Department for
Science, Innovation
& Technology

THE CASE FOR SPACE

Investing to realise its potential for UK benefit

know.space

July 2023

Contents

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to understand clearly and with certainty

know.space[1] is a specialist space economics and strategy consultancy, with offices in London, Edinburgh, and Dublin. Founded by leading sector experts, it is motivated by a single mission: to be the source of **authoritative economic knowledge for the space sector**.

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We would like to thank all the stakeholders consulted for their time and insights. We would also like to acknowledge the support of the UK Space Agency and the Department for Science, Innovation and Technology (formerly the Department for Business, Energy and Industrial Strategy) Space Directorate. Responsibility for the content of this report remains with **know.**space.

[1] **know.**consulting ltd. (CRN: 12152408; VAT: 333424820), trading as **know.**space

Executive Summary

Space inspires. Space drives innovation. Space is a fast-growing, highly-productive industry, employing a highly-skilled workforce to enable capabilities that are essential for our modern daily lives. Public investment is the origin story of space technology, and it is also the key to unlock the future potential of space for the UK.

Since the dawn of civilisation, space has fascinated humankind and inspired our brightest minds. This wonder has **motivated the achievement of remarkable feats, requiring innovative new technologies**. Development of these technologies has required decades of continual research and development (R&D) to meet the **uniquely challenging operating environment of space**. The technological advancements for space are **then deployed to unlock next generation technologies on Earth**. Our brightest minds succeeded, and created a network of in-space infrastructure, integrated to terrestrial ground networks that **enable many of the capabilities that are an essential part of our modern daily lives** – from navigation and communication on our digital devices, to synchronising energy, telecoms and banking networks, land monitoring, weather forecasting, and climate monitoring.

The continual R&D effort that bore these advancements was **predominantly funded by the investment of public funds.** Now is not the time rest on our laurels. The space sector is undergoing a rapid, transformative change, creating **a new generation of opportunities**, forecasted to be worth more than **$1 trillion within two decades**. We are only beginning to exploit the true potential of space, and though the UK is well-positioned to take advantage of the burgeoning commercial off-planet economy, it is **increasingly contested**, so these **opportunities are time-limited**. To secure the **UK's role as a space power** and exploit the **new generation of commercial opportunities,** continued **public investment is needed.**

Still, public funds are limited, necessitating careful appraisal of competing spending priorities – especially during a cost-of-living crisis. **Space must justify its case for investment against HM Treasury's standard appraisal criteria**, just like all other policy areas. It must demonstrate benefits, impact, return and value-for-money supported by robust evidence.

This report argues, supported by evidence, that **space excels when measured on these criteria**, meriting not just continued support and investment, but prioritisation, by the UK government. It does this by answering three key questions:

1. **What is the 'space economy'?**
   A brief of what activities an investment in space is funding.
2. **What are the benefits of space?**
   A concise overview of the main benefits and beneficiaries of space in the UK.
3. **Why is government investment needed?**
   A compelling rationale for public intervention to unlock societal benefits.

Lastly, we bring the benefits of UK government space investment to life, exploring examples of the benefits accruing from specific HMG investments in six **Case Studies**.

1. What is the 'space economy'?

Space is about so much more than 'just' rockets, astronauts, satellites, and interplanetary exploration. Whilst indeed core aspects of space activity, they represent just the visible tip of the proverbial iceberg, built on a broad foundation of industrial technology and capabilities developed by the space industry over decades. There exists an entire ecosystem of activities involved with the supply and use of space technologies and capabilities, which we call the 'space economy'.

The UK space sector is worth over **£17.5 billion in income** to the UK economy and **employs 48,800** people, offering some of the most productive and skilled jobs in the country[2]. The sector has exhibited extremely robust growth since the turn of the millennium with an average **long term growth rate of 6.4%**, **significantly outpacing growth of the wider UK economy** and **the global space economy** (both of which grew at 1.6%[3,4] on average per year over the period).

Space activities are growing globally, with the global space economy forecasted to grow at **5.1%** per year to 2040[5]). This is a significant industry, presenting a considerable economic opportunity: two recent estimates suggest that the global space economy was worth between **$386 billion** and **$469 billion** in 2021.

The UK plays an important part in the global space economy and is home to a healthy and growing space ecosystem. Boasting excellence across both business (with end-to-end capabilities throughout the space value chain) and academia (world-leader in fields of space science), the UK has cutting-edge expertise across multiple domains.

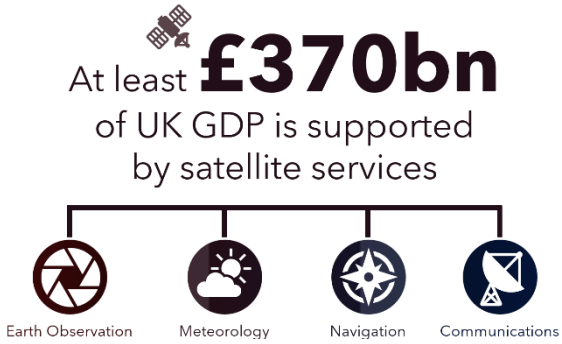
This is all despite the UK being a relatively low spender compared to the biggest space nations. The UK government spends around **0.05% of GDP** on space, which is only around a fifth of that spent by the US (0.24%)[6].

The sector's influence spreads throughout the economy, with wide-ranging applications across different sectors, providing and enhancing services to citizens, firms and public users. From earth observation data used by farmers to maximise crop yields, to the GPS watches used by runners, to the crucial navigation services used by ships, space underpins our daily activities.

[2] know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022
[3] ONS (2023). *Gross Domestic Product: chained volume measures: Seasonally adjusted £m.* Available at: https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi/qna
[4] As measured by The Space Report, which adopts a different segmentation, but is a long-running and commonly referenced measure of the global space industry. The Space Foundation (2022). Global Space Activity by Category, 2005-2021. Available from: https://www.thespacereport.org/resources/global-space-activity-by-category-2005-2021/
[5] Harmonised average CAGR computed across multiple sources.
[6] Note: definitions of space spending differ across countries, so caution should be used in comparing estimates.

2. What are the benefits of space?

The UK space sector is a **small yet highly significant sector**. **Global satellite services unpin at least 18% of UK GDP.**[7] The sector delivers substantial and varied benefits across government, society and economy, supporting key markets and services which citizens, firms and the government rely on every day, playing a **vital yet often hidden role**.



Notably, space is a **critical national infrastructure** and contributes to **wider government goals** (e.g. levelling up, science and technology superpower), whilst **promoting UK sovereignty and soft power**. Satellites provide unparalleled insight into our planet, vital to **climate change efforts**, as well as enabling cost savings and unlocking commercial opportunities. By **pushing scientific and technological frontiers**, space has transformed our lives on Earth. **Every day citizens rely on space**, from the more visible examples of satellite services (e.g. using GPS to navigate on our smartphones) to the numerous products which have spun out of the space sector (e.g. memory foam). Lastly, space is **unique is its capacity to inspire** and **unravel fundamental questions** about our existence, through advances in space science. This **unrivalled influence across the economy, society and culture** makes public space investment not only worthwhile, but essential.

The sector itself is **highly productive** (labour productivity of **£144,000**) and **R&D intensive** (**5 times** UK average), offering strong value for money. In the future, our reliance on space capabilities is expected to grow, as space becomes increasingly embedded into our lives. Investment today not only offers a **strong short-term return on investment** (e.g., **9.8:1** for the UK's ESA investments), but also opens up **future growth possibilities** for the sector and wider economy.

3. Why is government investment needed?

Government investments and interventions in the space sector play a critical role in **driving innovation, promoting scientific discovery**, and **supporting economic growth**, as well achieving the government's own strategic objectives.

The sector is characterised by multiple, interlinked **market failures**, which make government investment and interventions necessary to facilitate private sector activity. The development of space technologies and missions is **inherently risky** and requires **substantial upfront investment**. Meanwhile, firms face **network failures** and **coordination issues**, **knowledge barriers** and **appropriation of ideas and benefits** due to the unique characteristics of space. For these reasons, private companies may find it hard to justify and sustain long-term investments.

Whilst private actors are playing an increasing role in the space sector (e.g. NewSpace), public investment and support is crucial to realising these growing opportunities. Indeed, there is little evidence to suggest that government investment 'crowds out' private

[7] Includes services from satellites of all nations. know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022

investment, but ample examples of public investment generating leveraged follow-on private investment (e.g., OneWeb, Reaction Engines, LaunchUK, ARTES).

Many space activities also hold **public good attributes**: they are **non-excludable** (benefits are available to all, regardless of whether they have contributed) and **non-rivalrous** (use by one agent does not affect use by other agents). For example, navigation satellite signals are available to all and usage by one user does not impact its use by others. This creates a key role for government, since these public good attributes limit the scope for commercial returns, and so reduce the incentive for private investment, yet there is strong potential for widespread benefits that government investment could unlock.

National and international government agencies (e.g. NASA, ESA, UK Space Agency) are also instrumental in **coordinating** and **distributing** public funding, as well as in **promoting cooperation and knowledge exchange** across the space sector. Space debris provides a powerful example of the need for government to coordinate actors to achieve a mutually beneficial outcome: in this case, all satellite owners limiting their debris.

As the UK's **critical national infrastructures** become increasingly dependent on space-based services over time, governments must provide a reliable source of funding and support to enable space activities.

Additionally, the sector is of strategic importance in the UK's **regional development**, offering a boost for 'levelling up' objectives and developing local supply chains.

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HMG INVESTMENT & SUPPORT

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TO OVERCOME MARKET FAILURES

- Provision of public goods
- Missing markets
- Coordination & network failures
- High barriers to entry
- Tragedy of the commons
- Knowledge barriers

IN DEVELOPING SPACE CAPABILITIES

- Transportation
- Communications
- Exploration
- Navigation
- Science
- Earth Observation
- Meteorology
- Generic technology

UNDERPINNING UK ECONOMIC ACTIVITY

- Agriculture
- Maritime
- Forestry
- Atmosphere
- Meteorology
- Defence
- Built environment
- Transport
- Flooding
- Coastal

... at least **18% of UK GDP** is supported by satellite services

DELIVERING WIDE-RANGING BENEFITS TO THE UK

SOCIETAL

- Services to citizens
  Weather & climate services are worth ~**£1bn per year**
- Sovereignty & self-reliance
- Social & environmental benefits
- Resilience of Critical National Infrastructures

ECONOMIC

- Commercial opportunities
  Global market forecast: **$1.1tn by 2045**
- Highly skilled jobs
  3 in 4 UK space employees hold a primary degree or higher
- High productivity
  2.5x UK average labour productivity
- GDP contribution of **£7bn**
- R&D investment
  5x UK average R&D intensity
- Efficiency within government
- Catalysing private investment
  £12bn invested in UK industry 2012-22

SCIENTIFIC & INSPIRATIONAL

- Scientific advances
- Soft power & influence
  1st in field-weighted citation impact of research
- Inspirational value
  2,000 UK applicants for ESA astronaut selection

1 Introduction

Space inspires.

Since the dawn of civilisation, space has fascinated humankind and inspired our brightest minds. This wonder has **motivated the achievement of remarkable feats**: from launching a satellite into orbit, inhabiting an orbiting laboratory,[8] discovery of countless distant galaxies and stars, to landing on the Moon.

Space drives innovation.

Necessity is the mother of invention.

Achieving these feats **required innovative new technologies** that simply did not yet exist. Development of these technologies and capabilities has required decades of continual research and development (R&D) to meet the **uniquely challenging operating environment of space**.

Space presents a unique combination of constraints and requirements for hardware and software: low mass (weight); low volume (size); low power (energy autonomy and efficiency); high-stress tolerance (launch vibration; thermal extremes); radiation-hardened; microgravity-capable; high reliability remote operation over long-duration and long-distance wireless connectivity, with a strong degree of autonomy. *'Space is hard'*, as the oft-quoted saying goes, but **technological advancements developed to meet the challenges of space are then deployed to unlock next generation technologies on Earth**.

Space capabilities are essential for our modern daily lives.

Space represents the next frontier of capabilities and resources for humankind.

Our brightest minds succeeded, and created a network of in-space infrastructure, integrated to terrestrial ground networks that **enable many of the capabilities that are an essential part of our modern daily lives**. For example, space enables our …

- **digital devices** (Apollo missions provided impetus for microchip development);
- **weather forecasts** and extreme weather warnings;
- precise **positioning** and convenient **navigation** (including emergency services);
- real-time **monitoring and surveillance** from the ultimate vantage point;
- synchronisation of **networks** (power grid, telecoms, banking, internet, etc.)
- monitoring of **climate and planetary health** – motivating urgent action required;
- **connectivity** in the extreme (live event broadcast; rural broadband; remote SOS);
- quest for **scientific knowledge**, and understanding of our place in the universe;
- **planetary protection** (from the threat of asteroids); and
- a wide range of critical **safety, security and defence** applications.

[8] The International Space Station has been continuously inhabited since 2000.

Public investment is the origin story of space technology …

The continual R&D effort that bore these technological advancements was **predominantly funded by the investment of public funds** by the UK and other governments around the world – often collaboratively.

… and public investment is the key to unlock the future potential of space for the UK …

… and the next frontier of commercial opportunities for the UK

Now is not the time rest on our laurels. The space sector is undergoing a rapid, transformative change, creating **a new generation of opportunities**, forecasted to be worth more than **$1 trillion within two decades**. We are only beginning to exploit the true potential of space – whether that is broadband everywhere, limitless clean solar power, hypersonic travel, manufacturing of game-changing materials. But though the UK is well-positioned to take advantage of this burgeoning commercial off-planet economy, it is **increasingly contested, so these opportunities are time-limited**. This increased activity also presents threats and risks that need to be managed and mitigated – such as the risk of collisions with the proliferation of space debris. Though private investment into the sector is increasing, much is focused on operations leveraging previously developed capabilities for commercial gain. **To secure the UK's role as a space power and exploit the new generation of commercial opportunities, continued investment is needed.**

… and the case for investment can be justified with convincing evidence

Public funds are limited, and awarded requiring careful appraisal of competing spending priorities – especially during a cost-of-living crisis. Accordingly, **space must justify its case for investment against HM Treasury's standard appraisal criteria**, just like all other policy areas. It must demonstrate benefits, impact, return and value-for-money supported by robust evidence.

This report argues, with evidence, that **space excels when measured on these criteria**, meriting not just continued support and investment, but prioritisation, by the UK government. It does this by answering three questions:

1. **What is the 'space economy'?**
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3. **Why is government investment needed?**
   A compelling rationale for public intervention to unlock societal benefits.

The investment benefit pathways are brought to life by considering a set of **Case Studies**, selected to cover a range of funded activities and benefit types, which track specific HM Government investments through to realised benefits for a wide range of UK beneficiaries.

2 What is the 'space economy'?

Space is about so much more than 'just' rockets, astronauts, satellites, and exploration. Whilst indeed core aspects of space activity, they represent just the visible 'tip of the proverbial iceberg', built on a broad foundation of industrial technology and capabilities developed by the space industry over decades. This iceberg provides an enabling platform of opportunity for life to prosper into the future.

The term 'space economy' is used to describe the entire ecosystem of activities involved with the supply and use of space technologies and capabilities. As defined by the Organisation for Economic Co-operation and Development (OECD), the 'space economy' encompasses …

"… the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space."

2.1 Space technology and its capabilities

The following are the most common space technologies and capabilities:

Figure 1 Leading space technologies and capabilities

TRANSPORTATION	A system of technologies that enable our ability to launch satellites, spacecraft and humans to space, and to travel between orbits and onwards to distant destinations.
COMMUNICATIONS	Constellations of satellites and related subsystems that allow us to send signals to Earth for the purpose of fixed and mobile telecommunications services (e.g. voice, internet) and broadcasting (e.g. live TV).
EARTH OBSERVATION	Constellations of satellites and related subsystems that allow us to measure and monitor Earth, including its climate, environment and people.
METEOROLOGY	Constellations of satellites and related subsystems that allow us to monitor the weather and climate of the Earth, and better forecast our weather patterns, including dangerous extreme weather events.*
NAVIGATION	Constellations of satellites and related subsystems that allow us to position ourselves, locations and assets, navigate between locations, and use a ubiquitous timing reference for a variety of critical networks (e.g. energy, communications, finance).
SCIENCE	A range of research activities, including space science (the study of phenomena occurring in space or on other planets) and space-related Earth science (using space-based observations to study the physical and chemical constitution of Earth and its atmosphere).
EXPLORATION	Some of humankind's most advanced technologies developed to enable crewed and uncrewed spacecraft (space stations, landers, rovers and probes) to explore the universe beyond Earth's atmosphere.
GENERIC TECH.	Refinement and application of technologies not initially developed for space (e.g. artificial intelligence, data analytics software).

know.space

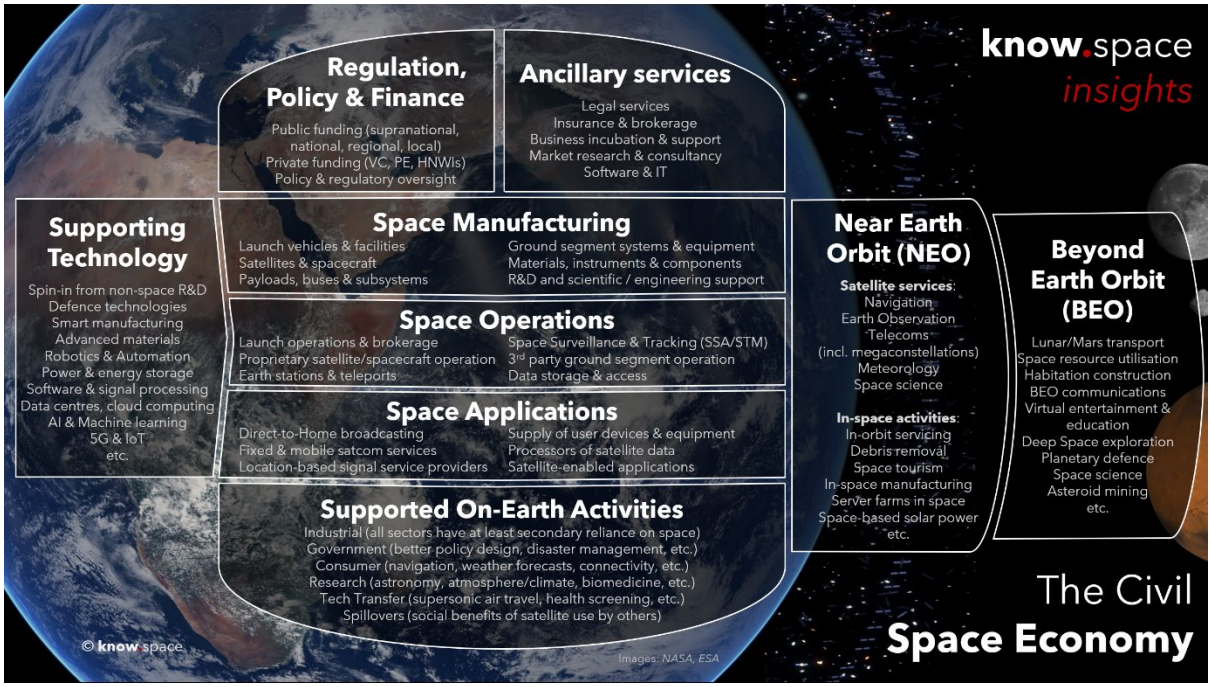
Source: know.space elaboration incorporating OECD descriptions[9]
Note: Meteorology is often considered a branch of Earth Observation (including by OECD), but is separated out here to highlight the important role that satellite-derived observations play in understanding our planet's weather and climate.

[9] This list and technology descriptions incorporate technology descriptions from: OECD (2022). *Handbook on Measuring the Space Economy, 2nd Edition.* Available at: https://www.oecd-ilibrary.org/science-and-technology/oecd-handbook-on-measuring-the-space-economy-2nd-edition_8bfef437-en

Defence: There is an inescapable duality of use in respect of space technologies – with applications of the same technology possible in both civil and defence domains. The UK government has recently published a pair of strategies – the *National Space Strategy* and the *Defence Space Strategy* - bringing together our civil and defence activities into one integrated approach for the first time.

2.1.1 Industry value chain

Figure 2 The civil space economy



Source: know.space insights

Traditionally, the **'space industry'** includes the following core space-related activities:[10]

- **Space Manufacturing**
  Design and/or manufacture of space equipment and subsystems
  including: launch vehicles and subsystems, satellites/payloads/spacecraft and subsystems, scientific instruments, ground segment systems and equipment (control centres and telemetry), suppliers of materials and components, scientific and engineering support, fundamental and applied research.
- **Space Operations**
  Launch and/or operation of satellites and/or spacecraft
  including: launch services, launch brokerage services, proprietary satellite operation (inc. sale/lease of capacity), third-party ground segment operation, ground station networks, in-orbit servicing, debris removal, Space Surveillance & Tracking (SST), space tourism, in-space manufacturing.
- **Space Applications**
  Applications of satellite signals and data[11]
  including: Direct-To-Home (DTH) broadcasting, fixed and mobile satellite communications services (including Very-Small-Aperture Terminals (VSATs)), location-based signal and connectivity service providers, supply of user devices and equipment, processors of satellite

[10] know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022

[11] The definition of the space industry does not include activities leveraging satellite applications for operational purposes (e.g. ride-hailing, food or grocery delivery, usage-based car insurance, etc.), which instead count as part of the wider space economy and are captured in the 'Wider UK GDP supported by satellite services' analysis.

data, applications leveraging satellite signals (e.g. GPS devices and location based services) and/or data (e.g. meteorology, geographic information system (GIS) software and geospatial products), other (e.g. Quantum Key Distribution).

- **Ancillary Services**
  Specialised support services
  including: launch and satellite insurance (inc. brokerage) services, financial and legal services, software and IT services, market research and consultancy services, business incubation and development, policymaking, regulation, and oversight.

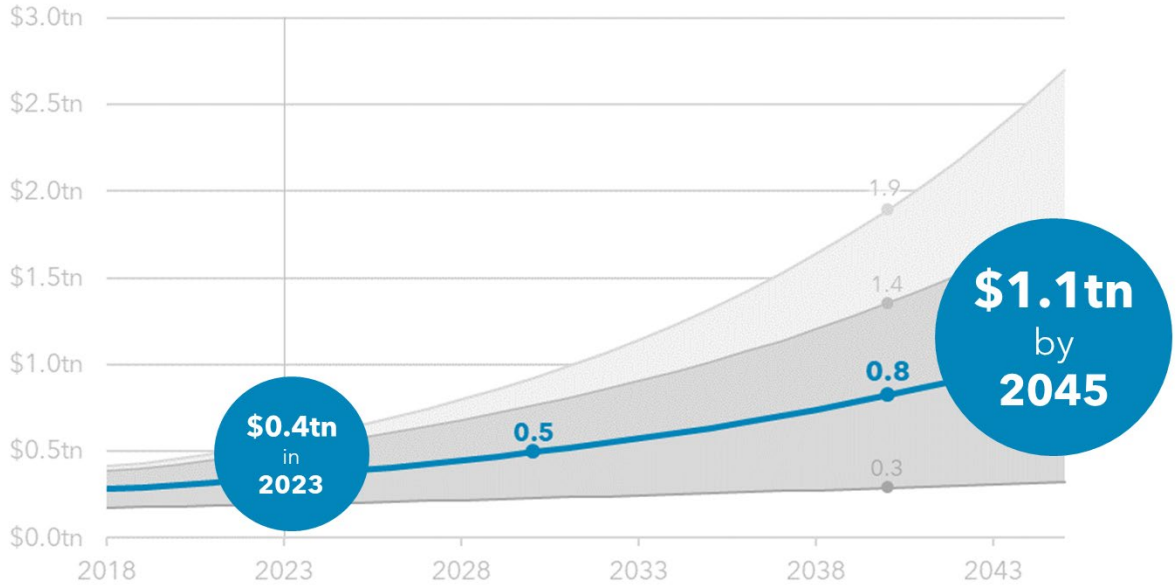
The outputs of the UK space industry are used to considerable benefit by a large and increasingly wide range of **public sector users, commercial users** and **consumers**.

2.2 The global space economy

Space activities are growing globally, with the global space economy bucking growth trends in the wider economy. Estimates vary hugely, given differing definitions of the space economy, but what is certain is that this is a significant and growing industry, presenting a considerable economic opportunity. Two recent estimates suggest that the global space economy was worth between **$386bn**[12] and **$469bn**[13] in 2021.

The global space economy has demonstrated strong growth since the turn of the millennium (**1.6%** per year[14]), with growth accelerating in future years (**5.1%** per year to 2040[15]). It is estimated that the global space economy will be worth a staggering **$1.1tn by 2045**, as the new opportunities in the sector are realised.

Figure 3 Estimated global space economy growth to 2045



Source: know.space analysis of: Institute for Defence Analyses (IDA) Science and Technology Policy Institute (STPI) (2020). Measuring the Space Economy: Estimating the Value of Economic Activities in and for Space; Organisation for Economic Co-operation and Development (OECD) (2014). The Space Economy at a Glance 2014; Satellite Industry Association (SIA) (annual). State of the Satellite Industry Report; The Space Foundation (annual). The Space Report; UBS (2018). Longer Term Investments – Space; Morgan Stanley (2017). Space: Investment Implications of the Final Frontier; U.S. Chamber of Commerce (2018). The Space Economy: An Industry Takes Off; Bank of America Merrill Lynch (2017). To Infinity and Beyond – Global Space Primer. Notes: All values are nominal prices in US dollars. Interpolation between present estimates and forecasts achieved using a fitted compound annual growth rate (CAGR).

[12] Satellite Industry Association (2021). *State of the Satellite Industry Report*. Available at: https://sia.org/news-resources/state-of-the-satellite-industry-report/
[13] The Space Foundation (2022). *The Space Report*. Available at: Space Foundation Releases The Space Report 2022 Q2 Showing Growth of Global Space Economy
[14] The Space Foundation (2022). *Global Space Activity by Category, 2005-2021*. Available at: https://www.thespacereport.org/resources/global-space-activity-by-category-2005-2021/
[15] Harmonised average CAGR taken across multiple sources (listed under Figure 3).

Space investment has also grown rapidly: global investment from 2015-2019 was more than twice that in the previous 10 years (2005-2014)[16].

Global space investment hit an all-time high of **nearly $50bn in 2021**.

Source: Space Capital[17]

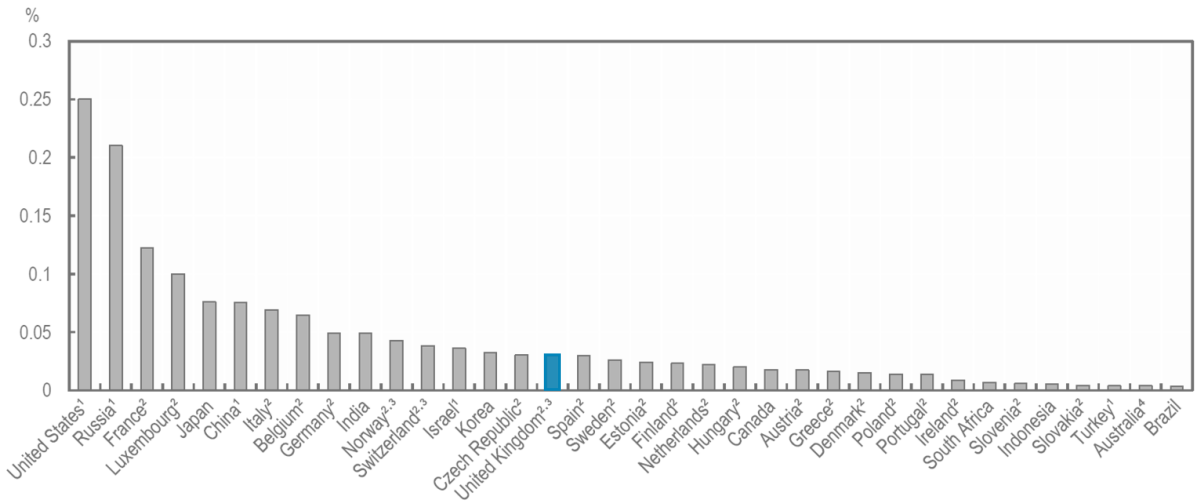
As growth in the global space economy accelerates and New Space is disrupting old patterns of activity in the sector, **now is a time of significant opportunity to space nations globally**. Yet, there is a **risk of the UK missing out on new markets** (e.g. small satellite launch, satellite constellations, in-space manufacturing etc.) and even losing its current strengths, given **fierce global competition** to capitalise on the growing global space economy and the rapid pace of change within the sector.

2.3 UK's role in the global space economy

The UK plays an important part in the global space economy as a thriving space nation and is home to a healthy and growing space ecosystem. Boasting excellence across both business (with end-to-end capabilities throughout the space value chain) and academia (world-leader in fields of space science), the UK has world-leading expertise across a number of economic and science domains.

This is despite being a relatively small spender compared to the biggest space nations. The UK government spends around **0.05% of GDP** on space, which is only around a fifth of that spent by the US (0.24%)[18] and also smaller in magnitude to that spent by European nations such as Italy (0.07%) and Germany (0.06%)[19]. A wider comparison is shown below.

Figure 4 UK government space budget against selected countries (as % of GDP, 2020)



Source: OECD (2022) OECD Handbook on Measuring the Space Economy, 2nd Edition
Notes: 1. Conservative estimates, including defence programmes. 2. Includes contributions to the European Space Agency and Eumetsat. 3. Includes contributions to one or several EU space programmes (e.g. Copernicus, Galileo/EGNOS). 4. Includes only civil R&D. Notes: GDP is a measurement of the market value of all final goods and services produced in the economy and it does not include the value of intermediate inputs. Budgets include data for civil and defence programmes, when available.

[16] Space Capital (2020). *Space Investment Quarterly: Q1 2020*. Available at: https://www.spacecapital.com/quarterly
[17] Space Capital (2023). *Space Investment Quarterly Report: Dashboard*. Available at: https://www.spacecapital.com/quarterly
[18] Note: definitions of space spending differ across countries, so caution should be used in comparing estimates.
[19] Euroconsult (2022). *Government space budgets driven by space exploration and militarization hit record $92 billion investment in 2021 despite COVID-19, with $1 trillion forecast over the decade*. Available at: https://www.euroconsult-ec.com/press-release/government-space-budgets-driven-byspace-exploration-and-militarization-hit-record-92-billion-investment-in-2021-despite-COVID-19-with-1-trillion-forecastover-the-decade/

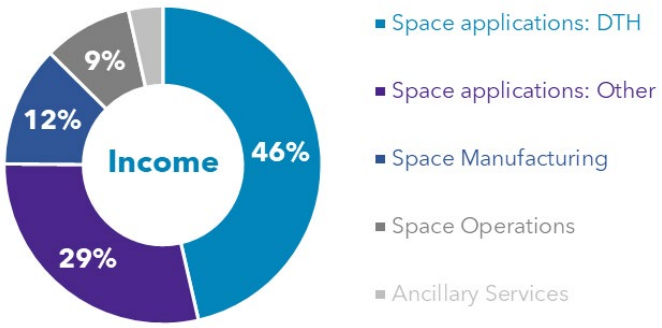
2.3.1 UK strengths across the space value chain

In 1962 the UK became only the third country to operate a satellite, launching its first science mission, Ariel 1. Today the UK is playing key roles in major international missions, notably on the James Webb Space Telescope and Solar Orbiter, a mission to study the sun and its effects on the solar system. This trend is set to continue, with the UK playing big roles on further ESA missions including Ariel (an exoplanet mission due to launch in 2029) and JUICE (studying Jupiter and its icy moons, which launched in April 2023).

Building on these scientific strengths, the UK has expertise across the space economy:

- **Space Manufacturing**
  The UK has deep expertise in the manufacture of spacecraft, satellites and complex payloads, as well as a strong supply chain delivering specialist components to the sector. For example, Airbus Defence and Space in Stevenage recently built Solar Orbiter, a spacecraft designed to withstand temperatures of up to 600 degrees centigrade as it unlocks secrets about the Sun and its effects on our solar system.
- **Space Operations**
  Routine satellite operations activities are already carried out in the UK and UK start-ups are at the forefront of emerging space operations markets; for example, UK-based Astroscale is a leading player in in-orbit servicing. With the first attempted launch from UK soil in early 2023, and more launch attempts planned, the UK plans to become the leading provider of small satellite launch in Europe by 2030, with spaceports and launch vehicles coming on stream this year and next.
- **Space Applications**
  Direct to home television (DTH) accounts for the largest share of UK space applications activity; notably the UK is home to Sky TV, who use satellites to deliver TV services. However, the UK is also home to a diverse ecosystem of smaller companies who are leveraging satellite data for commercial applications from air quality mapping to agritech.
- **Ancillary Services**
  The full range of ancillary services companies in the UK, in addition to end-to-end supply chain capabilities, make the UK a 'one stop shop' for space activities.

Given the broad applicability of space data and services, it is perhaps unsurprising that around three-quarters of industry income comes from the commercialisation of these applications, particularly direct to home television (e.g. satellite TV). However, income is generated across all market segments, reflecting widespread space expertise and opportunity in the UK.



Source: know.space (2023) Size & Health of the UK Space Industry 2022

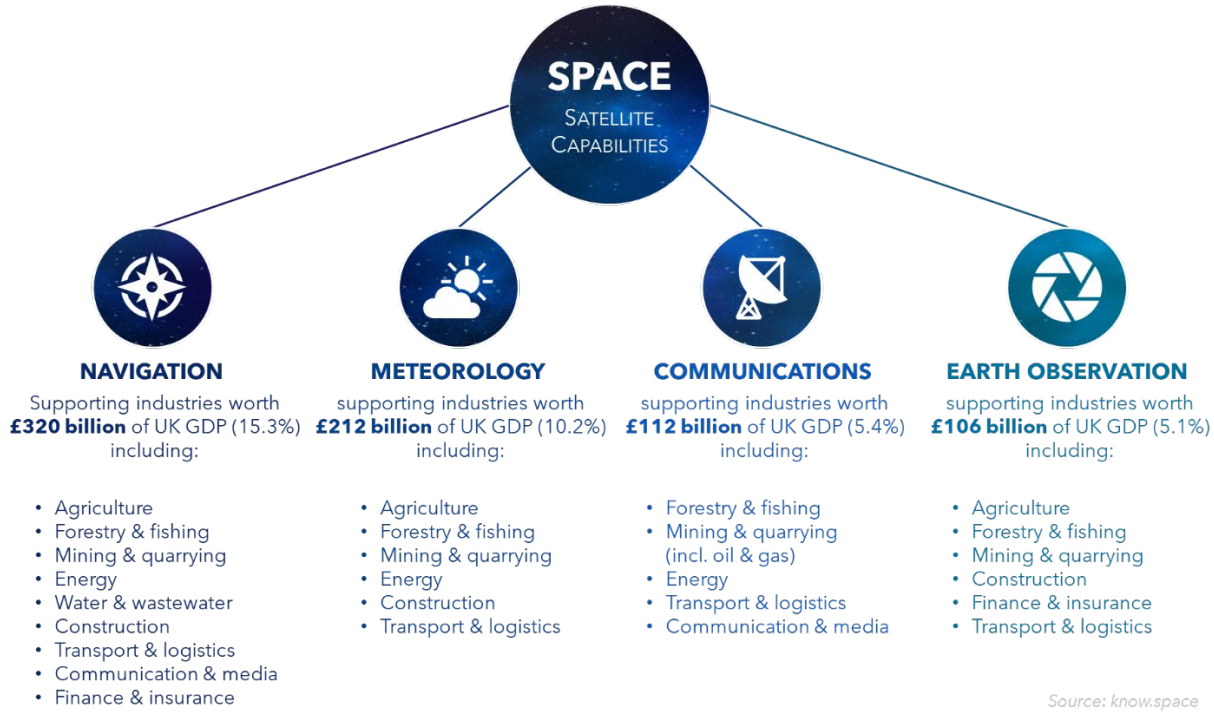
2.4 Space's role in the UK economy and society

The UK space sector is worth over £17.5bn in income to the UK economy and employs 48,800 people, offering some of the most productive and skilled jobs in the country[20]. The sector has exhibited extremely robust growth since the turn of the millennium with an average long term growth rate of 6.4%, far exceeding that of the UK economy as a whole and outpacing growth in the global space economy (1.6%[21] over the period).

2.4.1 Supporting UK industry

The true value and influence of space activities spans far beyond the space sector itself. Space is ubiquitous in our daily lives, and this is reflected in the breadth of UK industries and government policy areas supported by space activities.

Figure 5 Selected UK industries supported by satellite capabilities



Source: know.space elaboration of know.space (2023) Size & Health of the UK Space Industry 2022

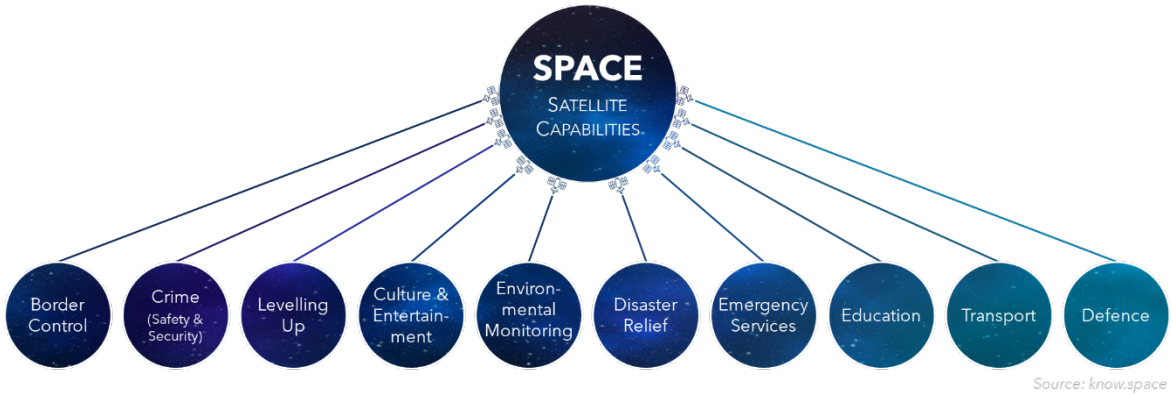
[20] know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022

[21] As measured by The Space Report, which adopts a different segmentation, but is a long-running and commonly referenced measure of the global space industry. The Space Foundation (2022). Global Space Activity by Category, 2005-2021. Available at: https://www.thespacereport.org/resources/global-space-activity-by-category-2005-2021/

2.4.2 Supporting government policy

The opportunites to improve efficiency and deliver better outcomes within government using space services have yet to be fully realised. Already space is deeply embedded into operations across government policy areas, from the use of satellite data in monitoring crime (e.g. illegal fishing, border control etc.) to traffic management (road, rail and air) to disaster relief (prevention and response).

Figure 6 Selected UK government policy areas supported by satellite capabilities



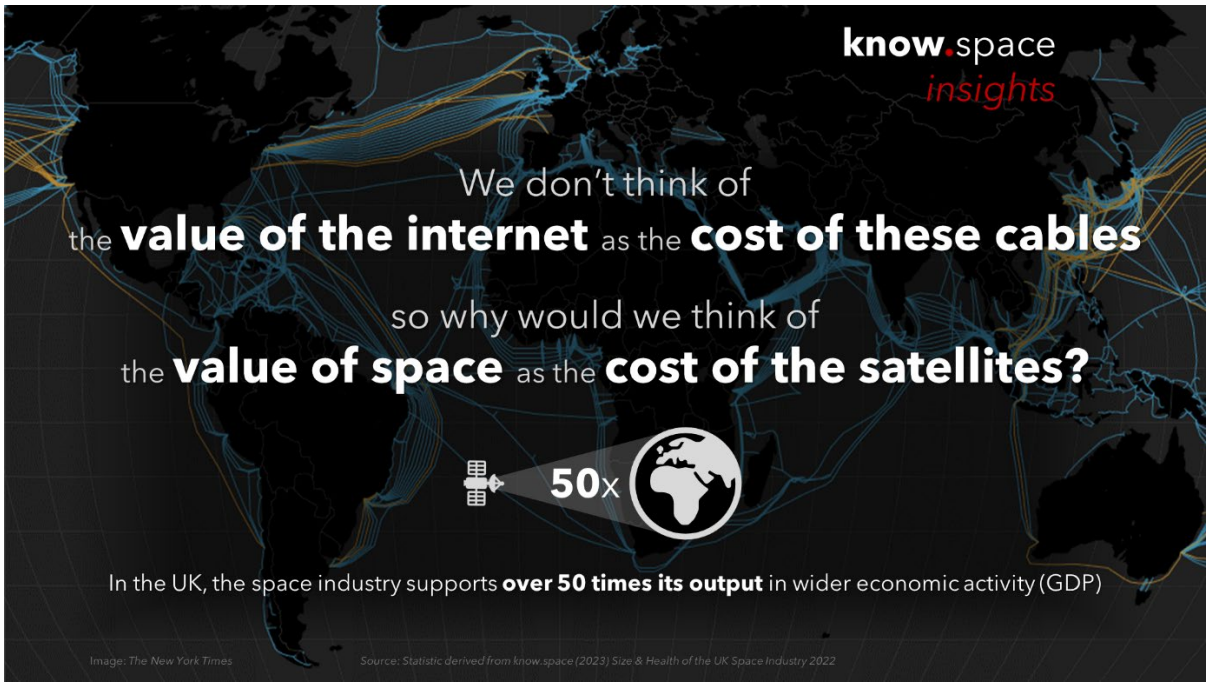
Source: know.space analysis

3 What are the benefits of space?

The UK space sector is a **small but highly significant sector of the UK economy**, with **satellite services supporting nearly 18% of UK GDP**[22]. The sector delivers substantial and varied benefits across government, society and economy, supporting key markets and services which citizens, companies and the government rely on every day, playing a **vital yet often hidden role**.

Notably, space is a **critical national infrastructure** and contributes to **wider government goals** (e.g. levelling up, science and technology superpower), whilst **promoting UK sovereignty and soft power**. Satellites provide unparalleled insight into our planet, vital to **climate change efforts**, as well as enabling cost savings and unlocking commercial opportunities. By **pushing scientific and technological frontiers**, space has transformed our lives on Earth. **Every day citizens rely on space**, from the more visible examples of satellite services (e.g. using GPS to navigate on our smartphones) to the numerous products which have spun out of the space sector (e.g. memory foam). Lastly, space is **unique is its capacity to inspire** and **unravel fundamental questions** about our existence, through advances in space science. This **unrivalled influence across the economy, society and culture** makes public space investment not only worthwhile, but essential.

Figure 7 The enabling power of space capabilities



Source: know.space insights

22 Total value of activities supported by satellite services. know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022

The sector itself is **highly productive and R&D intensive**, offering strong value for money. In the future, our reliance on space capabilities is expected to grow, as space becomes increasingly embedded into our lives. Investment today not only offers a **strong short-term return on investment**, but also opens up **future growth possibilities** for the sector and the wider economy.

3.1 Types of benefit

Benefits of space are **wide-ranging** and **substantial**, broadly falling into three categories:

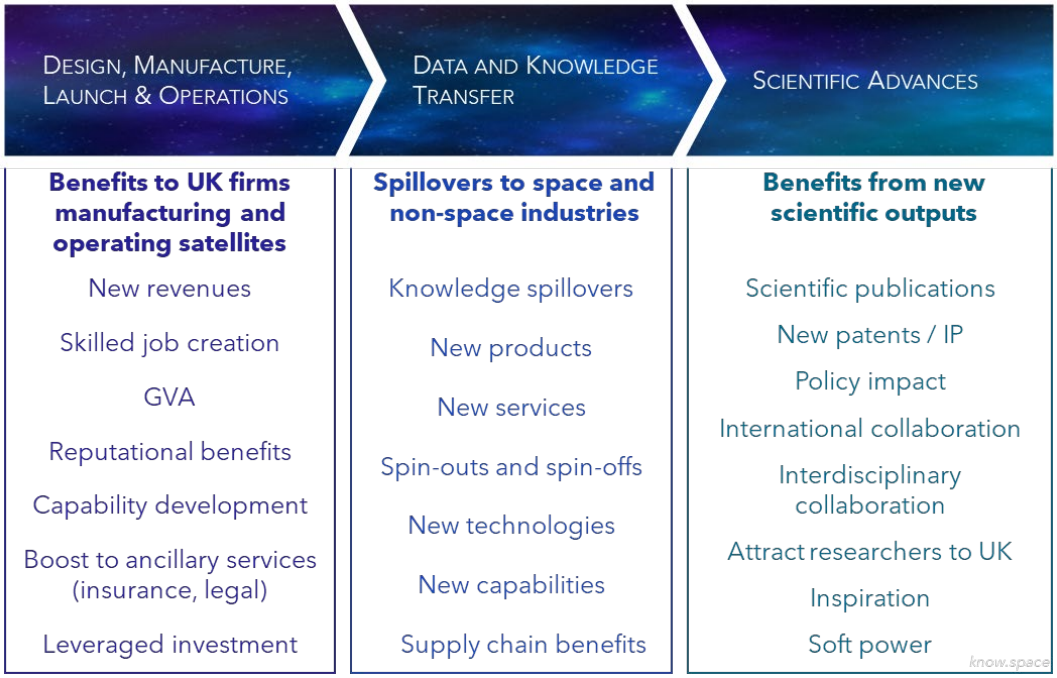
- **Economic**, e.g. underpinning UK GDP, creating jobs etc.
- **Societal**, e.g. tackling climate change, supporting UK sovereignty etc.
- **Scientific and inspirational**, e.g. improving our understanding of the universe

The **majority of these benefits accrue outside of the space sector**, often to people, firms and organisations who do not directly pay for space services or even realise that the services they rely on are enabled by space investment.

Benefits accrue over the **full lifecycle of a project or investment**, with different benefit classes taking on greater prominence at different stages.

For example, in the early stages of a science mission (during design, manufacture, launch and operations) benefits to those receiving investment, such as **new revenues** and **enhanced capabilities**, will flow to UK firms and organisations. As data and knowledge are created, substantial benefits to other people and organisations will emerge as **knowledge is shared** (both deliberately and tacitly), creating potential for **new spin-out technologies, companies and even sub-sectors**. The **scientific advances** ultimately achieved will then create further benefits, for example **innovation** from scientific knowledge creation and **inspiration** to future generations of scientists.

Figure 8 Evolution of benefits across the lifecycle of a science mission



Source: know.space elaboration

ESA's **Rosetta mission** provides a useful illustration of the benefits accruing over the lifecycle of a mission. Originally conceived as an idea in the early 1980s, the Rosetta spacecraft was launched in March 2004, attempting one of the most challenging science missions to date. Rosetta flew by two asteroids before hibernating for nearly three years then orbiting a comet until 2016.

The UK played a **crucial role in the instrumentation**, generating substantial benefits before the mission launched. Notably, Airbus Defence and Space in Stevenage were a major subcontractor for the platform and SciSys UK was responsible for the spacecraft Mission Control System development and maintenance. These contracts provided direct revenue benefits to firms, as well as boosting their reputations: SciSys UK won "Innovator of the Year" at the UK Computing Awards for Excellence 2004, in recognition of this work[1].

UK scientists benefitted throughout Rosetta's lifecycle, developing its instrumentation, being involved in **10 out of 21 experiments** and analysing its results. The mission also generated substantial public interest and inspirational value, with **more than 10 million people** following the comet landing in November 2014[1]. Despite being a science mission, the UK reaped varied socioeconomic benefits from involvement.

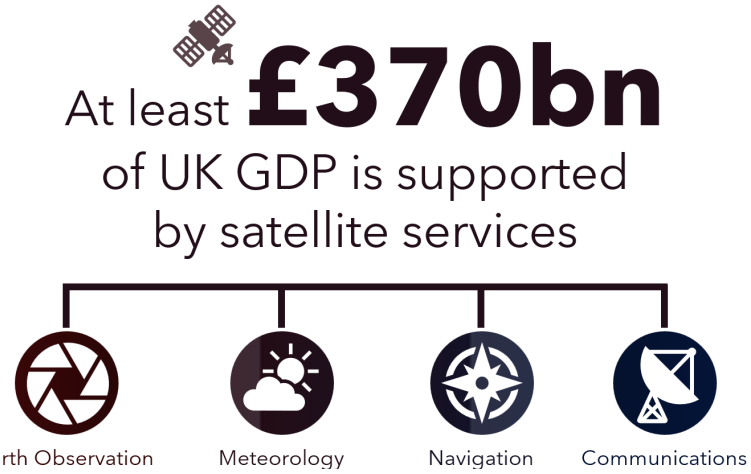
3.2 A vital part of the UK economy

The space industry has a disproportionately important and impactful role in the UK economy.

The sector's influence spreads throughout the economy, with wide-ranging applications across different sectors, providing and enhancing services to citizens, firms and public users. From earth observation data used by farmers to maximise crop yields, to the GPS watches used by runners, to the crucial navigation services used by ships, space underpins our daily activities.

The total value of industrial activities supported by satellite services is estimated as at least **£370 billion,** equivalent to approximately **18% of UK GDP**[23]. Most of these economic activities are supported by multiple different types of satellite services, with Global Navigation Satellite Systems (GNSS) alone underpinning £320bn (15% of UK GDP). The £370bn reflects the total value of output of those industries supported by satellite services and we can assume that this output would be significantly disrupted by a disruption to global satellite services.

Figure 9 UK GDP supported by satellite services



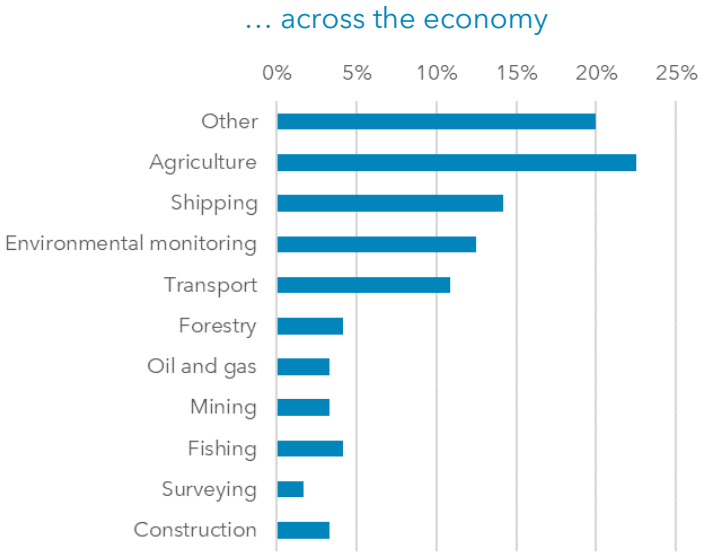
Source: know.space (2023) Size & Health of the UK Space Industry 2022

[23] Note that the GDP supported figure relates to the UK non-financial business economy only (which excludes financial services and the public sector), which accounts for approximately two thirds of the UK GDP. know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022

The use of satellite services is deeply embedded into our daily lives. A 2017 study estimated that the loss of GNSS (satellite navigation services) alone would have a UK economic impact of **£5.2bn over a 5-day period**, with applications in road, maritime, emergency services and justice accounting for **67%** of all impacts[24]. The loss of these services would have severe social (and often health) effects, notably impacting our emergency services (see Case Study).

3.2.1 Creating commercial opportunities

Space activities unlock commercial opportunities and give rise to **productivity/efficiency benefits** to firms in existing markets. These benefits are not limited to niche or high-tech markets but accrue across the economy. The chart shows the industries most often cited as generating commercial benefits in a meta-analysis of studies on the benefits of public space investment.



Source: Returns and Benefits from Public Space Investments 2021

Satellite data allows companies to make **better, more-informed decisions**. This often leads to **cost avoidance** as problems are detected earlier and can therefore be dealt with more quickly. For example, in agriculture, satellite images of crops allow farmers to detect diseases more quickly and treat fields in a targeted way, saving money on pesticides and avoiding the costs associated with failed crops. It is estimated that Copernicus satellites enable crop monitoring benefits of **€23bn[25]**.

Space activities also enable **new products and markets** outside of the space industry, as firms leverage satellite services and data. A key example is GNSS. GPS (one GNSS system) was developed in the 1970s, yet over **90%** of benefits have occurred in the last ten years[26], as complimentary technologies have been developed (particularly the miniaturisation of devices). Mobile apps commonly used in daily life such as Google Maps, Uber and Deliveroo all rely on satellite capabilities.

Furthermore, R&D in the **space sector catalyses the development of new products and services** outside of the sector. The harsh operating environment of space places stringent design restrictions on space technologies (e.g. low weight, able to withstand extreme temperatures etc.), which drives innovation. These ideas and technologies can then spin-out of the space sector, improving products for consumers on Earth.

[24] London Economics (2017). *The economic impact on the UK of a disruption to GNSS*. Available at: https://londoneconomics.co.uk/wp-content/uploads/2017/10/LE-IUK-Economic-impact-to-UK-of-a-disruption-to-GNSS-FULLredacted-PUBLISH-S2C190517.pdf

[25] PWC (2017). *Copernicus ex-ante benefits assessment*. Available at: https://www.copernicus.eu/sites/default/files/2018-10/Copernicus-Ex-Ante-Final-Report_0_0.pdf

[26] RTI international (2019). *Economic Benefits of the Global Positioning System (GPS)*. Available at: Microsoft Word - FinalReport_psg10.docx (rti.org)

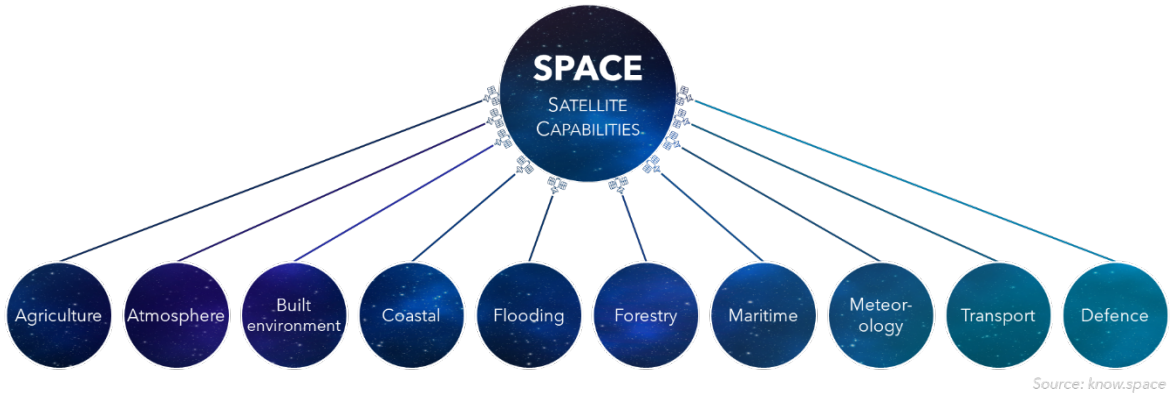
3.2.2 Improving efficiency within government

Against the backdrop of significant pressure on government spending, space activities have the potential to generate **largescale savings for the public purse**, as well as delivering improved services to citizens. Broadly, the uptake of space-derived services within government can lead to[27]:

- **Operational cost savings**: where a space-derived solution replaces a more expensive method (productivity and efficiency gains), e.g. more efficient mapping using earth observation data over costlier methods such as helicopters;
- **Exceptional cost avoidance**: additional costs which are avoided as a consequence of government actions which would not be possible without space, e.g. monitoring fly tipping;
- **Better policy decisions and regulation**: satellite data can enable more informed decisions, e.g. by assessing the success of past policy interventions.

These savings arise across government departments, with the potential for cost savings in varied applications and industries.

Figure 10 UK operational domains supported by satellite capabilities



Source: know.space

The uptake of space solutions within government is still in its infancy and the literature suggests significant potential for further benefits as the opportunities offered by space begin to be realised[28]. A 2018 evaluation of the Space for Smarter Government programme, intended to demonstrate the value of space solutions to government, estimated a potential **£40m per year** in potential benefits if just six, relatively small-scale solutions were taken up by government. This reflects a good return, with **each £1 of grant expenditure generating an *additional* £0.78 in economic activity[29]**.

3.2.3 Contributing to GDP

Despite its considerable importance in the wider economy, the space sector itself is relatively small. The sector punches far above its weight in the wider UK economy.

[27] Classifications adapted from London Economics (2018). *Value of satellite-derived Earth Observation capabilities to the UK Government today and by 2020*. Available at: https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf

[28] London Economics (2018). *Value of satellite-derived Earth Observation capabilities to the UK Government today and by 2020*. Available at: https://londoneconomics.co.uk/blog/publication/value-satellite-derived-earth-observation-capabilities-uk-government-today-2020-july-2018/

[29] London Economics (2018). *Economic evaluation of the space for smarter government programme (SSGP)*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/788728/LE-UKSA-Economic_evaluation_of_SSGP-FINAL_3.0_For_Publication.pdf

Contribution to GDP, measured as Gross Value Added (GVA), is a key parameter measuring a sector's impact on the economy overall[30]. The space industry directly contributed **£7.0bn** to UK GDP in 2020/21, equivalent **0.34%** of total UK GDP[31].

Public funding allows firms to generate revenues directly related to the funded activity. This enables firms to develop new capabilities and enter new markets, which in turn allows for further revenue generation.

Economic activity in the space industry will also generate further rounds of commercial activities, through increased demand to suppliers across the supply chain (indirect effects) and through the spending of space industry employees' salaries (induced effects). It is estimated that these effects contribute a further **£11.2bn** to the UK economy. This brings the total economic impact of the UK space industry to **£18.3bn**.[32]

Growth in the space sector has consistently outpaced growth in the wider economy. Since the turn of the millennium, the UK space industry has grown at an average rate of **6.4% per year**, and even through the financial crisis and 'productivity puzzle'[33] era, it grew at an average of **4.8% per year** in the decade 2009/10 to 2019/20 – more than **3.5 times as fast** as the UK economy as a whole (which grew at an average rate of 1.7% per year in the decade).

3.2.4 Creating highly-skilled jobs

Job creation provides another illustration of the economic importance of the sector. The space sector directly employed **48,800** people in 2020/21. This reflects significant growth in the sector since the turn of the millennium: since 2000/01, space industry employment has grown at an average of **6% per year**.

We can also consider indirect employment (those employed in the supply chain) and induced employment (jobs supported by the spending of employees). It is estimated that the space sector supported a further **78,000** indirect and induced jobs[34].

These 48,800 jobs supported are overwhelmingly high-skilled. It is estimated that **77%** of employees hold a bachelor's degree or higher. This is higher than any other sector in the UK.

Additionally, these jobs are overwhelmingly interesting and can provide fulfilling employment opportunities. **44%** of people join the sector because of the interesting work and **42%** of people join because they like space[35].

[30] Contribution to GDP at an organisation-level can be thought of as revenues minus costs (e.g. for inputs, such as materials).
[31] know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022
[32] Note: indirect and induced benefits are not considered by the Green Book (2022) to be attributable benefits. See HM Treasury (2022). *The Green Book (2022)*. Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020
[33] ONS (2015). *What is the productivity puzzle?* Available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/articles/whatistheproductivitypuzzle/2015-07-07
[34] Note: indirect and induced benefits are not considered by the Green Book (2022) to be attributable benefits. See HM Treasury (2022). *The Green Book (2022)*. Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020
[35] Space Skills Alliance (2023). *How and why people join the UK space sector*. Available at: https://spaceskills.org/census-routes#summary

3.2.5 Boosting productivity

This skilled workforce is reflected in high productivity, with average space sector labour productivity of **£144,000**. This means that on average those working in the industry create value of £144,000 a year.

This places the space industry as one of the UK's most productive sectors, with labour productivity **2.5 times** the UK average of **£56,614**. For comparison, this places the space sector well above the Manufacturing and Communication and Information sectors in terms of labour productivity.

This high labour productivity enables high wages in the sector. The mean space sector salary is estimated as **£49,000**, considerably more than the average UK salary of £31,000[36]. The space sector is an exemplar of a high-skill, high-productivity, high-wage sector.

… as a highly productive industry

Source: Size & Health 2022

3.2.6 Catalysing investment

Public investment can play a crucial role in attracting private investment, by providing visibility and credibility to firms. In recent years, the space sector has successfully attracted investment, with an estimated **£11.7bn** invested over the last ten years (2012-22), across **293 investment deals**. Private investment accounted for nearly **90%** of this, with venture capital representing the single biggest source of funding once mega-deals are excluded. Yet despite significant successes in attracting investment to the sector, investment fluctuates significantly year on year. Space organisations remain cautious about future investment prospects, with around **14%** of the industry expecting a fall in investment over the next 3 years.

Government support is crucial to continued private investment, both through general industry-wide support and through matched investments directly guaranteeing leveraged private investment. For example, it is estimated that the **£765m** in public funding to ARTES has generated leveraged private investment of **£553m**[37] (through matched investment by companies involved).

3.2.7 Intensively investing in R&D

The space sector is also heavily R&D intensive, reflecting the nature of activities undertaken. R&D investment is crucial to boosting productivity and cementing the UK's position as a science superpower.

In 2020/21 the sector had an estimated R&D expenditure of **£788 million**, equivalent to **11% of GDP contribution**. This makes the space sector **5 times** more R&D intensive than the UK average. The sector is also overachieving on R&D intensity targets, already being well ahead of the UK's overall Innovation Strategy target of 2.4% R&D intensity by 2027.[38]

[36] Space Skills Alliance (2020). *Pay in the UK space sector*. Available at: https://spaceskills.org/census-pay#summary
[37] Technopolis Group (2019). *An evaluation of UKSA funding through the ARTES programme: Final Report*. Available at: https://www.technopolis-group.com/wp-content/uploads/2020/02/An-evaluation-of-UK-funding-through-the-ARTES-programme.pdf.
[38] BEIS (2021). *UK Innovation Strategy*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf

3.3 Delivering societal benefits

Space underpins many of the services which citizens use every day. It is also a critical national infrastructure and plays a crucial role in national sovereignty and efforts to combat the climate crisis.

3.3.1 Providing services to citizens

Satellite services underpin **crucial services** which citizens rely on every day. Benefits are widespread and often substantial, ranging from **improved efficiencies** in our day-to-day lives (e.g. time savings from route mappings) to the **life-saving** (e.g. enhanced disaster response). These applications can have significant follow-on benefits as new technologies are adopted by users (e.g. more efficient route mapping leading to a reduction in emissions and congestion).

Key benefit classes include[39]:

- **Transport time and cost savings** (from satellite navigation).
- **Lives saved and injuries avoided** or reduced (through better disaster response, enhanced safety from navigation, etc.).
- **Connecting rural communities** (using satellite broadband).
- **Entertainment applications** (live TV, broadband, fitness tracking, etc.).
- **Improved weather services**.
- **Greater reliability of services** or product availability.

Many of the **smartphone apps** which we use every day are critically reliant on satellite services, particularly the use of GNSS for positioning and navigation:

- **Mapping apps**, e.g. Google Maps, Apple Maps. GNSS is integral to route mapping, which allows users to navigate quickly and easily. This generates time savings, reduces road congestion and saves fuel.
- **Ride sharing**, e.g. Uber, Bolt. GNSS is essential to the functioning of these apps, enabling users to match with a nearby driver and find their ride, and ensuring appropriate fares.
- **Food delivery apps**, e.g. Deliveroo, Uber Eats. The algorithms underlying these apps rely on GNSS data to select an appropriately positioned delivery driver/rider for each takeaway, route the driver to the delivery location and provide updates to users on how close their takeaway is.
- **Parcel delivery**, e.g. DHL, Yodel. GNSS enables consumers to track the delivery of their parcels, so they know when the parcel is near and need not wait at home all day.
- **Weather apps**, e.g. BBC weather, Met Office. Weather forecasts rely on meteorological satellite data and weather apps use this data in combination with GNSS signals to offer local weather forecasts.

These apps offer consumers significant time (and often cost) savings. It is estimated that by 2031, more than **10 billion GNSS-enabled devices** will be in use globally. This is more GNSS-enabled devices than people.

Source: EUSPA[40]

Whilst we lack a complete set of quantitative estimates, the evidence suggests that these benefits are considerable. It is estimated that weather and climate services (from earth observation) alone are worth nearly a **billion pounds a year** to the UK economy[41].

[39] know.space (2022). *Returns and Benefits from Public Space Investments 2021*. Available at: https://www.gov.uk/government/publications/returns-and-benefits-from-public-space-investments-2021
[40] EUSPA (2022). *EO and GNSS Market Report 2022*. Available at: https://www.euspa.europa.eu/2022-market-report
[41] London Economics (2018). *Value of satellite-derived Earth Observation capabilities to the UK Government today and by 2020*. Available at: https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf

3.3.2 Tackling social and environmental issues

Earth observation satellites play a critical role in our response to climate change, allowing us to monitor changes in our environment and take appropriate, evidence-based action. Satellites allow us to monitor anthropogenic CO_2 emissions, sea level rise, changes in Arctic ice etc., which in turn allows climate forecasting models to be developed. It is estimated that the anthropogenic CO_2 emissions monitoring benefits from Copernicus will be worth nearly **€30bn globally** in the period to 2035[42].

Figure 11 Satellite imagery showing rising temperatures in the Antarctic over 6 years

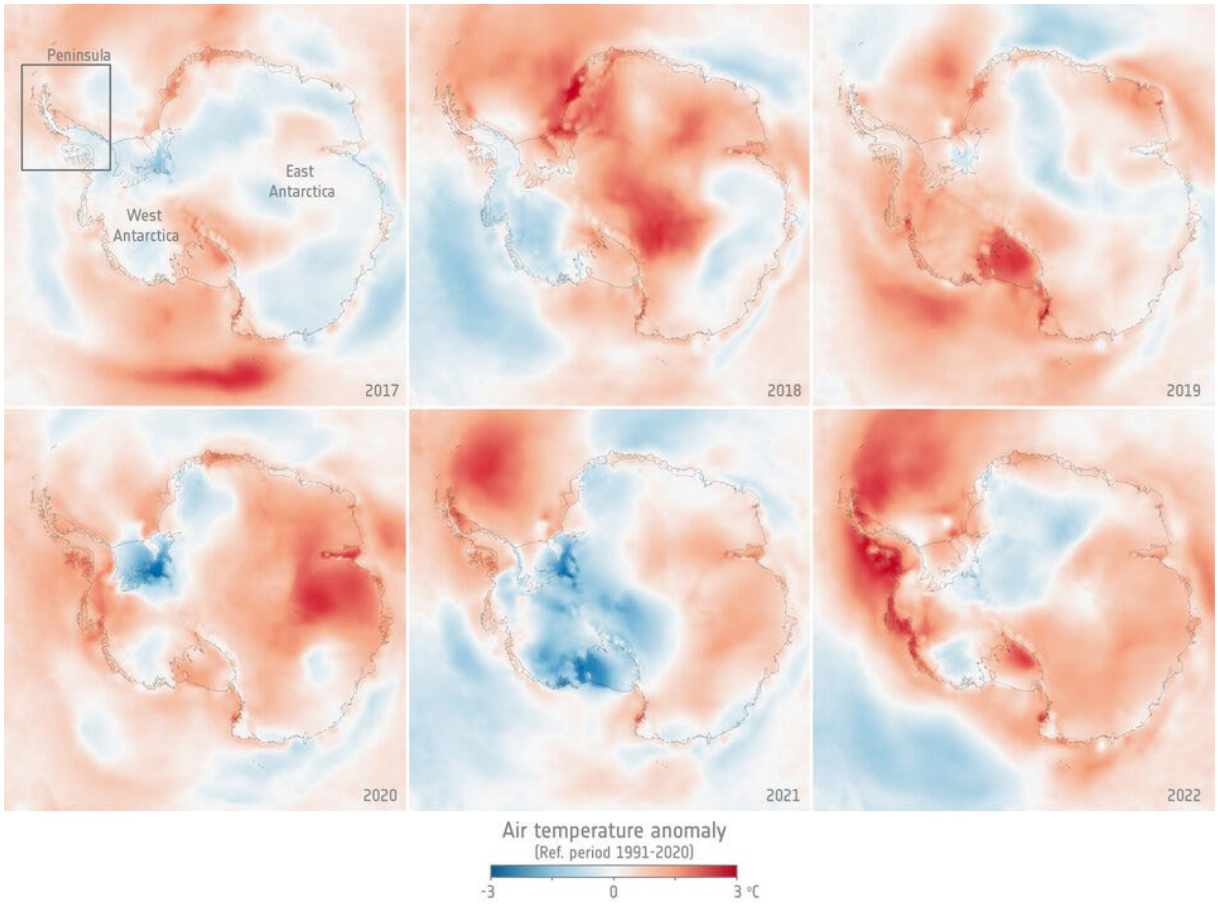


Image: ESA, Copernicus

Earth observation satellites are also used to monitor more localised environmental concerns, for example, deforestation, oil spills, air quality, peatland assessment, coastal change etc.

[42] PWC (2017). *Copernicus ex-ante benefits assessment*. Available at: https://www.copernicus.eu/sites/default/files/2018-10/Copernicus-Ex-Ante-Final-Report_0_0.pdf

Sentinel 1 and 2 satellites have enabled the **Yorkshire Peat Partnership** to assess the impact of their peatland restoration activities.

Peatlands are carbon-rich wetlands which, when healthy, have a natural net cooling effect on the climate, reduce flood risk and encourage biodiversity. By capturing CO2 from the atmosphere through photosynthesis, peatlands can 'lock in' vast quantities of carbon. It is estimated that UK peatlands lock in **3.2bn tonnes of carbon**. However, if managed badly, (e.g. peatland drained for farmland) peatlands can become a net source of greenhouse gases, as the decomposition of plant material releases CO2.

It is therefore crucial to actively maintain and restore out peatlands. Satellite imagery allows enables quick and efficient monitoring of peatland restoration activities, allowing the identification of peatland swelling which indicates healthy, restored peatland. In Yorkshire, the Sentinel satellites have enabled over **3,400 hectares** to be monitored and analysed.

This in turn delivers strong localised social benefits, reducing flood risk (a reduction in flood peak of **up to 33%)** and improving the quality of drinking water (43% of UK drinking water comes from uplands dominated by peatlands). This is in addition to the carbon trapping benefits, contributing to global climate change efforts.

Source: NEREUS, European Commission and European Space Agency[43], and UK Centre for Ecology and Hydrology[44]

Space can also deliver environmental benefits through efficiency savings; for example, Satcom enabled Air Traffic Control allows more efficient plane routing, leading to substantial CO_2 savings. A 2017 study estimated these benefits to be worth **$110m**[45].

The monitoring capabilities offered by earth observation satellites also help tackle varied social problems, for example:

- Potential for more effective air quality interventions **(£4.1m/year**)
- Wider agricultural benefits (reduced pollution) **(£12.3m/year**)
- Mapping benefits (easier mapping of natural resources and early detection of illegal planning) **(£8.3m/year**)[46]

3.3.3 Sovereignty and self-reliance

Many of the user benefits outlined can be realised through satellites operated and financed outside of the UK. Indeed, many of the data sources and signals we make use of are publicly available free of charge. GPS (an American system) is freely available to all, as is a large volume of high-quality earth observation data, notably Copernicus imagery. Yet, we remain reliant on other nations for vital services, which could have devastating consequences if they became unavailable. Taking GNSS as an example, it is estimated that a 5-day GNSS outage would have an economic impact of £5.2bn[47]. Currently, the UK is reliant on the US and the EU for these services, and is investigating options for sovereign capabilities – the development of which would require significant investment.

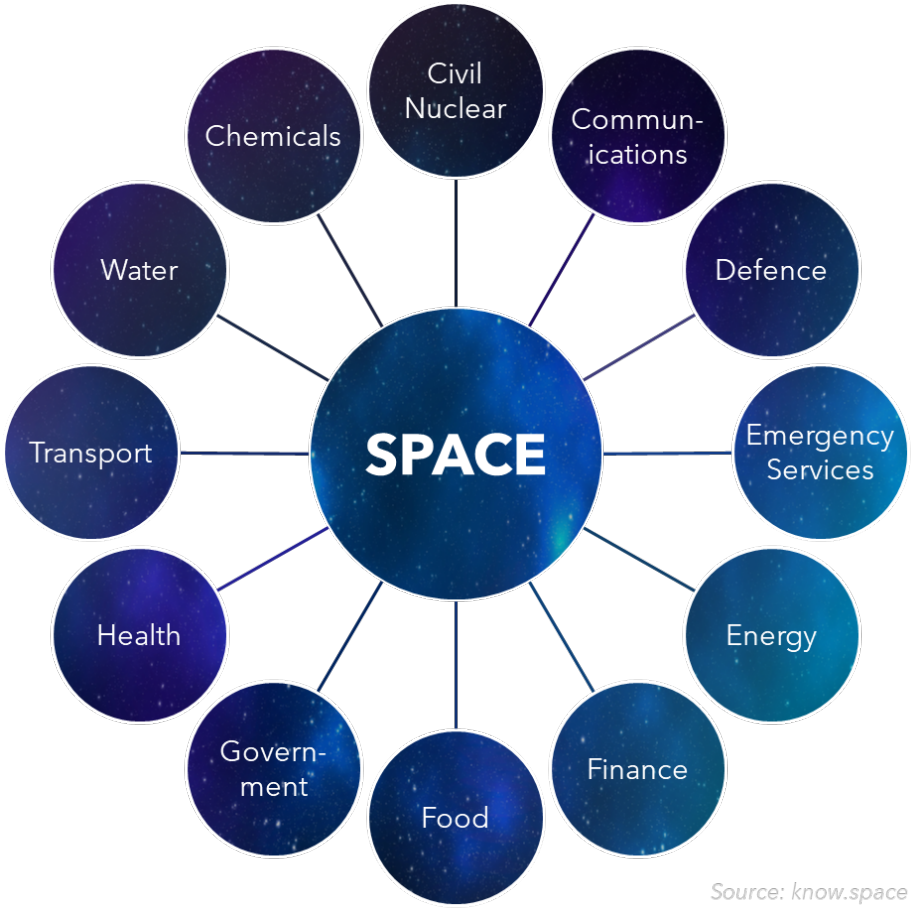
[43] *NEREUS, European Commission and European Space Agency* (2018) The ever-growing Use of Copernicus across Europe's regions. Available at: http://www.nereus-regions.eu/wp-content/uploads/2017/10/PUBLICATION_Copernicus4regions_2018.pdf
[44] Peatlands Factsheet. Available at: https://www.ceh.ac.uk/sites/default/files/Peatland%20factsheet.pdf
[45] Helios (2017). Satcom-enabled Air Traffic Control.
[46] London Economics (2018). *Value of satellite-derived Earth Observation capabilities to the UK Government today and by 2020*. Available at: https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf
[47] London Economics (2017). *The economic impact on the UK of a disruption to GNSS*. Available at: https://londoneconomics.co.uk/wp-content/uploads/2017/10/LE-IUK-Economic-impact-to-UK-of-a-disruption-to-GNSS-FULLredacted-PUBLISH-S2C190517.pdf

3.3.4 Critical national infrastructure

Critical national infrastructures (CNI) are the facilities, systems, sites, information, people, networks and processes **necessary for the UK to function and upon which our daily lives depend**.[48] The loss or compromise of these infrastructure could severely impact the availability of essential services we all depend on, potentially leading to loss of life, as well as significant economic and social impacts. There may also be an impact on national security, national defence or the functioning of the state if these infrastructures are compromised.

Space is acknowledged as a critical national infrastructure in its own right, whilst supporting various operations across the other twelve.

Figure 12 Space's cross-supporting role for other Critical National Infrastructures (CNI)



Source: know.space

The National Protective Security Authority (NPSA) is the authority responsible for the protection of our CNIs, with a mission to build resilience to national security threats. Investment in space not only delivers economic and social benefits to citizens, but also plays a critical role in underpinning essential services and national security. Space capabilities play a fundamental role in ensuring secure communications, navigation and intelligence gathering (e.g. through earth observation).

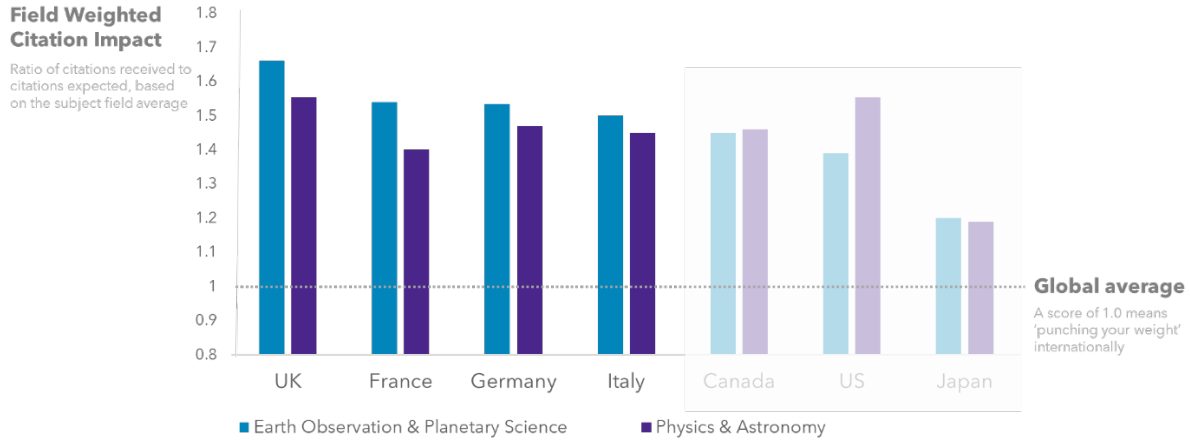
[48] National Protective Security Authority (2023). *Critical National Infrastructure*. Available at: https://www.npsa.gov.uk/critical-national-infrastructure-0

3.4 Advancing our understanding of the universe

3.4.1 Soft power

The UK has built a **global reputation** for scientific research and space science represents an important part of this wider research excellence. The UK has expertise in multiple fields of space science, with particular expertise in instrumentation. In recent years the UK has been involved in a number of **high-profile global missions**, including the James Webb Space Telescope (JWST), Solar Orbiter and BepiColombo. The UK has also been selected for **major roles** on upcoming ESA missions, including Ariel, a ground-breaking mission that will reveal the nature of distant exoplanets and stars.

Figure 13 Citation impact of UK space science, 2018



Source: know.space analysis[49]

3.4.2 Scientific advances

Besides the social, strategic and economic benefits realised (see above), there is a case for 'science for the sake of science'. UK public investment in space science has **demonstrably advanced our understanding of the universe**. As a notable example, the UK has invested strongly in the Gaia mission largely through ESA's science programme (£615m), as well as further UK Space Agency support for processing and analysing mission data (£23m). The Gaia mission, launched in 2013, is creating a three-dimensional map of our galaxy, revealing its composition and secrets about its formation. UK scientists have played instrumental roles from developing on-board electronics to processing the data.

[49] know.space (2021). *UK Space Science: a summary of the research community and its benefits.* Available at: https://span.ac.uk/wp-content/uploads/2021/04/SPAN-UK-space-science-nature-benefits-FINAL-REPORT-060421.pdf

More recently, UK scientists have played crucial roles on ESA's JUICE (Jupiter Icy Moons Explorer) mission (launched April 2023 and expected to reach Jupiter in 8 years' time). The UK Space Agency invested around £9m in the mission and the UK is leading the development of one instrument (the magnetometer, J-MAG), whilst contributing to the development of two others[50]. This magnetometer will be crucial to enhancing our understanding of the formation of icy moons, contributing to our understanding of bigger questions: What are the conditions for planet formation and the emergence of life? How does the Solar System work?

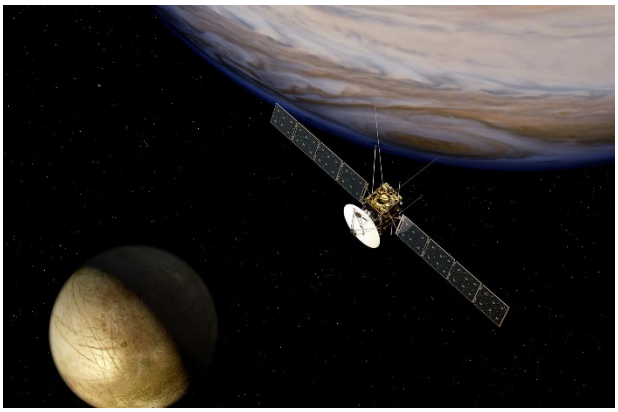


Image: ESA, Artist's impression of JUICE

3.4.3 Inspiration value

Finally, space has the **power to inspire**. With an increasing number of active satellites orbiting the Earth (over 7,000 at time of writing), with an increasing array of capabilities, we are only beginning to leverage the potential benefits from space. These benefits are incredibly **challenging to monetise**, yet this remains a key benefit class, with widespread public interest in space. Space science has the potential to **answer fundamental questions** about our place in the universe, whilst **encouraging future generations** to pursue careers in science and technology.

More than **22,000 people** across Europe applied for the ESA 2021-22 astronaut selection, with **2,000 applicants** from the UK. Of these, **3 UK astronauts were selected**, including the first ever parastronaut (an astronaut with a physical disability).

Source: ESA[51]

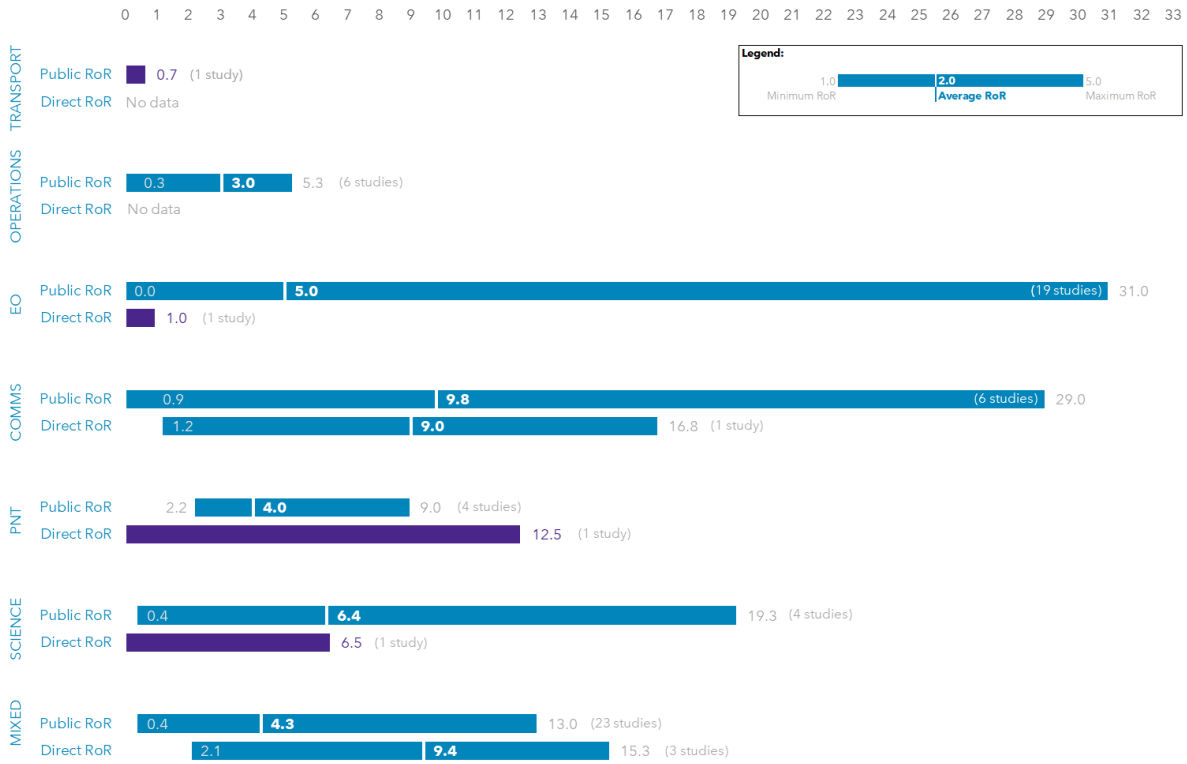
[50] UK Space Agency (2023). *Case study: Jupiter icy moon explorer (JUICE)*. Available at: https://www.gov.uk/government/case-studies/jupiter-icy-moon-explorer-juice

[51] ESA (2022). *Final figures show astronaut applicants from all ESA Member States*. Available at: https://www.esa.int/About_Us/Careers_at_ESA/ESA_Astronaut_Selection/Final_figures_show_astronaut_applicants_from_all_ESA_Member_States

3.5 Returns to public space investment

Public space investment not only delivers substantial and widespread benefits, but also offers strong rates of return to public investment. Whilst it is not appropriate to give an average return to space investment (given how varied investments can be), the evidence base suggests a potential for very high returns. Average public returns across different areas of investment vary from **£3 for every £1 spent** on space operations to **£9.8 for every £1 spent** on communications.

Figure 14 Rates of return to public space investments



Source: know.space[52]

Notably, a recent evaluation of the UK's commitments to ESA estimated that **each £1 spent will generate a £9.8 contribution to GDP**.[53]

These returns are **considerably higher than those to general research and development (R&D) investments**. Though differences in methodology limit comparability: A recent meta-analysis found an average private rate of return of 20%, whilst suggesting that total social returns could be conservatively estimated to be roughly double this – implying that each £1 spent would lead to a £1.40 contribution to GDP.[54] Space investments are riskier than general R&D investments, but offer potentially far higher rates of return.

[52] know.space (2022). *Returns and Benefits from Public Space Investments 2021*. Available at: https://www.gov.uk/government/publications/returns-and-benefits-from-public-space-investments-2021
[53] Technopolis, know.space, Cambridge Econometrics and Science-Metric (2022). *Impact evaluation of UK investment in ESA*. Available at: https://www.gov.uk/government/publications/impact-evaluation-of-uk-investment-in-esa
[54] Frontier Economics (2023). *Rate of Return to Investment in R&D*. Available at: https://www.frontier-economics.com/media/5774/rate-of-return.pdf

4 Why is government investment needed?

Government investments and interventions in the space sector play a critical role in **driving innovation, promoting scientific discovery**, and **supporting economic growth**. The development of space technologies and missions is **inherently risky** and requires **substantial upfront investment**. For this reason, private companies may find it hard to justify and sustain long-term investments. Whilst private actors are playing an increasing role in the space sector, public investment and support is crucial to realising these growing opportunities. Furthermore, as the UK's **critical national infrastructures** become increasingly dependent on space-based services over time[55], governments must provide a reliable source of funding and support to enable space activities. National and international government agencies (e.g. NASA, ESA, UK Space Agency) are instrumental in **coordinating** and **distributing** public funding, as well as in **promoting cooperation and knowledge exchange** across the space sector.

In this section, we will explore the multiple, interlinked **market failures**, which make government investment and interventions necessary for the development of space innovations. We also provide an overview of the strategic importance of the space sector in the UK's **regional development**, offering a boost for 'levelling up' objectives and developing local supply chains.

4.1 The free market will under-deliver

Market failures are when resources are poorly allocated, leading to too much or too little provision of a product or service. These can arise because of *hidden* costs or benefits, which economists define as **negative** or **positive externalities**. These are costs or benefits which accrue to those not paying for a product or services; for example, UK citizens suffer from other nations' carbon emissions, but can benefit from GPS without paying a penny.

The most common and notable **market failures in the space sector** are outlined in the subsequent pages.

4.1.1 High costs of space investments and lack of finance

The high upfront costs and technical challenges associated with space activities often deter private sector investment, resulting in underinvestment in space technologies. The level of risk varies significantly among different market segments in the space sector, with some being riskier due to **immature markets** and regulatory **uncertainty**, generating high market barriers and the need for substantial initial investments[56].

In addition, the **long lead time** for the realisation of benefits is a major factor in limiting private investments in the space sector. **Large upfront investments** are needed for space technologies to develop, which makes it difficult for private agents to sustain the necessary level of funding over a long period of time. For this reason, R&D in the space sector is still largely reliant on government

[55] OECD (2022). *Earth's Orbits at Risk: The Economics of Space Sustainability*. Available at: https://www.oecd-ilibrary.org/science-and-technology/earth-s-orbits-at-risk_16543990-en

[56] European Investment Bank (2018). *The future of the European Space Sector: How to leverage Europe's technological leadership and boost investments for space ventures*. Available at: https://www.eib.org/attachments/thematic/future_of_european_space_sector_summary_en.pdf

funding to **de-risk** development, although commercial R&D spending is experiencing an optimistic positive growth trend[57].

Public procurement also plays a crucial role in **strengthening the demand for specific space-related services**. As found in a recent survey involving Italian companies in the earth observation sector (OECD, 2022), most firms in the field (**73%**) recruit customers through public tenders[58]. This further underlines the fundamental role that governments play in fostering the national and regional space sectors.

4.1.2 Space as a 'public good'

Space generates **far-reaching societal impacts** that extend to the entire population, spanning from public service provision to the locational services on our phones. In many aspects, space-derived services are generally available, and use by one user does not impact use by another user.

Non-excludable

Space is a **shared resource,** with aspects accessible to all and cannot be easily controlled or partitioned. Many benefits of space activities are available to everyone, regardless of whether they have contributed to their development.

Global Navigation Satellite Systems (GNSS) open signals are freely available and can be accessed by anyone with a receiver. This has far-reaching impacts on society: GNSS is a key enabler for transportation and logistics, military operations and scientific research.

Non-rivalrous

The use of certain space technologies by one user **does not deplete the availability** of those technologies to others.

Earth Observation (EO) data plays a fundamental role for a wide range of applications, including weather forecasting, climate research and disaster management. Its non-rivalrous nature enables multiple users to make use of it without compromising its value or usefulness for others.

Given these unique characteristics, many space activities can be considered as a **public good** (or quasi-public good). Since the benefits of such space investments can be shared by all and it is impossible to exclude people from enjoying these benefits, the **incentives for private individuals or firms to invest in such activities may be limited.**

The **technical challenges, high development risk** and **high upfront costs** of space activities make public investment and regulation necessary. In the absence of government intervention, private sector investment would likely be limited to certain domains[59], curbing the realisation of a long list of potential society-wide benefits of space technologies. Numerous beneficial space applications yield returns solely in the **long-term**, and even these are **uncertain**. **Incentives for private actors to invest are therefore low**, and where there is private investment, there may be adverse incentives to restrict access to crucial facilities to recoup costs[60].

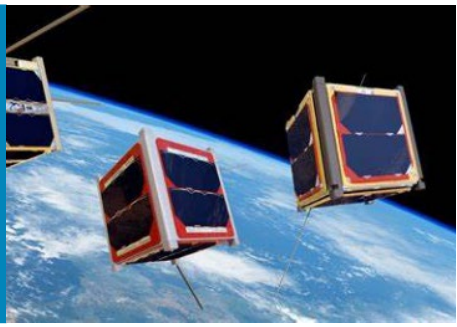
[57] Brukardt, R. et al. (2021). *R&D for space: Who is actually funding it?* Available at: https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/r-and-d-for-space-who-is-actually-funding-it
[58] OECD (2022). *Earth's Orbits at Risk: The Economics of Space Sustainability*. Available at: https://www.oecd-ilibrary.org/science-and-technology/earth-s-orbits-at-risk_16543990-en
[59] Oxera (2017). *Moonshots and market failures: the economics of space*. Available at: https://www.oxera.com/insights/agenda/articles/moonshots-and-market-failures-the-economics-of-space/
[60] Oxera (2017). *Moonshots and market failures: the economics of space*. Available at: https://www.oxera.com/insights/agenda/articles/moonshots-and-market-failures-the-economics-of-space/

4.1.3 Network failures and coordination issues

Shared **standards** in the development of space technologies provide companies with the opportunity to create products that can be sold to anyone using the same specifications. This results in greater compatibility and interoperability and ultimately greater innovation and efficiency in the space industry. However, establishing these guidelines requires government intervention and coordination to ensure that all stakeholders comply with standards.

A notable example is the **CubeSat standard**. CubeSats are built to standard dimensions, with one cube being 10cm X 10cm X 10cm. This is called 1U. CubeSats can be 1U, 2U, 3U etc. in size.

Design specifications are publicly available, as well as fundamental documents to ensure their compatibility (e.g. Acceptance Checklists (CAC), Interface and Fit-Check Procedures (CIFP) and specification drawings).



Source: CubeSat[61]
Image: University of Edinburgh

As states become increasingly dependent on space-based infrastructures, **international cooperation in developing guidelines and regulations** will be needed to preserve the space environment and ensure its accessibility for future generations. The Guidelines for the Long-term Sustainability of Outer Space Activities developed by the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS) is a notable example of this kind of coordination[62]. National space agencies and government departments are also fundamentally important in ensuring the efficient use of finite resources in space. An example is Ofcom's *Space Spectrum strategy*, aimed at regulating radio spectrum sharing for UK users[63].

4.1.4 Tragedy of the commons: space debris

Government intervention is needed to ensure coordination and avoid a '***tragedy of the commons***' situation in which a shared resource is depleted by individual users.

Space debris is a prime example of tragedy of the commons. Space debris refers to debris left by humans in space, such as remnants of old satellites, which have failed or been left in orbit once their mission is over. This debris poses a challenge to functioning satellites, with the potential for serious collisions, necessitating monitoring efforts and occasionally avoidance manoeuvres. The increasing amount of space debris in Earth's orbits will become a major societal challenge in the upcoming years, escalating the risk of collisions and damages to critical national infrastructures.

In 2021, there were **4,500** operational satellites, mostly commercial and concentrated in Low Earth Orbit (LEO) (OECD, 2022). Around **36,500** space debris objects larger than 10cm are orbiting earth at approximately **15,700 mph**, a sufficient speed to damage spacecrafts. (ESA, 2022; NASA, 2021)

Image: ESA. Space debris in Earth's orbits.

Whilst space debris poses a global threat, the incentives for individual satellite operators to take expensive measures to reduce their pollution of space (e.g. deorbiting satellites at end of life) are

[61] CubeSat (n.d.). *Developer Resources*. Available at: https://www.cubesat.org/cubesatinfo
[62] UN COPUOS (2020). *Guidelines for the Long-Term Sustainability of Outer Space Activities*. Available at: https://spacesecurityindex.org/wp-content/uploads/2020/11/IssueGuide_LTS.pdf
[63] Ofcom (2022). *Space spectrum strategy*. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0023/247181/statement-space-spectrum-strategy.pdf

insufficient if all other operators continue to pollute space. This creates a need for government intervention and international cooperation to coordinate (and regulate) actors and ensure that all satellite operators practice space sustainability. Moreover, given the enormous volume of debris already present in space, government intervention is necessary to lead efforts to clear this waste.

4.1.5 Appropriability

Given its non-excludable characteristics, **knowledge** generated through space innovations is difficult to confine to users willing to pay for it. This might discourage private actors from investing in innovation[64] (since they will only reap a fraction of the benefits). This inevitable issue can be contained through institutional action: the government can play a crucial role in offering intellectual property protection to companies investing in new space technologies, as well as financial support for the development of emerging innovations and promoting international standardisation and cooperation for the space sector.

In order to foster a culture of innovation, the government has a crucial role to play in creating a **regulatory environment** that encourages the incubation of original ideas and novel approaches to society-wide issues. Providing funding is just one aspect of this, which needs to be matched with a conductive framework that supports experimentation and risk taking in the pursuit of innovations. This requires a regulatory system that is both flexible and responsive to the evolving needs of innovative enterprises, and which provides clear guidelines and support for entrepreneurs and startups seeking to bring new ideas to market.

4.1.6 Knowledge barriers, access to skilled workers and STEM education

The highly specialised and technical nature of space-related jobs poses challenges for companies in **recruiting** skilled workers, particularly in engineering, scientific, and technical positions. Moreover, due to the limited availability of specialised workers, employees in these roles may find it easier to switch companies based on wage levels, leading to retention problems for the companies[65]. UK Space Agency's *Space Sector Skills Survey 2020*, recently found that the majority of businesses in the space sector (67%) faced one or more skills-related issues (recruitment difficulty, skill gaps, or staff retention problems), with the percentage increasing to 97% among businesses with 50 or more staff[66].

To address the skills gap in the long term, promoting STEM education at different levels of education is crucial. However, since the education system is a public good, it requires institutional policies and interventions to ensure equity and cannot rely solely on private investments. National governments can encourage students to pursue STEM degrees through scholarships, grants and inspirational programmes. In addition, given that women represent only 28% of the STEM workforce[67], targeted training and support can be devoted to closing the STEM gender gap over time.

In addition to the challenges faced by companies operating in the space sector, knowledge barriers can also affect organisations outside of the industry that could benefit from space-related technologies and innovations, but lack the specialised knowledge and infrastructure required to fully leverage these opportunities. For example, companies operating in transportation and

[64] Oxera (2017). *Moonshots and market failures: the economics of space*. Available at: https://www.oxera.com/insights/agenda/articles/moonshots-and-market-failures-the-economics-of-space/
[65] UK Space Agency (2021). *Space Sector Skills Survey 2020*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/964639/BMG_2081_UKSA_Space_Sector_Skills_Survey_2020_Report_V1.pdf
[66] UK Space Agency (2021). *Space Sector Skills Survey 2020*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/964639/BMG_2081_UKSA_Space_Sector_Skills_Survey_2020_Report_V1.pdf
[67] AAU (n.d.). *The STEM Gap: Women and Girls in Science, Technology, Engineering and Mathematics*. Available at: https://www.aauw.org/resources/research/the-stem-gap/

agriculture may have limited understanding of the potential applications of space-based data and technologies, and may not possess the technical expertise required to develop and implement these solutions. In such cases, knowledge barriers can act as a significant obstacle to collaboration and innovation, preventing these organisations from realising the full potential of space technologies in their respective fields.

4.1.7 Missing markets

The OECD (2022) describes the **emergence of markets** for space technologies as a *chicken and egg paradox*, in which private actors incur costly developments for emerging technologies only after the market is established, despite the necessity of those technologies for creating the market itself[68]. As a consequence, public funding of socially-desirable technologies is necessary to overcome the limitations of private investment.

The emerging **Active Debris Removal (ADR)** market, as analysed in a recent OECD (2022) report, has been generated through a combination of public and private initiatives, along with partnerships. This indicates that flexible and diverse collaborations between government and private actors are fundamental for promoting socially-relevant technologies and the emergence of space markets.

The emergence of the NewSpace ecosystem can be facilitated through public space policies. In the US, NASA's COTS program since 2006 has been an innovative example of successful public-private cooperation, which stimulated the growth of the private launch vehicles industry. Throughout the duration of this program, NASA was able to leverage $800 million, resulting in the development of two US medium-class launch vehicles and two automated cargo spacecrafts[69]. As the space industry progresses, there will be a need for the creation and development of new partnerships and cooperative procurement models[70].

In conclusion, the space sector presents a **variety of market failures**, generating **externalities**, appropriability problems and **high-risk investments**. These failures lead to **underinvestment** in socially-relevant technologies and an inability to fully capitalise on the benefits of space activities. **Government intervention, investment and coordination are therefore necessary to promote the development of the space sector to fully realise social and economic benefits.**

4.2 Positive displacement

4.2.1 Is public investment crowding-out private funding?

The concept of 'economic displacement' or 'crowding-out' refers to a decrease in economic activity in a certain area as a result of its expansion in another area[71]. In the context of public and private investments, an increase in government financial support and subsidies in a particular field could lead to a reduction in private, third and foreign investments[72]. This scenario highlights the potential

[68] OECD (2022). *Earth's Orbits at Risk: The Economics of Space Sustainability*. Available at: https://www.oecd-ilibrary.org/science-and-technology/earth-s-orbits-at-risk_16543990-en
[69] NASA (2014). *NASA Releases COTS Final Report*. Available at: https://www.nasa.gov/content/nasa-releases-cots-final-report
[70] ESPI (2017). *The Rise of Private Actors in the Space Sector*. Available at: https://www.espi.or.at/wp-content/uploads/2022/06/ESPI-report-The-rise-of-private-actors-Executive-Summary-1.pdf
[71] UK Government (2022). *The Green Book (2022)*. Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020#a3-distributional-appraisal
[72] know.space (2022). *Returns and Benefits from Public Space Investments 2021*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1069132/Returns_and_Benefits_from_Public_Space_Investments_2021.pdf

risks associated with overreliance on government funding in the space sector, as it could, in theory, lead to a reduction in private investments and ultimately hinder the sector's growth and innovation.

However, this hypothesis is supported by very limited evidence. According to the recent meta-analysis of studies on the returns to public space investment, anecdotal evidence of displaced economic activity has been **reported by only one recent study**[73]. There is little quantitative evidence to support this hypothesis, whilst there is more fruitful evidence suggesting the potential for 'crowding in' effects: private investment following public investment. The same meta-analysis found **evidence of 'crowding in' in 17 separate economic analyses** of public space investments.

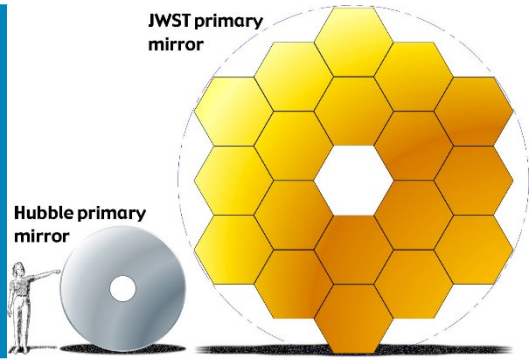
Indeed, if government investments are targeted at areas where there is market failure, then public investment should not displace private investment, since the incentives for private investment were never there. However, government investment may encourage private investors either through direct matched investments or by creating the right market conditions. For example, public funding may signal to private actors that a technology has commercial potential, leading to greater private investment[74] Following this logic, in the absence of UK government support, investment may simply go elsewhere, as countries compete for lucrative private investment.

Average cargo **launch costs** have **fallen by a factor of 20** since the '90s, to under **$3k per kg to LEO**

The space sector is changing rapidly with the **rise of 'NewSpace'**, as private firms invest heavily in areas which were previously the domain of government (enabled by technological developments lowering costs) and new opportunities are created. This does not the negate the need for government investment, but rather heightens the need for intervention to capitalise on the opportunities arising in the private sector and secure future benefits for the UK.

Some market failures are lessening, for example fixed costs for key activities are lower (e.g., launch costs falling by a factor of 10) and access to finance is arguably improving (e.g., Seraphim's dedicated space venture capital fund). Yet, many of the same key market failures continue to characterise the sector (barriers to entry etc.). This is particularly true of space exploration and 'big science' missions, satellites for public benefit (e.g. weather), collaborative R&D, long-term mission-focussed investments, creating the right environment (e.g. space sustainability and regulation) and addressing UK-specific needs (e.g. UK launch). Moreover, some market failures are increasing as we push scientific and technical frontiers further and further, creating a yet greater need for government intervention if we are to further our understanding of the universe.

As our space science knowledge base improves, science missions have a tendency to become bigger, more complicated and more expensive. For example, telescope mirrors need to be made larger and larger to improve their resolution and allow us to see further back in time. Whilst the Hubble telescope (launched 1990) has a 2.4m diameter mirror, the James Webb Space Telescope (launched 2021) has a 6.5m diameter mirror, allowing scientists to view much younger galaxies.



Source: RAND Europe and know.space (2022). SWOT Analysis of the UK Space Science Research Base
Image: NASA

[73] know.space (2022). *Returns and Benefits from Public Space Investments 2021*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1069132/Returns_and_Benefits_from_Public_Space_Investments_2021.pdf
[74] Medhurst, J., Marsden, J., Jugnauth, A., Peacock, M. and Lonsdale, J. (2014). *An Economic Analysis of Spillovers from Programmes of Technological Innovation Support*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/288110/bis-14-653-economic-analysis-of-spillovers-from-programmes-of-technological-innovation-support.pdf

4.3 Opportunities for all regions

The space sector has the potential to play a significant role in promoting **geographical equality** in the UK. As laid out in the recent *'Levelling Up'* strategy, opportunities for expertise development have historically not been equally available throughout the country, despite talent being equally dispersed[75]. The UK government is therefore focusing strongly on regional equality, investing substantially in infrastructural development and skills consolidation, as well as productivity and environmental sustainability. Although the space sector has been traditionally concentrated in London and the South East, recent government efforts to decentralise the sector are leading to a more even distribution of space-related activities across the country.

As envisioned in the *National Space Strategy* (NSS), the UK government is supporting the development of **regional space clusters**, favouring end-to-end skills building at the local and regional level[76]. There are currently 19 Clusters and Centres of Excellence across the British territory, as well as 7 proposed and developing spaceports[77]. UK Space Agency has recently announced a £6.5 million investment supporting 18 projects and space clusters[78], allowing regional expertise centres to develop around the emerging capabilities laid out in the NSS (e.g. EO, space debris tracking and removal, etc.).

These clusters not only aim to provide funding and opportunities for the development of local space industries, but also recognise the potential for skilled workers moving to the industry to improve regional productivity. By attracting domestic and foreign investments, these clusters encourage the development of local talent and create employment opportunities in the space industry. Additionally, they provide a platform for cooperation between businesses and research institutions, promoting knowledge sharing and driving the emergence of innovations and infrastructures across their respective regions.

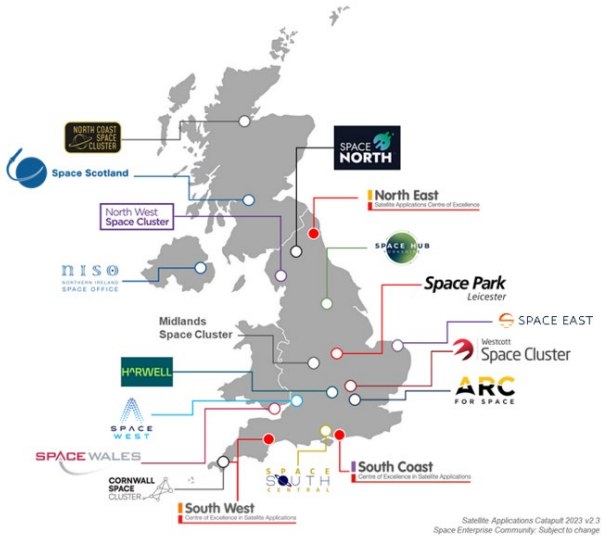


Image: Satellite Applications Catapult & know.space – Map of UK Space Clusters

The UK space sector is not only benefitting from the development of the Levelling Up strategy, but also contributing to it. It is helpful to consider public space investment in the context of the **six 'capitals'** that promote regional equality in the long term, identified by the UK government. The expansion of the UK's space industry has a positive impact on each of these factors, demonstrating its potential to drive regional equality and foster development across the country.

Physical capital

The UK's space sector is not only boosting the country's financial capital, but also contributing to the creation of physical capital by investing in **infrastructure development**. One such example is

[75] UK Government (2022). *Levelling Up the United Kingdom*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1095544/Executive_Summary.pdf
[76] UK Government (2021). *National Space Strategy*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1034313/national-space-strategy.pdf
[77] UK Space Agency (2022). *LaunchUK: the European leader in commercial small satellite launch*. Available at: https://www.gov.uk/government/publications/launchuk-brochure-the-uk-spaceflight-programme/launchuk-the-european-leader-in-commercial-small-satellite-launch
[78] UK Government (2023). *Levelling up boost for UK space sector with new growth funding*. Available at: https://www.gov.uk/government/news/levelling-up-boost-for-uk-space-sector-with-new-growth-funding

the leveraged effect of investing in launch vehicles, creating the conditions for private enterprises to secure investment and construct commercial spaceports. By 2030, the UK also aims to become a one-stop-shop for small satellite design, manufacturing, and launch. These infrastructural developments are just a few of the ways that the country is working to solidify its position in the global space industry.

Human capital

The space sector currently supports nearly **48,000 jobs** across the UK[79] and a recent evaluation of the UK's investments in ESA found that on average each **£1m of investment creates 9.8 person years of employment**[80]. The development of space sector capabilities can offer a substantial boost for the creation of **new high-skilled jobs** in areas which are currently underserved, and to **fill skills gaps**. This is due to the multiple adjacent markets offering space-related capabilities (e.g. data analysis, advanced and additive manufacturing, engineering).

Intangible capital

The development of disruptive space technologies has the potential to drive innovation across a wide range of industries. As underlined in the NSS, the UK aims to gain a leadership position in many emerging space sectors (e.g. in-orbit servicing, active debris removal, in-space manufacturing, space travel and habitation, space-based energy, in-situ space resource utilisation). Developing capabilities in these pioneering technologies is a sign of the UK's forward-looking attitude that will stimulate the creation of new **ideas** and **innovations**, and pave the way for future growth.

> ***Space-based solar power*** *(SBSB) has the potential to revolutionise the energy industry by providing a new renewable source of energy, reducing UK's reliance on fossil fuels and providing continuous power generation without requiring large land areas. A recent study estimates that for every £1 publicly spent, the development of a national SBSB program would support £1.8 (Frazer-Nash, 2021), generating economic growth and intangible value (e.g. new innovations and ideas) across the UK.*

Financial capital

The development of regional space capabilities offers invaluable economic growth opportunities for regions that have historically lagged behind, attracting foreign investment and encouraging the establishment of businesses in the space sector and adjacent markets. The development of **regional clusters** and the establishment of **international partnerships** for knowledge exchange is a good illustration of governmental efforts in this direction. A notable example is the UK-Australia Space Bridge, aimed at facilitating cross-country cooperation in space-related activities[81].

> *The UK's 19 space clusters play a crucial role in attracting foreign direct investment (FDI) and international partnerships, as demonstrated by* ***Mangata****'s recent investment in* ***Scotland****. The global telecommunications company invested £10.5 million and created 38 job opportunities, with plans to increase these figures to £84 million and 575 jobs in the long term. These connections are instrumental in the UK achieving its NSS objectives, attracting innovative companies from around the world.* ***Astroscale****, a leading company in on-orbit servicing and manufacturing, established its UK facility at* ***Harwell Campus*** *in 2017, employing 120 individuals and operating a satellite operations centre.*

[79] know.space (2023). *Size & Health of the UK Space Industry 2022*. Available at: https://www.gov.uk/government/publications/the-size-and-health-of-the-uk-space-industry-2022
[80] Technopolis, know.space, Cambridge Econometrics and Science-Metric (2022). *Impact evaluation of UK investment in ESA*. Available at: https://www.gov.uk/government/publications/impact-evaluation-of-uk-investment-in-esa
[81] UK Government (2022). *Successful first year for UK-Australia Space Bridge*. Available at: https://www.gov.uk/government/news/successful-first-year-for-uk-australia-space-bridge; Orbital Today (2021). *Mangata Networks Will Invest £10.5m Into Scotland's Space Sector*. Available at: https://orbitaltoday.com/2021/04/06/mangata-networks-will-invest-10-5m-into-scotlands-space-sector/

Social capital

By inspiring the next generation of scientists, engineers and entrepreneurs, and by promoting **STEM education** and public engagement, the UK space sector is contributing to generating social capital both on the national territory and abroad. Successful projects include educational opportunities (e.g. ESA Ambassadors) as well as placement programs (e.g. Space Placement in Industry – SPIN), and academic and professional networks promoting cross-sector cooperation (e.g. Space Academic Network – SPAN).

Institutional capital

Through the establishment of space clusters and the growing involvement of local investment agencies and Local Enterprise Partnerships (LEPs) in their development, the UK space sector is gradually strengthening **local governance capabilities** and **leadership** over time.

4.4 Strategic national capabilities

4.4.1 To collaborate or develop our own capabilities?

When considering public investments, economists use the term '**leakage**' to describe those benefits manifesting outside the domestic economy, i.e. the extent to which effects "leak out" of a target area[82]. In other words, some benefits generated through UK government intervention in the space sector may accrue outside of the UK, for example by increasing the number of skilled workers and companies moving abroad or causing knowledge spillovers (especially given the non-excludable characteristics of space).

However, governments can address this issue by pursuing strategies aimed at strengthening the domestic economy's ability to capture the benefits of these investments. This can include:

- Encouraging **local procurement** and the development of **local supply chains**, as well as supporting local workers and businesses, are among the most effective ways to limit leakage in any sector. While gaps at the local level may exist in any sector, the long-term objective of this strategy is to fill those gaps at the national level, enhancing the domestic space industry's capacity to retain economic benefits within the country. This objective is in line with the UK's Levelling Up strategy and the development of space clusters, which will be instrumental in reducing this benefits loss over time.

- Given the scale of space challenges, pooling resources through **international cooperation** through ESA is often the most efficient way for advancing research and technological development. However, this limits leakage by making it easier to trace sub-contractors through international organisations.

- Although a limited part of its benefits ends up being realised elsewhere, public investment in the space sector makes it possible for the UK to develop its own **strategic capabilities**, without having to rely on other countries for maintaining critical national infrastructures and local supply chains in the long term.

[82] UK Government (2022). *The Green Book (2022).* Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020

5 Case Studies of HMG investments

To provide real world evidence of the public investment benefit pathways highlighted in this report, this section presents a set of six **Case Studies** selected to cover a range of space technologies/capabilities, user groups and benefit types.

Each Case Study tracks a specific HM Government investment from funded activity outputs through to realised benefits for a wide range of UK beneficiaries. An infographic-style summary follows each Case Study report.

The list of Case Studies is as follows (with page numbers):

1. Levelling up and growing the UK launch industry

HMG investment and support

The LaunchUK Programme has invested **over £50m**[83] in recent years to develop UK launch capabilities, across the length and breadth of the UK, including:

- **£31.5m** to support the development of launch capabilities from Scotland:
  - **Sutherland:** supporting Orbex to launch from Sutherland Spaceport.
  - **The Shetland Islands:** supporting Lockheed Martin and ABL to launch from SaxaVord Spaceport.
  - **Reading:** supporting Lockheed Martin to create an orbital manoeuvring vehicle.
- **£10m** in grant funding to support Virgin Orbit launch from Spaceport **Cornwall.**
- **£1.3m** supporting other local airports to assess potential launch capabilities and markets.

The UK has also been world-leading in launch regulation and **in 2021 the Space Industry Regulations came into force** which formally enabled the Civil Aviation Authority (CAA) to receive licence applications for spaceflight activities.

Creating a 'one stop shop' for small satellites …

The **increasing commercialisation of space** (New Space) and the trend towards miniaturisation of payloads is creating a market opportunity in the field of small satellite launch. With its strong **existing space ecosystem** and well-placed geography for **in-demand orbital positions**, the UK aims to take advantage of this market opportunity and become the European leader in small satellite launch, offering a **'one-stop shop'** for satellite manufacture and launch. Launch is characterised by **high risks** and **high costs**, as well as scientific, technological and regulatory complexities. As such, government support is crucial to realising this opportunity.

Seven locations have considered their **potential for becoming spaceports** across the UK:

- **Spaceport Cornwall** at the Cornwall Airport Newquay - operational in 2022
- **SaxaVord Spaceport** in Lamba Ness, Unst (Shetland Islands) - operational from 2023
- **Sutherland Spaceport** in Sutherland (Scotland) - operational from 2024
- **Spaceport 1** in Scolpaig Farm, North Uist (Scotland) - planning permission granted in 2023
- **Prestwick Spaceport** in Prestwick, South Ayrshire (Scotland)
- **Spaceport Snowdonia** in Llanbedr, Gwynedd (Wales)
- **Spaceport Machrihanish** in Campbeltown, Argyll (Scotland)

On January 9th 2023, the **first ever attempt at launch from UK soil** was made by Virgin Orbit from Spaceport Cornwall, launching a rocket horizontally from a modified Boeing 747. The rocket made it to space, but did not reach the orbit required to successfully place its satellites into orbit due to an anomaly with the second stage engine.

Looking forwards, there are several companies expected to launch from the UK, including: Orbex (Sutherland), ABL Space Systems (SaxaVord), Rocket Factory Augsburg (SaxaVord), HyImpulse (SaxaVord), Skyrora (TBC - SaxaVord), and Gravitilab (TBC - Spaceport 1). A first vertical launch (with a suborbital flight) is expected in 2023, with orbital launches expected in 2024.

[83] UK Space Agency (2023). *LaunchUK brochure: the UK Spaceflight Programme*. Available at: https://www.gov.uk/government/publications/launchuk-brochure-the-uk-spaceflight-programme

… to realise significant benefits for UK beneficiaries

Market creation	Enabling a new UK commercial launch market	Government investment is helping the UK to secure early-mover advantage in small satellite launch. This market is growing rapidly, with an average of 1,700 satellite launches per year predicted worldwide in the period to 2030[84], representing a considerable potential customer base.
Growth	Catalytic growth effects across the space sector	Launch supports wider space industry growth, by providing a boost to complementary activities. For example: firms may choose to manufacture their satellites near their chosen launch site – subject to leveraging additional funding, Orbex is considering a future state-of-the-art production facility in Scotland that could employ around 400 people.[85] Government funding is already supporting capabilities development in UK manufacturing. For example, grant funding has enabled MOOG to produce an Orbital Manoeuvring Vehicle (OMV) in Reading, as part of the spaceflight programme. The OMV will be able to deploy up to 6 satellites in LEO, launching them into custom orbits.
Industry benefits	Convenient & flexible launch offering for UK firms	Currently UK firms transport their satellites abroad well in advance of their expected launch date. A UK launch offering could enable faster turnaround and flexibility, especially important for certain scientific purposes where components may start to degrade, e.g. bio-medical research.
Strategic national capability	Sovereign capabilities: independent access to space	UK launch would provide the government with full end-to-end satellite capabilities. (i.e. the UK can design, build, test, launch, operate and use its own satellites). This is important for civil and military applications – with increased Ministry of Defence activity, national security applications could help to safeguard sensitive data and equipment.
Levelling up	Job creation, GVA & leveraged investment across the UK	The benefits of UK launch are expected to be concentrated in remote, often economically-deprived areas of the UK. In particular, the north of Scotland is well-placed to send satellites into polar orbit and sun synchronous orbit. Launch activities are expected to bring wider economic benefits, as space firms are attracted to the region, as well as tourists, generating ripple effects through the local economy. For example, a space cluster developed around Sutherland Spaceport could support up to 740 jobs and £56m in GVA for the Highlands and Islands region by 2030[86]. Already, Orbex is attracting private investment to the region, closing a £40.3m funding round in 2022[87]. It is hoped these efforts can help stop depopulation in remote areas.

[84] Euroconsult (2021). *Satellites to be Built & Launched*. Available at: https://www.euroconsult-ec.com/press-release/new-satellite-market-forecast-anticipates-1700-satellites-to-be-launched-on-average-per-year-by-2030-as-new-entrants-and-incumbents-increase-their-investment-in-space/

[85] Orbex (2022). *The countdown to launch has begun*. Available at: https://orbex.space/news/the-countdown-to-launch-has-begun

[86] Jacobs, Caithness Chamber of Commerce and UpNorth! Community Trust (2021). *North Highland and Moray Space Cluster Strategy*. Available at: https://www.focusnorth.scot/space-cluster/

[87] Orbex (2022). *The countdown to launch has begun*. Available at: https://orbex.space/news/the-countdown-to-launch-has-begun

Soft power	Prestige, influence on industry standards & space sustainability	Launch provides a highly visible example of the UK's status as a spacefaring nation, bringing prestige and visibility to the sector and the country more-widely. There is an opportunity for the UK to demonstrate leadership in space sustainability, with companies such as Skyrora and Orbex already leading the way. Skyrora are developing Ecosene, a kerosene fuel derived from plastic waste, which releases 70% less CO_2 than standard methods of fuel production[88]. Meanwhile Sutherland Spaceport aims to be carbon neutral, with a reusable Orbex rocket and their own eco-fuel, BioLPG, a propane made from renewable feedstocks[89]. UK launch also gives the UK an opportunity to pave the way on industry standards, for example, the Space Industry Act 2018, sets insurance requirements and limits launch operator liability.

[88] Skyrora (n.d.) *Ecosene*. Available at: https://www.skyrora.com/ecosene/
[89] Orbex (n.d.) *Building the world's most environmentally friendly space rocket.* Available at: https://orbex.space/launch-vehicle/environmental

LEVELLING UP & GROWING THE UK LAUNCH INDUSTRY

Over £50m HMG investment is generating benefits across the length and breadth of the UK

know.space

HMG's role in supporting launch

Overcoming key market failures:
high-risk, high-cost market, with scientific, technological and regulatory complexities

Goal: **European leadership in small satellite launch by 2030**

World-leading launch regulation:
Space Industry Act 2018

Capabilities in development

First UK launch in 2023
Virgin Orbit rocket launched horizontally but did not reach orbit

Plans to attempt the **first suborbital vertical UK launch in 2023**

7 potential spaceports across the UK:

1. Spaceport Cornwall
2. SaxaVord Spaceport
3. Sutherland Spaceport
4. Prestwick Spaceport
5. Spaceport Snowdonia
6. Spaceport 1
7. Spaceport Machrihanish

Benefits to the UK

UK commercial launch market creation

Rapidly growing market: **1,700 satellite launches globally** per year predicted worldwide in the period to 2030

Levelling up: job creation, GVA and leveraged investment in remote locations

e.g. A space cluster developed around Sutherland Spaceport could support up to **740 jobs** and **£56m in GVA** by 2030

Strategic national capability: sovereign access to space

End-to-end satellite capabilities (UK can design, build, test, launch, operate and use its own satellites)

Soft power: Prestige & influence on industry standards

UK leadership in regulation and space sustainability

Convenient flexible launch for UK industry

Faster turnaround crucial to some scientific applications

Catalytic growth effects across the sector

Potential future Orbex production facility could provide up to **400 jobs**

Department for Science, Innovation & Technology

2. Ensuring resilience of Critical National Infrastructures

HMG investment and support

The UK government has invested over **£80 million** in space weather forecasting projects and missions (e.g. Vigil, SWIMMR, SMILE, MOSWOC funding).

Protecting Critical National Infrastructures from extreme Space Weather events …

Space weather is a result of how the Sun behaves, the characteristics of Earth's magnetic field and atmosphere, and our location within the solar system[90]. Similar to how Earth experiences different types of weather such as rain and wind, space weather can manifest itself through events like solar flares[91] and coronal mass ejections[92] on the Sun's surface and into the solar atmosphere. When magnetic fields, radiation, particles, and matter from the Sun interact with Earth's magnetic field and upper atmosphere, disruptions to communication systems, power grids, and GPS can happen.

Extreme space weather events (also called *solar superstorms*) occur around every 200 years. Humanity experienced one in 1856, called the "*Carrington event*", along with a series of near misses causing major technological damage (e.g. the 1989 collapse of part of the Canadian Electricity Grid)[93]. By closely monitoring and predicting space weather, we can take steps to protect ourselves and our Critical National Infrastructures (CNI) from these impacts.

What **CNIs** can be impacted by space weather events? And how?[94]

EMERGENCY SERVICES

Failure of emergency and breakdown communication systems (e.g. eCall, bCall), making it impossible to provide location information to rescuers. These impacts are potentially amplified by other disruptions generating social

ENERGY

Geomagnetically induced currents (GICs) caused by space weather can damage transformers flowing through power grids, leading to power outages and expensive repairs, as well as property damages and casualties.

RAILWAYS, ROADS AND AVIATION

Radio communication failures, loss of navigation systems and railway signal due to GNSS failure. Temporary blockades of locomotives power from collapse of electricity grids. Flight cancellations and digital avionic systems failure.

SPACE

Anomalous satellite behaviours due to increased radiation, altitude losses and drag force increase in LEO, premature de-orbiting and orbital decay. In February 2022, SpaceX lost around 40 satellites due to a solar storm.

[90] Met Office (n.d.). *What is space weather?* Available at: https://www.metoffice.gov.uk/weather/learn-about/space-weather/what-is-space-weather

[91] Sudden and intense burst of energy from the Sun's surface, producing radiation and high-energy particles that can impact Earth's upper atmosphere.

[92] Large-scale eruptions of plasma and magnetic field from the Sun's outer atmosphere (corona).

[93] Cannon, P. et al. (2013). *Extreme space weather: impacts on engineered systems and infrastructure*. Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/swe.20032

[94] Sources for this graphic text are: Wattles, J. (2022). *SpaceX will lose up to 40 satellites it just launched due to a solar storm*. Available at: https://edition.cnn.com/2022/02/09/tech/spacex-starlink-solar-storm-satellites-scn/index.html; Abt Associates (2017). *Social and Economic impacts of space weather in the United States*. Available at: https://www.weather.gov/media/news/SpaceWeatherEconomicImpactsReportOct-2017.pdf; London Economics (2017). *The economic impact on the UK of a disruption to GNSS*. Available at: https://www.gov.uk/government/publications/the-economic-impact-on-the-uk-of-a-disruption-to-gnss; Oughton et al. (2017). *Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure*. Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016SW001491

Over the past decade, the UK has been on the forefront of space weather forecasting and research. The **Met Office Space Weather Operations Centre (MOSWOC)** is among the three global centres dedicated to predicting space weather. Since its establishment in 2013, it offers 24/7 space weather forecasts and alerts to a variety of entities, including the government, first responders, providers of critical national infrastructure, and the public[95].

The UK is playing a key role in ESA's **Vigil mission** (previously known as *Lagrange* or *L5*). Vigil will closely monitor the sun, from angles not possible from Earth, enabling the acquisition of near real-time data on potentially dangerous solar activity. This will increase the lead time in which measures to mitigate space weather's impact on Earth can be taken[96]. The UK contributed **£60 million** (€70 million) towards the mission's overall funding threshold of £75 million (€85 million), assuming a strong leadership position[97]. Through ESA, the UK is also supporting the **SMILE mission**: scheduled for launch in 2025, it will study the Earth's magnetosphere and contribute to our understanding of how it interacts with the solar wind[98].

In addition, to further explore the impacts, UKRI recently allocated **£20 million** to the **SWIMMR** (Space Weather Instrumentation, Measurement, Modelling and Risk) project, which aims to advance UK capabilities in space weather forecasting and monitoring. By financing a mix of interdisciplinary research projects, SWIMMR will help the UK understand the impacts of space weather on lower altitudes, including impacts on aviation and power grids, as well as space hardware and satellites[99].

… to realise significant benefits for UK beneficiaries

Avoided GDP cost	£13 billion reduction in GDP costs through forecasting	A space weather event with a 1-in-100-year likelihood could potentially cost the UK economy £15.9 billion without mitigation. Current forecasting capabilities have reduced this figure to £2.9 billion, resulting in savings of approximately £13 billion. Further advancements in forecasting could potentially reduce these costs even further, potentially lowering them to as little as £0.9 billion[100].
Avoided GNSS loss	A 5-day GNSS loss would cause a £5.2 billion impact	Given the wide reliance of all CNIs on GNSS-reliant services, a 5-day loss of GNSS would cause a £5.2 billion economic impact, affecting emergency, road and maritime applications particularly[101]. Preventive measures and mitigations can reduce these costs, avoiding society-wide disruptions and unrest.
Avoided supply chain disruption	Daily cost of £20 billion for an extreme event	A recent study found that a Carrington-level event in North America would generate a daily £20 billion impact ($25 million) considering domestic and international trade and supply chains[102].

[95] Met Office (n.d.). *The Met Office and space weather*. Available at: https://www.metoffice.gov.uk/weather/learn-about/space-weather/met-office-role
[96] ESA (2022). *Introducing: ESA Vigil*. Available at: https://www.esa.int/Space_Safety/Vigil
[97] UK Space Agency (2022). *Impact evaluation of UK investments in ESA*. Available at: https://www.gov.uk/government/publications/impact-evaluation-of-uk-investment-in-esa
[98] ESA (n.d.). Smile factsheet. Available at: https://www.esa.int/Science_Exploration/Space_Science/Smile_factsheet
[99] RAL Space (n.d.). *SWIMMR (Space Weather Instrumentation, Measurement, Modelling and Risk)*. Available at: https://www.ralspace.stfc.ac.uk/Pages/SWIMMR.aspx
[100] Oughton, E. et al. (2019). *A Risk Assessment Framework for the Socioeconomic Impacts of Electricity Transmission Infrastructure Failure Due to Space Weather: An Application to the United Kingdom*. Available at: https://onlinelibrary.wiley.com/doi/full/10.1111/risa.13229
[101] London Economics (2017). *The economic impact on the UK of a disruption to GNSS*. Available at: https://www.gov.uk/government/publications/the-economic-impact-on-the-uk-of-a-disruption-to-gnss
[102] Schulte in den Bäumen (2014). *How severe space weather can disrupt global supply chains*. Available at: https://nhess.copernicus.org/articles/14/2749/2014/

Enhanced power grids and GNSS resilience	Improved forecasting can enhance mitigation measures	By increasing the lead time that decision-makers have to react to a space weather event before it hits the Earth, mitigation measures can be put in place to avoid massive disruptions. This would reduce the risk of blackouts and days-long GNSS loss.

ENSURING RESILIENCE OF CRITICAL NATIONAL INFRASTRUCTURES

£80m HMG investment in space weather forecasting projects & missions

know.space

Importance of space weather

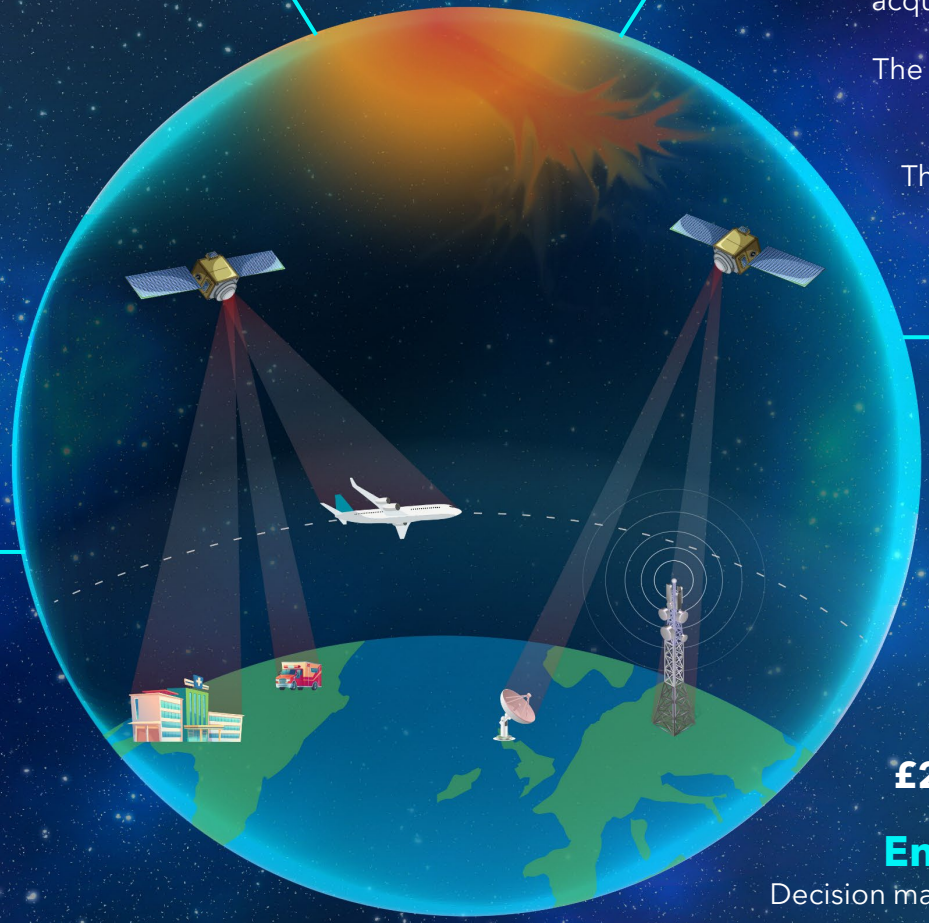
Space weather is a result of how the Sun behaves, the Earth's magnetic field and atmosphere, and our location within the solar system

When magnetic fields, radiation, particles, and matter from the Sun interact with Earth's magnetic field and upper atmosphere, **disruptions to communication systems, power grids, GNSS, and much more** can happen

Extreme space weather events happen about **once every 200 years**

Forecasting allows mitigation

By closely **monitoring and predicting** space weather, we can take steps to **protect** ourselves and our **Critical National Infrastructures (CNI)**



UK leadership in space weather forecasting

Key role in **ESA's Vigil mission** (£60m) to monitor the sun, acquiring near real-time data on potentially dangerous solar activity

The **Met Office Space Weather Operations Centre** is 1 of 3 global centres dedicated to predicting space weather

The **SWIMMR** (Space Weather Instrumentation, Measurement, Modelling and Risk) project (£20m)which aims to advance UK capabilities in space weather forecasting and monitoring

Benefits to the UK

Avoided GDP economic loss

£13bn reduction in costs of a 1-in-100-year space weather event as a result of government investment

Avoided GNSS loss

A 5-day disruption to GNSS has been predicted to cause a **£5.2bn of economic loss**

Avoided supply chain disruption

£20bn cost per day of disruption for an extreme event

Enhanced power grids and GNSS resilience

Decision makers have more time to react to space weather events, allowing mitigation measures to be put in place to avoid severe disruption

Department for Science, Innovation & Technology

3. Enhancing connectivity across the UK

HMG investment and support

$500m equity investment in **OneWeb** (November 2020)[103]

Securing a UK leader in global satellite communications …

OneWeb is a global communications network powered from space, headquartered in London. Connected to its constellation of 648 Low Earth Orbit (LEO) satellites and network of global gateway stations, user terminals will provide high-speed, high-bandwidth, and low-latency connectivity to digitally enable governments, businesses, and communities all around the world.

OneWeb is a UK technology and space industry success story. Following its 19th launch in May 2023, the company has 634 satellites in orbit (85% of all UK registered satellites), more than the satellites needed to initiate global services later in 2023.[104]

This achievement is more significant considering the exceptional circumstances of the COVID pandemic (which forced the company to apply for Chapter 11 bankruptcy protection) and Russia's invasion of Ukraine (which stalled OneWeb's launch programme, forcing a re-plan of alternative satellite launch plans).

In November 2020, the UK Government (HMG) led a successful bid to acquire OneWeb, making a significant strategic investment of $500 million (~£400 million) alongside $500 million from Bharti Global. This investment allowed the company to exit Chapter 11 and restart commercial operations, safeguarding UK jobs and securing the future of the company. Subsequent investments by Bharti Global, Eutelsat, SoftBank, Hughes, and Hanwha, brought total funding to $2.7 billion of equity investment without debt to complete its commercial transformation.[105]

In July 2022, OneWeb and Eutelsat announced their intention to merge, forming a single large powerful player, with combined revenues of €1.2 billion, to succeed in the highly-competitive global connectivity market.[106] As a shareholder, the UK Government has an important stake in the future of the business, whilst realising a range of benefits for the UK economy and our society.

… to realise significant benefits for UK beneficiaries

Jobs	~400 UK jobs secured	OneWeb currently employs ~560 people globally, of whom **~400 staff are based in the UK**. These are predominantly **highly-skilled high-value jobs** in **Science, Technology, Engineering and Mathematics (STEM)** roles that support and contribute to the UK's skills agenda.
GVA	Contribution to UK GDP	The expanding UK activities of OneWeb, its suppliers, and its distribution partners could generate **significant Gross Value-Added** over the coming years, aiding COVID-19 recovery and contributing to all Cabinet Office Social Value themes at scale.

[103] Dept. for Business, Energy & Industrial Strategy (2020). *UK government to acquire cutting-edge satellite network.* Press Release. Available at: https://www.gov.uk/government/news/uk-government-to-acquire-cutting-edge-satellite-network
[104] OneWeb (2023). *OneWeb confirms successful deployment of 16 satellites including next-generation JoeySat.* Press Release. Available at: https://oneweb.net/resources/oneweb-confirms-successful-deployment-16-satellites-including-next-generation-joeysat
[105] OneWeb 2021). *OneWeb fully-funded with new $500m investment. Secures $2.4bn in total funding.* Press Release. Available at: https://oneweb.net/resources/oneweb-fully-funded-new-500m-investment-secures-24bn-total-funding
[106] Dept. for Business, Energy & Industrial Strategy (2022). *OneWeb merger with Eutelsat.* Available at: https://www.gov.uk/government/news/oneweb-merger-with-eutelsat

Leveraged investment	$2.2bn of leveraged private investment	HMG's $500m investment attracted subsequent investment of **$2.2 billion from international private investors** (Bharti Global, Eutelsat, SoftBank, Hughes, and Hanwha).
Strategic alignment	Supporting delivery of national strategies	OneWeb's operations and capabilities directly contribute to the key goals and pillars of the ***National Space Strategy***, whilst also contributing over time to the ***Defence Space Strategy*** and ***Capability Management Plan***.
Industry growth	Catalytic growth of UK industry	The Government's **strong signal of support** for the UK space industry and 'pull power' of a **global champion** is catalysing growth across the UK space industry. 94% of all CAA space licenses issued to date have been for OneWeb, and 85% of UK-registered satellites with the UN are OneWeb satellites.
Export revenues	Selling to the world from the UK	By nature, global satellite services provision is **highly export-intensive**, with revenues flowing back to the UK for re-investment and wealth generation. With a **forecasted global LEO market value of £14bn by 2028**, a 1% growth in LEO market share would generate £140m per annum in revenue.
Expanded UK network connectivity	Cost-effective network deployment	**Carrier** In a recent test, and UK first, BT Group **successfully transmitted 4G data using a OneWeb satellite** in Low Earth Orbit to connect an EE mast to the mobile core network (instead of a traditional line-of-sight microwave or fibre connection). In April 2023 OneWeb was selected, in partnership with BT and Clarus, to deliver remote community broadband in trials for the HMG's *Very Hard to Reach Premises* connectivity programme.[107] Such technology will enable BT Group to deploy mobile coverage to **harder-to-reach areas** in a **faster and more cost-effective** manner, and is expected to play an important part in its ambition to enable digital solutions anywhere in the UK by 2028.
	Fast reliable connectivity for rural, remote, and temporary communities	**Citizens** OneWeb reaches geographies and sectors where it is either impractical or economically unviable to deploy fibre. Expanding **fast and reliable 4G and 5G connectivity to ultra-remote locations** will create **equal opportunity** in support of HMG's *Levelling Up* initiatives by bringing work-from-home **job opportunities** and access to a wider range of **education and wellbeing** resources, as well as help **transform the way numerous industries operate** – particularly those with a significant remote footprint such as maritime or agriculture. Across the country, it can also connect **emergency responders**, **disaster recovery units** and other **temporary deployments** such as festivals, events, or construction sites.
Public & Private users	Supporting the UK Government and our Armed Forces	**Government** OneWeb will provide **connectivity services** at home and abroad, supporting digital enablement, intel gathering, crisis support, search and rescue (SAR), and humanitarian aid and disaster relief (HADR) and **military**

[107] OneWeb (2023). *OneWeb to Deliver Remote Community Broadband in Trials for UK Government Connectivity Programme*. Press Release. Available at: https://oneweb.net/resources/oneweb-deliver-remote-community-broadband-trials-uk-government-connectivity-programme

		operations across land, air, and sea domains. OneWeb's capabilities can complement the **resilience of the UK's military communications**, and also develop disruptive innovations to support **emergency services communications**.
	Enabling businesses in various domains	**Enterprise** OneWeb will provide community connectivity for **remote and rural areas** of the UK (and overseas territories), support **disaster response**, serve as a **terrestrial backhaul service** adding capacity to existing LTE/4G/5G systems, and a **redundancy back-up** for fibre to optimise costs of Project Gigabit. **Maritime** OneWeb are already trialling **digital remote operations solutions** for UK North Sea oil rig operators, providing real-time low latency connectivity from land to sea. This connection will also improve **crew wellbeing and safety**. With the launch of their Global Mobility Software, OneWeb will serve merchant, cruise, ferry, yacht and fishing **vessels**. **Aviation** OneWeb will deliver a **broadband-in-the-sky** experience and IoT services, evolving to enhanced **flight efficiency** and **maintenance operations** through data-driven analytics. This is enabled by innovative Adapted Global Mobility Software and an Electronically Steerable Antenna.
National Resilience	Strengthening Critical National Infrastructure (CNI) at times of disruption	Recent events in Ukraine, Turkey and, indeed, the Shetland Islands remind the UK and its overseas territories of the **vulnerability of terrestrial connectivity** and undersea cables. OneWeb strengthens the UK's CNI backbone and provides **instant resilience** for priority communication and data flows, where disruption can have significant financial, reputational, and societal impact.
Soft power	Golden influence	Through the merger with Eutelsat, the UK government will be at the centre of the combined group's global LEO business – enhancing the UK's diplomatic '**soft power'**, developing a lead role in the governance and use of technology deployments. The UK Government retains its **special share** and its **exclusive rights** over OneWeb – national security controls over certain operations, and preferential rights over domestic industrial opportunities, including future launch capabilities in the UK. OneWeb's capabilities give the UK substantial **strategic leverage** with 'Five-Eyes', the EU and NATO allies.
Academia	Nurturing the next generation of world-leading space talent	OneWeb is forging strong links with UK universities, innovation hubs and schools to help inspire the **next generation** to take-up careers in the space sector, particularly in STEM.

ENHANCING CONNECTIVITY ACROSS THE UK

£400m HMG equity investment in OneWeb

know.space

Global connectivity champions

OneWeb is a global communications network powered from space, headquartered in London, whose constellation of **Low Earth Orbit (LEO) satellites** will provide high-speed connectivity worldwide

634 satellites in orbit, the **2nd largest constellation in the world**, with plans to initiate global services in 2023

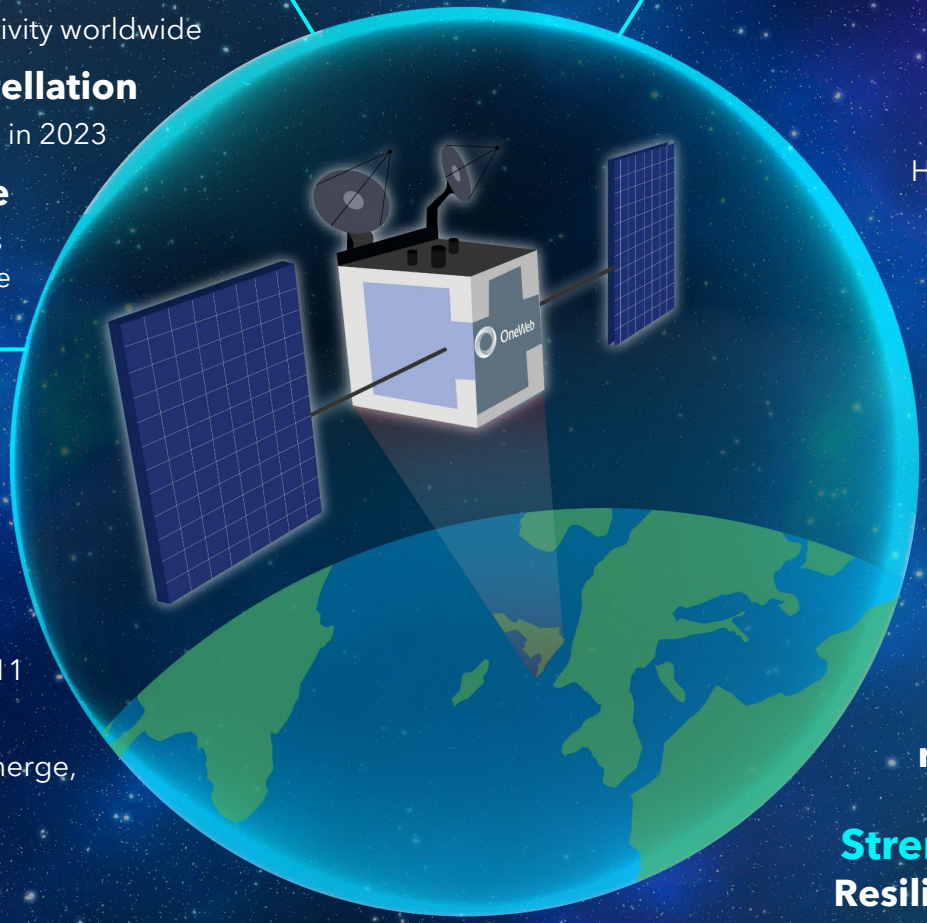
In partnership with BT, OneWeb will deliver **remote community broadband** in trials for the HMG's Very Hard to Reach Premises connectivity programme

HMG's investment in OneWeb

In March 2020, OneWeb was forced to file for **Chapter 11** bankruptcy protection, as a result of complications from the COVID pandemic

In November 2020, the UK Government led a bid to acquire OneWeb, making a **strategic investment of $500m** (£400m) alongside $500m from Bharti Global. OneWeb exited Chapter 11 and **resumed commercial operations**

In 2022, OneWeb and Eutelsat announced plans to merge, creating a **single large powerful industry player**, with combined revenues of **€1.2bn**



Department for Science, Innovation & Technology

Benefits to the UK

~400 UK jobs secured

Highly-skilled, high-value STEM roles that support and contribute to the UK's skills agenda

$2.2bn in leveraged investment

HMG's investment attracted **foreign private investment** from Bharti Global, Eutelsat, SoftBank, Hughes, and Hanwha

Supporting national strategies

Supporting delivery of the **National Space Strategy** and **Defence Space Strategy**

Export revenue potential

The **global LEO market** is forecasted to be worth **£14bn by 2028**

Expanded UK network connectivity

Expanding fast and reliable broadband connectivity to **ultra-remote communities**, supporting **Levelling Up** goals

Strengthening Critical National Infrastructure

Resilience for priority communications, where disruption can have financial, reputational and societal impact

4. Routing Emergency Services to citizens in need

HMG investment and support

Over **nearly 20 years**, the government invested in the EU's **Galileo** satellite navigation system, a European alternative to the US' GPS (Global Positioning Service), whilst providing crucial support to **UK organisations to facilitate the uptake of satellite-enabled Positioning, Navigation and Timing** across the full range of UK industrial sectors.

Key investments include:

- **£1.3bn**[108] towards the EU Galileo and EGNOS[109] programme budget (infrastructure, operations, provision of services)
- **30.4m** towards the ESA GNSS Evolution Programme (EGEP) (development of technologies associated with GNSS)
- **£26.1m** towards ESA ARTES 20 Integrated Applications Promotion (IAP) (developing pilot applications)
- **£9.2m** on EU/GSA H2020 (developing applications and market uptake)
- **£12.6m** in Innovate UK funding to support satellite navigation and PNT

Galileo and GPS are part of **GNSS** (Global Navigation Satellite Systems) and work together to provide the navigation and positioning services citizens rely on (the use of these services is freely available to all[110]). UK government investment helped to pay for the underlying infrastructure, whilst encouraging varied applications of the technology within the UK.

Enabling more efficient routing of emergency services …

Our **emergency services rely on satellite navigation and positioning services every day** to deliver lifesaving work. GNSS is utilised at **every stage of operations** by ambulance crews, the police, the fire brigade and the coastguard to respond quickly and efficiently to emergency situations. The UK's investments (outlined above) have **increased the availability and accuracy** of available satellite signals, and **increased the ubiquity** of location-enabled devices available to process those signals to **locate emergencies more accurately and quickly**.

Imagine you are at the scene of a serious roadside accident where someone requires urgent medical care, and you call 999. Your call is answered by the emergency service response centre.

With GNSS: your smartphone is equipped with Advanced Mobile Location, which uses GNSS in combination with other sensors to estimate where you are with **accuracy within the tens of metres**. Your smartphone has **automatically transmitted your location** to the emergency response centre and your call handler simply asks you to confirm your location.

Emergency service vehicles are fitted with GNSS devices, which mean that emergency response centres automatically **know where every emergency vehicle is**. The most appropriately placed ambulance is quickly sent to the scene of the accident, taking the **most efficient route** there. The **ambulance arrives quickly** to treat the patient.

Without GNSS: your phone only has access to your network-based location from your mobile network operator. This is **not sufficient to identify your location** because the cell radius is too

[108] London Economics (2017). *The economic impact on the UK of a disruption to GNSS*. Available at: https://londoneconomics.co.uk/wp-content/uploads/2017/10/LE-IUK-Economic-impact-to-UK-of-a-disruption-to-GNSS-FULLredacted-PUBLISH-S2C190517.pdf
[109] European Geostationary Navigation Overlay Service (EGNOS).
[110] The most robust Galileo signals are reserved for government-authorised users (e.g. military, safety, security agencies).

large (accurate to a few kilometres only)[111]. Your call handler asks you where you are, and you struggle to describe your location. You waste precious minutes discussing where you are.

On the ground emergency responders radio-in their location to the large team of dispatchers at the emergency response centre, who plot the locations of emergency vehicles on detailed maps. The closest ambulance is estimated and sent to the scene. A sub-optimal choice of ambulance is made, and the ambulance arrives later than another one nearby might have. The patient's condition has deteriorated in this time.

The key impact of GNSS to the emergency services comes from the **time savings generated**, which in turn generates **considerable economic and social benefits.**

… to realise significant benefits for UK beneficiaries

GVA	Total economic benefit from lives saved & avoided costs	The total value of GNSS to the UK is estimated to be **£13.6bn**[112] **per annum**, of which **42.6% (£5,805m)** comes from the value of GNSS to the emergency services (police, ambulance, fire brigade and coastguard)
Avoided human costs	Lives saved, reduced severity of injuries and reduced pain	GNSS enables emergency vehicles to arrive more quickly at the scene of an accident, saving lives, limiting the potential severity of injuries and reducing the amount of time those injured spend in pain. It is estimated that **each minute of additional response time has an associated cost of £990**,[113] mostly reflecting the value of potential lives lost.
Efficient public services	Time and cost savings enabled by an improved information base	The use of GNSS reduces the time spent by call handlers and emergency response teams in locating emergencies and finding the most appropriately placed response vehicles to send out. GNSS allows for more efficient vehicle servicing, since servicing schedules can be tailored to the exact movements of a vehicle (e.g. the distance travelled at each speed etc.). Security and surveillance robots also rely on GNSS to traverse a space. Whilst, their use is in its infancy, it is estimated that these benefits are already worth **£5.7m per year**.
Increased public safety	Greater awareness of police location & efficient use of police time	Police resources can be more efficiently managed when the exact location of police officers and cars are known. This allows resources to be spread out effectively when police are on patrol. GNSS is also used in offender tracking, where those who might otherwise have been in prison are tracked (primarily using ankle tags). This allows more freedom for offenders, for example allowing them to work, whilst saving money on prisons. These benefits are estimated at **£31.5m**.[114]

[111] European Commission (2017). *Pilot project on the design, implementation and execution of the transfer of GNSS data during an E112 call to the PSAP*. Available at: https://ec.europa.eu/docsroom/documents/24781/attachments/3/translations/en/renditions/pdf
[112] Based on unpublished analysis by London Economics.
[113] Based on unpublished analysis by London Economics.
[114] Based on unpublished analysis by London Economics.

ROUTING EMERGENCY SERVICES TO CITIZENS IN NEED

£1.4bn HMG investment in Galileo and EGNOS, and funds to facilitate UK uptake of GNSS

know.space

Locating emergency callers

Our emergency services **rely on satellite positioning and navigation** services every day to deliver lifesaving work

- Your smartphone estimates your location within tens of metres
- Your location is automatically transmitted to the emergency response centre
- The best placed emergency vehicle is located and sent to your location
- The emergency vehicle takes the most efficient route
- Emergency services arrive more quickly, a potentially life-saving time saving

Benefits to the UK

GVA benefit from lives saved and costs avoided

GNSS worth **£5.8bn per annum** to the emergency services, accounting for **>40%** of the total estimated value of GNSS to the UK

Lives saved, reduced injury severity and reduced pain

GNSS allows emergency vehicles to arrive quickly at the location of an incident – additional response time costs **£990 per minute**

Efficient public services

Time savings for call handlers & emergency response teams,
More efficient vehicle servicing,
Potential for security and surveillance robotics:
Benefits already worth **£5.7m per year**

Increased public safety

Greater awareness of police location and efficient use of police time
£31.5m in benefit from offender GPS trackers, saving police resources and allowing more flexibility, e.g. allowing offenders to work

Department for Science, Innovation & Technology

5. Commercialising revolutionary new UK technologies

HMG investment and support

The UK government invested **£64.7m** in **Reaction Engines** (2015-2021)[115]. It is estimated that the 2015 UK Space Agency investment alone (£50m) has resulted in a **gross economic impact of £379.3 million**[116].

Commercialising and driving adoption of revolutionary new UK technologies …[117]

Reaction Engines is a British company that specialises in developing advanced propulsion systems for space launch vehicles and hypersonic aircraft. One of the company's key achievements is the development of SABRE (Synergetic Air Breathing Rocket Engine) and its associated technological breakthroughs in thermal management. This technology is capable of propelling an aircraft from a standstill to 5-times the speed of sound within the Earth's atmosphere, and a remarkable 25-times the speed of sound for accessing space.

SABRE's revolutionary cooling technology is a versatile innovation that offers uniquely high performance with low weight and low drag characteristics, which can effectively enhance the efficiency and sustainability of multiple industries:

- **Aerospace** The SABRE technology is a **fundamental enabler for all forms of zero-carbon emission aviation**: fully electric, fuel cell or hybrid propulsion systems, or gas turbines powered by hydrogen. Being capable of substantially reducing these emissions, Reaction Engines will contribute to the UK's *Net Zero Strategy* and 2050 targets. Projects where the technology are being further developed and applied include the Aerospace Technology Institute (ATI) funded *Robustly Achievable Combustion of Hydrogen Engine Layout (RACHEL)* and *Liquid Hydrogen Gas Turbine (LH2GT)* projects led by Rolls-Royce,[118] Clean Aviation funded *NEWBORN* and *TheMa4Hera* projects, and *Project FRESSON*, which will demonstrate first flight of this technology in 2024. Reaction Engines is also part of the *HVX Programme*, using SABRE technology to enhance UK defence capabilities through the development of state-of-the-art hypersonic technologies, in combination with Rolls-Royce among others.
- **Energy** The versatility of SABRE technology enables it to **address various thermal management challenges associated with the decarbonisation of heavy industry** such as pre-cooling and intercooling in carbon capture and storage systems, heat rejection in hydrogen fuel cell applications, and waste heat recovery of powerplants and industrial processes. By increasing the efficiency of these processes, the carbon footprint is reduced, while simultaneously cutting operating costs. An example spinout of the SABRE technology is the NAMMO Westcott installation.[119]
- **Automotive** Application of the technology within elite motorsport enables aerodynamic coolers that are lighter, smaller, and enable faster lap times, leading to **significant performance enhancements for teams on the F1 grid**.

[115] Reaction Engines (2016). *Reaction Engines secures funding to enable development of SABRE demonstrator engine*. https://reactionengines.co.uk/reaction-engines-secures-funding-to-enable-development-of-sabre-demonstrator-engine/
[116] Aerospace UK (2022). *Synergetic Air-Breathing Rocket Engine (SABRE) Programme Evaluation Report 2022*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1127327/Synergetic_Air-Breathing_Rocket_Engine__SABRE__Programme_Evaluation_Report_2022.pdf
[117] This section draws on information from the Reaction Engines website: https://reactionengines.co.uk/
[118] Dept. for Business, Energy & Industrial Strategy, and Dept. for Transport (2023). *Over £110 million to unlock zero emission guilt-free flights*. Press Release. Available at: https://www.gov.uk/government/news/over-110-million-to-unlock-zero-emission-guilt-free-flights
[119] Aerospace UK (2022). *Synergetic Air-Breathing Rocket Engine (SABRE) Programme Evaluation Report 2022*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1127327/Synergetic_Air-Breathing_Rocket_Engine__SABRE__Programme_Evaluation_Report_2022.pdf (p.43)

- **e-Mobility** The Reaction Engines HXLIFE™ (Heat eXchange Lightweight Isothermal Flexible Extraction) Foils are a unique thermal management system for e-Mobility batteries (electric vehicles), developed using Innovate UK and Advanced Propulsion Centre grants.[120] HXLIFE adapts their **aerospace heat exchanger technology for the e-Mobility sector**. Thin, lightweight, and flexible, they are designed to deliver greater safety and performance. As well as enabling faster charge times and longer vehicle range, HXLIFE Foils offer significant safety benefits when compared to more traditional battery thermal management systems.
- **Maritime** Reaction Engines have set up a new company, Sunborne Systems, with Kiko Ventures and the UK-Government-funded Science and Technology Facilities Council (STFC) which has created **novel ammonia-cracking technology**. It can solve the world's hardest decarbonisation problems, including shipping, power generation, and high-energy industrial processes.

… to realise significant benefits for UK beneficiaries[121]

GVA	£379m gross economic impact between 2015-21	A recent study assessed the impact of UK Space Agency's investment of £50 million in Reaction Engines in 2015. The findings revealed that **each £1 million in grant funding yielded a return of £6.3 million** throughout the UK, considering both direct and indirect benefits. In essence, the 2015 investment resulted in a **total gross economic impact of £379.3 million**, generating an annual return of £54.2 million.
Jobs	600+ jobs supported, growing 24% annually	The number of permanent employees at Reaction Engines increased significantly between 2015 and 2021, with a growth rate of **24%** per year. While the direct employment of 250 people is significant, the impact of the company's activities is even greater, potentially **supporting over 600 additional jobs** in the UK through its supply chain.
Supply chain	Enabling capability development across the supply chain	Despite being a relatively small business, Reaction Engines has a disproportionately large footprint, boosting the manufacturing capabilities of its **650 active suppliers**. The company's manufacturing needs and requirements for space access components have enabled suppliers to enhance and broaden their capabilities for application to other markets.
Leveraged investment	£81m follow-on private investment	To date, the UK government's pledge has **leveraged £81 million of private investment**. This includes £22.6m from BAE Systems, who hold an 18% stake in the business. Boeing and Rolls-Royce also invested in 2018 and are shareholders alongside institutional funds including Artemis and Baillie Gifford.
R&D	£96m additional R&D funding	The UK government's pledge has led to an additional **£96 million of research-related inflows** between 2015 and 2021.

[120] Aerospace UK (2022). *Synergetic Air-Breathing Rocket Engine (SABRE) Programme Evaluation Report 2022*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1127327/Synergetic_Air-Breathing_Rocket_Engine__SABRE__Programme_Evaluation_Report_2022.pdf (p.43)

[121] This section draws on information on: Aerospace UK (2022). *Synergetic Air-Breathing Rocket Engine (SABRE) Programme Evaluation Report 2022*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1127327/Synergetic_Air-Breathing_Rocket_Engine__SABRE__Programme_Evaluation_Report_2022.pdf

Commercial innovation	£10m+ of commercialised revenues	Contracts and revenues resulting from spin-out **commercialisation of applied technologies** and innovations total **£10.4m** (as per end of 2021).
Exports	Expanding to international markets	There is **significant export potential** for Reaction Engines products. The company has secured contracts in the US and through its growing US team is seeking to further penetrate this important market. Other key markets are also being explored include EU and Japan.
Spillovers	£233m of spillover impacts	Positive externalities of R&D investments include knowledge exchange, licensing of IP, productivity spillovers (additional contracts and revenues). The company may have generated up to **£233.3 million** in spill-over economic impacts.
Soft power	Development of national capabilities and local talent	In addition to the quantified estimates, there are several other potential benefits of Reaction Engines' activities. These include **scientific breakthroughs**, **talent inspiration** and **increased national security**. Reaction Engines is also one of seven UK launch companies, and if its SABRE technology advances sufficiently, it could provide the UK with more **resilient launch alternatives**, reducing its reliance on foreign launch service providers. Moreover, Reaction Engines' intellectual property, which includes 12 granted patents registered in several countries, could also contribute to the UK's **soft power**, with many non-public internal IPs (35+) and ongoing patent applications.

COMMERCIALISING REVOLUTIONARY UK TECHNOLOGIES

£65m HMG investment in Reaction Engines' SABRE technology

know.space

Revolutionary new UK technologies

Reaction Engines is a British company pioneering **advanced propulsion systems** and **sustainable technologies**

SABRE (Synergetic Air Breathing Rocket Engine) can propel a hypersonic aircraft from a standstill to **5x the speed of sound** within the Earth's atmosphere, and **25x the speed of sound** to access space

Technology applications

Aerospace SABRE technology is a fundamental enabler for all forms of zero-carbon emission aviation

Energy Potential in thermal management challenges associated with decarbonisation, e.g. carbon capture

Automotive Enables aerodynamic coolers that are lighter and smaller, improving performance at the pinnacle of motorsport

e-Mobility Enabling faster charge times, longer vehicle range and offer significant safety benefits

Benefits to the UK

£379m gross economic impact 2015-21
Each **£1m** in grant funding yielded a **return of £6.3m**

>600 jobs supported
250 direct employees, with further supply chain support
Employment growth rate of **24% per year**

£81m in leveraged investment
from **BAE Systems**, **Boeing** and **Rolls-Royce**

£10.4m in commercial revenues
from **spin-out commercialisation** of applied technologies

Strong export potential
US contracts secured, with ambitions in the EU and Japan

£233m in spillover impacts
Positive externalities: **knowledge exchange**, licensing of **IP**, **productivity** spillovers

Supporting UK soft power
e.g. 12 granted patents registered in several countries

Department for Science, Innovation & Technology

Images: Reaction Engines Ltd.

6. Automated land monitoring for rural payment schemes

HMG investment and support

The UK government has invested **approx. £1 billion** in civil Earth Observation (EO) systems and technologies **over the past decade**, including the EU's Copernicus programme. In November 2022, the Government committed to **invest £315 million in EO and climate programmes** (2023-2027), including £200 million of unused funds owing to continuing delays to UK participation in the EU Copernicus programme.[122]

Ensuring fair support to ensure sustainability of our food chain …

The Rural Payments Agency (RPA) is an executive agency of the UK Department for Environment, Food and Rural Affairs (DEFRA) with responsibility for delivery of subsidies and other payments to support the UK farming and food industry and to incentivise better environmental outcomes. The RPA manages over 40 schemes across England, the majority of which involve financial support based on land parcel size and use – including:

- **Basic Payment Scheme (BPS)** – the UK's continuation farming support payments under the EU's Common Agricultural Policy, which is winding down.
- **Countryside Stewardship** – providing financial incentives for farmers, foresters and land managers to look after and improve the environment.
- **Sustainable Farming Incentive** – a new scheme which pays farmers to produce public goods such as water quality, biodiversity, animal health and welfare and climate change mitigation, alongside food production.

Each year the RPA pays out over £2 billion of support payments in England. Farmers must apply for support, based on the amount of eligible land they cultivate and the environmentally sustainable practices they have employed. This means that the RPA must have a reliable, accurate and up-to-date (maximum 3 years old) database of all agricultural land cover across England.

Since mid-2000s, satellite imagery has played a key role in the update and validation of the RPA's land database. Each year the RPA systemically reviews and updates its land data using four methods: Proactive Land Change Detection (PLCD, which utilises aerial photography, satellite imagery and Ordnance Survey MasterMap updates); farmer requested edits; Field Officers identifying change on farm visits; and 'control with remote sensing' inspections, which use satellite imagery (commercially-procured very high-resolution imagery from WorldView 2 and 3, plus GeoEye-1). This data allows land cover change and changing boundaries to be detected, ensuring that farmers are paid fairly in accordance with their actual land use. Since 2016, RPA has also published the **Crop Map of England (CROME)** data source, which is critically enabled by Sentinel-1 satellite data, for free public use.

Given its successful use of satellite data to support remote inspections, the RPA is expanding its use of satellite imagery. In the winter of 2022, RPA used Sentinel-2 satellite imagery to develop a trial of what would be the **first national land monitoring system** for the **Sustainable Farming Incentive (SFI)** – a new scheme that aims to help farmers manage land in a way that improves food production and is more environmentally sustainable. For example, validating compliance with environmental requirements (e.g. maintaining green cover to promote soil health and stability over the winter period) for **all land parcels signed up to the scheme across all agricultural land in England**. The satellite data will also be used to monitor and evaluate the effectiveness of the new scheme over time.

[122] UK Government (2022). *UK secures £1.84 billion investment for ESA programmes with support for Earth Observation sector*. Available at: https://www.gov.uk/government/news/uk-secures-184-billion-investment-for-esa-programmes-with-support-for-earth-observation-sector

Further expansions of satellite imagery data are envisaged (e.g. to validate additional elements of the Countryside Stewardship scheme, such as: mowing events, buffer strips). The RPA is also working with the **Defra Earth Observation Centre of Excellence (EOCoE)** to explore future applications across Defra.

… to realise significant benefits for UK beneficiaries

Operational cost savings	Efficient data collection, reduced headcount	EO satellites provide data over extremely wide areas, giving access to imagery of the whole of the UK at resolutions suitable for land cover mapping. Alternative solutions (e.g. aerial photography or Field Officers, of which RPA employs approximately 200) offer far more localised data, and so would be far more costly to cover large areas. England alone has a land area of just over 13 million hectares, making more manual methods of land cover data collection extremely expensive. The RPA also spends less time dealing with manual corrections – possibly requiring a revisit – saving taxpayer money.
Increased coverage of monitoring	Large-scale data rather than small sample	BPS inspections by Field Officers have always been sample-based, whereby less than 5% of claims would be validated against land data per year. Adding aerial photography data only provides coverage of one third of the country's land, and only once per year. Satellite data can provide data across all land parcels at monthly or weekly frequency, enabling population-based payment claim validation, in addition to enabling validation of seasonal environmental requirement compliance.
Allocative efficiency	More accurate payments (fewer errors, reduced fraud), more equitable allocation of funds	Since the RPA started proactively re-assessing land cover data annually (PLCD) in 2017, the change rate (number of land parcels manually adjusted) has dropped year-on-year since PLCD was introduced, reflecting the increasing accuracy of the RPA land use dataset. By enabling widespread checking of land parcel accuracy, satellite data ensures that payments are made only to those who meet the necessary criteria, and payments accurately reflect farm size. This in turn avoids overpayment, saving taxpayer money. Accurate land measurement and monitoring means accurate payments to farmers and land managers. The more accurate land cover database allows the RPA to distribute rural payments as fairly as possible. This in turn ensures maximum social benefit from taxpayers' money, as the scheme is best placed to achieve its objectives when grants are distributed as intended.
Reduced burden on farmers	Fewer farm stoppages for inspections; Less time correcting errors	Traditional inspections involve an in-person farm visit by a Field Officer, requiring the farmer to take time out to accompany the inspector around and provide validation information. Remote inspections are less intrusive to farmers – assessments are automatic and do not require farm operation stoppages. It is the responsibility of farmers to check that the RPA's land cover data is accurate. If an error is spotted, farmers must request a correction before payments are made. As the accuracy of the

		RPA's dataset improves, farmers should have to spend less time making corrections to land boundaries.
Increased transparency	Clear, sharable land use mappings	Digital maps derived from satellite imagery are shared with farmers, so they can easily see why payments have changed and have the opportunity to challenge a boundary decision.

AUTOMATED MONITORING FOR RURAL PAYMENT SCHEMES

~£1bn HMG investment in civil Earth Observation capabilities

know.space

Supporting a key industry

The Rural Payments Agency (RPA) uses **satellite imagery to deliver vital subsidies**, worth over **£2bn/ year**, supporting the UK farming and food industry

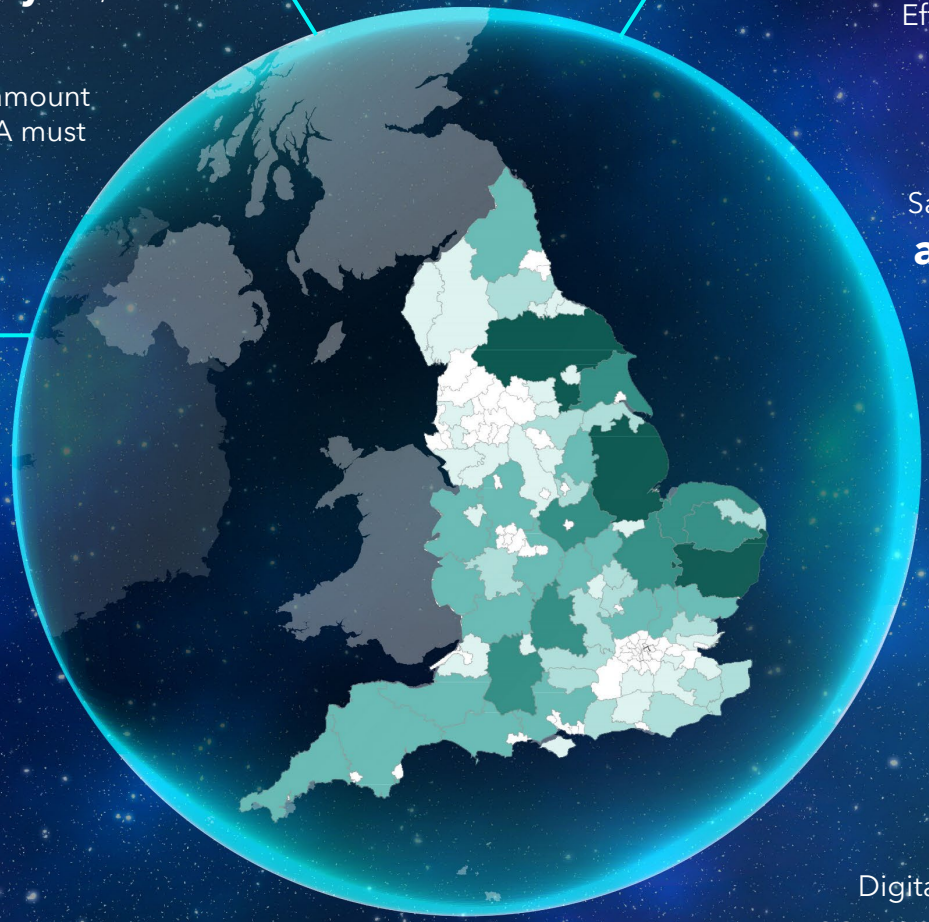
The subsidies which farmers receive depend on the amount of eligible land they cultivate. This means that the RPA must have a **reliable, accurate and up-to-date database of all agricultural land** cover across England

A growing role for satellites

Since the mid-2000s, satellite imagery has played a key role in the **update and validation of the RPA's land database**

Satellite data, in combination with other sources, allows land cover change and changing boundaries to be detected, ensuring that **farmers are paid fairly** in accordance with their land use

RPA is now expanding its satellite use: in 2022 the RPA trialled the use of Sentinel-2 data for the Sustainable Farming Incentive (SFI)



Benefits to the UK

Operational cost savings for government

Efficient data collection, with satellite imagery covering extremely wide areas, **saving taxpayer money**

Increased coverage of monitoring

Satellite data enables **largescale data collection at a regular frequency** (monthly or weekly), compared to manual inspections carried out once a year on <5% of claims

Delivering an equitable system

Widespread checking of land parcel accuracy leads to **fewer errors, reduced fraud and a more equitable allocation of funds**

Saving precious time for farmers

Traditional inspections require farm stoppages as farmers accompany a Field Officer around their farm
Remote inspections are automatic

Increased transparency

Digital maps are shared with farmers: they can **understand why payment changes have been made** and challenge decisions

Image: Adapted from Defra (2023) Land use and crop maps in England 2021

Department for Science, Innovation & Technology

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… now you **know.**