Highlights from Five Case Studies written by SPAN Fellows

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The case studies were prepared for the UK Space Agency to support the business case for future investments in the European Space Agency. The funding for the case studies was awarded under the direction of the National Space Partnership whilst operating a pilot programme from January 2022 to March 2022.

National Space Partnership https://www.linkedin.com/company/national-space-partnership

THE SUCCESS IN COSMIC VISIONS & OPPORTUNITIES FOR FUTURE UK LEADERSHIP

An extract from the case study written by Dr Lucia Fonseca de la Bella

Euclid is a ground-breaking ESA medium mission envisioned to map the geometry of the Universe and answer the big questions about our Universe! Euclid will fly an extremely sophisticated space telescope set to explore the dark Universe. Over the course of its six-year mission, operating 1.5 million km from Earth, Euclid's 1.2 m diameter telescope will map the 3D distribution of up to two billion galaxies up to 10 billion light-years away – around a third of the observable Universe. By revealing the Universe's large-scale structure, and its pattern of expansion, the mission will cast light on the mysterious dark energy and dark matter making up the vast majority of the cosmos.

Recommendations:

- ESA is an excellent partnership for collaborative science missions
- A science pathway and investment for phase zero studies are essential (responsibility of STFC for space science: astrophysics, fundamental physics, solar system)
- Maintain strong leadership in ESA with UK bilateral and national programmes
- Support knowledge transfer and strong industry-academia partnerships

Ensuring UK Space Mission Engineering Success – From Cosmic Vision to Voyage 2050 and beyond

An extract from the case study written by Dr Leah-Nani Alconcel

The space science research funded by ESA and UKSA is a pillar of engineering success in the UK. It funds technological innovation that keeps the UK competitive in proposals for mission opportunities from ESA and NASA. Innovation carried out by individuals working as space mission engineers enables them to move between critical industrial sectors. It produces the company founders, executive leaders, programme managers, and academics needed to ensure the UK's continued capacity to lead in the space sector and beyond. The practice of space instrument development and innovation over the past 20 years also exemplifies the success of the "be what you can see" model for female engineers, with women in influential positions providing developmental support and mentorship and enabling their junior colleagues' progression. This case study highlights activities that enable the National Space Strategy's Ten Point Plan, specifically Points "3. Unleash innovation across the space sector" and "9. Upskill and inspire our future space workforce".

Recommendations:

- A national spacecraft design and development programme that includes dedicated funding for instrument-based innovation
- Formal mentorship programmes for women and underrepresented groups in the UK space sector

Hunt for Dark Matter

An extract from the case study written by Dr Fionagh Thomson

UK investment in ESA, coupled with technological innovation from ESO (with UK support and membership), and UK investment from the treasury has enabled the UK space sector to flourish in a number of fields, including the Hunt for Dark Matter. Investment in ESA has brought many benefits but no more than long-term international collaborations, built on trust in complimentary skills, knowledge and capabilities to deliver large-scale astrophysics projects, and enable ground-breaking projects to succeed, such as GAIA and, in the future, EUCLID. No one country could achieve this alone. Key to the UK space industry progressing is the UK having access to key capabilities, that may or not be held within the UK. Without investment in ESA, international cooperation would suffer, the gold-star teams built through global funding would dissolve and high calibre UK students, interested in studying large-scale and blue-sky astrophysics (galactic or extragalactic), would travel overseas to study, leading to the inevitable 'brain drain'. Any innovations developed through the support of ESA investment, directly or indirectly, would (perhaps) never have happened.

Why search? In 1897, the discovery of the unknown electron by the UK physicist JJ Thomson led to the harnessing of 'electricity', that underpins all of modern society. What untold benefit to society might the discovery of dark matter and dark energy bring?

Quantum Technologies in the Space Domain

An extract from the case study written by Dr Susan Spesyvtseva

The strength of the UK's Quantum Technology sector is built on demonstrated UK leadership and heritage in quantum information science. Recent investment in industry-led technology development has facilitated the development of a wealth of cutting-edge quantum technologies that promise to revolutionise many industries and service provision if transitioned to the space domain. The UK is well-placed to capitalise on its leading position in quantum technologies by linking to capability in its strong space sector.

The most well-developed space quantum technology is satellite quantum key distribution. At present, quantum key distribution for securing communications is limited to a few hundred kilometres due to the absorption of single photons in optical fibres. However, placing quantum light sources into orbit so that they could operate in the vacuum of space would facilitate quantum key distribution on a global scale.

Quantum-enhanced clocks are poised to supercharge the next generation of Global Navigation Satellite Systems and provide ultra-precise timing and positioning anywhere in the world.

Quantum sensor-equipped satellites based on quantum technologies such as optical clocks, magnetometers, cold-atom platforms, accelerometers, and gravity gradient sensors could monitor the Earth with unrivalled accuracy. This would allow us to fight climate change with space, but would also facilitate fundamental science such as testing general relativity and equivalence principles, detection of gravitational waves, and aid in the search for dark matter. Commercial applications include gravity mapping for inertial navigation; space weather monitoring; and extra-terrestrial surveying and earth observation for oil, carbon sequestration, climate change, flooding, and natural disasters.

The opportunities are significant, yet building and launching these technologies into orbit is a considerable challenge as payloads need to survive the rigours of launch and the harsh radiation, thermal, and vacuum environment in space.

Recommendations:

Development of a UK National Space Quantum Technology strategy to leverage the substantial UKNQTP investment in Quantum Technologies for use in space and downstream applications:

- Dedicated national funding stream for new quantum space missions with low TRL, and higher TRL missions with national strategic priority focus.
- ESA funding for space quantum science, and other less (immediately) strategic areas.
- Development of supply chain of miniaturised and ruggedised quantum components.
- Creation of a skilled base of researchers and engineers versed in space quantum technologies to form the skilled, diverse and networked workforce with the know-how needed for UK leadership in space quantum technologies, via CDT and small satellite programme.

How the UK Benefits from ESA Earth Observation Missions?

An extract from the case study written by Steve Baker

UK Industry Benefits: many elements of UK industry have been involved in the building of space instruments for ESA EO missions. For example Matra Marconi Space (now part of Astrium UK) built the imaging radars (SAR & ASAR) on the ERS and Envisat satellites. After the launch of ERS-1 <u>dozens of start-ups and consultancies were created to exploit and enhance the data stream from these EO missions.</u> The National Remote Sensing Centre set up as a spin-off from DRA Farnborough.

UK Technical Leadership: RAL Space (UK) designed, developed and delivered the Along-Track Scanning Radiometer (ATSR) instrument that flew on ERS-1 <u>and measured sea-surface temperature to an accuracy 5 times better than anything before</u>. This was followed by the ARSR-2 on ERS-2 and the Advanced ATSR on Envisat. RAL continued to build on this experience and developed the Sea & Land Surface Temperature Radiometers that are now fitted to the Sentinel satellites. RAL Space also developed the Global Ozone Measurement Experiment (GOME) on ERS-2.

Knowledge Transfer to Industry: ATSR Black Body Calibration gave the instrument an unprecedented accuracy of 0.1 degrees C. The black-body calibration scheme was developed by scientists and engineers at UCL as an example of innovative and world-leading technology. The knowledge was transferred to AEA Technology (now ABSL) where it was further developed and deployed on future missions.

Growth of Scientific Knowledge and Capability: Within the UK Met Office <u>the **Hadley Centre** is a world-leader in climate research & modelling and is a key advisor to government climate policy</u>. In the early days climate modelling was limited by the data available and by computing power and only focused on the atmosphere, whereas the Earth’s Climate is the really the result of interactions of a number of complex systems. As EO missions matured and computing power increased the Hadley Centre introduced improvements – like adding the effects of ocean circulation and heat exchanges in “Global Coupled Models”. These continual improvements make models ever more realistic and detailed. Confidence in climate model prediction is increased. Better, more accurate information is supporting UK government policy.

Ground segments: UK commercial involvement does not end at launch. The UK has had major involvement in the ground-based data processing of all European EO missions. The UK is recognised for having considerable software expertise in EO data processing: developing many new improved algorithms and methods. For example the UK was chosen by ESA to lead the consortium selected to reprocess the entire 15-year ERS-1/2 mission archive for Radar Altimeter and Microwave Radiometer instruments. Today UK universities are leading the design of algorithms in the fields of sea surface temperature and cloud masking and motion detection in support of the EE Harmony mission.

Recommendations:

- UK needs to continue involvement in EO missions
- UK needs to be in the ESA collaboration on EO missions in order to:
  - Afford to be part of complex missions and complex programmes
  - Maintain the expertise of UK industry across the field
  - Maintain the world-class expertise of UK academics in this field
- Acknowledged expertise allows the UK to have a major influence on future missions to ensure that they are addressing the important questions.