UK EO Technology Strategy

Prepared by CEOI on behalf of the UK Space Agency

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UK EO Technology Strategy - Executive Summary

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The UK Space Agency's overall objective in Earth Observation is to maximise its potential for the economy, science and society.

The UK Earth Observation (EO) Technology Strategy will support the UK Space Agency in future investment decisions in EO technology, its influencing and convening power. It will help to ensure that the UK receives best return from the national and bilateral programmes, and from the investment in ESA and other European EO programmes. This will be achieved through the selection and development of technologies of greatest relevance to future EO missions, both ESA and non-ESA, including national, European and global commercial opportunities. It also seeks to ensure continuing technological capability in areas of importance to the UK and support the development of new and innovative ideas.

Our 10-year vision is for the UK to become the world leader in new EO technologies

The aim is that over the next decade innovative new technologies developed by the UK EO space sector make substantial contributions to economic growth, new jobs and societal benefit, with UK entities competitive in global EO commercial, institutional and science markets.

The four key objectives of the UK EO Technology Strategy are:

- **Economic Impact:** Develop EO technologies which lead to increased exports and economic growth
- **Innovation**: Keep the UK at the forefront of EO technology development by supporting new and innovative ideas that offer tangible benefit to future missions
- **Capability**: Strengthen capability where the UK already leads, has the potential to build a lead or to overtake existing capability elsewhere
- **Return on UK Government Investment:** Maximise the benefit to be derived from the UK funding to ESA and other institutional bodies

The strategy builds on the strength and breadth of the existing UK technology capability in a highly competitive international environment, in areas including: passive microwave; UV/visible imaging and spectroscopy; IR imaging, radiometry and spectroscopy; SAR/radar technologies.

There is a growing demand for future EO missions, with a diversity of requirements and implementation pathways. This strategy is based on an understanding of the potential future EO mission opportunities and the strength of the user pull in different mission types - science, operational and commercial. These missions provide a basis for targeted technology development and to identify the priority EO community requirements.

The strategy articulates UK technology aspirations in the ESA EO programme and in other national investment decisions in relation to EO. It is implemented through UK government actions, and through the Centre for EO Instrumentation technology development and added value programmes.

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1. Introduction

The UK Earth Observation (EO) Technology Strategy will support the UK Space Agency in future investment decisions in EO technology over the next decade. It will help to ensure that the UK leverages the best return and maximise the opportunities arising from the UK investment in international EO programmes, including ESA and Copernicus. This will be achieved through the selection and development of technologies of greatest relevance to future EO missions, both ESA and non-ESA, including national, European and global opportunities. The UK Space Agency has set up the Centre for EO Instrumentation (CEOI) to implement and manage UK EO technology development on its behalf.

The strategy takes as its starting point the UK Space Agency Vision for EO for the period 2017-2040, as described in the presentation at the NCEO-CEOI EO Science and Technology Conference in June 2017. The process used to build the strategy is described in Section 2, which also summarises the UK Space Agency ambition for Earth Observation, together with the underpinning UK capabilities, drivers and mission opportunities in EO.

The EO technology strategy will build on the strength and breadth of the existing UK technology capability in areas including: passive microwave; UV/visible imaging and spectroscopy; IR imaging and radiometry; SAR/radar technologies. The strategy seeks to ensure continuing technological capability in areas of importance to the UK and to encourage new and innovative ideas. Section 3 describes the overall vision for EO technology and identifies the main strategic objectives.

Strategy implementation, described in Section 4, will be through UK government actions, both national and international, and through the CEOI programme. It will position EO as a fundamental infrastructure, supporting development of the EO technologies to underpin industrial strategy, policy and societal needs, to foster innovation, economic growth and the development of skills.

The CEOI programme will support the implementation of this strategy though a programme of technology development, workshops and community engagement. The technology programme will target the mission opportunities available to the UK community and develop the technologies needed for future flight opportunities.

Consultation with the UK EO technology and science community was undertaken during a dedicated session at the May 2017 CEOI Emerging Technologies Challenge Workshop, via an email survey and informally through individual discussions. Input from these consultations has been incorporated in the production of this strategy.

The UK EO Technology Strategy has been prepared for the UK Space Agency by the CEOI.

2. Building the Strategy

2.1 Strategy Development Process

The UK Space Agency's overall objective for the EO Technology Strategy is to *use its influencing power, convening power and domestic funding wisely*. This is particularly in relation to the UK investment into ESA, where leverage will be sought to ensure UK entities gain maximum benefit from ESA, Copernicus and Eumetsat programmes, and also to make the maximum contribution possible to growth in jobs and the economy.

The UK EO Technology Strategy has been formulated in consultation with the UK academic, industrial and institutional EO community. Its purpose is to identify the technologies which have the highest priority for development, taking into consideration the potential future mission and other implementation opportunities.

Figure 1 shows how the strategy has been developed through an assessment of the UK EO technology landscape, and examination of external drivers and potential exploitation opportunities.

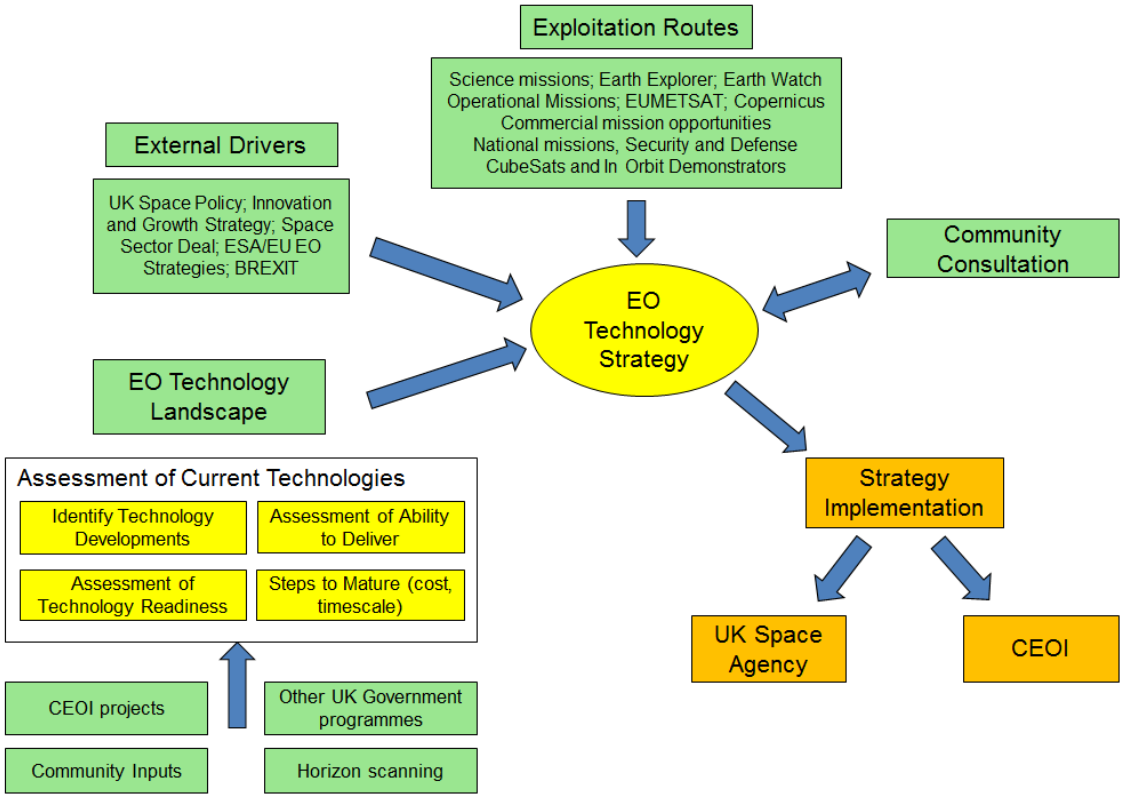


Figure 1 EO Technology Strategy development process

2.2 UK Space Agency Ambition for Earth Observation

The UK EO Technology Strategy builds on the UKSA Vision for EO for the period 2017-2040, as presented to the NCEO-CEOI EO Science and Technology Conference in June 2017. This vision, outlined below, has the overall objective to **maximise the potential of Earth Observation for the economy, science and society.**

The trend in EO is for increasing private and public/private investment in missions and data processing and provision, with data use by commercial and public services (including meteorology and science).

By 2040 it is expected that satellite Earth observations will provide the data to underpin mass market and business applications, global cutting-edge science, and also policy and operational decision making. The UK Space Agency is seeking to strengthen significantly the UK's participation in EO, ensuring that it is recognised for the role it can play in delivering a sustainable service-based economy.

In setting actions and priorities, UKSA will build on the decision to be the lead funder of EO in the European Space Agency. The objective is to develop a broad and deep ecosystem of companies, big and small, dealing in the entire spectrum of Earth observation issues. This will cover all aspects from early research and technology development, manufacture and launch, but also the infrastructure and services needed to move, validate, share and interpret the data into a format suitable for use and exploitation.

In relation to the EU Copernicus programme, the recent UK government 'Future Partnership Paper on Science and Innovation' outlined that, as the UK leaves the EU, one of the UK's core objectives is to continue to collaborate with European partners on major science and technology initiatives. Given the unique nature of the EU Copernicus programme, the paper states the UK intention to discuss with the EU all options for future cooperation, including possible new arrangements.

The UK will target exports to global markets of satellites, instruments, data and applications, based on in-country skills and technologies in EO. Finally, it will look at how to avoid the emergence of an EO skills gap to maintain full capability for the jobs that will be created in the UK.

Key Priorities

The key priorities for Earth observation for the period 2017 – 2040 in markets, technology and data are:

1. Leveraging return from ESA – both funding and European positioning
2. Maximising the opportunities in Copernicus and EU programmes and ensuring optimal data access post Brexit
3. Positioning EO as a fundamental infrastructure, with tools to underpin industrial strategy, policy and societal needs
4. Foster innovation and growth (applications, technology, bilateral etc.)
5. Skills and education

The commercial EO sector is expected to provide a fast-growing market for EO services and export opportunities over this period. The vision identifies the scope and importance of EO, the future EO market and ecosystem, the key partners (global and national) and the roles of the UK Space Agency. It includes key actions to be carried out by the Agency and the main priorities.

2.3 The EO Technology Landscape

The UK has a well-established capability in EO space technology, with world leading and sustainable industrial and academic capability. However, there is growing international competition, especially from international 'new space' activities and from countries with substantial national programmes, and the UK therefore has a significant challenge to maintain its competitive position.
Good evidence of current UK strengths is provided by:

- The many existing EO instruments of UK design and build, which have been well proven through flight programmes.
- The continuing success by UK-led teams in developing EO instruments for the next ESA missions.
- Major EO instrumentation projects for export/commercial opportunities in an advanced stage of development.
- Recent ground-breaking advances in EO technologies.

Table 1 provides a summary assessment of the strength of the overall UK capability in the main technology themes, together with the growth trend of the future market.

Technology Theme	UK Strength	Market Trend	Comments
Radar/SAR	✓✓✓	✓✓✓	Excellent & established UK capability; Significant commercial/operational markets
Passive microwave	✓✓✓	✓✓✓	Excellent and broad UK capability; Ongoing operational/science markets
Optical imaging	✓✓✓	✓✓✓	Excellent & established UK capability; Significant commercial/operational markets
Optical spectroscopy	✓✓✓	✓✓✓	Excellent and established UK capability; Significant commercial/operational markets
IR imaging	✓✓	✓✓✓	Growing UK capability; Growing commercial/operational markets
IR radiometry	✓✓✓	✓✓✓	Excellent and broad UK capability; Ongoing operational/science markets
IR spectroscopy	✓✓	✓✓✓	Growing UK capability Ongoing operational/science markets
LIDAR	✓	✓✓	Some UK capability; Viability of space-based LIDAR sensing to be established
Radar Altimetry	✓	✓	Some UK capability; Strong competition within Europe
UV spectroscopy	✓✓	✓	Good UK capability Limited user pull and mission opportunities

Table 1 Assessment of UK Strength vs Market

The strategy builds on this strong UK technology capability in areas including passive microwave; UV/visible imaging and spectroscopy; IR imaging, radiometry and spectroscopy; and SAR/radar technologies.

In these and other areas, the UK has the potential to maintain and further develop its world leading capabilities. Key to achieving this is the progression of the technology from initial development under UK national funding, through to implementation with national or other leveraged funding,

targeting well-defined future missions in export markets, commercial markets, for ESA or other government/institutional organisations.

2.4 External Drivers for the Strategy

The EO technology strategy has not been developed in isolation; a number of factors have been considered to ensure that the strategy is robust to changing circumstances, and so that the EO technology programme can be adapted to respond to new opportunities. This section outlines the main drivers of the strategy.

The development of a **UK Space Growth Partnership and Space Sector Deal** is currently under discussion between industry and Government, with the aim to grow the space sector and to increase exports, economic growth and job creation. Data flowing from the ESA/EU Copernicus programme will contribute to the requirements for EO data by **DEFRA and other government departments**, but other sources of EO data will also be required. The EO Technology Strategy and the associated implementation programme will respond to these requirements and opportunities as they develop.

The UK Space Agency is producing an overall **Space Technology Strategy** in consultation with the Agency's Space Technology Advisory Committee (STAC) and will address the development of technologies for all aspects of satellites, launchers and instruments, as well as for the exploitation of space data and for technology transfer. The UKSA Space Technology Strategy identifies three underlying reasons that justify public support for space technology, viz: to grow the knowledge base; to meet societal needs; and to support the growth of commercial space markets such that the contribution of UK industry to the economy is increased. These align well with the technology targets in EO science, operational and commercial/ export missions.

The UK will build on the decision to be the largest financial contributor to the ESA EO programme, including the EO Envelope Programme (EOEP5), InCubed and the Climate Change Initiative (CCI) programme. The ESA science and operational EO programmes provide data which are an important contributor to NERC National Centre for EO (NCEO) science. The UK also contributes strongly to other development programmes in ESA in preparation for future operational missions (meteorology and Copernicus EO programmes). Access to these key programmes and the resulting contracts to UK industry to develop EO instrumentation are vital elements underpinning the development of UK technological capability.

The strategy will also take into account trends and game changers in EO that have the potential to be disruptive in their impact such as:

- the growth in data (high-resolution, high-frequency, video, commercial constellations);
- new technologies for EO and miniaturisation
- the digital economy (IT, cloud computing, data intensive geo-informatics);
- the new industrial and academic landscape following Brexit;
- Copernicus long term guaranteed operational data;
- space launch capability;
- international policy;
- competition arising from the programmes of other national space agencies.

Coherence will be maintained with related activities, including the Space Growth Partnership, and activities in the UKRI (Research Councils and Innovate UK), DSTL, ESA and the EU Copernicus and Horizon 2020 programmes (subject to the Brexit negotiations).

2.5 Exploitation Routes

Placing UK EO technologies into commercial space missions and into national/bi-lateral and international missions (commercial, operational and scientific) is a vital step to proving capability and to establish the technology space heritage.

Commercial missions, including those for export, are typically driven by sales of data or value-added services. They occur in a highly competitive environment, and carry significant business risk. Such missions usually require relatively mature and lower cost technologies to be rapidly configured for a specific opportunity. Whilst it is sometimes possible to anticipate instrumentation requirements for commercial missions, the mission opportunities are often not made public owing to commercial sensitivity. Thus, the strategy has to be responsive and ready to assess quickly whether urgent UK government support is required to capture these commercial opportunities.

Institutional EO science missions, driven by challenging science requirement, are a major driver of innovation, usually demanding new sensor types or greatly improved performance from existing sensor configurations. Technology development may be targeted typically at ESA's Earth Explorer missions. Therefore, UK support will be directed at raising the technology readiness from initially low levels (typically TRL 2-3) to levels likely to achieve acceptance on demanding science missions (TRL 5-6). Timescales are often long, and costs substantial for a high-performance one-off scientific mission. However, once instrumentation has been developed, it then becomes available for: operational missions; for commercial missions; and for export opportunities to other national space agencies.

Operational missions are driven by societal need. The missions implemented by the EU for Copernicus and Eumetsat for meteorology typically require multiple models of the same spacecraft design, with well-defined payloads. This presents a more attractive business opportunity for instrument providers and satellite builders, and is seen as less commercially risky with better long-term prospects than one-off scientific missions. It is possible to target technology development for operational missions as the requirements are often well known in advance, and government funding can be crucial to allow UK consortia to bring instrumentation to a sufficient level of maturity to gain access. Technology development tends to be evolutionary rather than revolutionary, although there is still room for innovation.

A unifying technology theme for all these mission types is miniaturization. UK teams have proven capability in designing miniaturized low-power instrument concepts whilst maintaining high instrument performance. This enhances the likelihood of adoption on all missions, and allows use on smaller spacecraft platforms, thus reducing the cost of access to space. This paves the way for anticipated national and bilateral missions using small spacecraft and CubeSats, which will feature in flight opportunities in the coming years. It is also highly enabling for payloads for High-Altitude Pseudo Satellites (HAPS) which are likely to be available for defence/security applications, for commercial imaging and for environmental monitoring in the next 3-5 years.

In addition, CubeSats, HAPS and aircraft provide a cost-effective way of validating new instrumentation concepts, facilitating acceptance for major space missions. This can be considered as an important step in the R&D process before spaceflight.

3. EO Technology Strategy - Vision and Objectives

The vision is that, over the next decade, the UK will become the world leader in new EO technologies, with UK entities: growing sustainable capability; developing new and innovative EO instruments and space technologies aligned to priority user needs for future scientific, operational, and commercial EO missions. These new technologies will make substantial contributions to economic growth, new jobs and societal benefit.

The strategy will be underpinned by technology horizon scanning of other sectors and identification of new EO mission concepts for science (ESA, bilaterals and national), societal benefit (e.g. climate/ environment/maritime monitoring) and for commercial/export opportunities. It will assist in the development of a common understanding between UKSA and ESA of UK technology capabilities and priorities and identify potential benefits from application of EO technologies into other fields (space and terrestrial, including security and defence) to maximise growth.

Obj. 1 Economic Impact: Develop EO technologies which lead to increased exports and economic growth

- Promote the technology developments where the UK excels in the existing international competitive landscape
- Support technology developments with larger markets (e.g. constellations, operational mission series and/or multiple missions)
- Position UK organisations to take significant roles in national, bilateral or international EO missions, so as to lead to export/growth opportunities.
- Support technology developments that will lead to growth of EO applications, of the service sector and spill-over benefits into other areas of the economy

Obj. 2 Innovation: Keep the UK at the forefront of EO technology development by supporting new and innovative ideas that offer tangible benefit to future missions

- Promote technology developments which might have a disruptive effect or facilitate the exploitation of established technologies
- Encourage the transfer of knowledge between academia and industry to maximise the pull-through of innovation
- Undertake horizon scanning to identify disruptive technologies and new mission concepts that can be promoted internationally
- Improve the competitiveness of UK technologies by reducing cost, size, mass and/or power requirements.
- Reduce implementation risk by increasing the technology readiness level, and implementing elegant breadboards and/or airborne demonstration flights.

Obj. 3 Capability: Strengthen capability where the UK already leads, has the potential to build a lead or to overtake existing capability elsewhere

- Promote areas of existing UK competence including: passive microwave; UV/visible imaging and spectroscopy; IR imaging, radiometry and spectroscopy; and SAR/radar technologies
- Develop capability to prepare the next generation of EO technologists and technology leaders, to build a strong overall EO technology community in 5-10 year timeframe
- Increase the strength and depth of the UK EO technology community to enable it to support future growth
- Facilitate networking with EO scientists and the EO applications community to increase understanding of future EO requirements and of the relevance of technology developments

Obj. 4 Return on ESA Investment: Maximise the benefit to be derived from the UK funding to ESA and other institutional bodies

- Identify technology requirements for ESA missions and other institutional flight programmes and articulate to ESA the UK technology development priorities
- Promote UK capabilities and areas of strength to ESA, Eumetsat and similar organisations
- Facilitate field, airborne, and/or in-orbit demonstrations to prove viability and scientific credibility of instrument concepts.

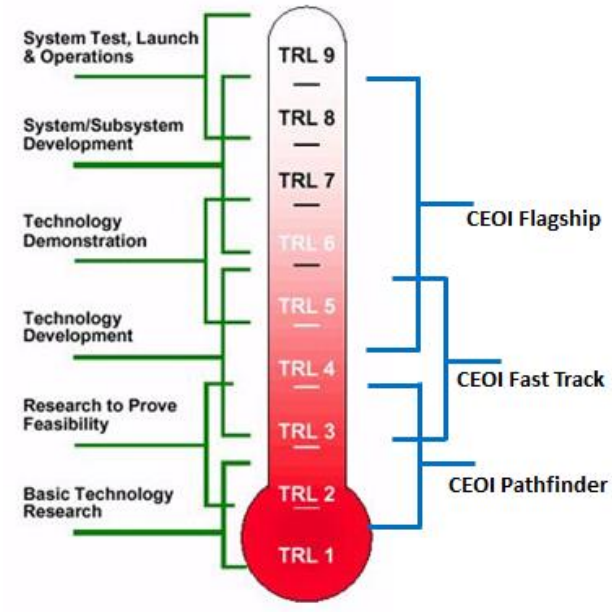
4. Strategy Implementation

The strategy is implemented through UK Space Agency policy activities, through ESA and other programmes, and through the technology development programme and other activities of the Centre for EO Instrumentation.

The strategy guides investment of the UKSA EO technology funding to maximise UK geo-return from the investments into ESA and prepare UK technology teams for institutional, commercial and export business. Development of EO technologies and space instruments will be supported through grants and other actions, whilst broader application of the technologies will be pursued through technology transfer activities.

The landscape for EO is changing very rapidly at present, with the development of commercial EO constellations, aiming to provide timely and frequent information about the Earth's surface, human activities and rapid changes in the environment. The data is used to underpin and enable the development of new applications and services. In parallel, the continuing deployment of high quality institutional EO systems, including the next generation of Eumetsat meteorological satellites and the evolution of the Copernicus constellation is driving the availability of publically available EO data. These provide significant opportunities for the UK to develop its EO technology capability and to capitalise on UK strengths to maximise economic growth and exports.

The CEOI programme typically funds technologies in the range TRL 3-4 and when the end-user application is better established, up to TRL 6. This level of development is designed to take technologies to the point where the main technology risks have been retired, and they are sufficiently proven to be taken up by ESA and other bodies into the mission implementation phase. Development of EO CubeSat or other small missions to TRL 9 may also be funded where there is a strong identified business case and where the UK budget and strategic objectives are met.



TRL9 - Actual system "flight proven" through successful mission operations
TRL8 - Actual system completed and accepted for flight ("flight qualified")
TRL 7 - Model demonstrating the element performance for the operational environment
TRL 6 - Model demonstrating the critical functions of the element in a relevant environment
TRL 5 - Component and/or breadboard critical function verification in relevant environment
TRL 4 - Component and/or breadboard functional verification in laboratory environment
TRL 3 - Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 2 - Technology concept and/or application formulated
TRL 1 - Basic principles observed and reported

Fig 2 CEOI Project Types vs Technology Readiness Level (TRL)

The CEOI programme will be defined in an annual plan in line with the EO technology strategy. The programme will identify potential breakthrough technologies through a horizon scanning programme and Emerging Technologies workshops. UKSA and CEOI will work with other UK organisations to identify additional funding sources e.g. in the UKRI (Research Councils and Innovate UK), DSTL, the space sector deal, ESA and the EU Horizon 2020 programme (subject to the Brexit

negotiations). This will ensure that all potential sources of investment are accessed and that the full leverage of investments into Europe and elsewhere is used to advance UK capability. The programme will continue to search out and encourage collaboration with all sectors with relevant technologies, both space and non-space.
The programme will target the growth agenda and opportunities presented by 'New Space' for low-cost EO constellations. It will also look for synergies with the developing needs of the security and defence sector.

EO technology horizon scanning and road mapping will continue, building on the roadmaps developed in the earlier phases of CEOI and co-ordinating with the National Space Technology Strategy Group (NSTSG) Space Sensing roadmap, to ensure the logical development of technologies. Engagement with the community will continue to enhance understanding of aspirations and capabilities.

We will continue to identify opportunities for CEOI developed instruments and technologies for non-space applications, in industry, environmental science and in defence through the CEOI technology transfer programme.

The strategy will be widely circulated in the UK to promote awareness. Information about UK EO technology capability and products will be provided to the UKTI and other Government organisations to advertise UK EO technology to potential export and bilateral partners and to provide a broader understanding of UK objectives in EO technologies. It will be made available to ESA and other appropriate non-UK bodies to encourage harmonisation of EO programmes within and outside the UK.

The EO Technology Strategy process will continue with the active assessment of mission opportunities, informed by the future EO mission landscape, identifying the links between technologies and potential future EO missions. Where application to multiple future missions can be identified, this serves to increase the probability of implementation. By further linking missions to downstream services, the potential exists to identify those technologies which can maximise growth and economic activity.