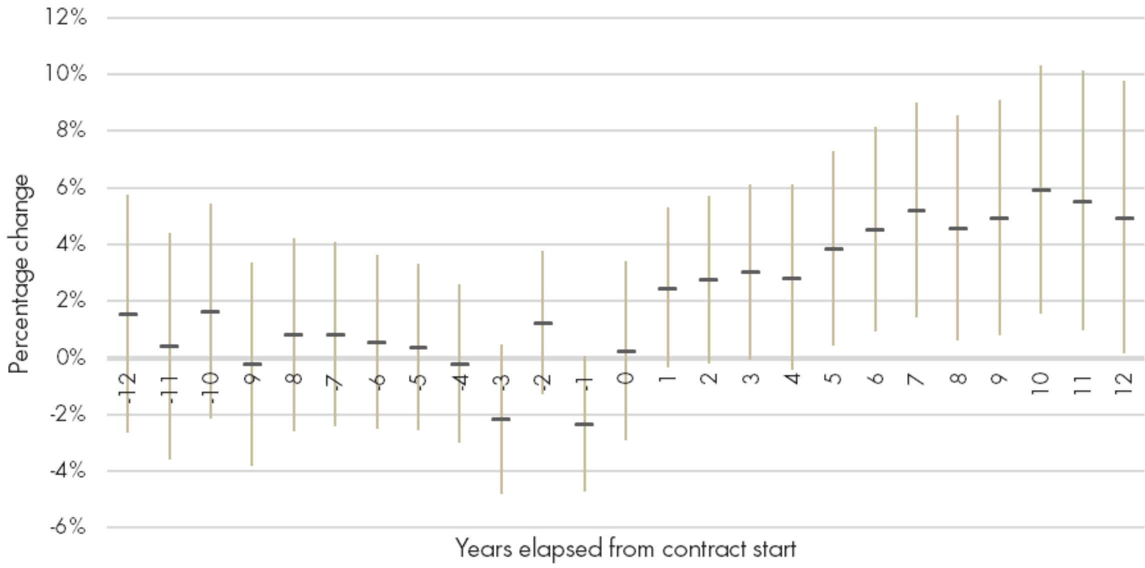
While turnover per worker provides a useful indicator of productivity, GVA per worker is a more precise measure that accounts for the value generated by firms after deducting input costs. Our analysis found that £1m of ESA contract funding led to an average annual increase of 3.9% in GVA per worker over the time period of the analysis, with a 95% confidence interval of 2.0–5.9% (see Figure 15 below). The sustained increase in both measures provides robust evidence for the long-term role of ESA investment in enhancing firm-level productivity within the UK space sector.

Figure 14: Effects of ESA contracts on company turnover per worker among UK beneficiaries



Source: Ipsos UK calculations based on ESA contract and ONS BSD data.

Figure 15: Effects of ESA contracts on GVA per worker among UK beneficiary companies

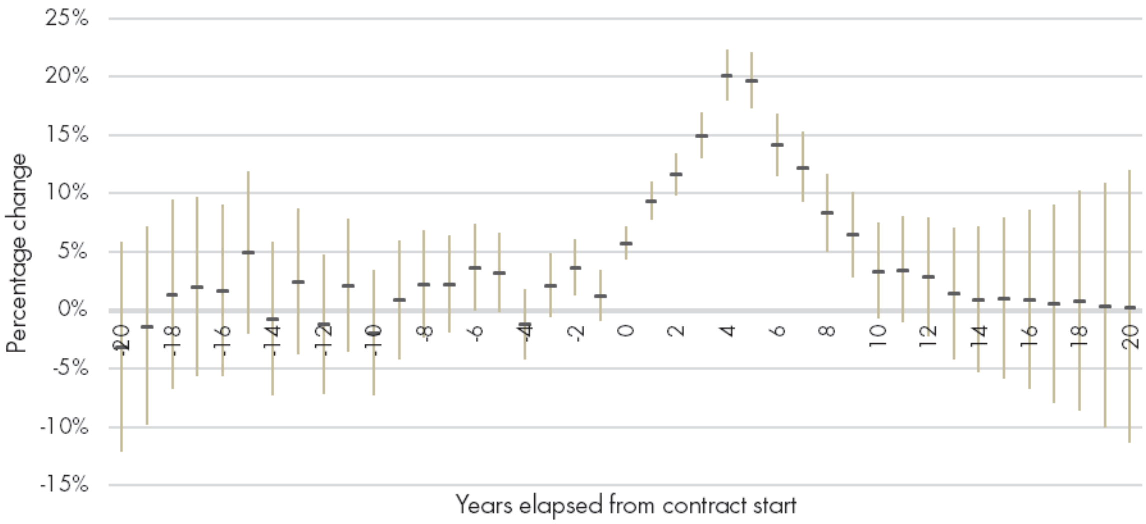


Source: Ipsos UK calculations based on ESA contract and ONS ABS data.

2.2.4. Effects on private R&D investment

Our analysis provides strong evidence that ESA contracts significantly impact R&D expenditure among UK beneficiary firms. We found that £1m of ESA contract funding led to an average annual increase of 6.6% in R&D expenditure among beneficiary firms over the time period of the analysis (see Figure 16 below), with a 95% confidence interval of 3.1–10.2%. The impact on R&D expenditure persists for several years, peaking four years after the contract award. Beyond this point, the effect begins to decline and is no longer statistically significant after ten years. However, it is important to note that this loss of statistical significance is partly due to the aforementioned reduction in sample size over time (as discussed in Section 2.2 above). Nevertheless, the estimated effect size is small after roughly 13 years post-contract award, suggesting that any long-term R&D expenditure impact is limited, regardless of sample size constraints in the analysis.

Figure 16: Effects of ESA contracts on R&D expenditure among UK beneficiary companies



Source: Ipsos UK calculations based on ESA contract and ONS BERD Survey data.

2.2.5. Policy findings from the events timeline analysis

In addition to providing a robust basis for our VfM assessment, the results presented above provide insights into policy significance. This is because using staggered DiD allows us to identify economic impact timelines: how quickly impacts arise and for how long they are sustained (and whether they dissipate over time). These impact timelines are important for policymakers to understand for three main reasons:

- First, they affect how a BCR is calculated (ensuring that the impact gestation periods reflected in the **lagged** value of benefits are matched with the costs that generated these benefits). This is especially important when gestation periods are long (e.g. more than ten years).[23]
- Second, these impact timelines shed light on the nature and extent of the economic impacts generated – particularly by examining their combined sequence, e.g. a peak in R&D (as a 'driver' variable) might relate to GVA and employment (as a 'driven' variable whose behaviour depends on the R&D activity).

[23] A UKSA-commissioned review of the literature published in 2021 concluded that there is a median lag of six years before benefits start to emerge and that these impacts have a median duration of 17 years. See: UK Space Agency (2022c).

- Third, understanding the lead time to economic impacts is crucial when deciding on changes in ESA funding. Depending on the programme, some economic impacts of the type considered here will be faster than others, and there are important aspects to consider, such as the relationships between time to impact and the size of these impacts in GVA, employment and GVA per worker terms.

The table below summarises the key findings on impact timelines.

Table 4: Key findings on impact timeline for each impact aspect

Impact aspect	Conclusions on impact timelines and policy significance
R&D employment	R&D employment impacts peak at over +15% five years after contract commencement, dissipating steadily over the following seven years before reaching a steady state with negligible net impacts. This tells us that ESA participation is associated with a temporary boost to R&D activity with the potential to generate broader knock-on effects that benefit the UK economy.
R&D expenditure	As expected, R&D expenditure follows a similar impact timeline to R&D employment, exhibiting a fairly sharp early peak reflecting how R&D drives the broader and more sustained economic impacts.
Employment	Employment associated with ESA contracts grows rapidly, peaking at around +7% and with a flatter dissipation profile than R&D, with impacts continuing at a low level for 16+ years after contract commencement. However, most employment impacts persist up to eight years after contract commencement.
Turnover	Turnover starts to increase two years after contract commencement (at around +5%), grows rapidly for another two years to +8% and then climbs more gradually, peaking at 14 years after contract commencement. The impact has not dissipated at the 20-year point.
Turnover per worker	Growth in turnover per worker initially lags and then rises gradually, peaking at +11% 14 years after contract commencement.
GVA	GVA initially peaks at around +8% after four years, then exhibits fluctuating but sustained impacts that are still observable 12 years after contract commencement.
GVA per worker	GVA per worker is the key impact measure from an HMT perspective. It exhibits modest impacts after one year (+2%) but continues to grow gradually for 12 years, peaking at +6% after ten years. Productivity is a preferred metric because it avoids the problems caused by displacement effects when GVA is used (i.e. industrial relocation).

These results clearly demonstrate that ESA participation has noteworthy and sustained economic benefits on average across all programmes. **One key confirmation is that long (10+ year) timeframes must be considered when assessing the economic impact of ESA participation** – both *ex-post* and *ex-ante* when assessing what to expect from increased funding for ESA programmes.

2.2.6. Domain-specific analysis of direct economic benefits

This section presents the results of the SDiD analyses disaggregated by ESA programme domain to assess the extent to which the economic impacts of ESA contracts differ across programme areas. As above, we examine the effects of ESA funding on economic growth, employment, productivity and private R&D investment for five ESA domains: Telecommunications, EO, Mandatory Programmes and Activities, Human and Robotic Exploration, and Other Programmes and Activities. Due to limited sample sizes in the available dataset, we could not conduct robust econometric analysis for the Space Safety and Space Transportation ESA domains. The findings presented here focus on domains with sufficient statistical power to generate reliable impact estimates. This disaggregated analysis enables a more granular understanding of how economic outcomes vary by ESA programme area, offering valuable insights for domain-specific policy and investment decisions.

Our analysis identifies statistically significant impacts across a range of outcome variables for three ESA programme domains: **Telecommunications**, **EO**, and **HRE**. In contrast, we do not observe statistically significant impacts across the outcome measures considered for the Mandatory Programme and Activities or Other Programmes and Activities domains.

- **Telecommunications**: On average, £1m of ESA contract funding led to an **annual 6.8% increase in firms' turnover** and an **annual 7.1% increase in GVA** over the time period of the analysis. Employment impacts were also positive, with an **annual 2.8% increase in total employment** and an **annual 2.7% increase in R&D employment** over this time period. Our analysis also found that ESA contract funding was associated with productivity gains. On average, £1m of ESA contract funding led to an **annual 5.8% rise in GVA per worker** for firms over the time period of the analysis. Finally, there was a notable boost in private innovation activity, with **R&D expenditure increasing annually by an average of 5.8%** per £1m of ESA contract funding over the time period of the analysis.
- **EO**: On average, £1m of ESA contract funding led to an **annual 4.9% increase in firms' turnover** and an **annual 4.6% increase in GVA** over the time period of the analysis. However, we saw no employment effects at conventional levels of statistical significance.[24] The analysis also found that ESA contract funding was associated with productivity gains. On average, £1m of ESA contract funding led to an **annual 3.8% rise in GVA per worker** for firms over the time period of the analysis. Finally, there was a boost in private innovation activity, with **R&D expenditure increasing annually by an average of 3.8%** per £1m of ESA contract funding over the time period of the analysis.
- **HRE**: On average, £1m of ESA contract funding led to an **annual 2.9% increase in firms' turnover** and an annual **3% increase in GVA** over the time period of the analysis. However, we observed no employment effects at conventional levels of statistical significance.[25] The analysis also found that ESA contract funding was associated with productivity gains. On average, £1m of ESA contract funding led to an **annual 3% rise in GVA per worker** for firms over the time period of the analysis. Finally, there was a boost in private innovation activity, with **R&D expenditure increasing annually by an average of 2.6%** per £1m of ESA contract funding over the time period of the analysis.

[24] This refers to a threshold of $p < 0.05$, meaning that the observed effects are not statistically distinguishable from zero with at least 95% confidence.

[25] This refers to a threshold of $p < 0.05$, meaning that the observed effects are not statistically distinguishable from zero with at least 95% confidence.

3. Scientific and technological achievements and returns

This chapter presents findings on the impact of the UK's investments in ESA on science and technology and capabilities and capacities in the UK space sector. First, we present the advancements in science and technology attributable to the UK's investments in ESA, followed by increased capabilities within the UK space sector for developing new space technology, products and missions. Then, we explore how the UK's investments in ESA help attract and retain talent and knowledge generation in the UK space sector. We consider how these impacts relate to the UK's NSS and wider government priorities in space, science and technology throughout.

Key findings on the scientific and technological advancements and returns of the UK's ESA membership

- **Advancements in 'blue-sky' science and technologies:** Programmes like GSTP and NAVISP have advanced early-stage and 'blue-sky' technologies, such as next-generation Global Navigation Satellite System technologies developed under NAVISP.
- **Advancements in instrument development and operationalisation:** Advancements in foundational instrumentation have been achieved through involvement in critical missions across domains such as space science, EO and space safety, where UK leadership in Vigil has enabled researchers to adapt and iterate previously existing instrument designs to meet new operational requirements.
- **Limited advancements in mission development:** The limited number of UK industrial primes has limited overall mission development and leadership technologies. However, large missions like TRUTHS and Vigil have advanced some domains.
- **Advancements in down-stream exploitation and infrastructure development:** Down-stream data exploitation and infrastructure development remain key strengths of the UK space sector. Key capabilities are being maintained and developed in EO and space weather, with important advances in climate data and space weather. ESA contracts are often supplemented by national funding programmes, such as the Centre for EO Instrumentation (CEOI) and the Space Weather Instrumentation, Measurement, Modelling and Risk (SWIMMR) programmes.
- **Increased scientific output:** The UK is a leader in European space science and research, enabling knowledge sharing and attracting and retaining the UK's space science workforce.

3.1. UK science and technology advancements through ESA

UK involvement in ESA projects, programmes and missions has led to significant technological and scientific advancements. Advancements in the context of the space domain can be marginal but still provide significant added value to the UK, especially where they lead to new expertise, capabilities, facilities or infrastructure or support the growth of the UK space ecosystem more generally.

The diversity of ESA's programme portfolio has resulted in a breadth of scientific and technological advancements in the UK across all domains and at various Technology Readiness Levels (TRLs).[26] Technological advancements occur across the development chain, progressing from 'blue-sky' foundational technology development at low-TRLs to downstream exploitation and commercialisation of developed technologies. These development stages intersect and overlap, bringing together academic, industrial and governmental actors. Acknowledging this complexity, we follow a linear pathway of technology development in this report, highlighting areas of success and opportunities for future engagement:

- Low-TRL, 'blue-sky' scientific and technological development, including infrastructure required for future developments.
- Instrumentation development, building on and implementing cutting-edge technologies into operational instruments.
- Mission development and integration of instruments and technologies into larger missions.
- Downstream exploitation and application of data and technologies, including modelling and commercialisation.

The following subsections present programme-level examples of results observed.

3.1.1. Low TRL/foundational research (Future-Oriented Space Missions and Growth)

A key aspect of all early-stage technology development efforts is the 'stamp of approval' provided by securing and completing an ESA-funded and overseen project. ESA is renowned for its rigorous standards and technical support provision. Being awarded ESA early-stage technology R&D funding and gaining access to ESA facilities and expertise[27] benefited UK companies' and academic institutions' reputations and was indispensable for technical development. Some stakeholders indicated that UKSA-funded national early-stage funding programmes, such as the National Space Innovation Programme, do not offer the same standard of technical support, limiting technical review primarily to the application process and with less access to suitably qualified and experienced personnel.[28] One interviewee stated that,

[26] TRLs are a measure of the maturity of a technology, ranging from TRL 1 (basic principles observed) to TRL 9 (actual system proven in operational environment).

[27] INT_12_SS.

[28] INT_16_SS.

for a company developing an experimental, novel or innovative space technology, there is no better validation than an ESA project with a stamp of approval at the end to signal reliability and high quality.[29]

A notable challenge facing early-stage technology development is transitioning these low-TRL activities to more mature stages with clear mission applications. UKSA is developing industry support packages to guide companies to advanced stages, ensuring that innovations progress beyond foundational technologies and that actors across UK industry and academia can capitalise on them. With 94% of UK bids in ESA's Basic Activities being open competition, continuity for successful projects is crucial, leveraging facilities like the European Space Tribology Laboratory for further development and testing.[30]

Basic Activities and Mandatory Contributions

Discovery and preparation funds under ESA's basic activities support initiatives ranging from blue-sky research to foundational innovations for future space science missions. These comprise 1) Discovery activities, facilitated by the Open Space Innovation Platform[31] to promote new ideas and seek answers to foundation problems, and 2) Discovery and Preparation Activities,[32] which lay the groundwork for space missions and programmes in ESA's short-to-medium-term future.

This early-stage preparatory R&D is particularly crucial for upcoming space science missions. Funded under basic activities, ESA's Science Core Technology Programme (CTP) ensures early and effective preparation of the Agency's future science missions by preparing the critical enabling technologies underpinning mission development.[33] After the initial stages of new technology development have been pursued through ESA's Basic Technology Development Element programme,[34] a CTP-funded activity carries them to higher stages of technological maturity, up to full-scale engineering models ready for the design phase.

One notable example is the development of cryocoolers for missions like Atmospheric Remote-sensing Infrared Exoplanet Large-survey (Ariel)[35] and Advanced Telescope for High Energy Astrophysics.[36] These projects have advanced cooling technologies essential for mission success and have **boosted the capabilities of the Rutherford Appleton Laboratory (RAL), operated by the UK Science and Technology Facilities Council (STFC), in designing space cryogenics** and in Honeywell driving manufacturing activities.[37] Another example is the Gaia Near-InfraRed (NIR) project, which progressed from a baseline study to an ESA-funded core technology programme. This project involves hardware

[29] INT_17_SS.

[30] MAN_INT_1.

[31] European Space Agency (2019a).

[32] European Space Agency (2019a).

[33] European Space Agency (2025a).

[34] European Space Agency Directorate of Technology, Engineering and Quality (2025).

[35] European Space Agency (2025b).

[36] European Space Agency COSMOS (2025a).

[37] know.space (2022).

studies to enhance instrument capabilities for future missions. Supported by UK industry, this ongoing work is crucial for building expertise and leadership in this mission concept.[38]

In addition, RAL Space has supplied thermal blankets for many satellites and was responsible for building multi-layer insulation (MLI) blankets that protect the Mid-Infrared Instrument (MIRI)[39] from the heat of the rest of the spacecraft as part of the US National Aeronautics and Space Administration's (NASA's) James Webb Space Telescope (JWST) programme.[40] This programme developed new technologies on which later publications were based.[41]

The benefits of this early-stage technology development extended beyond space science, with use cases across the ESA portfolio. An example from the Discovery programme is the BioCeMe project,[42] a cellular agriculture project investigating the potential for food production in space to minimise the need for future crewed missions to transport large quantities of long-shelf-life food. As part of this project, a UK SME was awarded €100k for a feasibility study into animal protein production in the space environment. Although the project is in its early stages and no system or technology has yet been developed, it represents an important step towards creating sustainable food sources in space.[43] One of this project's key benefits to the UK SME involved is reputational, with this initial funding proving that they can secure ESA contracts.

Basic activities also ensure the future readiness of ESA's infrastructure, including mission control systems and the software that supports mission operations, e.g. managing ground stations and buildings and feasibility studies into low-orbit ground station terminals, such as those built in the Shetland Islands.[44] Although not mission-specific, these facilities provide essential support across various programmes, including science, human and robotic exploration and EO.

Navigation Innovation and Support Programme (NAVISP)

ESA's NAVISP programmes enabled UK-based entities to pursue ambitious space-based navigation research. NAVISP's funding model allowed UK firms to pursue high-risk, high-reward research that could shape the future of global navigation infrastructure.[45] NAVISP Element 1 funds 'blue-sky' research, supporting high-risk, high-reward innovations that industry would not independently pursue within a Positioning, Navigation and Timing (PNT) context.[46] Early-stage funding provided by NAVISP enabled companies to explore the low-TRL R&D necessary to de-risk technologies targeted at commercial investment or those that could form part of a larger mission, particularly in navigation and timing

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[38] NSSP_SEBP_INT_2.

[39] European Space Agency (2025c).

[40] NASA (2025).

[41] INT_13_SCI.

[42] European Space Agency Nebula (2025).

[43] European Space Agency (2023c).

[44] INT_11_SCI.

[45] INT_1_NAV.

[46] INT_1_NAV.

infrastructure.[47] NAVISP has demonstrated a strong pipeline of technology development from proof-of-concept and foundational research at TRLs 1–2 through to demonstrations at TRLs 4–6, helping UK firms develop technologies that can be leveraged for future commercial success.[48] Examples include:

- **Advanced Global Navigation Satellite System (GNSS) receivers**, which enhance accuracy and integrity in autonomous systems.[49]
- **Next-generation GNSS augmentation technologies** that improve precision and reliability, reduce the risks of jamming, spoofing and signal loss and provide the UK with an independent and resilient capability.[50]
- **Advanced cybersecurity for PNT**, which ensure resilience against global cyber threats.
- **Quantum navigation in space**, which is a key emerging field for future deep-space exploration missions that seek to replace traditional satellite-based positioning with atomic clocks and quantum sensors.[51] Critical early-stage research funding allowed a UK company to collaborate with UK universities in quantum-based navigation, positioning the UK as an innovator in the field.[52]

General Support Technology Programme

ESA's GSTP has a major role in advancing technological developments and R&D within the UK space sector. The support offered helped companies progress from early-stage concepts to more developed technologies. Moreover, GSTP has helped support new technologies by facilitating the creation of intellectual property and scientific publications.[53] Despite challenges, such as financial and administrative hurdles, the programme assisted in bridging the gap between innovation and commercialisation. Examples our interviewees cited include the following:

- Following a significant breakthrough around 2016, a company sought grant funding for feasibility studies through UKSA's National Space Technology Programme.[54] This initial support laid the groundwork for transitioning to ESA's GSTP-funded workflow, which allowed the company to pursue further technological goals. GSTP enabled an initial de-risk project, which successfully led to a follow-on contract. **This progression culminated in securing funding to build a payload for the ISS**, demonstrating the technology's development to a level suitable for in-orbit applications. GSTP's potential to validate technology in orbit was an advantage and essential for proving

[47] INT_5_NAV; INT_2_NAV.
[48] INT_1_NAV.
[49] INT_4_NAV.
[50] INT_Scoping_NAV; INT_NAV_UKSA.
[51] INT_2_NAV; INT_5_NAV; INT_4_NAV.
[52] INT_2_NAV.
[53] INT_1_TECH; INT_4_TECH.
[54] UK Space Agency (2022a).

technological capabilities. Achieving such demonstrations would have been challenging without GSTP funding.[55]

- A UK company that developed infrared/optical sensors for EO satellites under GSTP was able to **develop technologies to an extent where they were picked up for inclusion on Copernicus and Expansion missions**, highlighting the success of GSTP in developing early-stage technologies applicable to other ESA domains.[56]
- One UK company highlighted its collaboration with ESA over the past five years in adapting a specific technology for spacecraft components. They **successfully completed an initial visibility project** and are now working with Airbus to increase the TRL further. In another project, they raised the TRL from around three to six for certain material combinations and applications, demonstrating positive progress in their R&D efforts.[57]

Space Safety

COSMIC,[58] a key element of ESA's Space Safety portfolio, was considered a **good opportunity to develop smaller-scale, space-tested technologies in the UK**, with a pathway to fly cheaper instruments on 'miniaturised missions with a shorter lead time.'[59] COSMIC seeks to broaden the remit of the Space Safety domain, funding small projects that utilise experimental technologies in innovative ways, such as destructive re-entry testing or laser momentum transfer. One COSMIC participant reported that success through GSTP enabled them to demonstrate a technology in space, opening the door to applications in space safety after further development and reflecting the flexibility of GSTP's early-stage technology funding.

Due to **these projects' low-cost nature** and the **experimental nature of the technologies** they seek to develop, COSMIC allows for a higher risk appetite than usual within ESA, which is very attractive to UK participants with expertise in relevant technologies. As COSMIC is a relatively new programme, funded for the first time at CM22, participants were concerned that the **breadth of opportunities available may limit the effectiveness of any single project** and that UK funding to these projects did not necessarily align with existing UK technological expertise.[60]

ESA's COSMIC programme has developed or invested in some technologies readily available on commercial markets and can be implemented into other missions or projects. ESA funding has been valuable to COSMIC participants due to the technical rigour associated with ESA funding and the **reputational benefits to UK industrial participants** of engagement with ESA programmes.[61]

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[55] INT_1_TECH.

[56] INT_20_EO.

[57] INT_4_TECH.

[58] European Space Agency (2025d).

[59] INT_9_SS.

[60] INT_15_SS; INT_16_SS; INT_17_SS.

[61] INT_16_SS; INT_17_SS.

3.1.2. Instrument development and operationalisation

The UK is recognised for its strengths in instrumentation development. The UK's established heritage in various instrumental domains enabled involvement in ESA space missions and contributed to cutting-edge scientific research. The UK has played a key role in advancing TRLs of key instruments from conceptual stages to fully operational systems across various ESA space science missions. As past missions like Gaia and Herschel have already been evaluated for their impacts (although the impacts are ongoing),[62] the focus here is on recently operational missions or future missions.

Basic Activities and Mandatory Contributions

The UK's involvement in major space science missions is facilitated through two main mechanisms. **Firstly, the UK's mandatory financial contributions to the ESA Science Programme cover shared mission costs, payload development, mission operations and support for scientific instrumentation across all member states.** These mandatory contributions enable the UK to participate in these missions and to access the data they generate.

Secondly, in addition to the mandatory ESA contributions, targeted national investments through UKSA and associated research councils, such as STFC, provide specific funding for instrumentation development. This additional funding is delivered and overseen through the National Space Science Programme (NSSP).[63] It has enabled the UK to lead the design, development and testing of key instruments on several missions, such as MIRI, which was developed for the JWST, and four of ten instruments hosted on Solar Orbiter. This funding approach allowed **the UK to balance the advantages of collective European collaboration with targeted national investments**, ensured leadership in the mission's critical aspects, and provided influence in the scientific design of key space science missions. Such an approach was particularly important in an ESA programme area where the UK could not direct investments towards specific missions during CM negotiations.

A key area of UK expertise is in the development of magnetometers, as demonstrated by UK contributions to the Solar Orbiter and Jupiter Icy Moons Explorer (Juice) missions.[64] The Solar Orbiter mission, which provides images of the Sun from unprecedented proximity, hosts ten instruments, many developed with significant UK contributions. Imperial College London was central to developing the Magnetometer (MAG) instrument.[65] Other UK institutions lead on three other key instruments: Solar Wind Analyser (SWA), Extreme Ultraviolet Imager and Spectral Imaging of the Coronal Environment.[66] Similarly, the UK took a leading role in developing the J-MAG magnetometer for the Juice mission,[67] which was essential for studying Jupiter's icy moons.[68] This effort, also led by Imperial College London,

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[62] UK Space Agency (2017); know.space (2023).

[63] UK Space Agency (2021).

[64] European Space Agency (2025e); European Space Agency (2025f).

[65] Imperial College London (2025).

[66] UK Space Agency (2023a; European Space Agency (2020).

[67] European Space Agency (2022c).

[68] UK Space Agency (2023b).

emphasises the UK's expertise in magnetometer technology. Additionally, the University of Leicester and the Open University were involved in refining the instrument's design and sensor calibration.[69]

The UK's participation in previous missions laid the groundwork for advancing science and technology in future projects. Historical missions such as Cassini,[70] a joint ESA, NASA and Italian Space Agency mission to Saturn that launched in 1997, facilitated new endeavours like Juice, where UK scientists have built upon past discoveries to explore Jupiter and its moons. This heritage, coupled with optical design and calibration expertise, has also been applied to missions such as Euclid and Sentinel,[71] significantly contributing to climate and environmental monitoring.[72]

Another area of UK expertise is infrared and mid-infrared astronomy, as demonstrated by its contributions to the MIRI on the JWST. Building on expertise from missions like Herschel and the Infrared Space Observatory,[73] the UK's work on MIRI, developed by a consortium of ten European countries led by the UK, involved developing its design, performance verification and data analysis tools.[74] RAL Space contributed to the thermal engineering, integrating a cryocooler system from NASA's Jet Propulsion Laboratory to maintain optimal detector temperatures, which was critical in ensuring MIRI's success. MIRI was built with significant involvement from UK and European industrial partners,[75] with UK scientific and instrument design capabilities exceeding the supply capabilities for infrared sensors of the UK supply chain, requiring further European involvement. This highlights a disconnect between the scientific and industrial capabilities present in the UK and identifies potential missed opportunities and chances for growth in the UK space sector.

Beyond these missions, the UK is actively leading the upcoming Ariel mission, with University College London (UCL) spearheading the science development and the Rutherford Appleton Laboratory managing the payload module. This includes assembling, integrating and testing the payload as well as developing the cryogenic Active Cooler System. Scientists at the University of Cardiff and UCL are creating mission simulations to refine Ariel's data retrieval algorithms, with the University of Oxford providing optical ground support.[76]

Earth Observation

EO is an integral part of the UK's contribution to ESA and thus has seen many advancements in recent years. The UK-led TRUTHS mission aims to spearhead the 'gold standard' in climatic observation and calibration. TRUTHS will host a series of instruments to continuously measure incoming solar radiation and outgoing reflected radiation to evaluate Earth's energy ratio. The UK plays a significant role in developing TRUTHS' key instruments. Teledyne e2v Space Imaging led the development of the

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[69] INT_9_SCI.

[70] European Space Agency (2025g).

[71] European Space Agency (2025h); European Space Agency (2025i).

[72] INT_5_SCI.

[73] European Space Agency COSMOS (2025b).

[74] INT_2_SCI.

[75] INT_13_SCI.

[76] INT_5_SCI.

mission's Hyperspectral Imagining Spectrometer, which will measure Earth, Sun and Moon radiation from ultraviolet to infrared.[77] The mission's Cryogenic Solar Absolute Radiometer, which will measure solar radiation traceable to SI-units, was developed by the UK's National Physical Laboratory (NPL) and Airbus.

Although the concepts around the spectrometers on board are well-established, adapting them for use in space requires technological advancements that UK institutions are leading.[78] UK investment in TRUTHS will progress these instrument concepts from approximately TRL 4 to TRL 6, demonstrating their viability in space and applicability to on-orbit measurements.[79] Instrument development is ongoing and on track, ahead of the mission's preliminary design review.[80]

The UK's involvement in ESA's CCI has significantly advanced various climate monitoring technologies, moving them from R&D to operational use. The datasets generated by the initiative have contributed to climate research, policy-making and commercial applications, such as climate risk assessment and adaptation planning. These technologies have contributed to the scientific understanding of climate change. UK scientists have played a key role in analysing and interpreting the data, leading to numerous high-impact publications and improved climate models.[81]

In addition to TRUTHS and CCI, and as part of the UK's involvement in ESA's FutureEO programme, **UK scientists led the development of a new instrument for generating high-resolution wind maps.**[82] Copernicus, the EO component of the European Union's space programme, has been a major contributor to the UK's EO technology development landscape. Technological advancement in some EO fields has been limited since the UK's re-engagement with Copernicus, following several years outside of the programme following Brexit.

Due to uncertainties surrounding the UK's future in Copernicus during Brexit, UK organisations could not develop technologies that Copernicus satellites would have hosted. Since re-engagement, pre-existing technologies have been adapted and enhanced for use in the latest missions. However, developing novel and innovative technologies has slowed for Copernicus programmes.[83] When considered in alignment with the very long lead times for technology development associated with ESA programmes like GSTP, the uncertainty surrounding UK involvement in Copernicus seriously impacted the UK EO sector's ability to develop new and novel technologies that could be leveraged in future Copernicus mission opportunities.

[77] UK Space Agency (2024b).

[78] INT_16_SS.

[79] INT_33_EO.

[80] INT_33_EO.

[81] Expert_review_CCI.

[82] INT_14_EO.

[83] INT_11_EO.

Human and Robotic Exploration

The UK has made notable contributions to lunar and planetary exploration missions through investments in ESA, enabling the development of new technologies and re-purposing existing technologies. The Lunar Pathfinder mission,[84] developed via a commercial partnership with Surrey Satellite Technology Ltd (SSTL), aims to re-purpose and re-develop existing low earth orbit technology for deep-space communications, with the goal of facilitating the next generation of lunar exploration by enabling reliable communications for lunar orbital vehicles and lunar surface vehicles. Led by the UK, this ambitious project is facilitating developments in radiation-hardening techniques, orbit stabilisation and advanced ground communication infrastructure.[85]

Other examples include the following:

- **UK-developed mass spectrometers have been critical** for detecting water on the Moon and Mars across the Prospect payload package[86] and ExoMars missions,[87] with potential applications in planetary science and future resource utilisation for crewed lunar and Martian exploration missions.[88]
- **The UK is developing key aspects of the propulsion system for ESA's upcoming Argonaut lunar lander**,[89] ensuring UK industry is involved in and benefits from ESA's lunar exploration roadmap.[90] UK-developed imaging technologies are also used in space docking, robotic operations and planetary landings.[91]
- **UK contributions to the Juice and Gaia missions have strengthened the UK's global reputation in planetary and astrophysical research** and ensured that instrument development capabilities are maintained and leveraged in future ESA space science and exploration missions.[92]

Space Safety

As an operational space weather satellite, Vigil requires technological advancements to facilitate near real-time, near-continuous data delivery. Building on previous instrumentation heritage, funding provided to UK institutions through the UK's investments in Vigil enabled the successful development **of two key instruments** designed to meet Vigil's operational goals: the Plasma Analyser (PLA)[93] and the MAG.[94]

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[84] European Space Agency (2021).

[85] INT_1_HRE.

[86] European Space Agency (2025j).

[87] European Space Agency (2025k).

[88] INT_2_HRE.

[89] European Space Agency (2025l).

[90] INT_3_HRE.

[91] INT_2_HRE.

[92] INT_4_HRE.

[93] European Space Agency (2025m).

[94] INT_7_SS; INT_8_SS; INT_9_SS.

The PLA, built by UCL Mullard Space Science Laboratory (UCL MSSL), builds on the SWA built for Solar Orbiter while changing polarity. UCL MSSL had expertise in building electron ion instruments, but the reversed polarity proton ion instruments are a new UK capability developed because of UK investments into Vigil. A demonstrator model built for PLA highlighted a few problem areas, with work continuing ahead of the preliminary design review in February and a critical design review in mid-2026. As a result of this continued heritage, **the UK is 'now the first port of call for electron and plasma detectors**, and that could only have been achieved through Vigil.'[95]

Vigil's MAG instrument, built by Imperial College London, builds on the designs formulated by the Solar Orbiter and Juice magnetometers, with the development team estimating that '90% of MAG is derived from Juice and Solar Orbiter', with adjustments as necessary for the operational nature of the mission and the specific design requirements of Vigil. **Existing instrument development heritage provides a demonstrated capacity for successful delivery and also enables continuous development** based on previous documentation and testing, giving ESA and industrial partners and managers confidence that the instrument will be delivered to spec and on schedule.[96]

Successes through the development of Vigil have also opened opportunities for future bilateral engagements with international partners, such as NASA and the US National Oceanographic and Atmospheric Administration (NOAA) and involvement by UK institutions in instrument development for missions such as IMAP and HelioSwarm.

3.1.3. Mission development and integration of instrumentation, including on-orbit testing and demonstration

Despite the UK's successes in early-stage technology and instrumentation development, its national capacity to manufacture, test and integrate a full mission is limited. The fixed number of industrial primes in the UK essentially limits the UK's ability to capitalise on these contracts as and when they arrive. Exceptions exist where a UK prime has been awarded large-scale manufacture and management contracts, such as Airbus UK developing Vigil. However, geo-return constraints often limit the capacity for UK institutions to successfully bid for large-scale mission integration and management contracts, representing a key opportunity for the UK and underscoring the importance of funding space sector investments throughout the development pipeline to enable UK stakeholders to benefit at all levels.

Earth Observation

HydroGNSS, a reflectometry mission that ESA will fly as part of its Scout Missions within FutureEO to measure climate variables, is an example of the UK identifying and leveraging scientific and instrumental heritage to scope, develop and propose a discrete mission concept.[97] The concept for HydroGNSS was proposed over 15 years ago, with SSTL developing demonstration tools through internal funding and UK

[95] INT_7_SS.

[96] INT_9_SS.

[97] INT_18_EO.

national funding streams such as the Centre for Earth Instrumentation. The UK proposed the mission to ESA and is now leading the design and development of the required technologies.[98]

The UK-led and developed TRUTHS mission provides an opportunity for the UK to test and integrate an EO mission. Building on UK heritage in developing its instruments, the TRUTHS mission will see the testing and integration of hardware and software components led by Airbus UK. RAL space continues the UK's role in testing and integrating the mission, conducting many of its calibration activities utilising their vacuum and clean room facilities and radiometric calibration facilities provided by NPL.[99] TRUTHS, therefore, provides a strong example of the UK's national capacity to build, test and integrate a complex EO mission, levering its position as the foremost investor in the mission. As the mission development continues, it remains a proving ground for UK capabilities.

Focused on commercial innovation in EO, ESA's InCubed-2 programme has also resulted in technological development for UK companies funded under the programme, including:

- **A space-based nitrogen monitoring instrument** enabling farmers to track the use of nitrogen fertiliser applied to their land, which has progressed from TRL 3 to TRL 6–7, with variation in subsystem development.[100]
- **Instrument and imager stabilisation and thermal regulation technology** that has developed from TRL 3 to TRL 9 and is now fully operational.[101]

Space Safety

The development of Vigil is being led and managed by Airbus UK, which is responsible for the space segment and the design and manufacture of the satellite bus. As previously discussed, instrumentation is being developed by a range of European institutions, including two in the UK. While Airbus UK is not directly involved in instrument development, it does have a hand in guiding the general process as a project manager.[102]

The development of ClearSpace-1, a key aspect of ESA's Active Debris Removal/In-Orbit Servicing (ADRIOS) portfolio, is being led by ClearSpace SA in Switzerland with significant involvement from ClearSpace UK and other UK-based ADRIOS and space sector companies such as Astroscale, D-Orbit and Deimos. **ClearSpace-1 is a unique opportunity for the UK ADRIOS sector**, representing a complete end-to-end mission development process, developing a range of associated required technologies and assembling them into a cohesive mission. Previous ADRIOS approaches have taken a more piecemeal approach, with incremental developments and demonstrations. Required technologies cover a range of disciplines, including guidance, navigation, control, algorithm development and robotics.[103] Some technologies are available off-the-shelf and will require adjustment to the specific design parameters of the

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[98] INT_18_EO.

[99] UK Space Agency (2024b).

[100] INT_13_EO.

[101] INT_15_EO.

[102] INT_4_SS.

[103] INT_10_SS; INT_11_SS; INT_12_SS.

mission, while others still need to be developed. Technologies are still developing ahead of launch in 2028, with consideration for the recent re-evaluation of the mission as a more traditional 'core' ESA-style technology development mission rather than service provision.[104]

3.1.4. Downstream exploitation and application of data and technologies, including calibration

Increased or developed downstream exploitation of data derived from key space missions and programmes is a key benefit of the UK's investments in the ESA, offering significant opportunities for the space sector to develop value-added services and applications with broader socioeconomic impact. However, these downstream benefits are critically dependent on sustained upstream investment. By investing in instrument and mission development, as well as data processing, storage and fusion, the UK aims to ensure it is at the cutting edge of scientific discovery in diverse disciplines, ranging from EO to space weather. Without relevant upstream capabilities, the UK would have less influence over mission specifications and data standards, which are essential for effective downstream use. In this sense, upstream investment advances the UK's position in scientific discovery, from EO to space weather, and enables the subsequent commercial viability and societal relevance of downstream applications.

Earth Observation

Investments in ESA EO programmes have enabled UK-led and supported advancements in science and technology, including the downstream exploitation of EO data to further scientific and technological progression in modelling, calibration and data processing. The nation's involvement in projects like the TRUTHS mission presents opportunities to lead in satellite calibration, opening up the potential for bilateral engagement[105] and providing **unparalleled accuracy in climate records**. Such capabilities not only enhance the UK's negotiating power in international collaborations but ensure long-term returns on investment.[106]

The ESA CCI represents a key platform through which data and infrastructure have been developed. UK involvement in that initiative has been instrumental in its success and widespread adoption. Through CCI, the UK has contributed to developing cutting-edge algorithms and processing techniques designed to generate high-quality, consistent and long-term climate data records from multiple satellite sensors. The initiative has fostered the development of novel methods for data harmonisation, cross-calibration and uncertainty characterisation, ensuring data accuracy and reliability.[107]

Datasets generated and maintained through CCI have improved modelling capabilities and provided governance around essential climate variables, allowing targeted research and collaboration across Europe. The CCI program has accelerated knowledge and understanding of these variables, with the climate modelling user group providing updates to relevant sectors on the leading science on each topic area.[108]

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[104] INT_3_SS.

[105] INT_5_EO.

[106] INT_17_EO.

[107] Expert_review_CCI.

[108] INT_2_EO.

The CCI Open Data Portal (ODP) is a primary example of such technological achievements. The UK is involved in user requirements and system design, with infrastructure from the Centre for Environmental Data Analysis integrated into the CCI ODP web platform. The engineering and data expertise provided by the UK has enabled the management and integration of diverse datasets from multiple Essential Climate Variable (ECV) projects.[109]

The CCI Sea Surface Temperature (SST) project aims to make climate data records for sea surface longer, more stable and more accurate. The most recent data release, which is freely available, included over 40 years of sea surface temperature variables. **UK researchers are leading the scientific aspect of this work, including calibration of decades-old data, retrieval of additional data sets and integration into long-term models**. As most sea-surface science teams focus on specific instruments or datasets, the CCI SST project's focus on gathering and calibrating a diverse array of relevant datasets is unique and instrumental to understanding the impacts of climate change on Earth's oceans.[110]

The CCI's integration of various satellite datasets into comprehensive climate datasets is innovative, particularly in data fusion, combining datasets from different satellite missions to create more accurate and consistent records, and long-term modelling, utilising historical data to provide context for current climate changes, essential for effective climate modelling. **The UK has been at the forefront of developing these innovative approaches**, particularly in atmospheric composition, ocean colour and land cover monitoring.[111]

UK participants in CCI have also led work in other disciplines, including the following:

- **Cloud mapping** in multiple layers of the Earth's atmosphere, reducing uncertainty and increasing the volume of available data.[112]
- **Biomass mapping**, increasing quality, reducing errors and broadening the temporal coverage of available data from two to eight dates to facilitate more effective trend analysis.[113]

ESA's FutureEO programme, particularly its 'Block 4: Science for Society' programme, has supported the development of a range of EO data platforms, algorithms and data science tools, including the CS4EO Platform, a free platform for EO data and digital twin systems.[114] The CS4EO Platform has approximately 150–200 monthly users, approximately one-third of which are based in the UK, showing the **UK's capability in using downstream data via ESA participation**.[115]

NAVISP

Through NAVISP funding, **the UK contributed to developing the VHF Data Exchange System**. This radio communication system operates between ships, shore stations and satellites, progressing from TRL 2

[109] INT_28_EO.

[110] INT_29_EO.

[111] Expert_review_CCI.

[112] INT_25_EO.

[113] INT_31_EO.

[114] INT_10_EO.

[115] INT_10_EO.

to TRL 5 and meeting key objectives towards operational deployment.[116] In addition, GMV's Timing Lab, created under NAVISP, provided the infrastructure to develop resilient timing systems for banking, telecoms and defence applications, leading to GMV securing an international contract for the Square Kilometre Array Observatory.[117]

Space Safety

Vigil's technical development interfaces with developing national space weather operations to increase forecasting and real-time capabilities. **The Met Office Space Weather Operations Centre (MOSWOC) is spearheading the UK effort to provide world-class space weather modelling and forecasting,** which, while funded nationally, is supplemented and enabled by data derived from ESA missions like Vigil and Solar Orbiter. MOSWOC was established in 2011 in response to HMG adding solar storms to the National Risk Register. It was built on scientific and non-operational space weather capabilities and established a full operational capability in 2014.[118] MOSWOC was established with support and guidance from space weather experts at the U.S. Oceanic and Atmospheric Administration Space Weather Prediction Center and has grown into one of the world's foremost space weather data and forecasting centres and the only truly operational space weather service in Europe. ESA is also developing a central space weather data portal, which is being developed with input and assistance from UK industrial partners and space weather experts. Exploitation of space weather data was supplemented by the success of the Space Weather Instrumentation, Measurement, Modelling and Risk programme (SWIMMR). This national programme provides funding for projects to improve the UK's monitoring and prediction capabilities in space weather. SWIMMR is highly regarded in the space weather sector and considered a key programme underpinning the UK's ability to capitalise on its leadership in Vigil.[119]

Active debris removal missions, like ClearSpace-1 and UK national mission CLEAR, are developing UK-based capabilities in active debris removal and laying the groundwork for future in-orbit servicing missions by developing the underlying technologies. Active debris removal is one of multiple potential in-orbit services envisioned by UKSA, ESA and industrial participants, with uncertainty surrounding which services will develop into established markets. Some interviewees expressed scepticism that active debris removal will develop an active customer base, especially as regulations and best practices emerge to encourage sustainable de-orbiting at end-of-life, such as those developed in the ESA Zero Debris Charter.[120] In-orbit servicing, manufacturing and refuelling were considered more likely to develop into active fields, and early UK-based technology development and industrial growth are building a foundation for UK leadership.

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[116] INT_5_NAV.

[117] INT_2_NAV.

[118] INT_5_SS; INT_6_SS.

[119] INT_5_SS; INT_6_SS; INT_9_SS; INT_13_SS.

[120] INT_10_SS; INT_12_SS.

Telecommunications and Applications

Participation in ESA programmes, particularly the Business Applications and Space Solutions (BASS) programme,[121] has significantly benefited technology development and demonstration, especially in communications, a niche area with limited funding opportunities.[122] The BASS programme supports investment into space by demonstrating its applications in AI, quantum computing, engineering and biology, allowing strategic alignment between funding calls and critical technology areas.[123]

The ARTES programme has supported the development of unique mesh capabilities within Europe, benefiting multiple antenna designs. The programme has enabled industrialisation and innovation, allowing companies to optimise production techniques and gain unique intellectual property. The mesh properties have been optimised for specific applications, enhancing performance and creating a competitive advantage.[124] One company has developed Insurtech software, the Global Events Observer, which serves the insurance industry by monitoring global assets valued at approximately 200 trillion USD. The system immediately reports to insurance companies if a catastrophe impacts an insured asset.[125]

Funding has enabled job creation and expertise development and increased TRLs. One company increased its TRL from 2–4, now aiming for TRL 5.[126] Another organisation expanded from seven employees to about 30, allowing the automation of previously manual processes.[127]

3.2. Increased capability for developing new space technology, products and missions

3.2.1. Preserving and enhancing heritage capabilities

ESA funding has allowed UK organisations to maintain capabilities by upskilling the workforce in science, technology, engineering and mathematics (STEM), preventing talent loss. In some cases, ESA funding supports UK organisations in developing new capabilities and growing their workforce. One notable example of the impact of ESA investment on sustaining UK space capabilities is GSTP. When Kinetic, a UK company with a long history in electric propulsion, decided to withdraw from space, GSTP engaged with other companies to fill the gap in capabilities. This intervention enabled companies like Mars Space to secure funding and expand significantly, growing from 2–85 employees. Another company has hired an additional 33 employees due to GSTP funding.[128] These examples illustrate how the UK's investment in GSTP has helped preserve and grow the UK's technological heritage, ensuring that expertise and capabilities are expanded rather than lost.[129]

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[121] European Space Agency Business (2025).
[122] INT_2_TEL.
[123] INT_8_TEL.
[124] INT_1_TEL.
[125] INT_6_TEL.
[126] INT_4_TEL.
[127] INT_6_TEL.
[128] INT_TECH.
[129] INT_10_EO.

ESA investment also plays a key role in retaining pivotal space capabilities in the UK space sector. SSTL's involvement in HydroGNSS enabled them to retain payload engineers with experience in reflectometry.[130] Engineers with these skills are hard to find, emphasising the valuable role of ESA missions and programmes in preserving rare capabilities in the UK, enabling organisations to remain involved in key areas aligned with UK strategic objectives, such as climate science.

Large, UK-led missions (including TRUTHS) and ESA programmes with significant heritage of UK involvement (such as Copernicus) have **maintained and grown domestic capabilities, building the UK's reputation as a leader in EO science**. The UK's long history of involvement in Copernicus, for example, has been critical to developing the UK's capabilities in EO and climate science.[131] The UK is now seen as a leader in this area, leveraging this reputation to assume significant leadership in other ESA programmes such as CCI.

Significant UK investments in ESA, including through TRUTHS, signal the strength of UK commitments to develop sovereign capabilities and guide industry's internal capability development strategies. In this way, some stakeholders consider TRUTHS essential to preventing capabilities losses, particularly in developing large, complex science satellites and processing cutting-edge data.[132]

Examples of capabilities losses attributed to changes in the UK's investment in ESA underscore ESA's significant role in maintaining UK capabilities. Several organisations reported capabilities lost related to Copernicus dissociation, prompted by Brexit in 2020. Substantial capability losses were reported in infrared, with much going to Italy.[133] Copernicus dissociation also affected UK space facilities. For example, Honeywell closed a UK-based facility due to costs and profit concerns arising from Copernicus dissociation.[134] Despite the UK's re-entry into Copernicus in 2023, the three-year gap was enough that a combination of lost capabilities and a gap in engagement with current technology and practice has made the UK less competitive in Copernicus bids, posing an ongoing threat to the continuity of capabilities in this area.[135]

ESA funding has supported UK organisations in enhancing capabilities through investment in new infrastructure and updating heritage technologies. For example, SSTL is building dedicated clean rooms as part of their delivery of HydroGNSS.[136]

3.2.2. Developing new sovereign capabilities and reducing foreign dependency

ESA investments have supported UK organisations in tapping into new capabilities that had previously faced a shortage. Through its contracts, ESA missions and programmes support UK organisations in developing new capabilities, particularly in areas with limited commercial pathways or

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[130] INT_18_EO.
[131] INT_23_EO.
[132] INT_8_EO.
[133] INT_3_EO.
[134] INT_8_EO.
[135] INT_8_EO.
[136] INT_18_EO.

long lead times. In this way, ESA contracts – like other public sector funding mechanisms – provide support in areas where organisations would otherwise be limited in making a business case for growing and retaining certain capabilities.

The UK's investments in ESA have also supported knowledge transfer among UK organisations, supporting the growth of domestic capabilities. For instance, the UK has historically lacked infrared sensor suppliers, with only two suppliers with major capabilities.[137] As part of their involvement in TRUTHS and Copernicus-CHIME, a hyperspectral imaging mission aiming to map changes in land cover, Teledyne E2V collaborated with their US entity to transfer materials to the UK, supporting the development of sensors for ESA missions and programmes.[138] Subsequently, ESA funding, mainly Copernicus and TRUTHS, has enabled Teledyne E2V to work with UK universities on sensor technologies, supporting the UK space sector in reducing its import dependence and building the foundation for a UK supply chain.[139]

ESA investments have enabled the UK to develop sovereign capabilities in strategically important areas, ranging from end-to-end mission development to key areas like lunar navigation and PNT. For example, the UK's investments in NAVISP have played a key role in developing lunar navigation capabilities. GMV uses NAVISP funding to support ESA's Moonlight program, ensuring the UK remains engaged in lunar navigation missions.[140] GMV is involved in developing next-generation lunar navigation solutions, positioning UK industry to contribute to a future UK-led lunar rover mission.[141] NAVISP is also instrumental in building the UK's Sovereign PNT Capabilities. NAVISP Element 3 is strategically critical to the UK's goal of reducing reliance on foreign-controlled GNSS services.[142] GMV's ESPAS test bed project gave the UK government a working demonstration of an independent system similar to the European Geostationary Navigation Overlay Service (EGNOS), informing long-term policy decisions on PNT sovereignty.[143] Similarly, Telespazio's resilient PNT system for UK aviation security helped bridge the post-Brexit gap in navigation services.[144]

TRUTHS is building the UK's capability to deliver a large-scale satellite mission end-to-end, a strategically important effort to enhance the UK space sector's competitiveness and influence in the ESA ecosystem and on the global stage. TRUTHS's capability growth and upskilling benefits include both upstream (satellite design and manufacture) and downstream (ground segment and data processing). On the upstream side, the mission offers a rare opportunity for the UK to design and develop a large-scale, complex mission, leveraging significant UK expertise in the scientific underpinnings of the mission and historical involvement in developing some of the mission's instruments.[145] It has grown UK capabilities in

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[137] INT_20_EO.
[138] INT_20_EO.
[139] INT_20_EO.
[140] INT_2_NAV.
[141] INT_2_NAV.
[142] INT_1_NAV.
[143] INT_2_NAV.
[144] INT_5_NAV.
[145] INT_23_EO; INT_5_EO.

optical instruments,[146] an area where the UK has previously experienced skills shortages[147] that would be challenging to develop through commercial pathways.[148] For example, SSTL has built a Centre of Excellence for Space Optics as part of its delivery of TRUTHS instrumentation, intended to support the development and maintenance of capabilities in space optics and instruments where this has previously been a challenge.[149] On the mid- and downstream side, TRUTHS is positioned to foster capability growth in ground segment and calibration,[150] including related hardware development.[151] One industry stakeholder believes that involvement in the TRUTHS mission will significantly enhance the UK space industry's overall competitiveness and enable it to compete effectively with companies or subsidiaries like Airbus France in a few years.[152]

While providing significant benefits to the space sector, capability growth related to the UK's ESA investments also contributes to wider benefits, as the technologies and applications developed from UK space capabilities have wider impacts in other sectors.

- The Aeolus-1 mission, primed by Airbus UK, significantly impacted weather forecasting capabilities in the UK and across Europe.[153]
- Involvement in ESA-funded projects has increased UK scientists' understanding of satellite development and its relevance to earth science – particularly for scientists not previously involved in space science.[154]
- CCI has contributed to the UK's world-leading scientific capabilities in sea surface temperature and contribution to global climate initiatives.[155]

3.2.3. Growing and diversifying the supply chain

Participation in ESA programmes has significantly strengthened the UK space sector supply chain by bolstering new entrants and the growth of SMEs. Through its missions and programmes, ESA provides opportunities for small space companies to grow and for companies in other sectors to branch into the space sector. Together, these impacts support UK supply chain growth and diversification. These impacts are most apparent in technology and commercialization-focused ESA programmes, including GSTP, Telecoms and InCubed-2, where greater risk-tolerance from ESA provides a gateway for new entrants and yet-unproven SMEs.

[146] INT_5_EO.
[147] INT_17_EO.
[148] INT_18_EO.
[149] INT_18_EO.
[150] INT_6_EO; INT_04_EO; INT_21_EO.
[151] INT_5_EO.
[152] INT_23_EO.
[153] INT_33_EO.
[154] INT_14_EO.
[155] INT_6_EO.

GSTP has facilitated the entry of new companies into the UK space sector, expanding and diversifying the supply chain. For example, GSTP funding in the monopropellant thruster project enabled new entrants to participate in the space industry, demonstrating that the programme does not restrict participation to established space companies.[156] GSTP also plays a crucial role in helping smaller companies develop technologies and capabilities, enabling them to scale up and become suppliers to larger prime contractors, thereby enhancing mission capabilities.[157] In this way, GSTP provides a point of entry and avenue for developing small space companies, expanding technological capabilities in the UK and, over time, decreasing reliance on European imports.

Similarly, **the UK's investments in telecommunications have supported the growth and diversification of the UK space sector**. For instance, the programme has facilitated a start-up to establish a UK branch to focus on 5G and 6G technology. ESA funding supported the startup in hiring new employees and recruiting key technical expertise.[158]

EO programmes, particularly InCubed-2, have also played a significant role in supply chain development. InCubed-2 supports startups and SMEs by focusing on innovative and commercially viable solutions. In recent years, the programme has enabled many UK SMEs to grow their technical capabilities.[159] For example, organisations involved in the Mission and Agile Nanosatellite for Terrestrial Imagery Services (MANTIS) project, the first satellite mission launched under the InCubed programme, increased their capabilities in mechanical and thermal engineering and technical project management and systems engineering.[160] In this way, InCubed has supported the growth of early-stage SMEs, feeding into the broader UK supply chain.[161] It also enables collaboration between SMEs and larger organisations, increasing the UK supply chain's connectivity.[162]

3.2.4. Uncertainties for benefit realisation and missed opportunities

The UK space sector faces uncertainties and barriers that hinder benefits realisation from ESA investments, particularly in the Science and EO domains.

The UK's industrial sector encounters several challenges in Science missions. Despite past achievements, profitability remains limited due to flat funding in mandatory programmes and difficulties securing prime leadership roles in missions.[163] Unlike countries with a strong aerospace heritage, such as France and Germany, the absence of a robust mid-level to high-level industrial base limits opportunities for UK companies to act as prime contractors or significant subcontractors in ESA projects.[164] The UK essentially has one extensive system integrator capable of acting as a prime contractor, Airbus Defence and

[156] INT_2_TECH.
[157] INT_3_TECH.
[158] INT_4_TEL.
[159] INT_9_EO.
[160] INT_15_EO.
[161] INT_13_EO; INT_9_EO.
[162] INT_15_EO.
[163] INT_1_SCI.
[164] INT_12_SCI.

Space UK, limiting the capability of UK industry to participate at the highest levels of ESA missions. When the UK does win a prime contract, the significant value of those contracts often necessitates sub-contracts and smaller mission contracts flowing to other member states due to geo-return principles, even when the UK has a company well suited to the contract's needs. One interviewee suggested that, while UK companies winning prime contracts is an immense success for UK industry, there may be benefits to knowing when to forfeit the prime contract in order to help other aspects of industry develop and receive experience working in the ESA ecosystem.[165]

Cost negotiations between subcontractors and primary contractors are often challenging, with UK companies experiencing tighter financial constraints than their European counterparts.[166] Historical factors, including foreign entities' consolidation and acquisition of key aerospace companies, have diminished the UK's domestic capability to compete for and execute large ESA contracts.[167] Consequently, UK funds are often allocated to components sourced from other European countries due to a lack of domestic suppliers.[168]

To address these issues, **strategic investments are needed to reduce foreign dependency and enhance self-sufficiency**.[169] Developing these capabilities requires a strategic approach that embraces calculated risks, similar to Germany's focus on building new capabilities over simple assembly and integration contracts. Additionally, maintaining a consistent mission schedule is crucial to retaining engineering expertise, as evidenced by the gap between the Cluster and Solar Orbiter missions. Both missions focused on understanding the interactions between the Sun and the Earth, risking losing valuable workforce skills in the interim.[170]

In the EO domain, particularly for TRUTHS, **gaps persist in the capabilities needed to deliver large missions**. Specifically, there are deficiencies in optical engineering and instrumentation within the academic sector and industry.[171] Additionally, while TRUTHS presents opportunities for supply chain development – particularly in sourcing components and other aspects of mission delivery[172] – realising these opportunities depends on prime contractors diversifying their procurement strategies.[173] Some evidence suggests that opportunities to diversify procurement for TRUTHS have not been fully pursued.[174] At the same time, developing the supply chain while relying on known established suppliers that present less risk is challenging.[175]

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165 INT_13_SCI.

166 INT_13_SCI.

167 INT_12_SCI.

168 INT_1_SCI.

169 INT_1_SCI.

170 INT_6_SCI.

171 INT_12_EO; INT_17_EO.

172 INT_33_EO.

173 INT_5_EO.

174 INT_17_EO.

175 INT_33_EO.

3.2.5. Attracting and retaining the UK space workforce

The UK's ESA investments, particularly in HRE, EO and commercialisation programmes across the investment portfolio, have contributed to workforce expansion, particularly in SMEs. SMEs involved in EO programmes, particularly those aimed at developing downstream applications and commercial products such as InCubed-2 and FutureEO Block 4, have reported increased headcounts directly linked to ESA funding.[176] Some organisations have experienced significant growth, with one SME reporting a 35% increase in headcount due to InCubed-2 funding.[177] Others have seen more modest expansion, focusing on strategic hires with critical skills essential for long-term development.[178] Similarly, ESA HRE contracts have strengthened the UK's specialist space sector workforce by driving SME growth.[179]

Beyond EO and HRE, the UK's investments in GSTP have contributed to workforce expansion and talent retention, mainly by providing new projects and challenges to sustain existing expertise. Some firms have seen significant workforce growth due to GSTP funding, with one company hiring an additional 33 employees[180] while another expanded from two to 85 employees.[181] Even where direct job creation is less evident, programme stakeholders believe GSTP has helped maintain workforce stability.

Workforce expansion was not limited to SMEs; large primes also reported growth, particularly those involved in Navigation and Telecommunications contracts.[182] Beyond direct hires, ESA funding has supported expertise development, enabling companies to scale operations, automate processes and expand research activities in key areas such as climate science.[183] However, the extent of workforce expansion varies by programme, with our programme-level economic analyses revealing that only companies receiving contracts in Telecommunications experienced increases in total employment on average (2.8%).

While many UK organisations report growth, others report the opposite, particularly in areas where ESA investment has waned or disappeared, including Copernicus.[184] This difference illustrates the dynamic nature of talent attraction and retention, emphasising how continuity of investment supports retention and growth of talent and domestic capabilities.

Continued investment in key areas like satellite navigation and reinvestment in some programme areas affected by Brexit, such as Copernicus, has helped retain talent in the UK space sector. The loss of UK access to Galileo and EGNOS following Brexit meant a significant funding gap for UK firms, which previously benefited from an annual £250m investment in these programmes.[185] NAVISP funding has since become the primary mechanism for sustaining the UK's position in satellite navigation, helping

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176 INT_9_EO; INT_10_EO; INT_13_EO; INT_19_EO.

177 INT_19_EO.

178 INT_9_EO.

179 INT_2_HRE.

180 INT_TECH.

181 INT_10_TECH.

182 INT_2_NAV; INT_6_TEL.

183 INT_28_EO; INT_6_TEL.

184 INT_21_EO.

185 INT_1_NAV; INT_Scoping_NAV.

to prevent a major talent drain at a fraction of the cost.[186] Organisations previously involved in Galileo contracts report high retention rates, supporting expertise development and knowledge transfer, whereas high turnover – especially among younger employees – risks sector-wide knowledge loss.[187] Meanwhile, the UK's re-engagement in Copernicus has helped some UK organisations retain talent. One organisation impacted by the UK's withdrawal from Copernicus reported that, while it had to consolidate its UK operations from two sites to one, continued engagement in UK space programmes may have helped retain key capabilities.[188] These examples highlight the importance of strategic reinvestment in sustaining the UK's specialist space workforce amid post-Brexit challenges.

The UK's investments in ESA, particularly EO, Space Safety and Telecommunications, have played a key role in fostering early-career growth and attracting new talent to the UK space sector. ESA contracts have enabled some organisations to support internships and placements, providing entry points for young professionals. For instance, one SME whose primary business is FutureEO contracts has taken on approximately three interns annually since its founding in the late 2010s.[189] High-profile ESA missions with significant UK involvement, such as Vigil and the Rosalind Franklin Mars rover, serve as talent magnets, drawing early-career engineers and providing opportunities for career progression within the institutions and companies involved.[190]

Establishing a Doctoral Training Centre focused on satellite and terrestrial communication, supported by industry partners through investments in ESA Telecommunications programmes, represents a strategic initiative to develop future expertise.[191] As the only programme of its kind in the UK, it directly addresses long-term workforce needs, reinforcing the role of ESA investment in developing and sustaining a pipeline of skilled professionals for the UK space sector.

UK investment in ESA has supported the growth of national capabilities, particularly in EO. With around half of its funding from ESA, the National Centre for EO has been able to sustain employment, expand its expertise and enhance the UK's capacity in EO research and innovation. This success highlights the role of ESA investment in maintaining and developing UK national scientific and technical capabilities.[192]

By providing broad opportunities, ranging from long-term, complex missions to instrument development, data science and downstream applications, ESA missions and programmes provide career progression and upskilling opportunities essential for attracting and retaining a skilled UK space workforce. Participation in ESA science programmes is particularly influential in researcher careers due to the scale and prestige of these projects. ESA fellowships are considered highly beneficial to researcher development, with past participants progressing to successful scientific careers.[193] Similarly, experience in ESA CCI projects has enabled researchers to secure additional ESA funding, advance into

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186 INT_1_NAV; INT_Scoping_NAV.

187 INT_3_HRE.

188 INT_11_EO.

189 INT_10_EO.

190 INT_4_SS.

191 INT_1_TEL.

192 INT_24_EO.

193 INT_16_EO.

leadership positions and establish independent research teams. For example, one researcher leveraged their ESA experience to obtain a UKRI Future Leaders Fellowship and build their own team. At the same time, involvement in the CCI Greenhouse Gases (GHG) project has supported the employment of PhD students, many of whom have subsequently transitioned into industry or public-sector organisations.[194]

The experience gained from involvement in ESA missions and programmes also supports career progression, with industry employees frequently transitioning to senior roles in fields such as EO and defence.[195] However, the retirement of experienced professionals, such as those from the MIRI team, presents a key challenge, underscoring the need for effective knowledge transfer to junior engineers, postdoctoral researchers and graduates and continued investment to sustain expertise and maintain key capabilities.[196] More broadly, the sector's investment in training and skill development is reflected in the significant number of research fellowships and PhDs secured through ESA space missions, reinforcing their role in fostering a skilled and sustainable workforce.[197]

The UK's investments in ESA provide valuable opportunities for UK organisations to attract talent and develop their workforce, particularly through large, high-profile missions such as Vigil, TRUTHS and the Rosalind Franklin Mars rover, as well as through the sheer range of opportunities afforded through ESA missions and programmes. UK companies involved in ESA EO programmes report a competitive advantage in recruitment, as job seekers are drawn to the prestige and complexity of ESA-funded work.[198] Missions like TRUTHS, Vigil and the Rosalind Franklin Mars Rover are particularly influential in attracting engineers eager to work on large-scale projects with a significant UK component.[199] Large missions like Vigil also inspire talent at all levels, from undergraduates and MSc students to PhD candidates and early-career engineers, reinforcing the UK's capability pipeline.[200] One university that features Vigil in its MSc programme reports that having strong examples of the UK's involvement in cutting-edge space work inspires the next generation of talent, enhancing training and research quality.[201]

Across industry, including SMEs, organisations report that involvement in ESA-funded missions and projects attracts new talent. Many potential new hires are drawn to the broad opportunities available through ESA work, noting the technical challenge and wider societal benefits of ESA space missions.[202] For many large industry players involved in contracts across the ESA investment portfolio, the broad scope of ESA engagements – from planetary exploration to climate science – enhances their competitiveness in attracting employees.[203] The UK's investments in ESA allow talent to be involved in

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[194] INT_24_EO.

[195] MAN_INT_3.

[196] NSSP_SEBP_INT_6.

[197] UK Space Agency (2024a).

[198] INT_22_EO.

[199] INT_18_EO; INT_33_EO; INT_4_SS; INT_8_SS.

[200] INT_4_SS.

[201] INT_8_SS.

[202] INT_33_EO.

[203] INT_33_EO.

cutting-edge work, supporting talent attraction and retention. For example, organisations involved in GSTP indicate that access to new, cutting-edge projects helps sustain motivation and career progression.[204]

Furthermore, the UK's investment in ESA lunar programmes provides career opportunities rarely found outside the US. However, other nations like Italy have made more significant investments, securing a stronger presence in key mission components.[205]

The UK's investments in ESA support the visibility of UK space capabilities on the European and global stages, contributing to international talent migration to the UK. ESA programmes facilitate the movement of skilled professionals across member states, providing UK companies greater access to talent through ESA networks and consortia.[206]

UK participation in ESA also bolsters the recruitment of PhD students and early-career researchers, drawing top students and researchers to the prestige and technical challenge of working on international space missions.[207] Many PhD graduates remain in the space sector, though limited job availability in the UK means some seek opportunities abroad.[208] One senior researcher reported hiring 22 software engineers and eight to ten PhD students / early-career researchers in their projects in recent years.[209] While not all of these roles are entirely attributable to ESA, the research group's engagement in several ESA-funded projects is a significant factor in attracting top talent.[210]

ESA involvement enhances the reputation of UK organisations, making them more attractive to skilled professionals and supporting talent retention. The prestige of working on ESA missions plays a crucial role in recruiting high-quality technical staff, drawing professionals to the excitement and significance of space exploration.[211] Missions such as Gaia and JWST have been particularly influential in developing expertise in data science, algorithm development, database management and engineering, skills that are highly sought after across multiple industries.[212] However, while ESA projects contribute to the broader UK economy by producing highly skilled professionals, the space sector faces retention challenges, as these skills are often transferable to more lucrative roles in finance and tech.[213] The Space Sector Skills Survey indicates that 16% of the organisations that faced retention challenges reported their staff wanting to leave the space sector for another sector.[214] Interviewees, therefore, highlighted the importance of maintaining enthusiasm and engagement in space projects to compete with other industries

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204 INT_2_TECH.

205 INT_1_HRE.

206 INT_3_EO.

207 INT_12_EO; INT_22_EO.

208 INT_22_EO.

209 INT_22_EO.

210 INT_22_EO.

211 MAN_INT_3; UK Space Agency (2020).

212 MAN_INT_2; know.space (2023).

213 MAN_INT_3.

214 UK Space Agency (2023c).

for talent.[215] More broadly, working on ESA and UKSA programmes fosters a shared sense of pride, reinforcing the sector's ability to attract and retain talent in a highly competitive job market.[216]

Ensuring continuous opportunities in areas of UK strength and past involvement is essential for retaining talent and maintaining the UK's competitive edge in the ESA marketplace. The uncertainty around the UK's withdrawal from and re-entry into Copernicus illustrates the risks of disruption – some organisations considered relocating capabilities to European sites, which would have resulted in a loss of UK expertise and jobs.[217] One UK organisation had to consolidate its UK operations due to the initial withdrawal, though re-engagement has helped preserve key capabilities.[218]

Conversely, the Vigil mission demonstrates the benefits of mission continuity, as it builds on the UK's heritage in instrument and payload development, allowing institutions to train, recruit and sustain engineering and scientific workforces. For example, UCL MSSL's Plasma Analyser builds on its expertise from Solar Orbiter. However, unlike previous projects, Vigil's team consists mainly of early-career professionals, positioning them for leadership in future ESA missions such as Plasma Observatory and M-Matisse.[219] Without UK leadership in Vigil, UCL MSSL would have been unable to maintain these specialist capabilities. Ultimately, sustained ESA engagement is critical for talent retention, skills development and securing the long-term role of the UK in ESA's mission landscape.

Domestic funding, including from UKSA, provides an important complement to ESA funding in retaining talent and bridging gaps in skill development. While ESA investment supports workforce growth during mission development, domestic funding helps sustain expertise beyond mission launch, ensuring that specialist skills are maintained. This continuity is particularly important for smaller teams, as UKSA funding allows them to gain experience across the entire hardware lifecycle, strengthening the UK's technical capabilities and ensuring a resilient and skilled workforce in the long term.[220] For example, the UK's involvement in three of nine Gaia Data Processing and Analysis Consortium coordination units has benefitted skills. From PhD to senior levels, staff involved in Gaia are gaining valuable and broadly applicable skills in algorithm and database development, data science and data analysis. These skills help address the space sector's skillset shortage in the AI/data science field.[221]

While there is strong evidence that the UK's investments in ESA have contributed to attracting and retaining talent in the UK space sector, critical gaps remain in skill development, workforce stability and long-term career pathways. Industrial participants highlight persistent skills shortages, particularly in emerging technologies such as reflectometry for TRUTHS instruments and ground segment expertise, where UK-based teams rely on expertise from European counterparts.[222] This issue might be solved via campaigns and incentives for career changers to enter the space industry, targeting ESA programmes focused on areas where we lack skills and encouraging apprenticeships, placements and graduate schemes.

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215 INT_20_EO.

216 INT_20_EO.

217 INT_20_EO.

218 INT_11_EO.

219 INT_7_SS.

220 NSSP_SEBP_INT_1; know.space (2023).

221 know.space (2023).

222 INT_4_EO; INT_18_EO; INT_19_EO.

Other examples are the 'Cognitive Cloud Computing in Space' and OPS-SAT calls, which funded projects embedding AI into satellite operations.[223] The UK paid for these via 'basic activities', and UK entities are involved in a handful of projects under ESA's discovery theme. This could be encouraged more centrally by UKSA/DSIT.

Though apprenticeships, placements and graduate schemes are largely under the purview of companies, UKSA/DSIT could highlight areas of good practice and/or encourage an AI/ML focus for those initiatives. Existing programmes, such as those run by Astroscale[224] and initiatives like UKSA's SPIN,[225] could be highlighted or relaunched with a focus on priority skills gaps. UKSA/DSIT could do this in line with the Space Industrial Plan and Space Workforce Action Plan (which will have some focus on AI and data), aiming to benefit both domestic and ESA ambitions in the long term.

The UK struggles with talent retention in some areas, as higher-paying industries like fintech and construction lure engineers away from the space sector.[226] The lack of a stable, long-term ESA funding framework and coordinated national workforce strategy creates uncertainty for UK firms, making career planning difficult and limiting stable ESA-funded career pathways.[227]

Despite these challenges, UK leadership in space weather forecasting, particularly through Vigil, has strengthened expertise at institutions like the Met Office, bridging gaps between operations, academia and hardware development.[228] However, stakeholders emphasised the need for more significant national investment to sustain this advantage, warning that the UK risks losing its position in key areas of space science without a strong pipeline of researchers and technical staff.[229] Budget constraints have limited talent attraction in some programmes, particularly in smaller ESA-funded projects where funding is often insufficient for full-time hires.[230] While this has not yet led to significant talent losses, it poses a long-term risk, as part-time contracts offer limited career security.[231] Investment disparities with other ESA nations, particularly Italy, France and Germany, mean these countries benefit more from ESA-driven workforce expansion, reducing the UK's employment return per euro invested.[232] Addressing these gaps through targeted investment and strategic workforce planning is essential to ensuring the UK fully capitalises on its ESA participation and sustains a competitive, highly skilled space workforce.

[223] European Space Agency (2025n).

[224] Astroscale (2023).

[225] SPIN (2024).

[226] INT_1_HRE.

[227] INT_1_HRE.; INT_2_HRE.

[228] INT_6_SS.

[229] INT_6_SS.

[230] INT_29_EO.

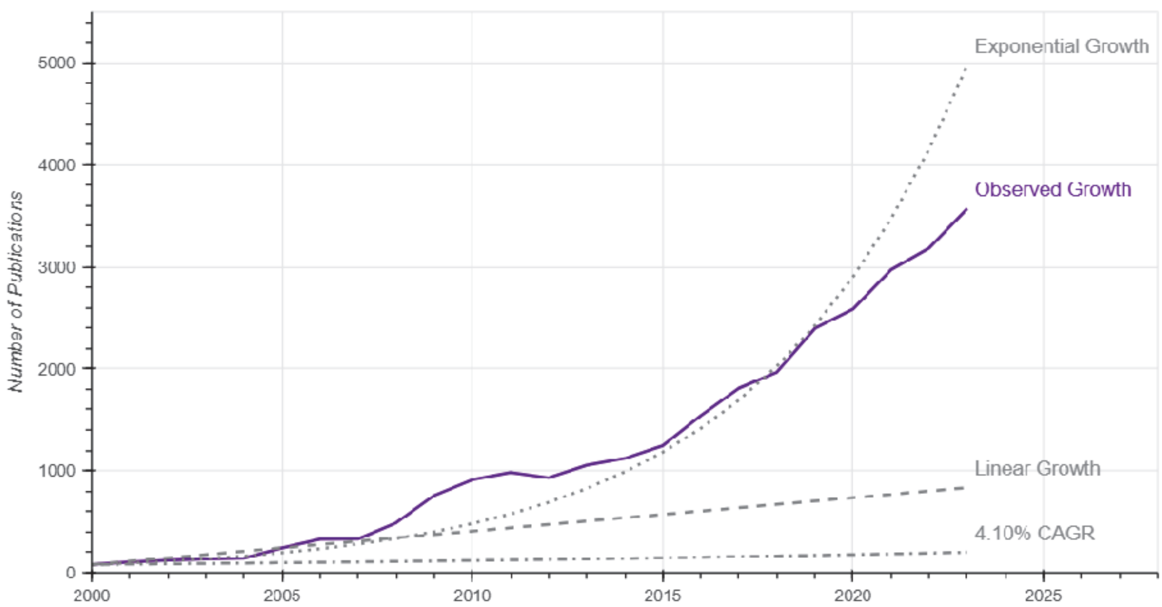
[231] INT_18_EO.

[232] NT_1_HRE.

3.3. Knowledge generation via scientific outputs

Scientific publications serve as indicators of scientific performance and benefits from ESA-funded programmes.[233] Following our analysis of available publications (for which the Technical Annex to this report describes the methods), the Compound Annual Growth Rate (CAGR) for ESA-funded publications from 2000 to 2023 across all countries was determined to be 17.96%. This means that, on average, the number of ESA-funded publications between 2000 and 2023 increased by 17.96%. Compared with global science's overall growth rate of 4.10%, this suggests extremely promising growth in ESA's scientific outputs.[234] Figure 17 shows the growth of ESA-funded publications, shown alongside what exponential growth would look like based on 2000 as a starting year, linear growth based on the growth rate between 2000 and 2010 (i.e. if the same growth rate between 2000 and 2005 had remained constant until the present year), and a 4.10% CAGR with 2000 as a starting year. These comparators indicate that ESA is significantly increasing its global share of publications. Such a stark increase suggests a potential benefit of ESA participation for the UK, given the amount of work the agency is funding.

Figure 17: Compound Annual Growth Rate (CGAR) for ESA-funded publications, 2000–2023



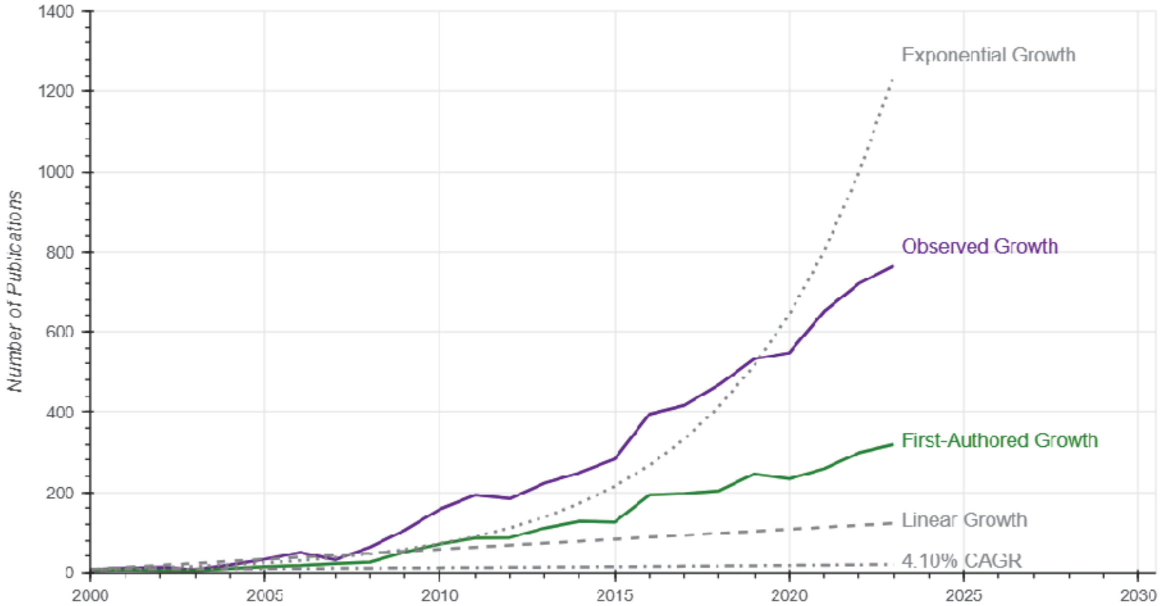
Source: OpenAlex. RAND Europe analysis.

Figure 18 does the same, filtering papers with at least one author affiliated with a UK institution. Doing so identifies a similar pattern to ESA-funded papers overall, with a significant publication growth rate over time.

[233] Other space M&E and market reports have included a similar approach, forming the basis for our work here. Know.space (2021) conducted a previous evaluation of the impact of research linked to UKSA funding, for which they matched ResearchFish data to dimensions, finding 3,098 articles and book chapters.

[234] Bornmann et al. (2020).

Figure 18: CAGR and UK first-author growth for ESA-funded publications, 2000–2023



Source: OpenAlex. RAND Europe analysis.

This data was then explored to find ESA-funded papers with UK authorship. This was done by counting UK institutions' presence in paper authorships. For instance, if the paper had at least one author affiliated with at least one UK-based institution, the paper was labelled as a scientific output of the UK. This approach is called full counting, where a full publication count is given to a country or institution when an author affiliated with them appears in a publication. In contrast to this approach, fractional counting is often used throughout the report. This approach assigns a fractional count corresponding to a country or institution’s share of the authorships. For instance, for a paper published by one French author and three Italian authors, fractional counting adds 0.25 to France’s publication counts and 0.75 to Italy’s publication counts.

Looking at the publication data, the UK is the leading ESA country in terms of ESA-funded publications. Using fractional counting, Figure 19 shows Germany as the leader in ESA-funded publications, followed closely by Italy, France and the UK.

Figure 19: Publications by ESA member states

Source: OpenAlex. RAND Europe analysis.

The following table presents more detail, providing a range of indicators related to publication volume for all ESA-member countries. Germany, the UK and France lead across ESA-funded publications, which likely reflects the scale of their ESA investments. Additionally, these countries all have high average yearly percentage increases in papers and high shares of first-authored papers in the dataset (although the latter should be interpreted cautiously, as authors' positions can be inconsistent and variable across scientific fields). In the UK's case, this amounts to almost one in ten ESA-funded papers having a UK author, surpassed only by Germany and Italy.

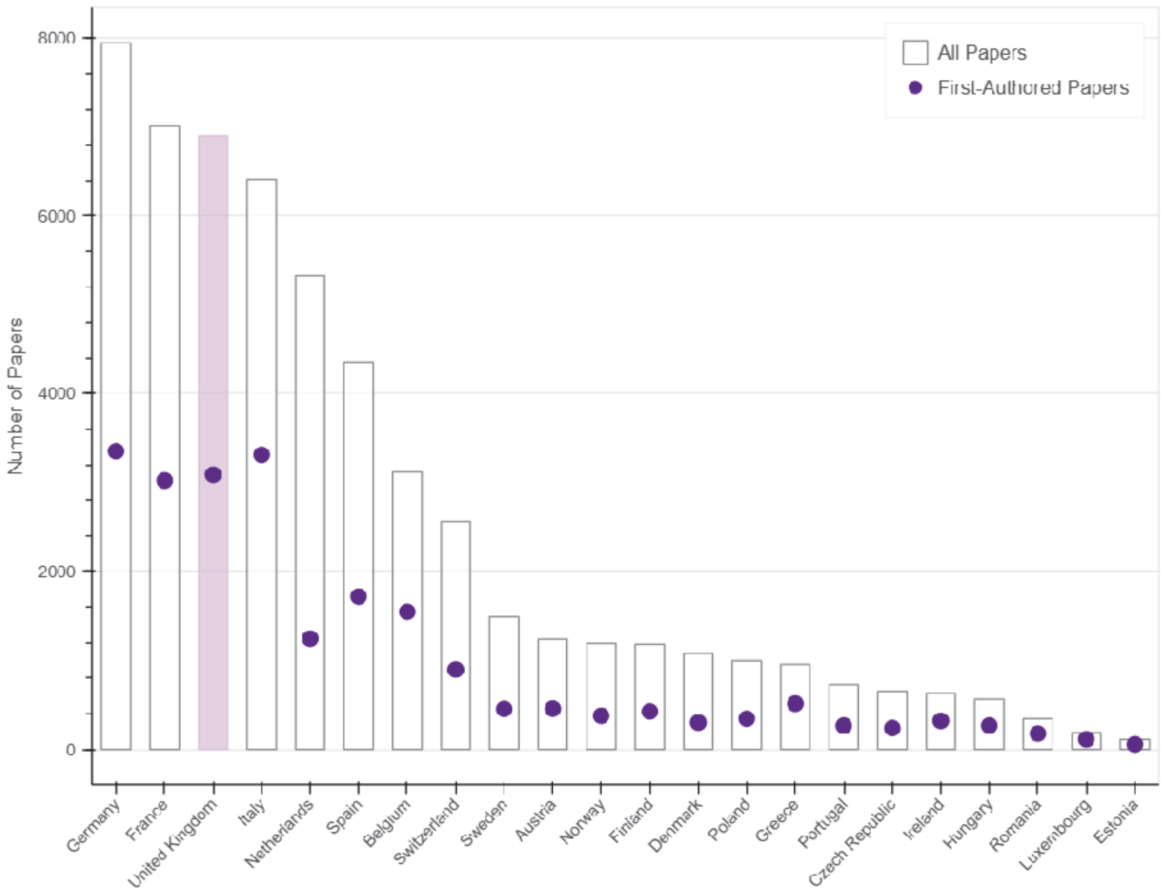
Table 5: ESA-funded publication counts across ESA member states

Country	Full Count	Fractional Count	Percent of Total (Fractional)	Average Papers Per Year (Fractional)	Average Yearly Percent Increase (Fractional)	First-Authored Papers	Share of First-Authored Papers
Germany	7947	3238.29	10.3	72	23.1	3353	10.62
France	7009	2887.89	9.2	64.2	15.6	3023	9.58
United Kingdom	6902	2725.4	8.6	58	29.1	3089	9.79
Italy	6412	2966.02	9.4	74.2	31.9	3313	10.5
Netherlands	5327	1995.77	6.3	45.4	24	1245	3.95
Spain	4355	1593.97	5.1	46.9	18.4	1718	5.44
Belgium	3118	1394.68	4.4	37.7	10.7	1546	4.9
Switzerland	2562	893.89	2.8	24.8	22.4	896	2.84
Sweden	1489	478.87	1.5	12.9	26.3	453	1.44
Austria	1237	453.61	1.4	12.6	21.2	456	1.44
Norway	1192	410.29	1.3	13.7	42.5	377	1.19
Finland	1181	401.97	1.3	13	33.1	425	1.35
Denmark	1077	334.85	1.1	11.2	27.9	300	0.95
Poland	994	364.67	1.2	15.9	66.6	344	1.09
Greece	955	430.3	1.4	18.7	27.8	513	1.63
Portugal	727	252.16	0.8	11.5	24.2	265	0.84
Czech Republic	653	229.27	0.7	8.8	33.2	237	0.75
Ireland	632	266.67	0.8	8.9	15.3	320	1.01
Hungary	561	219.02	0.7	8.1	21.6	266	0.84
Romania	342	161.22	0.5	7.7	64.2	176	0.56
Luxembourg	186	99.48	0.3	5.5	76	112	0.35
Estonia	108	47.16	0.1	2.8	27.5	54	0.17

Source: OpenAlex. RAND Europe analysis.

The relationship between papers (full counting) and first-authored papers for ESA member states shows a significant gap between the leading four countries, including the UK, and the rest – which is unsurprising given the relative population sizes and GNPs, shown in Figure 20 (where lines represent all papers with at least one author from the given country, and dots represent the first-authored papers). However, first-authorship conventions do not always signify who led the study or publication drafting across disciplines.

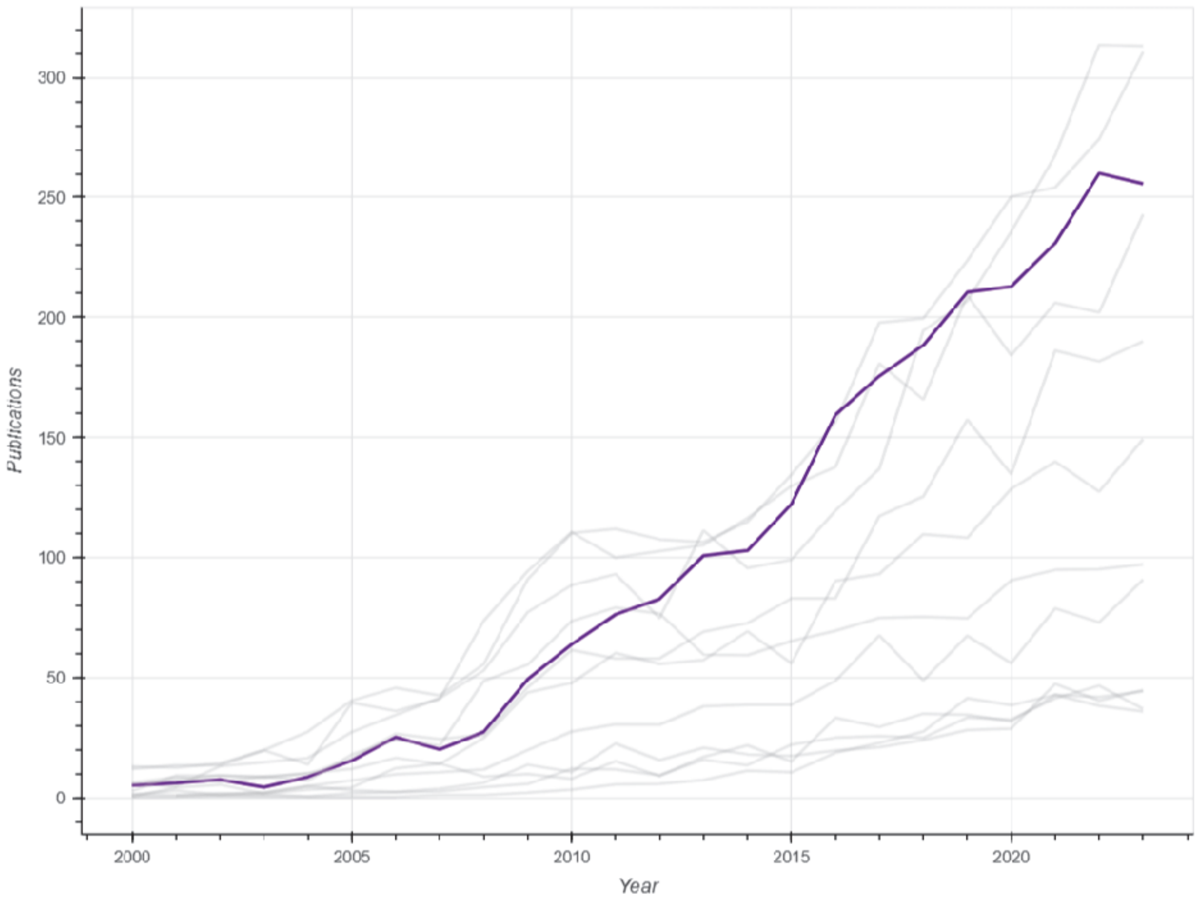
Figure 20: Comparison of countries by total ESA-funded papers and first-authored papers



Source: OpenAlex. RAND Europe analysis.

Figure 21 shows these figures over time for the 12 countries with the highest ESA contributions, presented as a line plot, with publications for the UK highlighted in purple and the other countries' lines in grey. For the UK, ESA-funded publications remain steady over time, with an increasing publication rate between 2005 and 2010. The data indicates that ESA-funded publications roughly correlated with ESA contribution, with the most prolific countries at the top of the most recent ESA investment figures.

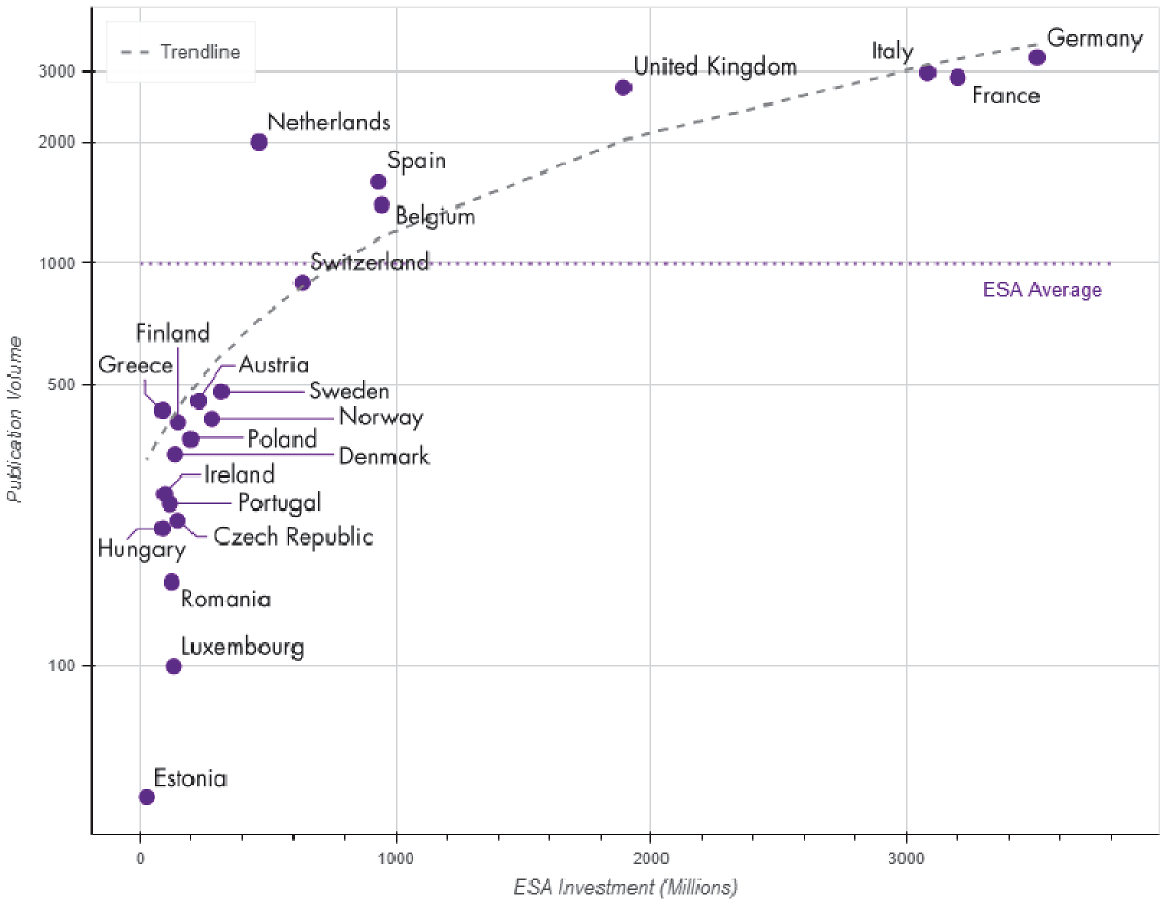
Figure 21: Publication rate by the UK and other ESA member states, 2000–2023



Source: OpenAlex. RAND Europe analysis.

Figure 22 shows the result of a linear regression using the fractional publication counts and ESA contributions for all ESA countries. The points on the scatterplot represent actual values, while the dotted trend line shows the expected values based on linear regression. The results show a correlation between the two, indicating that the more a country invests in ESA, the more it gets back in published research. **This indicates that the Netherlands and the UK are leading ESA countries in the number of publications resulting from their ESA investment, potentially signalling the strength of the UK's scientific expertise.** However, as discussed in the methodology annex, there does not appear to be a strong positive relationship between ESA contributions and average paper Field Weighted Citation Impact (FWCI). This indicates that ESA contributions are associated with more papers but not necessarily more influential ones.

Figure 22: A linear regression of the publication volume and ESA contributions of ESA MS

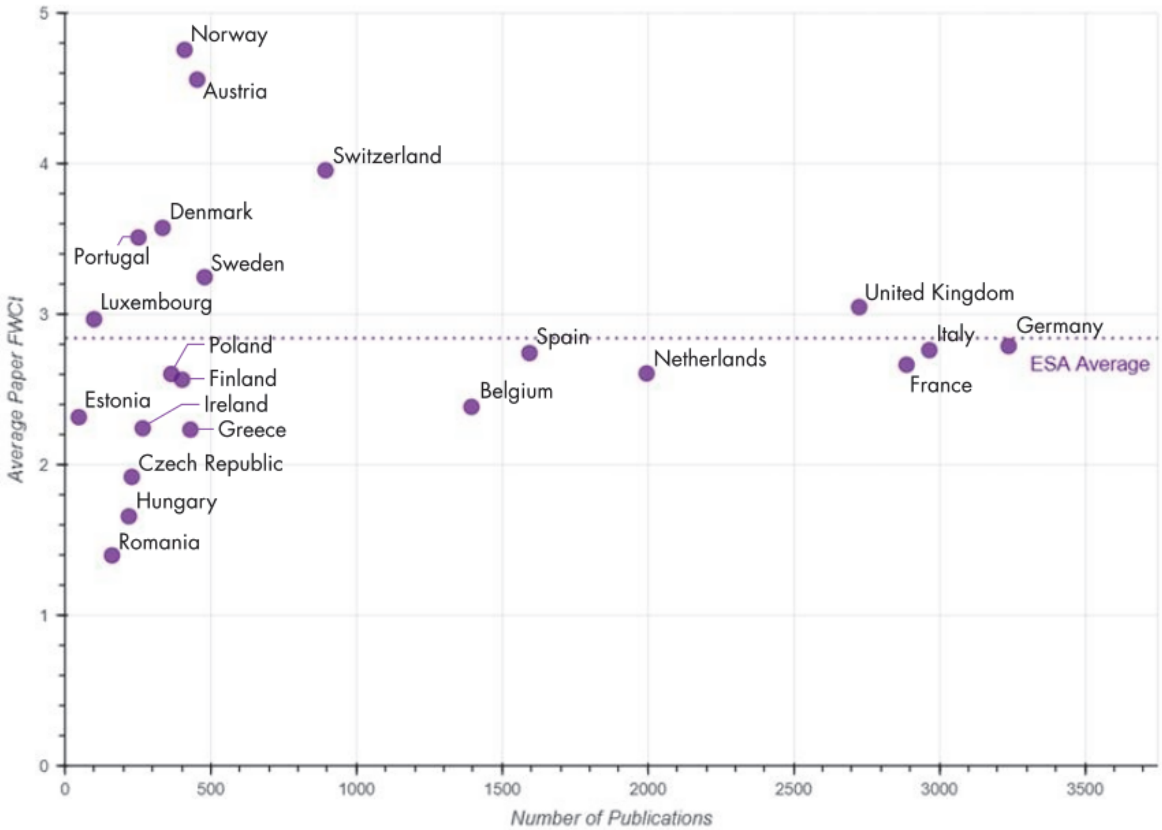


Source: OpenAlex. RAND Europe analysis.

This section's analysis of bibliometric indicators has focused on the number of publications as an indicator of scientific productivity. However, this approach is limited in that it does not identify whether the quality of these publications was high, which is itself difficult to measure and often conducted as part of national research assessment exercises like the UK Research Excellence Framework.

However, using citation impact as an indicator for the quality of publications, bibliometric analysis found that **the UK has established itself as one of the leaders among ESA member countries in space science, excelling in both publication volume and citation impact**. The comparative analysis shown in Figure 23 highlights that the UK ranks highly in the number of scientific publications and the average FWCI. This metric assesses the citation performance of papers relative to others in the same field and year.

Figure 23: Average Field Weighted Citation Impact (FWCI) per number of publications by ESA MS



Source: OpenAlex. RAND Europe analysis.

Several factors contribute to the UK's thought leadership in this domain. Participation in the CCI programme has bolstered the UK's global standing, facilitating the sharing of research findings across Europe and with international partners, including US ones. The UK's commitment to high standards in scientific research and integrity has solidified its reputation, particularly in the realm of ECVs, thereby enhancing the profile of UK climate modelling and elevating standards across Europe.[235]

The rest of this section explores what specific endeavours have led to the UK's leading position in scientific outputs within ESA by considering the science that supports the UK's space research. Several UK investments in ESA, particularly NAVISP, HRE, Science and EO, have supported UK scientific leadership and productivity. NAVISP has positioned the UK as a global leader in resilient PNT research, with GMV and Cranfield University producing high-impact scientific contributions.[236] NAVISP has enabled cross-sector knowledge sharing to support such research, ensuring that PNT research benefits not just the space sector but also terrestrial applications (e.g. telecoms, financial markets, and defence).[237] In HRE, the Lunar Pathfinder Relay Node mission provides radio-quiet conditions for deep-space astronomy, enabling potentially Nobel Prize-winning discoveries.[238] The UK's involvement in ESA's space

[235] INT_2_EO.

[236] INT_1_NAV; INT_2_NAV; INT_4_NAV.

[237] INT_NAV_UKSA; INT_Scoping_NAV.

[238] INT_1_HRE.

science portfolio, including Gaia, Juice and other missions, strengthens global knowledge of astronomy and planetary science.[239] Finally, the UK is a leader in ESA's CCI programme, with world-leading expertise in some areas of climate science, including sea ice and sea surface temperature, among others.[240]

3.4. Collaborative benefits

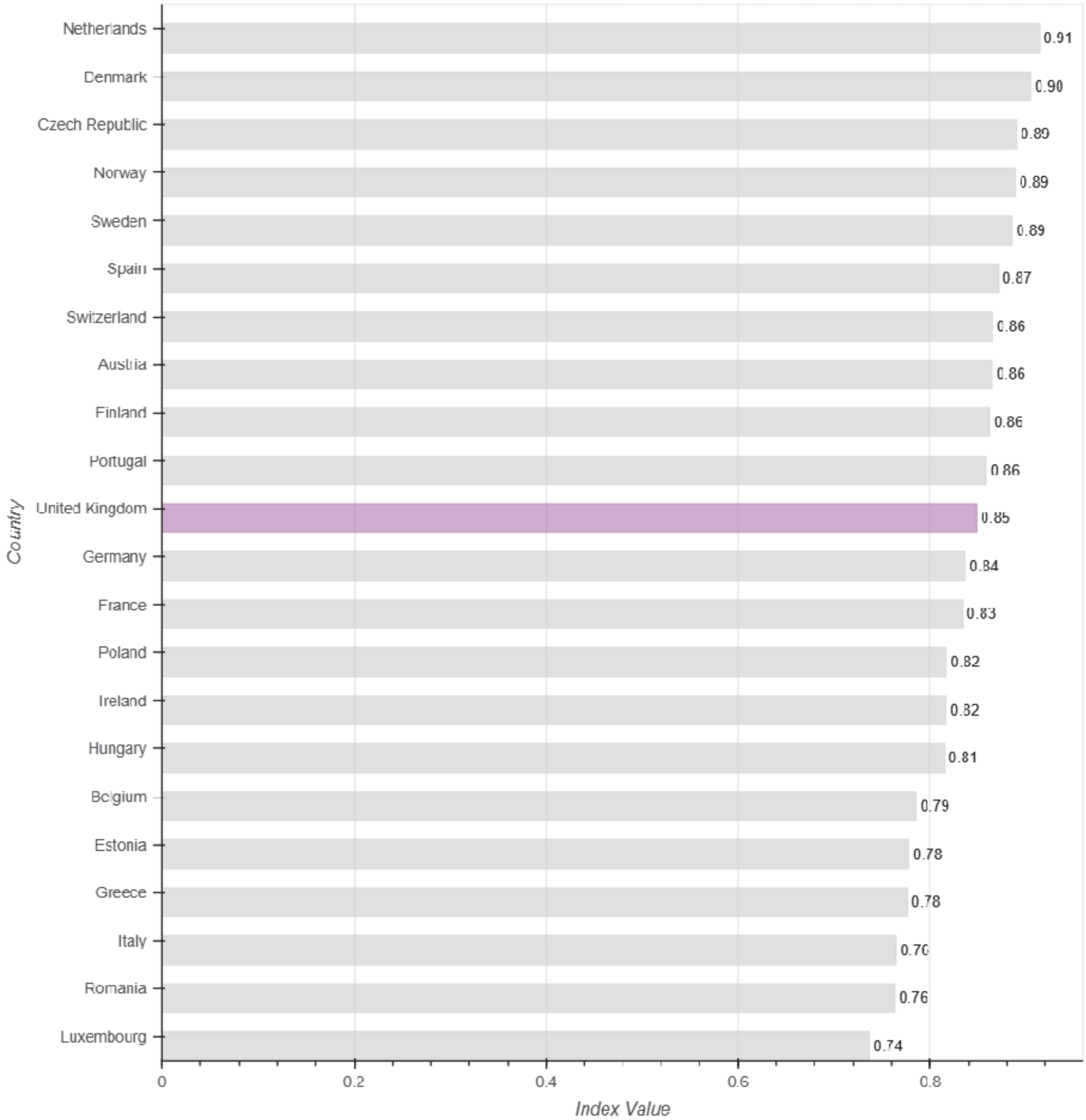
3.4.1. International collaboration

Bibliometric data showed high levels of collaboration between the UK and other ESA member countries, particularly those with relatively high ESA investment. Figure 24 shows the International Collaboration Index (ICI) for each country's ESA-funded publications. The ICI is calculated as the share of a country's publications that involves an international collaborator and ranges from 0 to 1. ESA-funded publications show particularly high rates of international collaboration, likely owing to the international nature of ESA and space science programmes. The UK falls in the top half of ESA countries for ICI, with the Netherlands, Denmark and the Czech Republic leading on this metric. This is notable since there does not appear to be any geographic bias in this metric or a bias towards top ESA contributors, suggesting that ESA membership entails high rates of international collaboration for scientists across member states.

[239] INT_4_HRE.

[240] INT_24_EO.

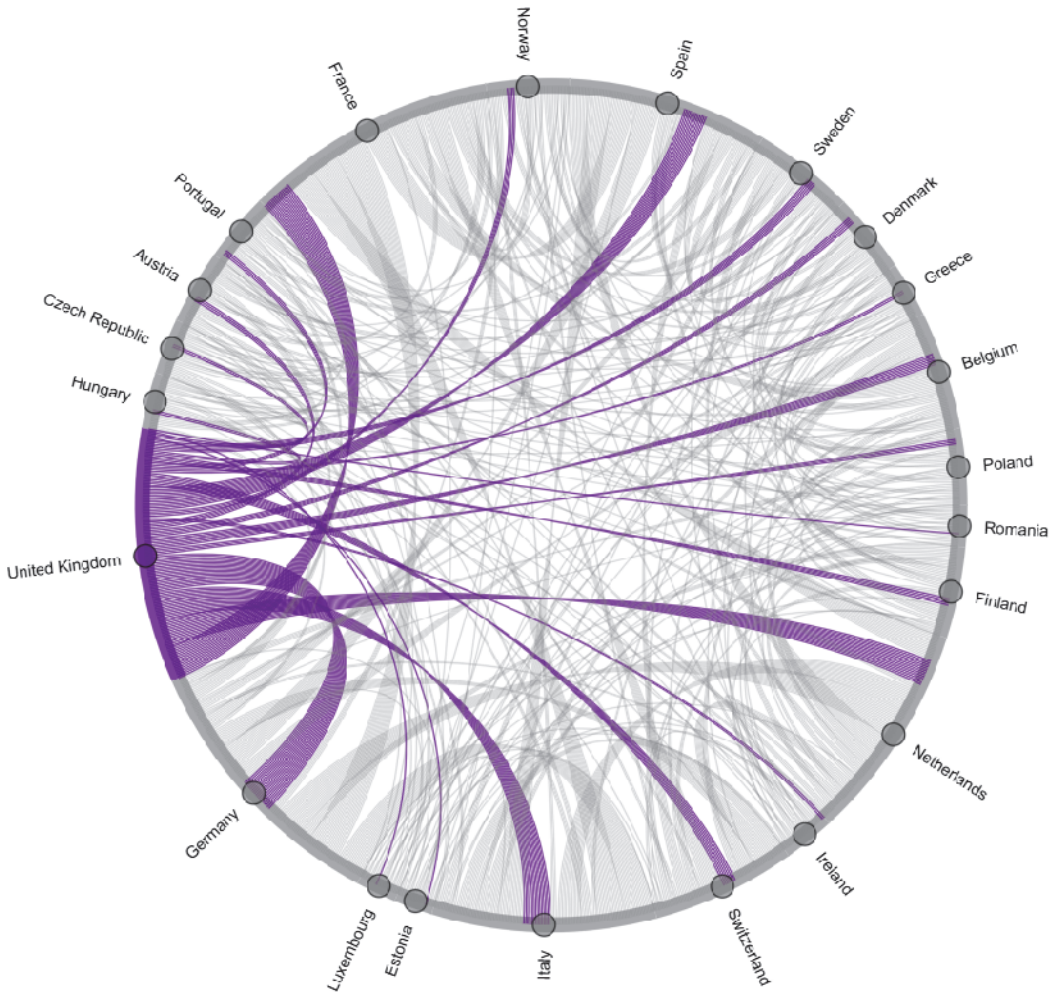
Figure 24: International Collaboration Index (ICI) for ESA-funded publications across member states



Source: OpenAlex. RAND Europe analysis.

Figure 25 shows the total number of collaborations between authors in ESA member states, calculated by taking each paper in the dataset and identifying how many include pairwise collaboration between each pair of ESA countries (e.g. how many papers involve a collaboration between the UK and Italy, the UK and Germany, etc.). The results show that the UK collaborates extensively with other ESA countries, particularly with the other largest space players: Germany, France, and Italy.

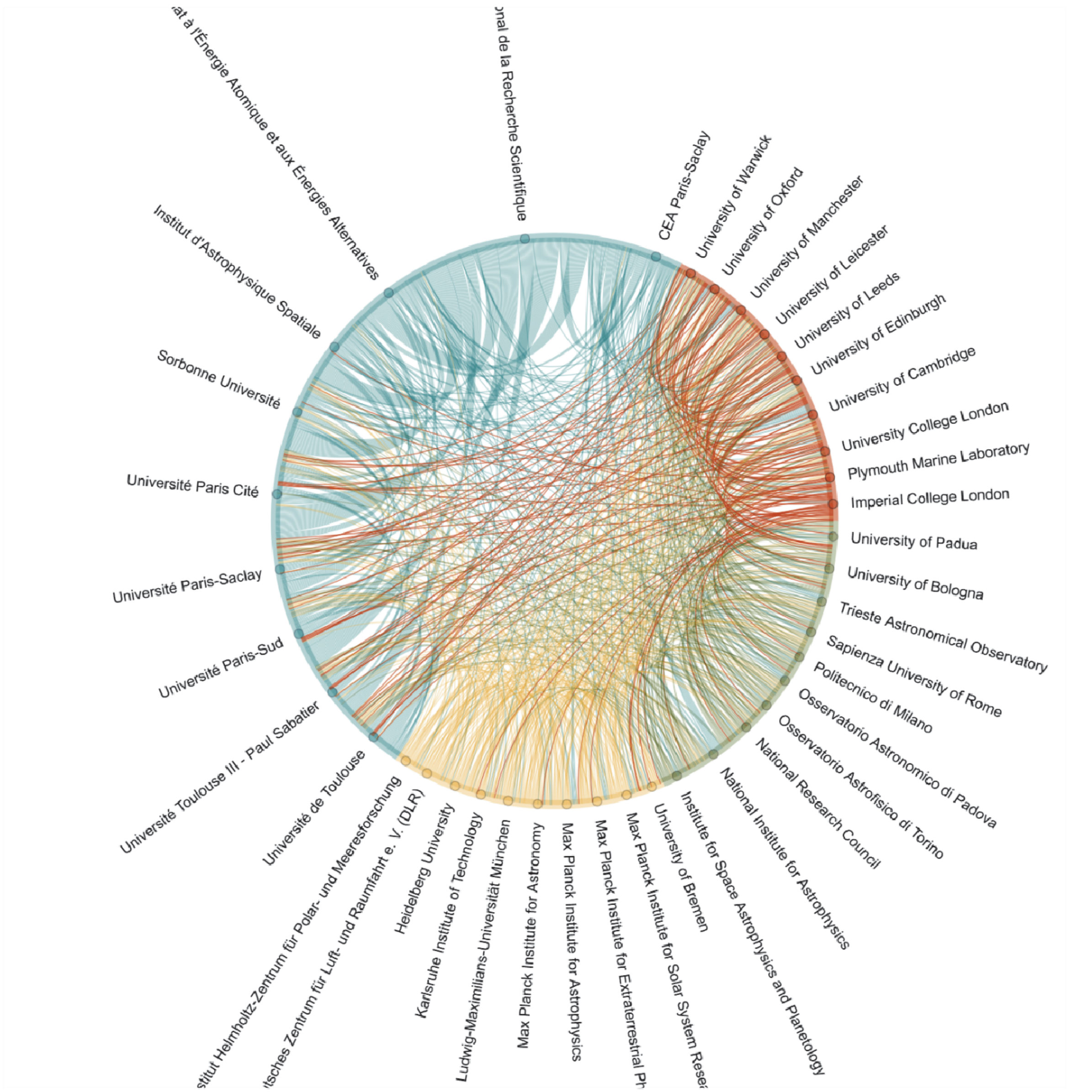
Figure 25: Number of collaborations between authors in ESA member states



Source: OpenAlex. RAND Europe analysis.

Examining collaborations with Germany, France and Italy in more detail, there is extensive collaboration between all four countries' leading institutions. The following chord plot takes the top ten institutions with the most ESA-funded publications from each country and plots their collaborations. For each institution on the plot, the connecting lines show the other institutions its researchers have collaborated with. As Figure 26 shows, UK institutions collaborated extensively with both international and domestic institutions.

Figure 26: Collaborations amongst the top ten institutions with the most ESA-funded publications in the UK, France, Germany and Italy



Source: OpenAlex. RAND Europe analysis. Institutions and their collaborations are coloured by country, with red for the UK, blue for France, yellow for Germany and green for Italy.

However, there are a range of barriers to the UK advancing and maintaining its lead in space science. First, no structured tracking system exists to measure how ESA-funded knowledge translates into commercial or policy benefits.[241] Additionally, UKSA has limited control over research direction, as ESA sets most of its science priorities.[242] This limitation can be addressed by seeking greater leadership in ESA

[241] INT_5_HRE.

[242] INT_1_HRE.

and improving national scientific research infrastructure to facilitate more effective monitoring of the impact of funding instruments on scientometric indicators. Funding also needs to be effectively targeted at research areas that benefit the UK's scientific global standing, e.g. funding that enables access to scientific instruments and their resulting research data.

Qualitative interviews also show that participation in ESA programmes has enabled UK organisations to forge more international partnerships. ESA's tenders sometimes have specific requirements for international participants due to geo-return requirements, which necessitate collaboration with other countries.[243] For example, projects like the Glacier Mass Balance Interconnectedness Exercise, a scientific effort to reconcile glacier mass balance measurements, have created extensive cross-border communities.[244] Being embedded into an international network helped UK participants build connections and develop track records supporting future collaborations.[245] While ESA is a forum for new international partnerships, it also offers a setting for recurring collaboration. Many interviewees, particularly those involved in ESA EO programmes, reported that there are often recurring partnerships between the same groups because of the nature of the work and the limited pool of experts.[246] For instance, CCI projects inherently involve collaboration across multiple organisations, yet many participants have worked together for years, even before the CCI projects started.[247] While this fosters strong networks and strengthens existing ties, it can limit the novelty of partnerships.

International partnerships through ESA have enabled UK organisations to access global research excellence to advance key technologies. For example, participation in NAVSIP has allowed the UK to collaborate globally on advanced PNT technologies, contributing to notable advancements and technological progression. Cranfield University worked with partners in Italy and Germany on a NAVISP Element 1 project, focused on multi-sensor fusion, integrating GNSS, LiDAR and Inertial Measurement Units.[248] The research aimed to enhance autonomous vehicle positioning, particularly in GPS-denied environments. The project has progressed from TRL 1–4, with the next phase requiring real-world testing.[249] In addition, Telespazio collaborated with Kongsberg Discovery, based in Norway, to develop a VHF Data Exchange System for maritime positioning.[250] The project advanced from TRL 2–5, proving concept feasibility.[251]

The UK's investments in ESA's HRE programme have similarly facilitated access to international research excellence. ESA membership provides access to a global research network, promoting knowledge-sharing among UK institutions, SMEs and international space agencies. Connections forged through ESA generate benefits for the UK even outside of ESA-funded activities, opening more opportunities for the

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[243] INT_10_EO.

[244] INT_10_EO.

[245] INT_10_EO; INT_22_EO.

[246] INT_22_EO.

[247] INT_25_EO; INT_26_EO.

[248] INT_4_NAV.

[249] INT_4_NAV.

[250] INT_5_NAV.

[251] INT_5_NAV.

sector. For instance, UK scientists and engineers can bypass bureaucratic obstacles through ESA networks, accelerating collaboration with NASA and other space agencies.[252]

International partnerships enabled by ESA also provide exposure to international communities and enhance UK leadership in space science. Exposure and leadership enabled by access to ESA networks strengthen the UK's position in the European and global space sectors, supporting wider opportunities for collaboration and influence. UK participants in the JWST mission, particularly with the MIRI, bolstered UK science leadership. As the European Principal Investigator, the UK worked closely with NASA to ensure a balanced 50/50 contribution between Europe and the USA. This collaboration was supported by UK funding agencies, which prioritised the science case and provided essential backing. The success of MIRI strengthened links between NASA and European partners.[253]

Furthermore, UK investment in Telecoms enabled stronger connections with ESA's 5G6G team, allowing the UK to participate in global industry events.[254] This participation facilitated knowledge exchange and direct engagement with senior ESA members, enhancing the UK's leadership in telecommunications.

3.4.2. Domestic partnerships

UK organisations' participation in ESA programmes, particularly in the EO domain, has led to new and enhanced domestic collaborations. Programmes like TRUTHS, FutureEO and InCubed-2 have forged numerous new partnerships within the UK. With its significant UK investment allowing for substantial UK involvement in mission development, TRUTHS has facilitated closer working relationships among existing UK partners while fostering new domestic collaborations.[255] InCubed-2 offers companies opportunities to collaborate on the development of commercial products, supporting connectivity among UK space sector organisations.[256] SMEs especially benefit from developing domestic relationships and creating further opportunities for collaboration with established players.[257] HydroGNSS, as part of FutureEO, has supported collaborations between UK industry and academic institutions.[258] The UK's strong involvement in CCI and FutureEO has also bolstered collaboration among UK climate scientists.[259]

Industry-academia partnerships between UK organisations have supported academic institutions in bidding for ESA funding. For example, Telespazio worked with the University of Reading on the CCI Water Vapour project and helped them with proposal preparation for Phase 1. The University of Reading team, having never bid for ESA funding before, benefitted from collaboration with Telespazio, a company with a long history of work on ESA missions and programmes. Subsequently, the University of Reading team managed the contracting process independently in Phase 2, illustrating how the UK's investments in

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[252] INT_2_HRE.

[253] INT_5_SCI.

[254] INT_2_TEL.

[255] INT_33_EO.

[256] INT_15_EO.

[257] INT_15_EO.

[258] INT_18_EO.

[259] INT_22_EO.

ESA support domestic collaborations and new entrants into the space sector.[260] Similarly, an industrial participant in COSMIC, a Space Safety programme, supported academic partners in accessing ESA funding, driving hundreds of thousands of pounds towards academic collaborations.[261]

Industry-academia partnerships have also supported knowledge sharing and expertise transfer. In some cases, UK companies have worked with universities on joint development projects in Phase 0 and Phase A, or workforce training, which increases connectivity and facilitates technology transfer. For example, ESA contracts enabled Teledyne E2V to collaborate with UK universities on developing readout integrated circuits and expand the spectrum coverage of infrared sensors.[262] In addition, Telespazio's NAVISP project has enabled them to work with UK universities to develop training modules for early-career engineers. The trained engineers later joined Telespazio, expanding their PNT workforce from two to eight engineers.[263]

The UK's ability to engage in effective knowledge sharing across the wider European space sector faces challenges due to Brexit. Before Brexit, international collaborations facilitated staff transfers, placements and swaps, which were instrumental in building capabilities.[264] However, these exchanges have become significantly more challenging post-Brexit. In the HRE domain, for example, cross-border partnerships have been harder due to barriers to data sharing and cross-border movement.[265]

[260] INT_28_EO.

[261] INT_17_SS.

[262] INT_20_EO.

[263] INT_5_NAV.

[264] INT_10_EO.

[265] INT_2_HRE.

4. Industrial capabilities and commercialisation efforts

This chapter presents findings on the impacts of the UK's investments in ESA on industrial capabilities and commercialisation efforts in the UK space sector. First, we explore the development or maintenance of industrial and commercial capabilities attributable to the UK's investment in ESA. Then, we present the commercialisation of scientific and technical outputs resulting from such investments in ESA. Finally, we explore related economic benefits, including indirect economic effects arising through the supply chain, ESA-derived benefits and spillover benefits.

Key findings on the industrial capabilities and commercialisation efforts developed because of the UK's ESA membership

- **Increased industrial capabilities:** UK involvement in ESA projects, programmes and missions has led to significant gains in industrial and commercial capabilities. These include gains in skills, behaviours, knowledge, tools, processes and infrastructure required by industrial and commercial organisations to achieve growth, market expansion and improved commercialisation.
- **Future investment:** UK-based firms have leveraged ESA investment to enhance their market position, expand commercial opportunities, and drive scientific and technological advancements, strengthening the UK industry's long-term competitiveness in the global space sector.
- **Commercialisation programmes develop technologies into market-ready products and services:** The UK's investments in ESA have contributed to commercialisation outcomes, enabling companies to develop, refine and bring new technologies to market. Commercially focused programmes such as GSTP, NAVISP, ARTES, InCubed-2, ScaleUp and the ESA Business Incubation Centres have demonstrated success in supporting companies in bringing new technologies to market, including establishing spin-offs and spin-ins to the space sector.
- **Benefits beyond funding recipients:** ESA funding benefits the UK beyond the directly funded companies, spanning geographically and industrially connected communities. Spill-over benefits also occur, extending the benefits of ESA funding beyond the space sector into other branches of UK industry and wider society.
- **Positive net economic impacts on local economic growth and productivity**: We found increases in turnover and GVA and positive spillover effects for local economies near UK contractors.

4.1. Industrial and commercial capabilities

UK involvement in ESA projects, programmes and missions has led to significant gains in industrial and commercial capabilities. These include gains in the skills, behaviours, knowledge, tools, processes and infrastructure required by industrial and commercial organisations to achieve their goals, such as growth, market expansion and improved ability to commercialise products and services. Capabilities advancements provide significant added value to the UK, especially in cases where this supports the growth of the UK space ecosystem more broadly.

The gains in industrial and commercial capabilities are varied, reflecting the diversity of the UK's involvement in ESA missions and programmes. These advancements occur across industrial and commercial pathways, progressing from enhanced R&D capabilities to improved market awareness for downstream exploitation and commercialisation. Capability development intersects and overlaps across industry players and sectors, bringing together academic, industrial and governmental actors. In turn, this strengthens the UK space sector supply chain, providing myriad opportunities for UK space sector organisations to leverage capabilities gains for future growth.

ESA missions and projects have strengthened the UK's industrial and export potential by advancing specialist capabilities, particularly in instrumentation and data exploitation. These enhanced capabilities have enabled UK-based organisations to develop new product and service lines, positioning them at the forefront of innovation and cutting-edge commercial offerings and thereby providing organisations with a competitive edge in the global marketplace.

GSTP has fostered specialist capabilities. While these have enabled technological advancements, they have also generated innovations that have led to the development of products that have gained traction in European and US markets, attracting international investment and private sector interest.[266] This benefit illustrates how ESA funding supports research and technology development and strengthens the UK's ability to compete globally, ensuring sustained industry growth and long-term commercial sustainability. Similarly, UK commercial entities involved in InCubed-2 have leveraged ESA-backed technologies and applications to drive business growth and attract investment, reinforcing the programme's role in de-risking innovation and enabling market entry.[267]

Furthermore, specialist capabilities developed through ESA missions have important implications for industrial and commercial capabilities. For instance, the UK's role in developing hyperspectral instruments for TRUTHS and related gains in specialist instrumentation capabilities positions the UK as a leading supplier, with few global competitors able to offer a comparable product.[268]

ESA missions also generate valuable data assets, opening commercial applications and service opportunities and strengthening the UK's downstream capabilities. UK contributions to HydroGNSS

[266] INT_2_TECH.

[267] INT_13_EO.

[268] INT_18_EO; INT_33_EO.

have strengthened UK capabilities in EO data management, positioning themselves for future satellite constellation development.[269]

Early-stage missions likewise contribute to developing specialist capabilities as industry prepares to exploit data generated through ESA science missions. For example, the promise of a UK-based ground segment for TRUTHS is already beginning to develop related capabilities in the UK, including advances in software, engineering and operational management. Once launched, TRUTHS and its UK-based ground segment are expected to drive bilateral collaborations with other nations interested in hosting TRUTHS data, such as Australia.[270] Additionally, TRUTHS's data validation and calibration functions will likely create new public and private sector market opportunities, including with NASA, illustrating the capabilities expected to be developed through large, UK-led missions.[271]

ESA programmes play a critical role in de-risking technologies and applications, enabling further investment and supporting industry-led R&D. ESA funding is important in supporting UK space sector organisations, including SMEs, to pursue R&D with less risk, supporting innovation and commercial opportunities. **ESA missions, such as those under the InCubed-2 and ADRIOS portfolios, have enabled companies to undertake critical R&D that would otherwise be financially unfeasible**. InCubed-2 funding has enabled early-stage SMEs to establish the R&D foundations necessary to attract commercial investors, ensuring both these organisations' short-term viability and long-term sustainability.[272] Similarly, ADRIOS missions enable companies to develop high-cost R&D with financial support, allowing them to build the necessary technologies for future commercial operations.[273]

GSTP funding has been particularly effective in helping companies progress from early-stage concepts to in-orbit demonstrations, creating pathways that enhance credibility and attract private investment. This is evident in cases where companies have received funding to develop payloads for the International Space Station, guided by UKSA and ESA, allowing them to demonstrate their capabilities and secure further backing.[274] **ESA funding also supports the transition from R&D to commercial service provision, particularly in areas such as EO, in-orbit servicing and navigation**. For example, a UK company involved in NAVISP highlights that the programme has been critical in supporting UK firms in moving from R&D to commercial contracts.[275]

ESA programmes provide an anchor for UK companies to ground their R&D efforts, recognising the markets created by ESA missions and programmes. For instance, the UK's substantial investment in TRUTHS has provided UK suppliers with a pathway to pursue new R&D projects, which they aim to pitch to ESA for further funding.[276] In ADRIOS, companies highlight that their interest lies not in

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[269] INT_18_EO.
[270] INT_21_EO.
[271] INT_33_EO.
[272] INT_18_EO; INT_12_SS.
[273] INT_12_SS.
[274] INT_1_TECH.
[275] INT_2_NAV.
[276] INT_18_EO.

making scientific breakthroughs but in developing operational platforms that enable commercial services, demonstrating how ESA R&D programmes serve as general enablers for broader commercialisation efforts.[277]

ESA funding has been instrumental in advancing foundational technologies with long development timelines, such as propulsion systems. For example, GSTP support for nuclear propulsion projects has helped companies secure government and institutional funding, ensuring continued innovation in critical areas that might not otherwise attract private capital.[278] This funding has also facilitated collaborations with key industry partners, including research institutions and engineering consultancies, strengthening the UK's broader innovation ecosystem.[279] By de-risking early-stage innovation, facilitating commercial adoption and enabling the development of long-term strategic capabilities, ESA investment reinforces industry growth, strengthens supply chains and enhances the UK's position in the global space market.

The UK's investment in GSTP has advanced commercial manufacturing capabilities, strengthening industry links and enhancing the UK's position in key space technologies. GSTP funding has advanced linear friction welding for spacecraft components and enabled hydrogen testing for future propulsion technologies, positioning the UK at the forefront of these fields.[280] While precise technology readiness gains are difficult to quantify, GSTP has been key in catalysing innovation and forging strategic industry partnerships, with one company noting it directly facilitated collaboration with a major UK prime.[281] Beyond technological advancements, GSTP has enhanced internal its expertise, supporting new projects, talent development and intellectual property generation.[282] This knowledge strengthens consultancy services, expands funding opportunities and reinforces the UK space sector's competitiveness.[283]

UK investments in ESA have played an important role in diversifying the UK space sector supply chain, driving the growth of specialised suppliers and expanding industrial capabilities. ESA contracts have enabled the emergence of new players in high-value sectors, such as in-orbit servicing, where the UK had minimal presence until recent years.[284] At the same time, ESA funding has supported SMEs in expanding their technical expertise, strengthening the UK's industrial base and contributing to a more resilient and competitive supply chain.[285]

ESA funding mechanisms, such as GSTP, have further supported supply chain development by enabling the development of new systems like the Synergetic Air-Breathing Rocket Engine concept (SABRE) developed by Reaction Engines, aiming to position the UK as a leader in advanced space technologies. These investments have broadened the UK's supplier base, reinforcing its competitiveness and resilience in the global space sector. However, Reaction Engines subsequently fell into administration in October

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277 INT_12_SS.
278 INT_3_TECH.
279 INT_3_TECH.
280 INT_4_TECH.
281 INT_4_TECH.
282 INT_4_TECH.
283 INT_4_TECH.
284 INT_23_EO.
285 INT_23_EO.

2024,[286] ceasing progress on SABRE and showing that these programmes are always associated with risk. Similarly, EO commercialisation programmes, including InCubed-2, helped integrate emerging businesses into the wider space sector, fostering collaborations between new entrants and established industry players.[287]

UK investment in applications-focused ESA programmes, particularly GSTP, has supported business growth and industry advancement by ensuring clearer pathways to commercialisation. Focusing on applications and commercial solutions in some areas of the UK's ESA investment, such as GSTP, enables UK companies to address specific technical challenges and customer needs. For example, developing a helical family of products was supported through GSTP funding, allowing the company to de-risk the technology and address issues such as passive intermodulation in antennas.[288] One interviewee involved in developing these products emphasised that GSTP's incremental funding approach has opened new customer opportunities and facilitated product development.[289] Another company highlighted a shift from technology push to application-driven funding, noting that while they had identified promising technologies, they lacked a clear strategy for development. In this case, GSTP funding was critical in enabling them to pursue further innovation that might have otherwise stalled.[290]

Interviewees who emphasised the alignment between the UK's investment in ESA programmes and UK national priorities, such as satellite de-orbiting, further reinforced the importance of market-driven investment. They considered **UKSA's support for satellite development essential**, as technologies must be tested in space before commercialisation. Projects with clear commercial applications contribute significantly to business growth, whereas some UK space sector organisations see theoretical studies with no direct market pathway as offering limited industry value.[291] These insights highlight the importance of prioritising ESA investments that drive tangible industry benefits, ensuring technological advancements lead to market-ready solutions and sector-wide growth.

Preference for application-focused investments is further underscored by evidence from one company which noted that it would no longer pursue projects like Proba-3, as it lacked a clear market pathway; instead, they now prioritise ESA programmes with commercial investment and well-defined intellectual property advantages, signalling a preference, among some UK stakeholders, for programmes with these characteristics.[292]

While ESA investment has strengthened the UK space sector, several barriers limit the full commercialisation and expansion potential of UK-developed space technologies. These challenges include programme constraints, market limitations and gaps in commercial strategy, which impact the sector's long-term sustainability and autonomy.

[286] Perry (2024).

[287] INT_9_EO.

[288] INT_5_TECH.

[289] INT_5_EO.

[290] INT_4_EO.

[291] INT_2_TECH.

[292] INT_7_EO.

One key challenge is that commercialisation is not a primary objective in all ESA programmes. For example, ESA's HRE programme prioritises scientific and technological development over market application, making it difficult for UK companies to translate ESA-funded innovations into commercial products.[293] While not suggesting that all funding mechanisms should have a commercial objective or that the UK should prioritise investment in ESA programmes with these aims, it indicates that a dedicated focus on commercialisation may be needed where this outcome is desired. Without a structured pathway from research to market deployment, these innovations risk remaining underutilised outside ESA contracts.

Beyond programme design, market expansion barriers persist. Some UK firms remain highly dependent on ESA contracts, with limited access to non-European markets.[294] While ESA funding has been essential in de-risking innovation, the lack of a clear commercial roadmap for UK-developed technologies has contributed to low commercialisation rates beyond Europe.[295] This dependence on ESA as the primary customer and funder limits the sector's ability to attract private investment and establish independent commercial pathways, posing risks for these firms if the UK's ESA investment strategy changes significantly.[296]

Additionally, while ESA's geographical return system supports domestic industry participation across member states, it can lead UK companies to source components or expertise from elsewhere in Europe in practice, which may limit opportunities to consolidate certain capabilities within the UK supply chain fully.[297] While the UK space sector remains deeply integrated within Europe, with myriad benefits, ESA funding structures reinforce inter-member state dependencies, presenting challenges to building greater technological autonomy at the national level.[298]

Many stakeholders indicated that clearer commercial strategies are needed to maximise the long-term impact of ESA investment. Currently, there is no ESA-driven commercial roadmap for UK-developed space technologies, leaving gaps in how companies transition from ESA-funded innovation to sustainable, market-driven applications.[299] Addressing these challenges will be critical to reducing UK entities' dependence on ESA contracts, expanding market reach and strengthening the UK's position in the global space economy.

4.1.1. ESA activities stimulating investment into the UK space sector

UK organisations have leveraged ESA investment to enhance their market positioning, expand commercial opportunities and drive scientific and technological advancements, strengthening the UK's long-term competitiveness in the global space sector. Stakeholders described many ways of leveraging involvement in ESA-funded projects and missions to support future opportunities. For

[293] INT_1_HRE; INT_5_HRE.

[294] INT_2_HRE.

[295] INT_2_HRE.

[296] INT_2_HRE.

[297] INT_2_HRE.

[298] INT_2_HRE.

[299] INT_5_HRE.

example, NAVISP-backed companies such as NSL, DDK and Focal Point have secured major private-sector investments following successful NAVISP projects.[300] GMV's Resilient Timing Lab & Knowledge Exchange research also helped secure an international multimillion-pound contract with the Square Kilometre Array for time synchronisation.[301] Such investments have enabled companies to develop commercial technologies and applications, such as Telespazio, which leveraged NAVISP funding to progress its resilient navigation technologies towards operational use in maritime and aerospace industries.[302]

UK flagship missions such as TRUTHS are catalysts for long-term strategies, signalling the UK's ambitions in space science and technology.[303] UK space companies and institutions use TRUTHS to align their future growth plans with emerging opportunities in EO and data-driven markets.[304] TRUTHS is expected to impact commercial satellite markets and the new space sector, improving measurement accuracy and data reliability and strengthening the UK's role in these industries.[305]

Participation in ESA programmes has been transformative for UK businesses and academia, facilitating strategic partnerships with key industry players and providing access to important networks that can be leveraged for future opportunities. For scientists, working on ESA programmes is highly regarded when applying for future career and funding opportunities. For instance, ESA EO missions provide access to global research networks, strengthening collaborations and positioning scientists for future academic and industry roles.[306] ESA has similarly facilitated network formation and collaboration in industry, giving SMEs and researchers access to business opportunities and insights into upcoming projects.[307] Collaborations forged through ESA member state consortia have generated new opportunities for the UK space sector. For example, the integration of satellite and terrestrial networks has led to collaborations with OneWeb and enabled 5G backhaul demonstrations via satellite, resulting in international contracts, including in Australia.[308]

UK space sector organisations have leveraged ESA funding to secure additional public sector funding, expanding their customer base and strengthening their position for future contracts. While most public sector follow-on funding comes from ESA, participation in ESA missions has also enabled organisations to secure contracts with NASA, the Japan Aerospace Exploration Agency (JAXA), the Indian Space Research Organisation and the UKRI, demonstrating the broader impact of ESA-funded expertise.

Many UK companies highlighted the benefits of establishing credibility within ESA, helping them become trusted suppliers and enhancing their competitiveness for future ESA opportunities. Developing a

[300] INT_1_NAV.
[301] INT_2_NAV.
[302] INT_5_NAV.
[303] INT_5_EO.
[304] INT_5_EO.
[305] INT_5_EO.
[306] INT_12_EO.
[307] INT_1_TEL.
[308] INT_1_TEL.

strong track record with ESA was considered crucial for sustaining and, in some cases, expanding capabilities, particularly in areas like space and climate science, which have limited commercial potential and fewer private funding opportunities. For example, TRUTHS and Copernicus contracts helped one organisation establish itself as a trusted ESA supplier; this led to a new contract for an ESA Scout mission, expected to create more than 20 new jobs.[309] Similarly, investments in ESA technology programmes have provided critical UK government support, securing additional funding and future project opportunities, including a National Security Strategic Investment Fund (NSSIF) initiative for larger systems.[310] These outcomes demonstrate the value of the capabilities through ESA, which UK companies can leverage to secure additional investment, supporting industrial growth and capabilities continuity.

ESA-funded projects have opened doors to wider opportunities in public sector funding, supporting diversified public funding streams for UK companies and enabling new partnerships. For example, capabilities gained through the UK's investment in the Aeolus-1 mission positioned UK organisations for participation in EarthCARE, an ESA-JAXA collaboration.[311] Likewise, UK engagement in the CCI programme has helped businesses diversify their ESA funding streams and expand their customer base within ESA.[312] This process has also led to new opportunities outside ESA, such as bidding on archival and data-related projects with the European Centre for Medium-Range Weather Forecasts (ECMWF) and the EO Data Hub.[313] Similarly, experience on Copernicus missions enabled one organisation to contribute to a NASA contract via a French partner, expanding the global footprint of their activities.[314] Furthermore, CCI involvement has facilitated internationally funded projects, such as GSR Australia's land cover mapping initiative and the UKRI's Living Coasts project, illustrating how ESA-backed networks create follow-on funding opportunities across sectors and geographies.[315]

ESA investment has also laid the groundwork for future UK capabilities. Developing a UK ground segment through TRUTHS is a key example, offering potential for future contracts with the UK Ministry of Defence (MoD) and other national initiatives.[316] These outcomes highlight how ESA participation enhances technical credibility and business development and creates a strategic pathway for UK organisations to secure long-term funding, expand their influence and maintain a competitive position in the global space sector.

The UK's ESA investments, particularly through GSTP, have played a crucial role in enabling market readiness and commercialisation of space technologies, stimulating additional investment in UK space companies. Companies have reported significant revenue generation and job creation due to GSTP funding. Leveraging multi-programme funding from GSTP and ARTES generated £5.7m in additional revenue, one firm secured £3m in private investment and £1.5m in internal investment,

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309 INT_20_EO.

310 INT_1_TECH.

311 INT_20_EO.

312 INT_28_EO.

313 INT_28_EO.

314 INT_11_EO.

315 INT_31_EO.

316 INT_04_EO; INT_21_EO.

creating 18 new jobs.[317] Another company successfully secured further financial backing, demonstrating GSTP's role in stimulating private sector investment and business growth.[318]

GSTP further supports market readiness by facilitating in-orbit demonstrations, a critical step in proving the viability of new technologies. Industry participants highlight the programme's value in de-risking innovation, enabling companies to transition from early-stage development to commercial deployment. As one interviewee explained, an initial GSTP project led to a follow-on contract, funding an in-orbit demonstration and a payload for the ISS, exemplifying GSTP's role in advancing UK technologies to global markets.[319] The interviewee noted UKSA's role in guiding the organisation towards the opportunity with GSTP, highlighting the Agency's role in facilitating awareness of opportunities for commercialisation through ESA.[320]

Participation in ESA programmes has enhanced the credibility and legitimacy of UK space companies, strengthening investor confidence and attracting further investment. ESA-funded projects and missions serve as a validation mechanism, demonstrating technical expertise, process efficiency and commercial viability. Stakeholders across EO, Space Safety, GSTP and Telecommunications report that ESA funding signals competency and credibility, supporting additional investment. UK firms engaged in GSTP, ADRIOS, InCubed-2 and FutureEO projects emphasised that ESA backing has been critical in securing private equity and commercial contracts.[321] For example, ESA funding has catalysed significant investment growth in Telecommunications, with one company securing £110m in Series C funding through participation in a 5G/6G initiative, supporting workforce expansion and increased technical capabilities within the firm.[322]

Beyond commercial activities, ESA funding has also strengthened the scientific reputation of UK organisations, providing greater visibility of scientific capabilities and supporting academic and industrial organisations in securing additional investment. A participant in ESA's CCI programme highlighted that involvement in ESA climate programmes validated their capabilities, enhanced recognition of the scientific capabilities within industry and demonstrated their social and environmental impact, further reinforcing the broader benefits of ESA participation.[323]

Wider recognition of scientific capabilities can support resilience and continuity within the UK space sector. For example, although one academic organisation was unsuccessful in securing further ESA funding for instrument development, the profile and legitimacy gained through ESA support attracted private investment, enabling continued development, technological advancement and career progression for researchers.[324]

[317] INT_11_TECH.

[318] INT_1_TECH.

[319] INT_1_TECH.

[320] INT_1_TECH.

[321] INT_6_TECH; INT_10_TECH; INT_10_SS; INT_19_EO; INT_14_EO.

[322] INT_2_TEL.

[323] INT_28_EO.

[324] INT_14_EO.

Through technical expertise and guidance, ESA programmes have supported capability development, technical maturation and commercial readiness, demonstrating the added value of the UK in pursuing commercialisation objectives through ESA programmes. Stakeholders involved in several ESA programmes aimed at commercialisation, including GSTP and InCubed-2, emphasised the added value of ESA technical expertise, market awareness and investor networks, which support successful commercialisation efforts. Support from UKSA and ESA has been invaluable in providing financial backing and robust technical assistance.[325] UK space organisations, particularly SMEs, describe the technical expertise ESA provides as incredibly beneficial.[326] Many UK organisations report seeking opportunities to commercialise through ESA because of its technical expertise and broader market awareness.[327]

ESA has also facilitated introductions to other companies and investors, providing UK space organisations with expanded opportunities to network and secure additional investment. This support has been crucial for some companies, who reported that working with ESA added credibility to their work, helped secure private equity and facilitated market expansion.[328] Some companies have reported that follow-on contracts often stem from initial GSTP funding, with visibility and recognition gained through ESA involvement facilitating these opportunities.[329] For example, a UK company developed the MHT-1 thruster and an electronic pressure regulator under GSTP, now key products sold in Europe and the US.[330]

4.2. The commercialisation of scientific and technical outputs

The UK's investments in ESA have contributed to commercialisation outcomes, enabling companies to develop, refine and bring new technologies to market. Commercially focused programmes such as GSTP, NAVISP, ARTES, InCubed-2 and ScaleUp have been crucial in transforming innovative concepts into commercially viable products. For example, stakeholders have described GSTP funding as instrumental in this process, supporting the development of key technologies such as large offset reflectors, thrusters and electronic pressure regulators, which are now successfully sold internationally.[331] The structured, multi-phase approach of GSTP – typically spanning 5–6 years from development to production – allows sufficient time for R&D, ensuring thorough de-risking and market readiness and allowing companies to commercialise with greater confidence.[332]

Other ESA programmes have also directly enabled commercial success. **NAVISP funding has supported the development of the VHF Data Exchange System**, expected to be market-ready by 2026.[333] Telecommunications projects have similarly driven commercialisation, with one 5G technology initiative

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325 INT_5_TECH.

326 INT_9_EO; INT_13_EO.

327 INT_9_EO; INT_13_EO.

328 INT_10_TECH.

329 INT_11_TECH.

330 INT_2_TECH.

331 INT_2_TECH; INT_5_TECH.

332 INT_2_TECH.

333 INT_5_NAV.

for drone delivery securing £1.5m in commercial contracts.[334] Interviewees indicated that involvement in ESA programmes helps them build trust with customers and investors, facilitating commercialisation.[335] Similarly, the ARTES programme enabled a UK company to develop a wrapped rib antenna, leading to commercialisation and export opportunities even before in-orbit demonstration.[336] Investments through ESA programmes have laid the foundation for securing additional funding and critical UK government support for future project opportunities, including an NSSIF initiative for larger systems.[337]

Within EO, InCubed-2 funding has fostered commercial opportunities in the fast-paced landscape of downstream EO applications and services, with nearly all recently funded UK applications leading to market potential. UK companies supported through InCubed-2 funding have developed new technologies and services, expanded their customer bases and positioned themselves for future growth. While many of the most recent entrants into InCubed-2 are yet to commercialise fully, the developments enabled by the programme have resulted in private investment ahead of full deployment.[338] The programme has also facilitated the formation of new commercial consortia for some funded organisations, strengthening the UK supply chain, enabling stronger industry collaboration and accelerating the path to market.[339] Some projects are already approaching full commercialisation, likely to launch new offerings and secure patents by 2026.[340] Additionally, InCubed-2-backed innovations have led to the development of complementary products and services, further broadening UK space organisations' commercial opportunities.[341]

However, **not all projects have met their commercial expectations**, reflecting commercial ventures' inherent risks and failure rates. For instance, Proba-3 contributed to UK geo-return and technological advancements within GSTP but has not yet led to commercial successes due to challenges such as the increasing costs of ESA-compliance requirements.[342] Likewise, while most InCubed-2-supported projects have resulted in clear market pathways, at least one has faced challenges in reaching full commercial readiness within the programme's timeframe.[343] Nevertheless, the examples of successful commercialisation outnumber those that have stalled, demonstrating that ESA investments have effectively driven market outcomes.

Receiving funding through ESA commercialisation programmes provides a clear signal of the competence and legitimacy of UK space companies, boosting confidence in commercial markets and expanding global opportunities. Many stakeholders indicated that receiving ESA funding provides a stamp of approval, increasing the desirability of UK-developed products in key export markets such as

334 INT_2_TEL.
335 INT_2_TEL.
336 INT_1_TECH.
337 INT_1_TECH.
338 INT_13_EO.
339 INT_9_EO.
340 INT_13_EO.
341 INT_9_EO.
342 INT_6_TECH.
343 INT_12_SS.

Korea, Japan and the US.[344] UK space companies have leveraged ESA support to build credibility, secure long-term investment and retain intellectual property rights, making participation particularly attractive for large-scale enterprises.[345] Beyond direct commercialisation, ESA-backed research has also informed strategic decision-making, with data from ESA programmes, such as CCI Cloud, guiding investment decisions, including UK firms' placement of solar farms. These examples highlight the commercial value of ESA investments, demonstrating their role in building market credibility and informing strategic industry decisions.

Through ESA, the UK has actively supported innovation and commercialisation in the space sector, with initiatives such as the ESA Business Incubation Centres and ESA Phi-labs playing a critical role in integrating SMEs into the ESA ecosystem. These initiatives provide startups with infrastructure, expertise and funding, enabling them to develop space-enabled technologies and commercially viable business models.[346]

As discussed in Chapter 2.1.2, the UK ESA BIC offers startups access to specialised facilities, business support and mentoring, helping them transition from early-stage concepts to market-ready solutions.[347] It is funded jointly by STFC and UKSA through ESA, with just over 60% of funding provided by STFC and just under 40% provided by UKSA because of the UK's investments into the broader ESA BIC programme. By fostering collaboration between academia, industry and government, **BICs bridge the gap between research and commercial applications, ensuring that UK space startups thrive in an increasingly competitive sector**.

Complementing these efforts, **ESA Phi-labs, recently secured by RAL Space, focus on developing high-impact technologies with strong commercial potential**. Phi-labs act as a collaborative innovation platform, leveraging the UK's space science and technology strengths to accelerate emerging innovations' commercialisation. By supporting the development of new applications and services, Phi-labs aim to create economic value and enhance the UK's competitive edge in the global space sector.

The UK ESA BIC's reported economic impact is substantial. For the financial year ending April 2024, **the programme delivered £70m in economic impact**, contributing to a cumulative total of over £350m since its inception. With a ROI exceeding 25× against a programme cost of approximately £13m, the UK ESA BIC has proven highly effective in driving business growth and economic sustainability.[348] The startups supported through the programme have raised over £230m in private investment, achieving a combined pre-money valuation of over £650m. These companies play a key role in the UK space economy, supporting over 1,000 highly skilled jobs and generating over £20m in revenues, with around 50% coming from exports. Notably, the UK ESA BIC startups maintain an exceptional five-year survival rate of over 95%, underscoring the programme's success in fostering sustainable, high-impact businesses.

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[344] INT_20_EO.

[345] INT_3_TEL.

[346] INT_5_SCI.

[347] INT_5_SCI.

[348] Internal STFC analysis. Based on: Technopolis analysis; ONS data; ESA BIC annual surveys; Beauhurst; Brycetech Size and Health Report 2020 & 2021.

As the UK continues to strengthen its role in space innovation and commercialisation, the ESA BICs and Phi-labs remain vital mechanisms for transforming cutting-edge research into real-world applications, reinforcing the UK's position as a leader in the global space economy.

4.2.1. SME success stories from the UK ESA BIC

Investments in the UK ESA BIC have supported the growth of UK SMEs and have driven innovation and commercialisation in the UK space sector. A few notable examples are outlined below:

- **Magdrive:** Founded in 2019 to apply to the UK ESA BIC, Magdrive were unsuccessful in 2019 but successful in 2020 following a success in a smaller BIC (Westcott, run by the Satellite Applications Catapult). After graduating from the UK ESA BIC, Magdrive raised £2m in private investment by the end of 2020 and leveraged grants from UKSA, ESA and other sources to achieve a total of £9m in grant funding by 2025, including success in ESA's ScaleUp programme. Derived from the initial injection of funding and expertise from the UK ESA BIC, this continued success allowed Magdrive to expand its facility, secure 6,000 square feet of manufacturing capabilities and establish its first flight test. Magdrive has grown from five employees in early 2021 to 25 in February 2025. In addition, their flight technology TRL rose from 1 to 6 in Q3 2022 ahead of flight tests, and they secured $10.5m in follow-on funding from venture capital sources.
- **B2Space:** B2Space joined the UK ESA BIC in 2018 to develop a stratospheric testing platform using stratospheric balloons. This 'Near Space Test Bench' allows businesses to test components in near-orbit conditions. With the support of the UK ESA BIC, B2Space expanded its network and participated in the 'Call to Orbit' programme. Post-incubation, the company raised over £3m, expanded its team and achieved a successful rocket launch in 2022, advancing its rockoon launch system and diversifying into consultancy services.
- **Astron Systems:** Founded in 2021, Astron Systems is developing reusable rockets for sustainable satellite launches. Addressing the high costs of launching smaller satellites, the company benefited from the UK ESA BIC's support, developing key components of its Aurora launch vehicle and securing private equity funding. Recognised as a Deep Tech Pioneer, Astron Systems aims to reduce launch costs and enable net-zero carbon launches, supported by a robust IP strategy.
- **Lúnasa:** Specialising in autonomous Rendezvous Proximity Operations (RPO) technology, Lúnasa joined the UK ESA BIC in 2022. With funding and support, Lúnasa advanced its technology development, secured pre-seed funding and plans to launch its first testbed by 2025. The latter will validate its vision-based navigation solution for RPO, establishing flight heritage and unlocking commercial contracts. The UK ESA BIC experience has provided support and a sense of community.

4.3. Spillovers

This chapter explores the wider spillover effects of the UK's investments in ESA. Spillovers can occur when investments in a project or firm benefit other firms, local economies, or sectors. Such benefits can occur through mechanisms such as the diffusion of knowledge, increased demand in supply chains (in addition to spillovers that flow along supply chains) or clustering of economic activity.

While not aimed at commercialisation, many other areas of the UK's ESA investment portfolio nevertheless have evidence of spillovers into commercial use. A prominent example of this is spillovers from the Science Programme. Universities have translated ESA-backed research into commercial ventures, exemplified by Cardiff University's spin-out companies. These companies use technology initially developed for scientific applications beyond space science. One such company, Sequestim, uses superconducting detector technology for security imaging, enabling video-rate imaging in scenarios like airport security, where individuals' body heat can be scanned without needing to stop and pose.[349] Another spin-out, Celtic Terahertz Technology Limited, focuses on optical and filter components with applications in high-frequency communication, among other areas.[350] The demand for these components has outgrown the capabilities of a university environment, necessitating industrial-scale production.[351]

Beyond specific spin-outs, ESA-driven R&D has enabled breakthroughs in Complementary Metal-Oxide-Semiconductor detector technology and semiconductor development, supporting applications in AI surveillance, tracking and radiation shielding.[352] Furthermore, technologies tailored for space science applications often find uses in other sectors. For instance, instruments developed for space missions are procured from companies catering to defence applications, suggesting dual-use potential.[353] Subject to UK Export Control, these instruments' sensitivity underscores their applicability in defence and other industries. Such spillovers often arise indirectly through capacity building and the R&D infrastructure associated with ESA projects, strengthening the UK's innovation ecosystem.[354]

Such spillovers from ESA science programmes are evident in scientific publications, where UK companies have been involved as authors of scientific research. Figure 27 shows the number of publications by each institution labelled as both a UK and a commercial institution in OpenAlex. While these are small numbers, they indicate some evidence of ESA funding being associated with spillovers between academia and industry.

[349] INT_2_SCI.

[350] INT_2_SCI.

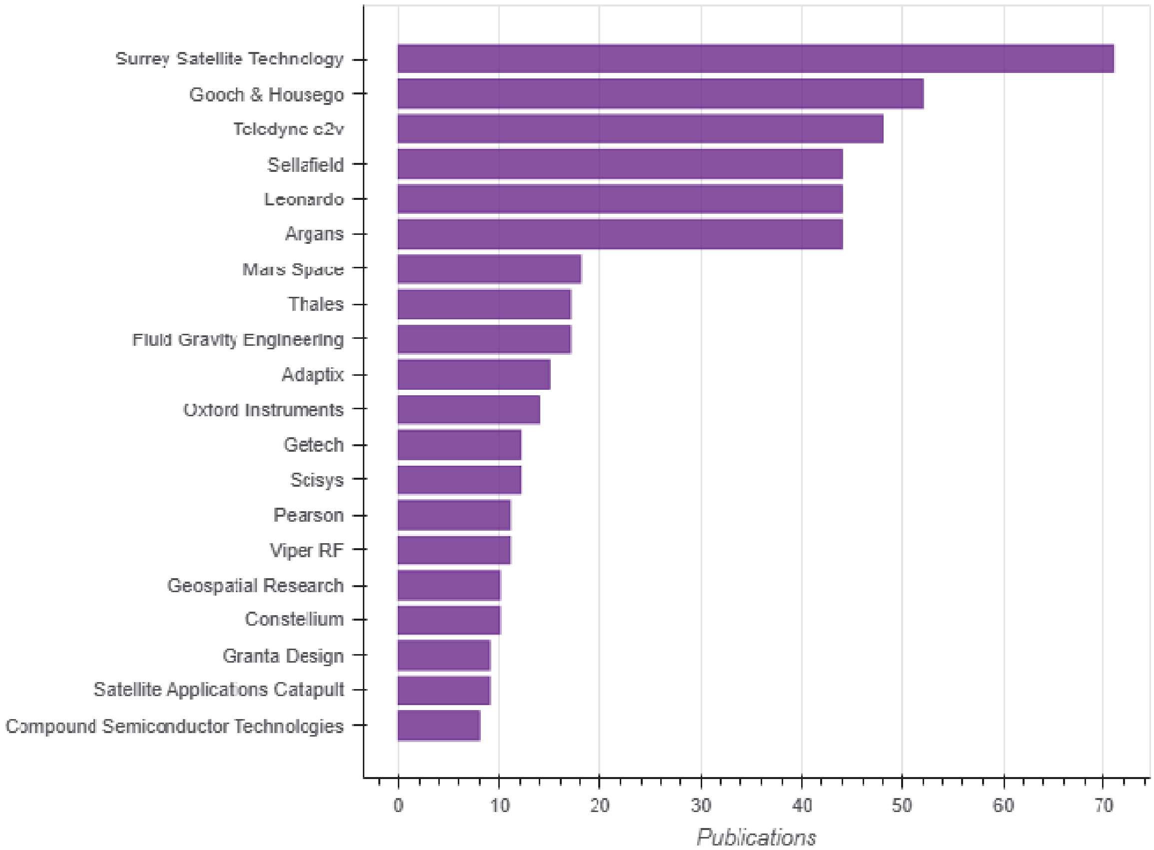
[351] INT_2_SCI.

[352] INT_3_SCI.

[353] INT_6_SCI.

[354] INT_3_SCI.

Figure 27: The number of publications authored by UK companies



Source: OpenAlex (Papers published 2000-2025). RAND Europe analysis.

To further capture the effects of spillovers, we combined two complementary strands of analysis. The first was a spatial econometric assessment of the local economic impacts of UKSA contracts, using firm location data and local area-level economic indicators to identify spillovers in employment, productivity, business density and clustering. The second drew on qualitative case examples to present a high-level summary of the indirect effects of ESA-funded activities, including technological advancements, enhanced data practices, international collaborations and the development of a skilled workforce.

4.3.1. Impact of ESA contracts at the local level

We conducted a series of econometric analyses to investigate the spatial impacts of UKSA contracts at the local level, which involved redefining the unit of analysis from the firm level to ONS 'Output Areas' (OAs), i.e. geographical areas located within a predefined distance from firms receiving contracts. The analysis was predicated on the assumption that the strength of local economic effects of ESA contracts will depend on:

- The **distance** of a given local area from firms awarded contracts (a distance-decay relationship).
- The **number** of firms located nearby that have been awarded contracts (i.e. a 'dose-response' relationship).

This exercise required mapping firm locations and drawing a boundary around each firm up to 20km within which economic activity could be observed. We accomplished this using ESA contractors' postcodes (provided by UKSA) and mapping them in QGIS (specialist mapping software). Full details are provided in the companion Technical Annex.

The main findings are as follows:

- **Increased activity within the OA of the firm:** Each contract led to an approximate 5.1% increase in the number of jobs within the OA where the recipient firm was located, a 6.3% increase in the turnover of firms based in the area and a 3.4% increase in turnover per worker.
- **GVA impacts:** Contracts were estimated to have led to a 4.7 and 2.8% increase in local GVA and GVA per worker, respectively, within the OA where the recipient firm was located.
- **Clustering**: The contracts awarded positively affected the number of firms in areas proximate to awarded contracts. These effects were most significant in areas 1km to 10km from areas in which the firms that received contracts were located.
- **Increased activity within proximate areas**: There were also positive economic impacts 1–10km from awarded contracts.

These findings indicate that UKSA funding has produced positive but not powerful locational spillover effects for local economies.

4.3.2. Qualitative evidence of spillover effects

In addition to the quantified economic impacts presented above, this evaluation has documented qualitative evidence of spillover effects from ESA investments with key illustrative examples presented below.

UK companies have leveraged ESA projects to develop new technological capabilities. For instance, the Supersharp InCubed project led to a spinout from the University of Cambridge, illustrating technology transfer and the growth of domestic talent. Similarly, the TRUTHS project by Airbus advanced satellite calibration expertise and expanded into front-end electronics for space instruments, creating jobs and enhancing UK industrial capabilities. Examples show the advancement into new areas by existing companies and new company growth, which shows the increasing strength of the UK supply chain. This development has enhanced the appeal of UK-developed products to international agencies, particularly in countries such as Korea, Japan and the US, opening substantial export opportunities and thereby contributing to the UK's Gross Domestic Product. The export of these products, for which Copernicus is a key example, signifies a return to the UK's economic output and a strengthened UK supply chain.

Other specific examples include:

- The MOSWOC showcases how involvement in ESA initiatives has **improved the UK's readiness and expertise in space weather events**, highlighting international knowledge sharing and enhanced prediction capabilities.
- The University College London-Mullard Space Science Laboratory (UCL-MSSL) developed the Plasma Analyser for the Vigil mission, **building on existing knowledge and enabling UCL to serve as systems engineering consultants for ESA**. This demonstrates internal knowledge transfer and the repositioning of expertise from international institutions to the UK.

- Developing **robust data standards and stewardship protocols for managing large EO datasets**, such as those from Copernicus, has had a spillover effect on other sectors like finance, insurance and urban planning. This effect demonstrates how knowledge cultivated in the space sector can be applied broadly across data-intensive industries. Indirect knowledge spillovers are also notable. For example, Earthwave, originating from a University of Edinburgh spinout, illustrates academic knowledge transfer and skill development within the UK workforce. Similarly, projects under NAVISP at Cranfield University have indirectly informed sectors requiring reliable navigation and resilience.

In conclusion, **ESA funding has fostered significant knowledge spillovers in the UK** through technological advancements, enhanced data practices, international collaborations and the development of a skilled workforce, ultimately benefiting the UK economy. UK contractors can leverage their position advancing technology at the forefront of space innovation to engage in the community, inspire others and share knowledge, encouraging the next generation of innovators. As part of TRUTHS, school talks provided exposure to space technology, which developed into including placement students working with the team. Earthwave's participation in conferences and workshops has led to interactions with the academic community and knowledge sharing. This type of engagement facilitates the dissemination of information and potential collaborations.

Such examples demonstrate the potential strengthening of the supply chain capability, such as expanding operations and new entrants and successful collaboration. Although it is difficult to draw the line to soft power benefits, the examples show strong international collaborations and technological advancements that are attracting attention internationally, as well as collaborations that can only support soft power. Spillovers from technological advancements are clearly benefiting other industries, further supporting UK business.

5. Socioeconomic, reputational and policy benefits

This chapter presents findings on the broader socioeconomic and reputational benefits of the UK's investments in ESA. First, we explore these benefits through a series of vignettes, including those related to GSTP and telecommunications. We then assess the benefits derived from public outreach and climate science activities. Finally, we discuss the impacts of the UK's investments in ESA on the UK's policy and decision-making and its global reputation in space R&D leadership.

Key findings on the socioeconomic benefits of the UK's ESA membership:

- **Recognition of UK expertise:** The UK's active involvement in various ESA missions has enhanced its reputation and recognition internationally, particularly in fields like climate monitoring and EO, allowing UK entities to become key contributors to global standards.
- **The central role of EO:** High-quality EO data contributes substantially to public sector applications in fields like disaster preparedness and environmental management, facilitating better decision-making through improved climate science.
- **Critical space monitoring:** The Vigil mission already plays an essential role in enhancing the UK's capabilities in space weather forecasting, underlining its importance following potential failures of existing missions, thus contributing to global safety protocols.
- **STEM engagement through space missions:** UK-led initiatives, such as Tim Peake's ISS mission, serve as powerful tools for STEM engagement, fostering interest in science and technology among students, although measuring long-term impact remains challenging.
- **Environmental management influence:** ESA's EO investments have facilitated the development of early warning systems and risk assessment frameworks, providing environmental benefits and enhancing the UK's capacity in climate science.
- **Data-driven approaches to policy:** Effective climate action and sustainable development strategies rely on collaboration between researchers, policymakers and other stakeholders, emphasising the need for integrating satellite data into governmental decision-making.

The breadth of the UK's ESA investment portfolio encompasses a wide range of programmes that yield numerous tangible benefits. However, this diversity also highlights evidence gaps in our analysis that should be acknowledged. Many of the predicted socioeconomic benefits are contingent upon the successful operational status of specific missions and the effective utilisation of data generated by these initiatives. Additionally, the complexity of various factors, such as the geographical distribution of expertise and the limited direct influence of the UK in certain technical domains, further complicates the assessment of these benefits. While the chapter outlines considerable advantages, it is important to recognise that not all impacts can be quantified effectively with the existing evidence, necessitating further research to capture the full spectrum of benefits derived from these investments. Section 6.1 discusses this further.

5.1. The benefits of more accurate and timely data

5.1.1. Understanding and monitoring climate change

The UK's investments in ESA EO missions and programmes have significantly enhanced the scientific understanding and monitoring of climate change. The Copernicus programme, for instance, provides a comprehensive satellite view that improves the accuracy and timeliness of climate models, allowing the Met Office to push research boundaries. This programme serves as a cornerstone for advancing climate research.[355] Similarly, CCI's long-term satellite datasets offer global coverage, consistency and comparability, making them the benchmark for many ECVs.[356] These datasets leverage data from multiple satellite missions, ensuring comprehensive global coverage and temporal resolution. The increased uptake of CCI data is driven by its unique features, such as longer timescales and high-quality time series data, which are crucial for climate studies.[357] This data helps understand changes over time and offers improvements in specific areas, such as monitoring polar regions.[358] Initiatives like the Copernicus Climate Change Service (operated by ECMWF) use CCI data in their climate model reanalysis to improve their model performance.[359] These investments have ensured that the UK and the global scientific community have access to the most comprehensive, consistent and accurate climate information, advancing our understanding and monitoring of climate change.

Moreover, CCI has played a pivotal role in crisis resilience and preparedness. The CCI datasets have been used to develop early warning systems and risk assessment tools for climate-related hazards, such as floods, droughts and heatwaves. For example, the CCI Soil Moisture dataset has been used to monitor and predict agricultural droughts, enabling better preparedness and response to food security crises.[360] Similarly, the CCI Land Cover dataset assesses the vulnerability of ecosystems and human settlements to climate change impacts, informing adaptation and resilience planning.[361]

5.1.2. National security

Participation in ESA programmes has reportedly bolstered the resilience of the UK's national security system by developing strategic technologies. A prime example is the ELORAN project, where GMV's testing of ELORAN jamming resistance has ensured the UK maintains a reliable backup for GNSS. This capability is crucial for safeguarding critical navigation and timing services against potential

[355] INT_2_EO.

[356] CCI expert review.

[357] INT_24_EO; INT_27_EO.

[358] INT_27_EO.

[359] INT_1_EO.

[360] CCI expert review.

[361] CCI expert review.

disruptions. Additionally, GMV's NAVISP-funded lab has been instrumental in developing contingency plans that enhance the resilience of critical infrastructure.

5.1.3. Economic or financial

Participation in ESA programmes has generated significant economic value for the UK across various sectors, thanks to advances in timely data. For instance, GMV's Secure Timing Lab plays a crucial role in maintaining stability of the finance sector by providing a backup for GNSS, which is vital as it faces potential losses of £5.2bn per day if GNSS services fail.[362] Furthermore, the downstream usage of Copernicus data has broad economic implications. Farmers utilise soil moisture data to optimise crop cycles, while energy companies leverage forecasts to manage energy demand better, demonstrating the data's value in enhancing operational efficiency and decision-making.[363] **Improved weather forecast accuracy**, driven mainly by EO programmes, also contributes to economic value. For example, CCI sea surface temperature datasets serve as a primary input for numerical weather prediction models by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).[364] CCI datasets also feed into the MET Office's weather forecast models, improving the overall output quality.[365]

5.2. Progress and inspiration

5.2.1. Broader impacts of space missions

Space missions advance our understanding of the universe and bring about technological innovations with far-reaching implications across various sectors, including healthcare. A prime example of this interdisciplinary impact is the Gaia mission, which has significantly advanced AI and machine learning capabilities within the UK. The sophisticated algorithms and data processing techniques developed for the Gaia mission, initially designed for astrometric measurements and stellar mapping, are now being adapted for medical applications.[366] These technologies are utilised in critical areas such as tumour imaging and 3D mapping, addressing urgent healthcare needs, particularly in diagnosing childhood cancers. By leveraging the advanced data analysis techniques honed through space exploration, healthcare professionals may be able to enhance diagnostic accuracy and improve treatment planning for young patients.[367]

5.2.2. Inspiration, public outreach and STEM engagement

ESA programmes have contributed to public outreach and STEM engagement in the UK, generating interest in space science and technology. Funding for public outreach comes from multiple sources, including mandatory ESA programme activities, the Science Programme, national funding and contributions from individual research teams. These investments have enabled a wide range of initiatives,

[362] London Economics (2017).

[363] INT_2_EO.

[364] INT_29_EO.

[365] INT_2_EO.

[366] INT_12_SCI.

[367] INT_12_SCI.

such as those coordinated through the European Space Education Resource Office (ESERO) and the National STEM Learning Centre in York, which play a crucial role in delivering space-related STEM education.[368]

Several high-profile missions have demonstrated the impact generated by ESA programmes on public engagement. **The Herschel mission, for instance, demonstrated effective coordination of public engagement activities by establishing a UK outreach group despite limited resources**.[369] Similarly, the Ariel mission has undertaken significant efforts in public engagement, though it faces financial constraints limiting its reach.[370] The Rosetta and Euclid missions have also shown how well-coordinated professional outreach, combined with the enthusiasm of scientists and academics, can enhance public understanding of space science. Despite these successes, ESA's public engagement strategies have been critiqued for lacking the resources and effectiveness of comparable organisations, such as NASA.[371]

The National Space Centre in Leicester is a testament to the impact of UK investment in ESA public outreach. Attracting approximately 300,000 visitors annually, including 80,000 schoolchildren, the centre provides a large-scale platform for engaging the public in space science.[372] Additionally, the UK's participation in ESA's human spaceflight activities has had a profound effect, particularly through Tim Peake's mission, which generated widespread public interest and led to short-term increases in STEM course enrolments.[373] However, a report warns against over-reliance on astronauts as the face of the space sector, noting that while 90% of children associate space careers with astronauts, the sector offers a far wider range of opportunities beyond human spaceflight. ESA received 23,000 applications for just five astronaut positions in 2022, highlighting the need to broaden the public's perception of careers in the UK space sector.[374]

STEM engagement extends beyond outreach activities to practical skills development. Programmes such as UKSEDS, SPIN and the Prospero Fellowship provide young people with technical and business experience alongside their studies.[375] The Space Skills Alliance has highlighted that sustained funding and industry support are necessary to expand these initiatives and ensure they adapt to the evolving demands of the space sector. UK-led missions such as TRUTHS have played a crucial role in inspiring early-career scientists,[376] with industry reporting that the diversity of ESA engagements – ranging from Mercury and Mars missions to EO satellites – is a major draw for the next generation of engineers and researchers.[377]

Despite these successes, stakeholders have highlighted two main areas needing improvement. For example, the UK lacks a national STEM engagement strategy to fully capitalise on the public excitement

[368] MAN_INT_1.
[369] MAN_INT_6.
[370] MAN_INT_6.
[371] MAN_INT_6.
[372] INT_4_HRE; MAN_INT_4.
[373] INT_5_HRE.
[374] Dudley & Thiemann (2024).
[375] Dudley & Thiemann (2024).
[376] INT_16_EO.
[377] INT_33_EO.

generated by space investments.[378] Additionally, the lack of systematic tracking of long-term career outcomes from STEM outreach initiatives limits the ability to assess their impact.[379] By addressing these challenges and building on existing strengths, the UK can continue to derive substantial benefits from inspiring the next and, indeed, current generation of STEM graduates.

Vignette: Human and robotic exploration

The UK's investment in ESA's HRE programme serves a dual purpose: advancing space exploration and inspiring the next generation into STEM. Space exploration has long been regarded as a powerful tool for engaging young minds, capturing imaginations and motivating students to pursue STEM careers. Through its ambitious projects and high-profile missions, HRE serves as a compelling entry point into STEM education.

However, while inspiration is often cited as a major justification for HRE investment, there are significant challenges in defining, measuring and ensuring its long-term effectiveness. Without clear metrics and objectives, the impact of space missions on STEM engagement remains largely anecdotal, raising critical questions about how best to leverage such missions for meaningful educational outcomes.

5.2.3. Challenges in inspiring the next generation into STEM

There are several challenges associated with understanding and maximising the impact of space activities, such as those funded through ESA, in inspiring the next generation in the UK space sector:

- **It can be difficult to define and measure the impact of inspiration:** The concept of 'inspiration' is widely embraced by scientists and policymakers but difficult to quantify. Although space missions generate excitement, proving their direct influence on students choosing STEM careers remains elusive.[380] Longitudinal studies that could track the long-term effects of space-related inspiration on career choices are expensive and difficult to sustain. Without robust data, decision-makers struggle to justify continued investments in STEM outreach through space programmes.
- **There is an additional need to clarify the goals of inspiration:** Aside from a concrete definition, is the goal to increase general interest in STEM, drive students toward specific careers in space-related industries or foster a deeper understanding of scientific literacy? A more strategic approach is required to ensure that space missions are not just inspirational events but part of a sustained effort to strengthen STEM engagement at different educational levels.
- **Targeting the right audience is also a challenge:** Much of the focus on inspiration is directed at young students, but inspiring the current generation – parents, educators, policymakers and industry leaders – is equally critical. These groups play a key role in shaping the environment that nurtures future STEM talent.[381] Space missions and astronaut role models can serve as powerful

[378] INT_5_HRE.

[379] INT_5_HRE.

[380] HRE_INT_Scoping.

[381] HRE_INT_Scoping.

engagement tools, but without a structured approach, inspiration risks being short-lived and failing to translate into action.

One of the most significant UK-led initiatives in STEM engagement was astronaut Tim Peake's 2015 mission to the ISS. His mission was a deliberate effort by UKSA to create national excitement around STEM subjects, using a real-life role model to make science and engineering more relatable.[382]

Through educational campaigns, school activities and interactive experiments conducted from space, Peake's mission provided a unique opportunity to engage students. However, while widely celebrated, assessing the mission's long-term impact proved challenging. A lower-cost study was conducted post-mission, but it lacked the depth required to draw robust conclusions about whether the mission led to a measurable increase in STEM engagement and career choices.[383] Furthermore, policymakers debated how best to leverage the mission's success. While used to highlight opportunities in STEM, some questioned whether such inspiration alone was enough to drive students toward these careers without further systemic support, such as better STEM education resources and industry pathways.[384] Learning from past missions can enhance STEM engagement strategies for current and future space initiatives, ensuring that the excitement from modern missions leads to tangible outcomes.

5.3. Environmental and societal benefits

ESA investments have provided substantial environmental benefits, particularly through EO activities. The UK has played a central role in processing and distributing EO data, facilitating its use in climate science, disaster preparedness and environmental management.[385] The UK has been involved in processing and archiving Sentinel data since 2014, with the UK ground segment serving approximately 100,000 users, according to one consulted stakeholder.[386] This data is widely valued within the scientific community and has been incorporated into numerous climate models and policy frameworks.[387]

EO data from ESA investments has had a transformative effect on public sector applications. Studies conducted by the Met Office and the ECMWF indicate that Sentinel data has provided unprecedented insights, with no other spaceborne instrument achieving a comparable impact in the past 20 years.[388] The availability of high-quality EO data has supported initiatives such as ESA's CCI, which has been instrumental in developing early warning systems and risk assessment tools for climate-related hazards, including floods, droughts and heatwaves. The CCI Soil Moisture dataset has been used to monitor and predict agricultural droughts, contributing to food security and resilience planning.[389] Similarly, the CCI

[382] Bennett, et al. (2018).

[383] Bennett, at al. (2018).

[384] HRE_INT_Scoping.

[385] INT_10_EO; INT_7_EO.

[386] INT_7_EO.

[387] INT_10_EO; INT_7_EO.

[388] INT_7_EO.

[389] CCI expert review.

Land Cover dataset has informed vulnerability assessments for ecosystems and human settlements, shaping adaptation and resilience strategies.[390]

ESA-supported EO programmes have also driven commercial innovation, with UK companies developing technologies that leverage satellite data for environmental benefits. The InCubed-2 programme, for example, has supported the development of the Supersharp thermal infrared satellite payload, which is expected to improve agricultural productivity by detecting heat stress in crops.[391] Another development under InCubed-2, the Messium Nitrogen Estimator, has shown the potential to increase crop yields by 10% and improve nitrogen use efficiency by 29%, mitigating the environmental impact of nitrogen runoff. [392] The Flexible and Intelligent Payload Chain, developed by SSTL and Craft Prospect, is anticipated to have wide-ranging applications, including land cover mapping, weather forecasting and disaster detection.[393] Meanwhile, the high-resolution imagery provided by the MANTIS programme is expected to support agricultural and maritime industries, further expanding the economic and environmental value of ESA investments.[394]

Vignette: GSTP

The UK's involvement in GSTP has not only led to the creation of significant technological innovations but also numerous socioeconomic benefits for the UK. As a result of intentional design, the wider benefits brought to the UK stem from the programme's focus on integrating economic and environmental sustainability into its programme selection process. Through comprehensive socioeconomic assessment criteria, GSTP ensures that projects are evaluated for their broader economic and social contributions in addition to technological excellence.[395]

One key GSTP-supported project involves using hydrogen peroxide as a propellant for space thrusters, which was developed in collaboration with Airbus.[396] This innovation is particularly relevant for lunar travel, offering a greener alternative to conventional chemical propulsion. The potential for reduced environmental impact and lower operational costs presents an opportunity for long-term economic benefits, especially as the global space industry shifts towards sustainable practices.

Another impactful GSTP-supported initiative focuses on advanced manufacturing techniques, including linear friction welding.[397] This process allows smaller material components to be joined together, reducing material waste and strengthening structural integrity. This innovation has applications in aerospace and broader engineering and manufacturing industries, supporting sustainability goals and improving cost efficiency.

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[390] CCI expert review.

[391] INT_19_EO.

[392] INT_13_EO.

[393] INT_9_EO.

[394] INT_15_EO.

[395] INT_1_TECH.

[396] INT_2_TECH.

[397] INT_4_TECH.

GSTP has also facilitated regional economic growth by distributing funding across the UK, ensuring that SMEs benefit alongside larger corporations. One particularly innovative UK-led development within the GSTP framework is the exploration of americium as a potential energy source for spacecraft. As a byproduct of plutonium, americium offers a novel approach to resource utilisation. It has the potential to provide a reliable power source for deep-space missions, exemplifying the UK's contribution to cutting-edge space research.[398]

Similarly, transitioning from thermal set composites to thermoplastic composites is expected to bring long-term environmental benefits.[399] These materials offer improved recyclability and reduce atmospheric debris from re-entering spacecraft, aligning with global sustainability efforts.

While some GSTP-supported projects have already demonstrated clear economic and societal value, others are in earlier stages of development. For instance, the creation of 'smart tanks' for measuring mass and distribution in space is anticipated to have broader applications in industries such as petrochemicals and aviation. The technology is expected to contribute to carbon emission reductions and efficiency improvements, with tangible benefits emerging in the next five to ten years as the technology is further developed and integrated into operational space infrastructure, with a planned launch to the International Space Station in early 2026.[400]

Vignette: Telecommunications

The UK's investment towards the Telecommunications programme has facilitated advancements in satellite-enabled connectivity, leading to important societal benefits. Two key areas of impact include logistics enhancement through 5G-enabled drones and providing disaster response data for humanitarian aid. One prominent initiative involves the deployment of 5G-enabled drones for mail delivery in remote and rural areas.[401] This project, set to expand to cover 12 islands in Orkney **off the north coast of mainland Scotland** over the next five years, improves logistics and also generates local employment. Postal workers are being upskilled to operate drones, enhancing their technical capabilities and securing new job opportunities within evolving industries.

Beyond logistics, the UK's investment in satellite telecommunications has played a critical role in disaster response. UK-based companies have provided free space-based data to aid agencies during global crises, helping coordinate relief efforts in affected regions.[402] This contribution underscores the humanitarian value of space investments, demonstrating how satellite technology can support real-time emergency response and recovery operations. Additionally, using satellite data for long-term public sector applications has proven invaluable, with governments and agencies leveraging it for infrastructure

[398] INT_4_TECH.

[399] INT_4_TECH.

[400] INT_1_TECH.

[401] INT_2_TEL.

[402] INT_6_TEL.

planning, environmental monitoring, and emergency preparedness, ensuring more effective decision-making processes.[403]

ESA-supported projects have also contributed to aviation services with lower emissions and enhanced safety, further highlighting the positive societal impact of satellite telecommunications.[404] The expansion of satellite-enabled communication technologies, including 5G connectivity and space-based data services, is expected to yield further socioeconomic benefits. Enhanced disaster response capabilities, improved logistics solutions, and continued workforce upskilling will contribute to economic resilience and societal well-being.

5.4. Impact on UK policy and decision-making

Through its investments in ESA, the UK seeks to improve policy and decision-making, enabling wider benefits with impacts extending far beyond the space sector. Wider uptake of science improves policy and decision-making in specific areas, such as climate and Net Zero. In other cases, ESA-developed technologies and missions provide important data for public services, such as space weather data integrated into the UK's approach to protecting Critical National Infrastructure (CNI), as discussed above. As one of the more distal impacts of ESA investment, impacts on policy and decision-making have long lead times and involve complex impact pathways with several intermediate activities, outputs and outcomes. Consequently, such impacts are most commonly observed in longstanding ESA programmes.

5.4.1. Climate, weather and environment

The relationship between the UK's investments in ESA and the resulting benefits for weather prediction and climate monitoring is evident. ECMWF develops data assimilation systems driven by satellite observations, ensuring physical consistency across various parameters essential for accurate analysis.[405] The UK Met Office, for instance, leverages these data assimilation processes, informed by investments in satellite data. The Copernicus Climate Change Service has recently conducted a socioeconomic study that suggests improved climate models will enhance weather forecasting and influence climate policies, particularly through the Met Office.[406] However, the pathway to these impacts is complex and indirect, making it challenging to pinpoint specific outcomes.

Copernicus data has played a crucial role in enhancing modelling efforts, which indirectly informs policy. Being positioned further down the value chain, Copernicus Services maintain a closer connection to policy users and stakeholders. For example, seasonal predictions generated by Copernicus inform government policies related to winter provisions, energy security and healthcare planning, such as hospital admissions during peak seasons.[407]

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[403] INT_8_TEL.

[404] INT_5_TEL.

[405] INT_1_EO.

[406] INT_1_EO.

[407] INT_2_EO.

While some researchers involved in algorithm development for ECVs may feel disconnected from the policy implications of their work, it is ultimately the modellers and economists who present findings to policymakers. Researchers provide datasets, but data selection for policy use often depends on convenience or personal relationships rather than scientific rationale.[408]

In Wales, the CCI biomass project has notably impacted local climate initiatives, primarily through the Welsh Government, which has established strong connections with local land use and monitoring efforts.[409] The project has served as a demonstration region for various initiatives related to climate policy. Nevertheless, its broader influence on UK climate policy remains ambiguous, often depending on individual relationships with government officials. Past connections have facilitated influence, but the absence of such relationships can diminish the capacity to shape policy effectively.[410]

The Welsh Data Cube, which includes biomass data, is utilised by organisations such as Forest Research and Natural Resources Wales. This resource allows users to analyse biomass levels quantitatively. The depth of data usage varies; while scientists may conduct in-depth analyses, policymakers may engage with the data at a more superficial level.[411] The Welsh Data Cube mirrors Australia's system, integrating Sentinel data to create land cover maps and monitor biomass changes, which can indicate forest degradation or loss. Inspired by the successful Australian model, the initiative aims to build a comprehensive, open-access system for broader use.[412]

All EO activities are highly relevant for monitoring current climate conditions. From a model evaluation perspective, CCI contributes to enhancing tools used for projections and evaluations. These tools, primarily global climate models, are essential for simulations of past and future climate scenarios. While the data gathered informs climate projections, the exact impact of CCI data on policymaking processes is challenging to measure due to the multiple layers of analysis and interpretation that precede engagement with policymakers.[413] Nevertheless, there are various examples of its uptake, as described below.

UKSA's EO team actively shares updates on ECVs with potential users. For instance, discussions at recent climate conferences have focused on tailoring ECVs for users, like the United Nations Framework Convention on Climate Change (UNFCCC). The agency's role includes signposting ESA's work and raising awareness of ECVs while gathering feedback from various bodies to relay back to ESA. The 'Unlocking Space for Government' workgroup also promotes using ESA outputs, especially CCI data, in policy applications in the UK.[414] Although the mechanisms for sharing ECV outputs across government networks exist, regular engagement has not yet been established.[415]

[408] INT_25_EO.
[409] INT_26_EO.
[410] INT_26_EO.
[411] INT_31_EO.
[412] INT_31_EO.
[413] INT_27_EO.
[414] INT_32_EO.
[415] INT_32_EO.

The ESA CCI datasets have been instrumental in supporting evidence-based policymaking at both national and international levels, facilitating decisions related to climate change mitigation, adaptation and sustainable development. Furthermore, the CCI has contributed to implementing international agreements, such as the Paris Agreement and the Sustainable Development Goals, by providing essential climate data and monitoring tools necessary for effective management.[416]

The upcoming TRUTHS mission is expected to support environmental policy. However, realising this benefit will depend on the mission's operational status and the scientific community's subsequent use of collected data.[417] The extent of the benefits derived from TRUTHS will hinge on improvements in the calibration and validation of current measurements, which may or may not have significant impacts on historical, current and future EO datasets relevant to policy.[418]

The CCI GHG initiative has underpinned many arguments in support of the Global Methane Pledge, a high-profile global initiative that played a vital role at the recent COP.[419] The capabilities and data outputs generated from CCI GHG will contribute to the UK GEMMA programme, which aims to measure the totality of UK emissions and the national carbon budget.[420]

5.4.2. Alignment with NSS and UK strategic space ambitions

Despite the strategic advantages gained from involvement in ESA programmes, the UK's direct influence is sometimes limited by the locations of ESA's centres of excellence, often situated outside the UK. While the UK is well-regarded within ESA, certain fields, such as optical expertise based in Italy, may hinder the UK's ability to lead in specific technical areas because the concentration of specialised expertise in certain countries can limit the UK's direct influence in those fields. For instance, optical expertise is predominantly based in Italy, meaning the UK may lack access to critical resources, collaborations, and knowledge essential for leadership in that particular domain.[421]

This observation highlights the potential benefits of making funding and investment decisions that align with UK strategic priorities and existing areas of strength for the UK space sector. By investing in programmes and areas where the UK has existing expertise or is seeking to develop that expertise in line with the goals outlined in key strategic documents, the UK can seek to leverage ESA funding to achieve those goals. For example, ESA established an Expert Service Centre for Heliospheric Weather at RAL Space in Harwell, partly due to the UK's extensive expertise in space weather.[422]

This same logic applies to technology development programmes and their implementations, infrastructure and ESA hubs. **GSTP has been recognised as an exemplary mechanism for funding non-commercial technology development, with the UK often cited as a model for how programmes should be**

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[416] Expert_review_CCI; INT_27_EO.

[417] INT_12_EO.

[418] INT_12_EO.

[419] INT_24_EO.

[420] INT_24_EO.

[421] INT_3_HRE.

[422] INT_5_SS.

implemented.[423] The flexibility and improved coordination of GSTP within UKSA have facilitated tailored projects that align with national strategy and goals. For instance, GSTP's support for the SSTL Lunar Pathfinder/Moonlight programme exemplifies how strategic importance can drive project approval, even when other programme areas turn down initial proposals.[424] However, GSTP is one of the most oversubscribed programmes, and there is growing concern that funding may be insufficient to meet rising demand. While the mechanism is effective, additional resources are needed to educate potential users about GSTP's operations and impact.[425]

In the Telecommunications programme, ESA funding has highlighted the significance of satellite communication in developing 5G and 6G technologies, both nationally and internationally.[426] UK representatives have chaired ESA's 5G Joint Activity Group, influencing future telecommunications architecture and policy decisions.[427] By aligning UK investments with key strategic documents and previously identified strengths of the sector, the UK can leverage ESA investments to continue to develop national capabilities and influence wider ESA programmes.

5.5. The UK's reputation in space R&D leadership on the world stage

The UK has established itself as a significant contributor to space R&D, although it sometimes falls short in some regards. Ranking as the fourth largest contributor to ESA's scientific initiatives, the UK holds substantial sway within ESA's governance structures and scientific advisory groups. The UK's position enables it to play an active role in defining ESA's long-term scientific framework, dubbed Voyage 2050, which is notably overseen by a UK academic.[428] Such leadership roles highlight the UK's role in directing ESA's future endeavours and priorities. However, previous issues with geo-return suggest that, despite significant funding and influence, the UK is not leveraging its position to maximise benefits and financial return.

The UK's involvement in ESA missions and advisory capacities illustrates its reputation for excellence in scientific research. Academics from the UK occupy essential roles in mission advisory and strategic science panels, ensuring that the nation's perspectives are adequately represented in the development of ESA science missions.[429] This engagement is reinforced by UK representatives holding key positions, such as the Chair of the Space Programme Advisory Committee for UKSA and participation on the STFC Council, along with active roles in ESA's Astronomy Working Group. These positions reportedly empower UK researchers to significantly influence strategic choices and advisory processes, thereby impacting space science research and policy direction.[430]

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[423] INT_6_TECH.

[424] INT_6_TECH.

[425] INT_6_TECH.

[426] INT_1_TEL

[427] INT_1_TEL.

[428]INT_12_SCI.

[429] INT_2_HRE; INT_2_SCI; INT_3_SCI; INT_5_SCI.

[430] INT_2_HRE; INT_2_SCI; INT_3_SCI; INT_5_SCI.

The UK's assertive advocacy for leadership positions in various missions underscores its dedication to guiding scientific projects. For instance, during the Juice mission, UK planetary scientists played a crucial role in pushing for the inclusion of their proposed instrumentation, supported by UKSA's prioritisation of the magnetometer instrument.[431] Similarly, MIRI on JWST was spearheaded by a UK PI, showcasing strong advocacy from the UK scientific community.[432] Such initiatives reflect the UK's commitment to ensuring its scientific ability is effectively utilised in international collaborations.

Additionally, **UK organisations have taken on the role of PI and co-PI for several key scientific missions**, including the upcoming Ariel mission scheduled for launch in 2029. Initially proposed as the ECHO mission, ESA re-envisioned and accepted Ariel, further illustrating the UK's leadership in space science.[433] The UK has also assumed a leading role in developing instruments and data centres for ESA-managed missions, such as the Plato mission, enhancing its influence and showcasing its expertise in specific space exploration areas.[434]

Stakeholders highlighted the importance of UK representation in ESA committees, advocating for prime contractors to have a more prominent voice in decision-making processes. Such steps would help align strategic goals and ensure that industry can effectively support and deliver on the scientific aspirations proposed by academia.[435]

5.5.1. Leadership in knowledge production and influence

The analysis in Chapter 3.3 shows that the UK has established itself as one of the leaders among ESA member states in space science, excelling in both publication volume and citation impact. Several factors contribute to the UK's thought leadership in this domain. Participation in the CCI programme has bolstered the UK's global standing, facilitating the sharing of research findings across Europe and with international partners, including those in the US. The UK's commitment to high standards in scientific research and integrity has solidified its reputation, particularly in the realm of ECVs, thereby enhancing the profile of UK climate modelling and elevating standards across Europe.[436]

The involvement of UK industry in ESA projects has further augmented the nation's reputation within the international space community. The UK is recognised particularly for its robust quality assurance practices, encompassing calibration and data quality checks essential for ensuring data reliability for missions like TRUTHS. This reputation directly affects the UK's standing and influence in global discussions around space science.[437]

UK investment and leadership in ESA CCI projects provide the UK with a platform to shape ESA's initiatives, thereby enhancing its reputation in climate science through active participation. The UK

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[431] INT_9_SCI.

[432] INT_13_SCI.

[433] INT_2_SCI.

[434] INT_1_SCI.

[435] INT_1_SCI.

[436] INT_2_EO.

[437] INT_23_EO.

possesses considerable expertise in EO, and involvement in CCI projects helps raise the visibility of UK organisations. However, there remains a pressing need to market these products effectively and demonstrate their value compared to datasets provided by other agencies.[438] The UK leads or serves as the principal investigator for 6 of 27 CCI-associated ECV projects, reflecting its substantial role in this area. The UK's contributions to the CCI have resulted in significant reputational gains within the scientific community, with UK-led projects and datasets establishing benchmarks for climate monitoring.[439]

Despite the early mission lifecycle stage, the UK's investment in the TRUTHS mission is already generating reputational benefits. The UK's strong legacy in metrology and data calibration and validation positions it as a leader in these fields.[440] The UK is also increasingly recognised as a hub for traceability, uncertainty and quality assurance in EO data.[441] This reputation extends beyond academia to UK industry players, such as Telespazio and GCI, whose enhanced standing due to their work on TRUTHS has opened up new opportunities within their organisations.[442]

Specific projects, such as those focused on sea surface temperature and lakes, exemplify the reputational gains experienced by UK scientists through their involvement in ESA initiatives. The sea surface temperature data developed by the UK is integrated into Copernicus services, including the Climate Change Service and the Copernicus Marine Environment Monitoring Service. The UK is a global leader in this field, particularly in temperature measurement. Recent discussions with EUMETSAT regarding future collaborations on sea surface temperature further affirm the UK's leading European expertise. Ongoing work on atmospheric gases, including ozone and aerosols, contributes valuable data to Copernicus, further cementing the UK's role in advancing climate science.[443]

5.5.2. Leadership in governance and international fora

The UK is a leading player in governance and international fora related to space R&D, particularly through its active participation in collaborative initiatives. An example is the Climate Modelling User Group (CMUG), which unites key modellers across Europe.[444] Regular meetings of CMUG have contributed to improved standards and consistency across ECVs while enabling focused efforts in areas such as the innovative inclusion of sea ice as an ECV.[445] CMUG also plays a key role in promoting the uptake of CCI data by raising awareness of and guiding users on available resources. With the Met Office at the forefront, the UK has a strong presence in CMUG, hosting meetings and significantly contributing to the forum's objectives.[446]

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[438] INT_26_EO.

[439] CCI expert review.

[440] INT_21_EO.

[441] INT_5_EO.

[442] INT_5_EO.

[443] INT_17_EO.

[444] INT_2_EO.

[445] INT_2_EO.

[446] INT_2_EO.

Participation in ESA projects has elevated the UK's global standing within the space sector. For example, the UK has become a member of the Open Geospatial Consortium and the Open-Source Geospatial Foundation, both of which establish global standards. Thus, the UK's involvement with ESA extends beyond European borders, with a substantial global impact on UK enterprises.[447]

The UK's leadership in CCI has further solidified its influence in shaping the future of climate monitoring and EO programmes, both within Europe and globally.[448] The political reputation reportedly gained from the UK's contributions to the CCI highlights a commitment to addressing climate change and supporting international efforts to monitor and mitigate its effects. This leadership has enhanced the UK's standing as a responsible member of the international community, dedicated to evidence-based policymaking and sustainable development. The UK's engagement in CCI has strengthened its position in international climate negotiations and forums, such as the UNFCCC and the Intergovernmental Panel on Climate Change.[449]

GSTP has also played a crucial role in enhancing the reputation and influence of UK space, industry and research institutions. The programme has allowed UK entities to bolster their credibility and visibility in the global space sector. As noted by consulted industry participants, collaboration with ESA through GSTP has significantly enhanced the credibility of UK companies. ESA involvement allows for the dissemination of achievements through various channels and assures customers of government support, which is vital for building trust.[450]

Involvement in GSTP is considered highly important for demonstrating government backing, which reassures customers regarding a company's ability to deliver.[451] The support provided by the programme, including financial backing and technical assistance, is invaluable for business development and future institutional missions. Companies have reported that GSTP has improved their standing with customers by showcasing innovation and the capacity to deliver new technologies, such as developing a 100 Newton thruster.[452] Additionally, GSTP funding has led to significant media coverage, keeping companies in the public eye and highlighting their technological advancements.[453]

In space safety, the UK is recognised for its impressive contributions to space weather monitoring.[454] While the US leads in operational space weather, the UK has carved out a respected position through collaboration rather than competition. The UK's MOSWOC has developed notable capabilities, earning respect from international partners, including NOAA. Celebrating its tenth anniversary, MOSWOC has hosted several events and received positive feedback for its impressive achievements, given its size.[455]

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[447] INT_23_EO.

[448] CCI expert review.

[449] CCI expert review.

[450] INT_1_TECH.

[451] INT_5_TECH.

[452] INT_2_TECH.

[453] INT_3_TECH.

[454] INT_14_SS.

[455] INT_14_SS.

6. Socioeconomic returns on public investment

This chapter draws together the main findings from a broadly scoped Value-for-Money perspective. It assesses the economic returns on the UK public investment in ESA using the results of the quasi-experimental Staggered Difference-in-Difference analysis outlined in Section 2.2. Here, we combine this econometrics-based analysis with the key points from the qualitative findings already presented. The chapter commences with a brief discussion of the overarching policy context pertinent to interpreting these results.

Key findings from the assessment of economic returns on UK public investment in ESA:

- **Range of benefits from ESA participation:** The scientific, technological, environmental and health-related impacts are both broad and substantial given how space science and innovation define cutting-edge progress, often resulting in advances occurring earlier than would otherwise have been the case.
- **Access to a large, pooled R&D effort:** The UK's relatively modest spending on civil space allows us to leverage the spillovers we obtain from our ESA partners' far more extensive collective spending. ESA contracts won by UK firms are a key impact pathway for this R&D spillover leverage.
- **Public benefit-cost ratio:** Every £1 of UKSA's public investment in ESA generated an estimated £7.49 of direct benefits to the UK economy.
- **GVA per worker**: £1m of ESA contract funding led to an average annual increase of 3.9% in GVA per worker over the time period of the analysis.
- **Economic impact**: The total economic impact associated with the programme was estimated at £27.802bn in constant 2023 prices.

6.1. The policy context for interpreting the results presented in this chapter

As demonstrated throughout this report, the UK's participation in ESA generates **a wide range of economic benefits for the UK that are technically challenging to quantify**. Whilst a benefit-cost ratio (BCR) provides a valuable summary of quantifiable economic returns, space-related innovation is now so integral to modern scientific and industrial systems that no single metric can adequately represent it. This is because space's extreme environment defines the science and innovation frontier: handling the extreme technical demands faced in space activities means that space research and innovation tend to define the 'art of the possible' in diverse fields. This accelerates scientific and technological progress, resulting in advances, spin-offs, and diffusion benefits that manifest faster than they might otherwise. **The preceding chapters provide a wealth of qualitative evidence to support the considerable breadth of the science-and-innovation-driven benefits ESA participation delivers for the UK.** Therefore, the overall value-for-money contribution is powerful and central to the UK's position and reputation as a 'science power' contributing to globally significant space innovation collaborations.

For this reason, relying solely on a BCR risks underrepresenting the broader return on public investment, and a more holistic approach is needed to inform policymaking on industrial strategy and public investment.

This evaluation applies state-of-the-art econometric methods to measure the direct economic benefits generated by ESA contracts (including impacts on employment, GVA and GVA per worker and R&D spending, among others). Based on these statistically significant and rigorously estimated results, a 'core' BCR has been calculated to represent the quantifiable portion of economic benefits. The result is a high-confidence, methodologically robust estimate grounded in empirical evidence.[456]

The resulting BCR has the key advantage of adhering to HMT Green Book guidance,[457] ensuring the metric is transparent, consistent and directly comparable to other BCRs produced using the same framework. Although higher BCRs have been reported for other space-related investments, these are not directly comparable to those presented in this evaluation due to differences in underlying assumptions and methodologies. Particular caution is required when considering the ROI rates estimated for NASA because US space spending is much higher than the UK's (and ESA's as a whole) and hence benefits from considerable economies of scale. However, these asymmetries in government budget allocations for civil space also create beneficial spillover 'leverage' advantages, i.e. how UK participation in ESA allows UK firms to benefit from more significant pooled ESA space investments.

Based on government data on civil space budget allocations provided to the OECD, Figure 28 clarifies these asymmetries in spending and associated economies of scale. These data do not cover China, Russia or the substantial military space budgets (an important consideration given space innovation's 'dual use' aspects). Nevertheless, though partial, the data provides a striking profile that highlights the potential for economies of scale to be exploited by higher-spending nations or groups of nations (notably ESA) whilst also drawing attention to the potential for lower-spending nations, like the UK, to benefit substantially from the space R&D/innovation spillovers made possible by participation in pan-national collaboration.

As we discuss below, ESA contracts won by UK businesses allow these firms to benefit from the spillovers that flow along ESA supply chains. **These ESA supply chains are a powerful means for the UK's spending on ESA to feed into this pooled R&D effort and, in turn, act as a VfM multiplier of our domestic R&D spending on civil space**. In effect, though hard to measure, the benefits we obtain from

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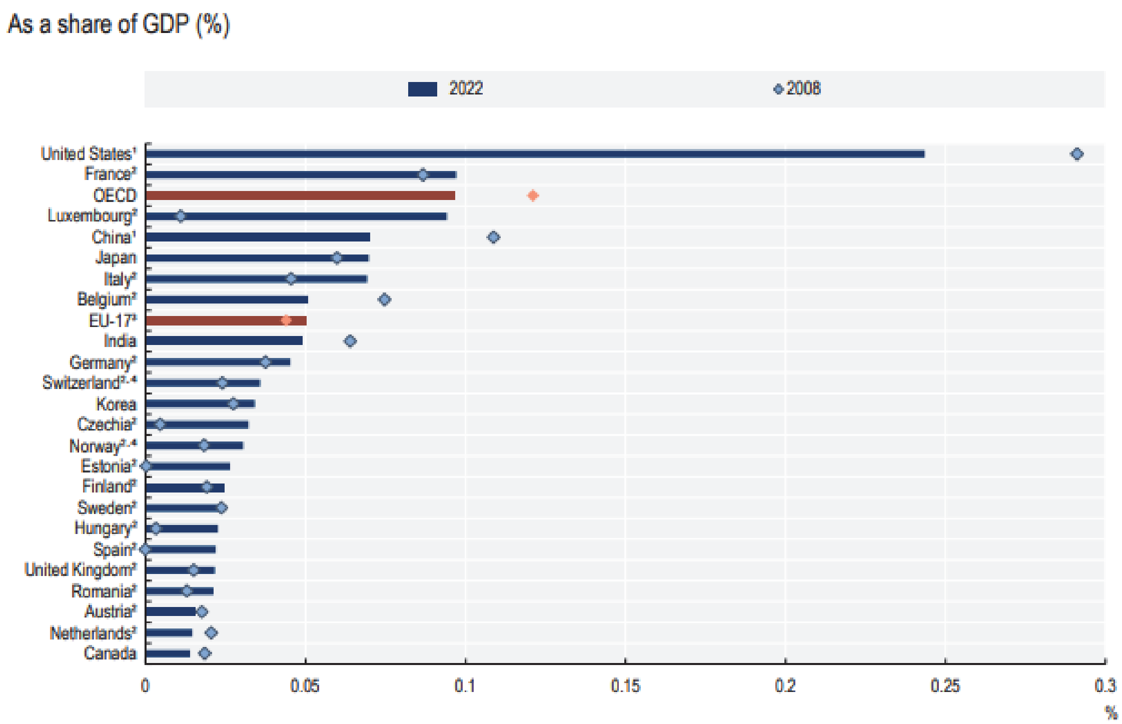
[456] The econometric analysis presented in Section 4.3.1 identifies statistically significant spatial spillover effects within a 20km radius of firms receiving ESA contracts. While these effects may generate additional economic benefits, they are excluded from the BCR to ensure a conservative and robust estimate. This is due to uncertainty regarding the extent of displacement beyond the 20km bandwidth, which the model cannot capture.

[457] This BCR captures the direct economic returns to public sector costs. Importantly, this is distinct from a BCR which seeks to measure social returns, accounting for the full range of societal costs and benefits, including any increases in private R&D expenditure that result from a public investment.

spending on ESA participation are boosted by this spillover-driven R&D leverage multiplier. The chart also makes it very clear why ESA participation is important in policy terms simply because ESA provides a pooled collective civil space R&D spending profile that closes the gap with the US.

As a range of prior benefit-cost ratio assessments for space have indicated (albeit using less restrictive methods than Green Book guidance), broad-level BCRs for space can be very high. The qualitative evidence presented in this report sets out the different aspects of these high, though hard to measure economically, national benefits that stem from international collaboration and pooled R&D spending.

Figure 28: Asymmetries in civil space government budget allocations (2008 and 2022)



Source: OECD Main Science and Technology Indicators. 1. Estimates, including military activities. 2. Includes contributions to Eumetsat and ESA. 3. Includes AUT, BEL, EST, FIN, FRA, DEU, GRC, IRL, ITA, LUX, LVA, LTU, NLD, PRT, SVK, SVN and ESP. 4. Includes non-EU member contributions to selected EU programmes (Copernicus and Galileo).

6.2. How to interpret the BCR findings

UKSA has expressed a strong preference for two critically important evaluation elements. Firstly, access to robust and credible BCR estimates that can withstand rigorous HM Treasury scrutiny and (to achieve this) avoid reliance on assumed benefits. Secondly, and in recognition of methodological restrictions, a clear exposition of the broader but often hard-to-quantify aspects of the VfM generated by UK participation in ESA. The combination of these two strands of analysis yields the necessary 'rounded' assessment of VfM. As discussed in Section 2.2 above regarding the BCR estimates, we have used state-of-the-art Staggered Difference-in-Difference econometric methods to provide a BCR based only on statistically significant (95% confidence interval) productivity benefits. This is now the 'gold standard' method for economic impact assessments of business and innovation support programmes and interventions. For example, it is being deployed to measure the economic impacts of Innovate UK's Catapults[458] in a similar way to this study.

The results below are for a 'core' HMT Green-Book-compliant public BCR assessment. They demonstrate strong public BCR performance that reflects the importance of the space sector to UK economic growth. This BCR estimate does not capture all-important economic spillover effects, which are difficult to measure accurately. Also, there are major broader social, environmental, security and health benefits stemming from the UK's participation in ESA that, whilst hard to quantify and monetise, are essential for UKSA to emphasise in budget submissions and strategic planning.

A major challenge in measuring potentially powerful spillover effects is the UK's lack of comprehensive data on the space supply chain systems that connect the businesses we have analysed. Given that spillovers flow along supply chains, often originating in major corporations such as Airbus (and the substantial pooled ESA spending that drives space innovation), these supply chain system spillovers' measured effects must await data that are not currently available.[459] These spillovers benefit both firms directly involved in ESA contracts (as the analysis presented in this report covers) and (crucially) **benefits created by the indirect effects on the larger number of firms that do business with those involved in ESA contracts and stand to benefit indirectly from ESA-stimulated innovation activities** (thus boosting GVA and employment across the UK). This could capture the economic impacts of non-space applications of ESA-driven innovation. As historical experience demonstrates, **the broader applications of space innovations are one of the most transformational drivers of economic progress**.

We examined the ESA participation Business Case assumptions on the overall expected national benefits, which shows a plausible and compelling case. However, it is also clear that data availability currently limits the ability to match these *ex-ante* expectations with *ex-post* economic evaluation conclusions. As a result, any BCR estimates based on empirical data will inevitably underrepresent the UK's broad-level benefits from ESA participation (many of which are extremely hard to measure economically). **Therefore, it is essential not to treat any data-limited BCR estimates as an accurate reflection of the overall nature and extent of national benefits.**

We recommend that UKSA explores methods in financial payments-based supply chain tracing to strengthen VfM estimation for their ESA portfolio when it becomes technically feasible. New exploratory work using financial payment data to trace supply chains is underway in the ONS and the Global Supply Chains Intelligence Pilot (GSCIP) run by the Department for Business and Trade.[460]

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[458] This econometric impact assessment is being carried out by the Innovation and Research Caucus under contract with Innovate UK.

[459] See for example: Isaksson et al. (2016).

[460] See: Office for National Statistics (2025). The main technical challenge faced in using such data (if/when more granular detail becomes available) is that an alternative to using the Standard Industrial Classification (SIC) to organise the data is required. The preferred solution would be to carry out detailed 'bottom-up' business unit-level financial payments tracing to map space supply chains in the UK within the secure environment provided by GSCIP and making use of the ONS Secure Research Service (SRS) capability (available to GSCIP) to integrate the data on the supply chain system structure with the other data sources that are available (as used in the Staggered Difference-in-Difference analysis presented in this study). This would provide the best means of measuring indirect space supply chain driven spillover effects, thus complementing the spatial proximity spillover effects measured in this study. Such work can only be carried out within government.

Therefore, future UKSA analyses may be able to fill this major evidence gap, allowing the production of additional high-confidence BCR estimates by combining the new data on space supply chain structures with the economic performance impacts of businesses. The latter would include firms directly involved in ESA contracts (as the analysis presented in this report covers) and (crucially) the indirect effects on the larger number of firms that do business with those involved in ESA contracts and stand to benefit indirectly from ESA-stimulated innovation activities (thus boosting GVA and employment across the UK). This approach could capture the broader economic impacts of non-space applications of ESA-driven innovation, which are well-known and powerful features of the economic growth impacts of space innovation (as captured in studies of NASA's indirect economic impacts).

The results presented here should be considered a minimum rather than a precise public BCR estimate. Additionally, UKSA could develop internal impact scenario-based BCR estimates to build on this solid and robust BCR, better informing major investment decisions. Whilst this lies beyond the scope of the current independent evaluation, using such internal unpublished scenario-based BCR estimates by UKSA would be warranted as part of within-government strategy analysis and advice. However, we strongly recommend using only robust estimates of indirect effects (e.g. in the supply chain) together with broader social, environmental, security and health benefits to add to the core direct effects of the public BCR, based upon examples drawn from the UK's ESA contributions, to avoid over-inflating the benefits.

6.3. Benefits

The return on public investment quantified in this analysis is derived from the estimated additional GVA per worker, as identified through the SDiD analysis detailed in Section 2.2. In line with HMT Green Book principles, we only include productivity-related benefits in this estimate, i.e. the statistically significant direct effects on GVA per worker observed among ESA contract recipients. We excluded other economic effects captured in the SDiD analysis, such as employment or turnover impacts, from the public BCR to maintain an approach to valuation aligned with Green Book principles (avoiding double counting in particular).

The results of the SDiD analysis indicate that **£1m of ESA contract funding led to an average annual increase of 3.9% in GVA per worker** over the time period of the analysis (see Figure 15 in Section 2.2). This is a relatively high productivity uplift compared to other analyses Ipsos carried out using the same (i.e. comparable) econometric method. When applied to the entire population of contract recipients and over the assumed benefit duration of eight years, we estimated the total aggregate productivity uplift associated with the programme at **£27.802bn** in constant 2023 prices.[461] Effects beyond this period are not included in the valuation, as the estimated treatment effect on GVA per worker becomes statistically significant only from the fifth year following the contract award. Given that the available data allow for a maximum of 13 years of post-treatment observation, this provides an effective window of eight years to

[461] We conducted a sensitivity analysis to account for the statistical uncertainty in the estimated treatment effect. This involved recalculating the aggregate economic impact using the lower and upper bounds of the 95% confidence interval for the estimated GVA per worker effect. The lower bound estimate of programme benefits was £4.922bn (based on the 2.0% lower bound effect size), while the upper bound estimate was £50.683bn (based on the 5.9% upper bound effect size).

observe statistically significant benefits.[462] As such, the estimated total economic impact reflects a conservative lower bound, constrained by the length of the observation window. Given the long development and commercialisation cycles associated with space-sector innovation, it is plausible that the true duration of productivity benefits extends beyond the period used in the analysis, in which case the economic impacts will be even greater. Broader economic benefits are not captured in this already substantial impact assessment, pointing to a substantial package of benefits for the UK.

6.4. Public sector costs

The total public investment (public sector costs) associated with this programme in the period under analysis are estimated at **£3.714bn** in constant 2023 prices. These include:

- **UKSA contributions to ESA (2013–2022):** The direct funding UKSA provided to ESA over this period, for which the direct economic benefits accruing to UK-based companies with ESA contracts have been calculated. This represents £3.656bn in constant 2023 prices.
- **UKSA overheads:** Estimated at £58m in constant 2023 prices, we derived this figure by modelling the costs of UKSA staff time on ESA-related activity and applying an appropriate overhead uplift to account for associated indirect costs. The technical annex provides further details on the estimation approach.

6.5. Public benefit-cost ratio

We estimate that UKSA's contributions to ESA have produced direct increases in GVA, driven by improved economic efficiency, of **£7.49 per £1 of public expenditure, a substantial increase on the previous estimate of £2.82 per £1**.[463] This is classed as 'very high' in Whitehall guidance (defined as any BCR above 4.0).[464] The previous assessment focused on short-term demand side effects and assumed that the spending stimulus produced no long-term improvements in productivity; the empirical evidence from the current analysis suggests that this was overly conservative and that contracts awarded through ESA have produced persistent effects on the productivity of beneficiary firms that have resulted in longer term economic benefits.

Our analysis adopts a quasi-experimental approach to estimating the economic impacts of UKSA investments in ESA whereas the previous assessment used a combination of macro-econometric modelling, ESA contractor self-reporting on economic impacts, and assumptions about the magnitude of spillover effects based on a literature review. Importantly, as the challenges of reliably quantifying these spillovers in the context of the evaluation of an individual programme are largely intractable, **our assessment does not incorporate an estimate of economic benefits that may arise from spillovers**

[462] Due to data availability, the observation window for post-treatment effects was limited to a maximum of 13 years. This is because the ONS Annual Business Survey, which provides the firm-level GVA data used in this analysis, is only available from 2008 onwards.

[463] Technopolis et al (2022)

[464] Department for Transport (2024)

whereas the previous analysis did, and these may potentially be substantial (a recent review by DSIT suggests that the social rate of return from R&D investments may exceed 15% per annum[465]). The previous analysis estimated that UKSA's contributions to ESA might deliver further social benefits of £6.98 per £1 of public expenditure in addition to direct GVA benefits of £2.82 per £1 spent but **this total estimated return of £9.8 per £1 is not directly comparable to our estimates presented in this report**. Table 6 summarises the previous assessment approach and headline findings for the purpose of comparison with our study.

Table 6: Technopolis et al (2022) approach to estimation of economic benefits of UKSA investments in ESA

Type of benefit	Approach	Ratio (public investment to GVA)[466]
Direct and indirect effects of ESA funded activities	Macro-econometric modelling to estimate the direct and indirect effects of UKSA contributions to ESA on GVA, compared to a counterfactual of doing nothing.	0.71
ESA-derived activities	Self-reported projections of economic impact from beneficiary companies.	2.11
ESA-derived spillovers	Literature review of spillover effects for investments in the space sector and extrapolation to the UKSA-ESA programme.	6.98
	Total	9.80

The return-on-public-investment metrics quoted above should not be understood as conventional Benefit to Cost Ratios (BCRs). They describe the relationship between total economic benefits and public spending, but do not account for the private costs incurred by firms to deliver these gains. Once additional private costs, in the form of additional R&D spending and capital investment, are accounted for, it is estimated that UKSA's contributions to ESA produced £6.42 of direct productivity gains per £1 of social cost.

6.6. The significance of the broader benefits of ESA participation

6.6.1. The scientific and technological significance of ESA participation

Through its diverse investments in ESA, the UK has achieved significant scientific and technological advancements across all technology domains and at various TRLs, from early-stage 'blue-sky' technological development to on-orbit demonstration and commercial deployment. Companies consider a successfully delivered ESA contract indispensable in acquiring future investments, grants, and contracts. The examples discussed in this sub-section are a summary and not intended to repeat the full spectrum of benefits discussed in the rest of the report and technical annex.

The UK's extensive heritage in instrument development, including magnetometers for space science missions such as the Solar Orbiter and Juice, makes UK institutions competitive in ESA bidding processes

[465] Frontier Economics (2023)

[466] Including overheads.

and extends beyond space science. UK investments in ESA EO missions have yielded critical technological advancements, notably for the instrumentation suite hosted on the UK-led climate observation and calibration mission TRUTHS. Advancements have also been made in human and robotic exploration and navigation, highlighting the strength of the UK's diverse industrial and academic base.

Although downstream exploitation and application development is a key strength for the UK, especially in EO and space weather (see 5.3 and 5.4.1), it is vulnerable to changing political and funding landscapes. Downstream exploitation of data derived from key space missions and programmes is a key benefit of the UK's investments in the ESA, offering significant opportunities for the UK space sector to develop value-added services and applications with broader socioeconomic impact.

Despite the UK's strengths in early-stage technology, instrumentation development and downstream data exploitation, its national capacity to manufacture, test and integrate an entire mission is limited. The limited number of industrial primes in the UK essentially constrains the UK's ability to capitalise on these contracts as and when they arrive. This represents a key opportunity for the UK and underscores the importance of funding space sector investments throughout the development pipeline to enable UK stakeholders to benefit at all levels.

6.6.2. The industrial, reputational, inspirational and socioeconomic benefits of ESA participation

UK involvement in ESA projects, programmes and missions has led to significant gains in industrial and commercial capabilities. These include gains in skills, behaviours, knowledge, tools, processes and infrastructure that industrial and commercial organisations require to achieve their goals, including growth, market expansion and bringing new technologies to market.

Participation in ESA projects has elevated the UK's global standing within the space sector, supplemented by specific areas of expertise. The UK holds substantial sway within ESA's governance structures and scientific advisory groups, leveraging its excellence in scientific research to empower UK researchers to significantly influence strategic choices and processes within ESA.

The UK has established itself as a leading ESA member state in publication volume and influence in space science. The UK's commitment to high standards and integrity in scientific research has solidified its reputation. It can leverage this reputation for key roles in missions across domains such as EO and space safety, the successful delivery of which further increases the UK's reputation.

ESA programmes are key in enabling public outreach and STEM engagement in the UK. Several high-profile missions that the UK has contributed to through ESA, such as JWST, Herschel, Euclid and Rosetta, have demonstrated space science's power in driving public engagement. Despite these successes, the UK lacks a national STEM engagement strategy to fully capitalise on the public interest and excitement generated by space investments.

The benefits of the UK's investments into ESA extend beyond the limits of the space sector. The UK has also played a central role in processing and distributing EO data, facilitating its use in climate science, disaster preparedness (e.g. via Vigil) and environmental management. The availability of high-quality EO data has supported initiatives such as ESA's CCI, which has been instrumental in developing early warning systems and risk assessment tools for climate-related hazards, including floods, droughts and heatwaves. More broadly, benefits secured through more ubiquitous/equitable access to internet data and benefits through space safety missions (in particular, earlier warning of solar activity through Vigil) are key advantages gained via space research and ESA membership respectively.

6.7. Conclusions on overall value for money

This chapter has provided strong and comprehensive evidence that ESA participation yields substantial VfM benefits for the UK. As is often the case, this can be most clearly stated by considering the 'denial costs' for the UK if ESA benefits were not contributing to economic growth and social, environmental and health outcomes. Benefits such as more ubiquitous/equitable access to internet data, earlier warning of solar activity (through Vigil) and other major impacts are all aspects of these noteworthy denial costs.

The data on national civil space budget allocations makes it clear that if the UK attempted to deliver on its space ambitions without ESA participation, it would need to increase spending dramatically and cease benefiting from the considerably greater scale of ESA's pooled space R&D effort. The loss of space R&D spillover inputs to the UK space effort would dramatically reduce its ability to exploit the economies of scale arising from pooled international activities and boost BCR performance to higher-than-average levels for business and innovation support programmes and initiatives.

In addition, the UK would cease to benefit from more global and public-good-related activities associated with collaboration in developing and using satellite data to mitigate natural threats and other challenges (e.g. climate science, disaster preparedness and environmental management). The technical annex discusses these aspects in detail. They further support the paramount importance of UK ESA participation, including global citizen and 'soft power' aspects.

7. Conclusions and recommendations

The UK's investments in ESA continue to deliver significant value to the UK's economy, scientific and technical advancements and commercial success, boosting the UK's reputation as a key player in space.

7.1. Summary of findings

7.1.1. Conclusions

Our headline conclusions are:

1. **The UK is a leading nation in ESA**: This is evidenced by its overall contribution, the number of contracts the UK industry and academics secure, its pound-for-pound performance on scientific publications, and its overall scientific and technical reputation globally. The UK also leads on significant missions, including in solar physics and planetary exploration.
2. **The UK's investments in ESA yield significant benefits for the UK's growth, employment, productivity and private R&D investment:** Being awarded an ESA contract leads to a sustained increase in turnover, with effects persisting for 20 years after the contract starts. ESA contracts positively impact UK firms' employment and R&D expenditure and give a lasting boost to productivity.
3. **The UK has taken steps to reduce the deficit in its geo-return:** Following sustained deficits in the UK's geo-return, the UK's return coefficient with ESA stood at 0.99 as of Q4 2024, representing a deficit of €41.18m.
4. **The UK has achieved significant scientific and technical advancements via ESA:** Examples include advancements in early-stage, 'blue-sky' technologies and foundational instrumentation via critical missions where UK leadership (e.g. TRUTHS, Vigil) has allowed innovators to show off their capabilities. However, there have been limited advancements in mission development because of a lack of UK industrial primes compared to those seen in early-stage technology and individual instrumentation development.
5. **Downstream exploitation has been a strength for the UK but is vulnerable:** Downstream data exploitation and infrastructure development remain key strengths of the UK space sector, such as in EO and space weather. However, national funds to better exploit the data produced as part of missions like JWST and Solar Orbiter are considered scarce and often separated across funders outside of UKSA, like STFC and Innovate UK, making for a fragmented landscape. Aligning

efforts towards ESA mission exploitation across the funding landscape would extend the benefits of ESA membership.

6. **Despite the UK's strengths in early-stage technology and instrumentation development, its national capacity to manufacture, test and integrate an entire mission is limited**: The limited number of industrial primes in the UK essentially constrains the UK's ability to capitalise on these contracts when they arrive. This represents a key opportunity for the UK and underscores the importance of funding space sector investments throughout the development pipeline to enable UK stakeholders to benefit at all levels. Recent investments in launch capabilities are positive steps here.
7. **Being part of ESA maintains and increases industrial space capabilities:** This benefit includes gains in skills, behaviours, knowledge, tools, processes and infrastructure, supporting growth, market expansion and an improved ability to commercialise products and services. Being part of ESA also brings benefits in support of the strategic policies of the UK, such as in EO, as well as position, navigation and timing capabilities, e.g. CCI and NAVISP.
8. **UK firms can leverage their ESA experiences for commercial gains:** UK organisations have leveraged ESA investment to enhance their market positioning, expand commercial opportunities and drive scientific and technological advancements, strengthening the UK's long-term competitiveness in the global space sector. Commercially focused programmes such as GSTP, NAVISP, ARTES, InCubed-2, ScaleUp and the ESA BIC help bring new technologies to market, including spin-offs and spin-ins to the space sector.
9. **The benefit-cost ratio from the UK's contribution is positive**: For every £1 invested by UKSA in ESA, an estimated £7.49 in benefits is generated for the UK economy.
10. **The benefits of ESA funding extend beyond funding recipients:** ESA funding benefits the UK outside of those directly receiving funding, extending to broader communities based on geographic proximity and industrial connection. Spillover benefits also occur, extending the benefits of ESA funding beyond the space sector and into other branches of UK industry and society.
11. **The UK's ESA involvement helps deliver on socioeconomic goals:** High-quality EO data contributes substantially to public sector applications in fields like disaster preparedness and environmental management, facilitating better decision-making through improved climate science. Other examples include space weather forecasting, inspiring the next generation via STEM education, early warning systems and risk assessment frameworks.

7.2. Could the same benefits have been achieved another way?

Stakeholders consulted for this evaluation concluded that most of the benefits realised through ESA would not have been possible otherwise. The vast majority of those interviewed felt they could not have accessed funds to support their projects or achieved the same goals had the UK not invested in ESA.

ESA's collective funding model facilitates resource pooling, enabling ambitious projects that might otherwise be financially unviable for individual nations.[467] This model mitigates financial risk, promotes international collaboration and strengthens diplomatic ties among member states. Most stakeholders interviewed emphasised that the majority of activities and missions the UK presently engages in would be impossible to recreate independently outside of ESA or, at the very least, would not achieve the same scale and complexity without ESA's collective resources and expertise.[468] For example, the UK's current capabilities are insufficient for handling major projects like Vigil independently, though some elements of spacecraft construction remain feasible through the UK industrial base.[469] Projects like ClearSpace-1 could potentially be developed nationally, but the UK often depends on ESA for more complex missions.[470] Essentially, ESA provides the overarching framework and resources to which the UK can contribute specialised expertise.

Participating in ESA also provides stability and consistency. ESA's structured project management ensures a general commitment to see a mission through to completion once initiated.[471] This approach contrasts with the UK's domestic approach, where changes in the political environment can stall or derail projects.[472] Nonetheless, national programmes remain vital for building robust UK capabilities. This dual approach – leveraging ESA's resources while strengthening national capabilities – ensures that the UK can remain competitive within ESA and beyond. Moreover, the UK's engagement with ESA does not preclude the development of bilateral relationships and the pursuit of international partnerships beyond ESA.

Overall, consultees felt they would not have achieved the same benefits had the UK not been part of ESA. We heard from companies who would not have other secured contracts with major funders, such as NASA, thanks to the heritage and credibility of completing ESA contracts.[473] Many would like to see even more investment in ESA to take better advantage of the pooled resources of members and collaborate more often with other countries, further building capabilities.[474] Some see ESA as a way to stay competitive with larger markets, such as the US or China, which the UK alone could not match.[475] Some even indicated that their companies would not exist without ESA.[476] Any pullback from ESA may also see capabilities leave the UK, with the impacts of Copernicus's withdrawal providing a small-scale example of how this could play out.[477]

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[467] SSS_INT_12; SSS_INT_15.

[468] SSS_INT_11.

[469] SSS_INT_4; SSS_INT_5.

[470] SSS_INT_6.

[471] HRE_INT_1.

[472] SSS_INT_12.

[473] INT_11_EO.

[474] INT_10_EO; INT_9_EO.

[475] INT_9_EO.

[476] INT_10_EO.

[477] INT_16_EO.

Many felt that the opportunities provided through ESA were unique and impossible to replicate with national or bilateral programmes. ESA also provides important longer-term work (e.g. through missions) that is an important stabiliser, whereas UK-funded projects tend to be on a 'quick turnaround' basis.[478] **GSTP acts as a helpful example**. A key advantage is its ability to facilitate in-orbit demonstrations, which is essential for validating technologies like propellant gauging in zero gravity. Achieving such demonstrations without GSTP funding would be challenging, as national programmes lack suitable support for this kind of R&D, and alternative workflows focused on launchers would not have accommodated the high costs involved.[479] GSTP also provides significant benefits by offering technical support (through technical officers) and insights not typically available in national programmes.[480]

Being part of ESA enabled participants to achieve more impact than they might have done alone. Taking the biomass mission as part of CCI as an example, the main algorithm development is based in Switzerland, using both C-band and L-band radar. The CCI project would not be feasible without this core capability. Building these complex datasets requires a variety of skills and capabilities. While the UK's contributions to the biomass mission include calibration, atmospheric effects and statistical analysis, many key algorithms are developed elsewhere.[481] Working with international partners like the US and Australia has also been beneficial, and a coordinated response from all partners is necessary to produce the data needed to inform climate change mitigation efforts.[482]

However, many of the same stakeholders advocated for establishing more or expanding national programmes to complement ESA opportunities, recommending a mix of national and ESA programmes to ensure a steady but diversified funding landscape while maintaining collaborations and employment in the UK space industry, much like the approach in France and Germany.[483] Others also suggested expanding programmes such as the Space Exploration Bilateral Programme (SEBP), part of UKSA's science programme.[484] All stakeholders interviewed about such alternatives spoke highly of the SEBP, suggesting that a funding mechanism of this type is long overdue.[485] Those advocating for technical support nationally caveated their comments by saying that this would involve scaling the UKSA into a technical agency, perhaps via running a national programme through ESA as Italy did, allowing for better domestic support. Some even suggested setting up a national space programme to better compete within ESA.[486]

[478] INT_9_EO.

[479] GSTP_INT_1.

[480] GSTP_INT_1; GSTP_INT_10; GSTP_INT_5.

[481] INT_26_EO.

[482] INT_31_EO.

[483] INT_23_EO; INT_3_EO.

[484] UKSA (2022c).

[485] INT_25_EO.

[486] INT_21_EO.

7.3. Recommendations for maximising ESA-related benefits

This list includes findings from the process evaluation that are relevant at a broader strategic level:

1. **The UK's role and influence within ESA:** The UK does not directly select contractors or administer funding within ESA but plays a crucial role in helping UK entities secure contracts. Through involvement in various ESA programme boards and committees, the UK influences procurement processes and manages risks. While the UK benefits from its ESA membership by influencing global space standards and regulations, there are concerns about bureaucratic processes and the need for more capacity to support individual bidding. The IPTF has enhanced strategic influence over basic activities, marking a shift towards more centralised oversight and coordination. UKSA should take a more proactive approach in engaging with other member states to encourage participation in missions and projects representing key UK strategic objectives. The UK should seek to leverage its position as a world leader in certain fields, such as space weather, and a major contributor to ESA's overall budget to align investments of other member states with its own strategic objectives.
2. **Challenges in strategy implementation and clarity:** A perceived gap in translating the UK's overarching space strategy into detailed implementation within ESA leads to confusion and misalignment with national interests among UK contractors, compounded by uncertainties about the roles and functions of UKSA and DSIT. While some feedback suggests the UK has a good strategy, it needs to recognise linkages better and harmonise efforts to realise its potential benefits fully. UKSA should seek to identify areas of existing heritage and expertise in the UK and support academia, industry and other UK entities in that field, providing funding and political support for further engagement with ESA and national programmes. By identifying and prioritising specific areas of interest, the UK can align the broad objectives outlined in the NSS and other key documents with clearly communicated investment decisions.
3. **Capability building via strategic investments:** The UK's investment in high-profile missions highlights strategic efforts to enhance national capabilities and leadership in EO and space weather monitoring. Both missions underscore the need for the UK to leverage its investments effectively and maintain its role in mission operations to capitalise on long-term benefits. Enhanced consultation and lobbying efforts could strengthen the UK's position and ensure continued involvement and influence in these areas. In addition, the UK faces challenges in downstream data exploitation, requiring enhanced data management and user uptake. A coordinated effort involving UKSA, DSIT, and MoD is crucial to facilitate data accessibility and support industry partnerships. Maintaining existing capabilities, such as the Newport data centre, and fostering end-to-end data delivery capabilities are essential for leveraging ESA membership benefits and ensuring competitive advantage.
4. **The need for long-term strategic vision and stability:** A long-term view of ESA strategy is crucial for providing UK industry with clear targets and stability, essential for effective planning and investment. There is a call for more assertive UK industrial policy and structural changes to ensure consistent direction and support for specific technologies or applications, signalling long-term government commitment and allowing industry to align investments with national priorities.

5. **The continuation of IPTF activities post-closure:** We understand that the IPTF will be closed once the UK's geo-return becomes more favourable. However, UKSA must continue workshops and direct engagement activities, as these have been extremely helpful for the stakeholders we interviewed. UKSA should establish mechanisms for regularly evaluating these activities, using participant feedback and bid success rates to adapt and refine them to ensure they remain effective.
6. **Capability mapping and data transparency:** The UKSA teams that work with ESA and UK contractors would benefit from detailed capability mapping exercises to identify the current strengths and gaps within the UK space sector. However, while ESA's EROC system will partially help with this effort, it is currently challenging to pinpoint these capability gaps accurately due to the lack of granularity in subcontracting data on subcontracted activities or technologies. UKSA could engage with ESA to negotiate additions to programme closure report templates that could ask companies to report on economic impacts such as jobs created and growth. While this may be challenging, the data would benefit all member states and help each make the case for space nationally. Based on the findings of this exercise, UKSA could develop a strategic capability development plan that should prioritise areas such as downstream data processing infrastructure, outlining specific actions, timelines and required investments to address identified gaps and enhance the UK's competitiveness within ESA.
7. **Enhancing influence within ESA:** While the UK already has a seat at the table through its involvement in the Industrial Policy Committee, programme boards and other committees, there is a need for UKSA to advocate more intently for the UK's needs. This advocacy should not solely focus on short-term gains or quick wins for industrial return but should be grounded in long-term strategic objectives. Developing long-term strategies for space is not an easy fix as it sits outside of traditional funding cycles and has long lead times, but it will allow the UK to exercise its influence more precisely. UKSA should use its influence to ensure that decision-making processes support the development of new capabilities within the UK rather than merely repeating existing ones or outsourcing them, actively using its position to secure favourable outcomes that align with the UK's and ESA's long-term goals to ensure sustainable growth and innovation in the sector. [487]
8. **The need for cross-government alignment on space:** Stronger cross-government alignment is needed to maximise the benefits of the UK's ESA membership. Despite various initiatives to promote alignment, such as via a National Space Council, space policy, decision making, procurement and R&D functions are still fragmented and spread across different government departments and agencies, as well as the military UK Space Command. Better alignment on space capability development and strategy is needed to streamline resources and focus on a whole-government approach to achieving domestic goals via ESA. Clarifying UKSA's role and enhancing its technical capabilities could support efforts to proactively align UK national space interests, work across government departments and agencies, leverage the UK's strengths and address capability gaps.

[487] European Space Agency (2025o).

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