UK SPACE AGENCY

National Space Programmes 2014-2015

Foreword

I am delighted to introduce this third edition of our brochure which summarises the activities and achievements of the UK's national space programmes. While the UK's strong involvement in the projects of the European Space Agency and of the European Union attract most attention, the UK's national space projects are no less important in delivering our six point civil space strategy, shown in the accompanying graphic.

In 2014/15 we completed the majority of projects in Phase 1 of the National Space Technology Programme (NSTP) and with our partners in the Technology Strategy Board, a compendium of the 'Space for Growth' was issued. We started phase 2 of NSTP by allocating £5 million to a very important set of projects designed to position the UK to exploit the multi-billion pound market enabled by the highly secure signal that will be provided by Galileo. The so-called 'PRS pilot projects' will lead to an integrated demonstrator by 2015.

Meanwhile our investment in Earth observation technology for science and for business has continued through the Centre for Earth Observation Instrumentation (CEOI). Earlier work from CEOI has helped prepare UK industry to win a £100 million+ contract for the microwave weather instrument for the next generation of European meteorological satellites.

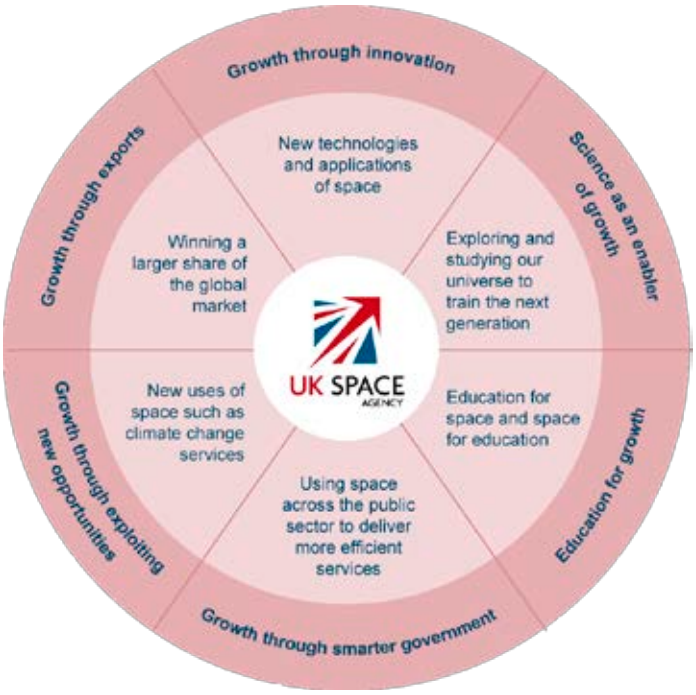
Our programme for in-orbit demonstration (IOD) has reached a critical step with the launch of UKube-1 and TechDemoSat-1 spacecraft in July 2014. Further IOD projects are now being planned.

Our long running science and exploration programmes in support of Cosmic Vision and Aurora remain at full speed, with key milestones in 2014/15 including delivery of all UK instrument hardware for LISA Pathfinder; and the launch of the astrometry mission GAIA which will rely on a data processing and analysis system financially supported by the UK Space Agency. A new round of our national technology programme for exploration known as CREST has awarded £2 million of funding and projects are now underway.

We have doubled our funding for educational projects to allow us to continue successful programmes such as 'Space for All', Mission X, and the National Space Academy, while at the same time initiating an exciting group of new projects to fully exploit the inspiration and educational potential of Tim Peake's mission to the International Space Station in December 2015.

Everyone in the UK Space Agency is dedicated to the success of the UK space sector. This brochure gives you some insight of how we are making a difference. Enjoy!

Dr Dave Parker
Chief Executive, UK Space Agency



Inside front cover: The Structural and Thermal Model of the BepiColombo Mercury Transfer Module in the Large Space Simulator at ESA's test centre in the Netherlands.
Credit: ESA/Anneke Le Floc'h

UK Space Agency Cosmic Vision National Programme

Objectives

The UK's Cosmic Vision National Programme provides support for the design, development and operation of scientific payloads on ESA missions in its mandatory Science Programme as well as ongoing bilateral missions with non-ESA states. Scientific exploitation of the missions is the responsibility of the Science and Technology Facilities Council which awards grants to scientists through its Astronomy Grants Panel. The Agency and STFC have agreed a dual-key process to ensure coherence and consistency in funding for space science missions.

Under the dual key agreement between the Agency and STFC, funding for generic technology to a proof-of-concept level (TRL 3) is available through STFC's consolidated grants process.

ESA's advisory structures select new missions to enter a competitive development phase aimed at raising Technology Readiness Levels (TRLs) via bread-board and instrument design activities. Cosmic Vision missions are expected to have reached a TRL of 5 prior to selection for implementation, meaning that they have been validated in a relevant environment. This TRL-raising activity is supported by the UK's Cosmic Vision funding, with a view to positioning the UK to maximise future investment return.

Funding and Management

The Cosmic Vision National Programme has a budget in FY 2014-2015 of £14 million. Under current Research Council rules, the Agency provides 80% of Full Economic Cost (FEC) of agreed proposals from academia, the remainder is provided by the University. Projects are not automatically expected to provide any additional external funding although industrial contributions are encouraged and frequently provided.

The UK involvement in Cosmic Vision is managed by the UK Space Agency. Statements of Interest (SOIs) are submitted to the Agency, outlining potential UK involvement in an ESA mission. SOIs are evaluated by one of the Agency's advisory bodies in terms of scientific return for investment and long-term strategic benefit. For the Cosmic Vision programme, the principal advisory body is the Science Programme Advisory Committee (SPAC).

When a project is ready to move from definition (Pre-Phase A) to development (Phase A), the Agency carries out a full peer review to assess programmatic issues such as feasibility and risk, in addition to UK investment return. At this stage, potential UK technology developments are clearly defined in response to ESA's Announcements of Opportunity (AO) for instrument delivery. This allows the UK to access its potential role within any consortium and focus on maximizing scientific return, leadership and technical capability.

Typically three missions enter into competitive assessment for a single launch opportunity.

In addition to study phase activities, the UK Space Agency's Cosmic Vision National Programmes budget currently funds operation of missions already launched and instrument and data processing systems for missions under development. Details of all UK Space Agency support to missions can be found in the accompanying table.

Within the Agency, programme managers oversee each Cosmic Vision project, supported by dedicated project boards or oversight committees. For multi-national instrument development projects for ESA missions, ESA and Member States manage the project using Steering Committees set up under the terms of signed Multi-Lateral Agreements (MLAs).

The Future

ESA member states are consulted on technology planning and the UK must focus on strategically funding technologies aligned to ESA programme concepts. This will enable the UK to be in a position to target key roles, which was a recommendation of the Space Innovations and Growth Strategy report.

Past investment has secured leading UK roles on payload development but as missions become ever more complex, the boundary between the spacecraft and the payload is less defined. Payloads requiring industrial management may become more common and therefore early funding of the UK community to target and secure ESA technology funding is an important goal. To that end, early stage funding of collaborations between industry and academia to develop sensors and their associated data handling systems has been identified as a high priority. Involvement in this development work is closely linked to the ability to exploit the science output and typically involves long-term collaborations between industry and academia.

The UK has involvement in both of ESA's M-Class missions selected in October 2011; M1 - Solar Orbiter and M2 – Euclid. Both M-Class missions have

progressed through their Assessment Phase and are now in development, with launches targeted for 2017 and 2020 respectively.

Following payload selection in February 2013, the UK is in line to make a significant contribution to ESA's first Large-Class mission, JUICE, through the JMAG magnetometer instrument being led by Prof Michele Dougherty, Imperial College London. Formally adopted by ESA in 2014, JUICE is planned to be launched in 2022.

The Agency awarded 'initial studies' funding for UK participation in all five of ESA's M3 mission candidates. The M3 mission candidates were EChO, LOFT, PLATO, STE-QUEST and Marco Polo-R. In February 2014, PLATO was formally selected to proceed to definition phase, with a formal selection to take place in 2015 and launch by 2024.

The Agency also hopes to support ESA's planned programme of new Small-Class missions, initially through utilising previous investment at Harwell and funding missions' operations capability for the first Small-Class mission, CHEOPS - an exoplanet space telescope.

Phase	Project	Summary
In Development	PLATO	The PLATO (PLAnetary Transits and Oscillations of stars) mission is designed to seek out exoplanets (planets beyond our solar system). The UK has particular expertise in focal plane arrays, instrument control and data processing. The Agency is supporting the early phase development of the CCD camera and read-out electronics (MSSL) and science-management and data processing activities (Warwick, Cambridge).
In Development	LISA Pathfinder LTP	LISA (Laser Interferometer Space Antenna) Pathfinder is a spacecraft that will test technologies for the future LISA mission. The aim of LISA will be to detect gravitational waves in space, opening up a completely new 'view' of the Universe. UK scientists from the University of Birmingham, the University of Glasgow and Imperial College London are collaborating on the LTP (LISA Test Package). Airbus Defence and Space is the spacecraft's main contractor. SCISYS Ltd is developing the satellite's on-board software. All flight hardware has been delivered and launch is scheduled for mid 2015.
In Development	JUICE	JUICE (Jupiter Icy Moons Explorer) is a mission to investigate the Jupiter system as an archetype for gas giants and investigate the potential emergence of habitable worlds around gas giants. It will study Jupiter and its moons Io, Europa, Ganymede and Callisto in unprecedented detail. Following instrument selection in February 2013, the UK's contribution will be the magnetometer (J-MAG) led by Prof Michele Dougherty at Imperial College London. Formal adoption of the mission by ESA is expected in November 2014.
In Development	JWST MIRI	The James Webb Space Telescope (JWST) will study the first stars and galaxies. It will also examine the physical and chemical properties of Solar Systems, including our own. The UK Astronomy Technology Centre (Edinburgh) is leading the MIRI (Mid Infrared Instrument) European Consortium of more than 20 institutes. The instrument was the first of the four JWST instruments to be delivered, arriving at NASA Goddard in May 2012. MIRI has now been integrated into the JWST Integrated Science Instrument Module and undergone cryogenic testing. JWST is scheduled for launch in October 2018.
In Development	Solar Orbiter	Solar Orbiter will be the first spacecraft to provide close-up views of the Sun's polar regions. The mission orbit is designed to be synchronous with the Sun's rotation providing long duration observations for the first time. This will enable the mission to observe the build-up of events such as solar storms. The UK is heavily involved in the development of instruments for the mission with MSSL leading the Solar Wind Analyser (SWA) suite and contributing towards the Extreme UV Imager (EUI), ICL with the Magnetometer and RAL Space is involved with the Spectral Imager (SPICE). In addition, Airbus Defence and Space is the Prime contractor for the mission.
In Development	Sunjammer	Sunjammer is a NASA mission to demonstrate solar sail technology. The space craft provides the opportunity for two UK instruments to gain in-orbit heritage: the Solar Wind Analyser (SWAN) is a miniaturised ion spectrometer that has been developed by MSSL, UCL, and the magnetometer (MAGIC) has been developed by Imperial College London and will measure the solar wind magnetic field. These instruments will be used in space weather prediction.

Phase	Project	Summary
In Development	Euclid	Euclid is a high-precision survey mission to map the geometry of the Dark Universe and would effectively look back in time about 10 billion years, covering the period over which dark energy seems to have accelerated the expansion of the Universe. With nine institutes involved, the UK has the lead role on the VIS (Visible Imager) for weak lensing, and is responsible for building the VIS instrument. It also has a strong involvement in the Science Ground Segment, including the lead role in the Shear Organisational Unit. Euclid is scheduled for launch in 2020.
In Development	Bepi-Colombo MIXS	Bepi-Colombo will be only the third spacecraft to visit Mercury in the history of space exploration. Mercury's harsh environment makes it a particularly challenging mission. The MIXS instrument led by University of Leicester is the key UK scientific involvement and the project is due for launch mid-2016.
In Operation	GAIA DPAC	Launched in December 2013, the European Space Agency's Gaia mission will examine the Milky Way in unprecedented 3-D detail. The spacecraft will survey more than one billion stars to make the largest, most precise map of our Galaxy to date. The UK Space Agency has made a £12 million contribution to the development of the pan-European Data Processing and Analysis Consortium project led by University of Cambridge.
In Operation	STEREO	The twin spacecraft of NASA's Solar Terrestrial Relations Observatory (STEREO) are sending back remarkable 3-D images of the Sun. A UK consortium, led by RAL Space, developed STEREO's Heliospheric Imager.
In Operation	Hinode	The Japanese Hinode mission is studying the processes involved in solar flares and Coronal Mass Ejections. Designed and built by teams in the US, Japan and the UK, Hinode has key involvement from MSSL and RAL Space.
In Operation	Swift	Swift is a NASA mission to study gamma ray bursts and their afterglow. The University of Leicester hosts the UK Swift Science Data Centre, providing immediate access to Swift's data 24 hours a day. The University supplied key systems designs for the XRT and built the low temperature CCD focal plane camera and the TAM (Telescope Alignment Monitor). MSSL helped build Swift's UVOT.
In Operation	Rosetta	Rosetta will be the first spacecraft to undertake the long-term study of a comet at close quarters. It is one of the most challenging missions ever undertaken and completed its rendezvous with Comet 67P Churyumov-Gerasimenko in August 2014. Rosetta has significant UK involvement from industry and science including the Ptolemy chemical analyser on the lander.
Post Operational Support	SOHO	The Solar and Heliospheric Observatory (SOHO) recently celebrated its twelfth anniversary in space. The joint ESA/NASA project is one of the most successful and longest lasting space science missions of all time. The UK has always been a major player in the SOHO project, from the design and construction to the operation and science.
Post Operational Support	Planck	The UK has provided instrument technology to the Planck mission which has examined the ancient radiation released shortly after the Universe was formed, known as the cosmic microwave background radiation. Operations and scientific exploitation involved multiple UK groups led by the University of Cambridge. Though nominal spacecraft operations have ended, the UK Space Agency continues to fund post operational support to organise data in a format suitable for scientific exploitation.
Post Operational Support	Herschel	ESA's Herschel Space Observatory was the largest ever infrared space observatory and collected radiation from some of the coldest and most distant objects in the Universe. A team led by Cardiff University built the SPIRE instrument, one of the three instruments on board. Scientific operations are ongoing. Herschel made its last observations in April 2013 before its liquid helium coolant ran out as scheduled. The Agency continues to fund post operational support to calibrate, process and archive the vast dataset the mission has created.

National Cubesat Programme

Subject to the outcome of the pilot cubesat mission, UKube-1, the Agency intends to establish a full National Cubesat Programme with regular launches.

Cubesats are miniaturised satellites that weigh less than 10 kg and use 'off the shelf' components where possible. As vehicles to carry scientific and commercial payloads, they present an exciting opportunity for those seeking rapid access to space for relatively low costs. The aim of a National Cubesat Programme would be to allow educational establishments and commercial organisations in-orbit flight experience for their scientific experiments and new technologies, providing relatively affordable space-based scientific data and quickly raising TRLs.

Funding for UKube-1 has been provided by the UK Space Agency, the Technology Strategy Board, and STFC. The cubesat was built by Clyde Space and the University of Strathclyde through a Knowledge Transfer Partnership, supported with internal funding from Clyde Space. Ground segment support will be provided by the Satellite Applications Catapult. From 21 payload proposals, four were selected: a CMOS Imager Demonstrator, FunCube, Janus, and TOPCAT. More information on these payloads is available on the Agency website. UKube-1 was successfully launched on 8 July 2014.

Meanwhile, following on from the original call for UKube-1 payloads, 30 proposals were evaluated and 11 grants awarded funding totalling £310,000 for research into further exploitation of cubesats, indicating the desire in the space community for a National Cubesat Programme. The UK Cubesat Forum has also been established, giving an independent, coordinated voice to this growing community.

Case Study – *UKube-1*

United Kingdom universal bus experiment (UKube-1) is the pilot mission of what the UK Space Agency hopes will be a national cubesat programme. Cubesats are shoebox-sized spacecraft which can be built quickly and cheaply. As such, they are designed to provide rapid and cost-effective access to space for innovative technologies, overcoming the traditional barriers to entry. The rapid turnaround and low cost also means that a cubesat can be of great benefit to education, helping to train the next generation of engineers and scientists and inspiring school pupils to take up STEM subjects.

UKube-1 was built by Clyde Space and the University of Strathclyde through a Knowledge Transfer Partnership. The spacecraft platform is £800,000; the partners are the UK Space Agency (£600,000), Technology Strategy Board (£100,000) and STFC (£100,000), including launch campaign and licence costs and development of the Ground Segment at RAL Space, Harwell Oxford. Additional product development investment has been provided by Clyde Space and the payloads are all self-funded.

The satellite was launched on the 8th July 2014 on a Russian Soyuz launch vehicle, from Baikonur, Kazakhstan.

The suite of payloads on UKube-1 includes:

- FunCube: An AMSAT-UK developed educational payload designed to allow school children to download operational data from the spacecraft, with the goal of enthusing them about space and physics.
- CMOS Imager Demonstrator: Technology demonstration of a camera using innovative sensors (developed by a collaboration between the Open University and Chelmsford company e2v Ltd).
- Janus: Demonstration of a random number generator using cosmic ray hits, which could potentially be used as a component of secure satellite communication systems (Airbus Defence and Space).
- TOPCAT: An experiment designed and built by students at the University of Bath to measure the ionosphere and improve our understanding of space weather effects.

UKube-1. Credit: Clyde Space

Case Study – *Gaia Data Processing and Analysis Consortium (DPAC)*

Gaia was launched in December 2013 from the European Space Agency's facility in Kourou, French Guiana, and is an ambitious ESA mission to determine the position and velocity of a billion stars; creating the largest and most precise 3D map of the Milky Way with data on the stars' brightness, temperature, composition and motion through space. It will gather the data via an integrated payload comprising two space telescopes with 10 mirrors collecting and focussing light into the three science instruments. The mirrors have a collecting area of approximately 0.7 square metres.

The light captured by Gaia's mirrors will be analysed by the instruments using the billion pixel focal plane of CCDs (Charged Couple Devices). This focal plane consists of 106 large area, high performance, CCDs supplied and tested by the UK's e2v.

Gaia will observe each star approximately 70 times over five years, giving an average of 40 million observations per day; this will cover about 1% of the stars populating the Milky Way. In addition Gaia is expected to provide information on thousands of other objects such as asteroids and comets within our Solar System and planets, brown dwarfs, supernovae and distant galaxies beyond our Solar System.

The processed data and archive from Gaia is expected to reach one petabyte (approximately 1.5 million CDs) and in order to analyse and process such a large volume of data, the Gaia Data Processing and Analysis Consortium (DPAC) was established. DPAC is a consortium of approximately 450 people over 20 countries providing the computing software and hardware to populate and manipulate the Gaia database. The UK has key roles providing a data processing centre and leading the prime photometric processing to determine key stellar characteristics; this work is led by Professor Gerry Gilmore of the University of Cambridge with RAL Space, Edinburgh and the University of Leicester. University College London's MSSL also has a major role in the spectroscopic science studying stellar velocity with the Open University.

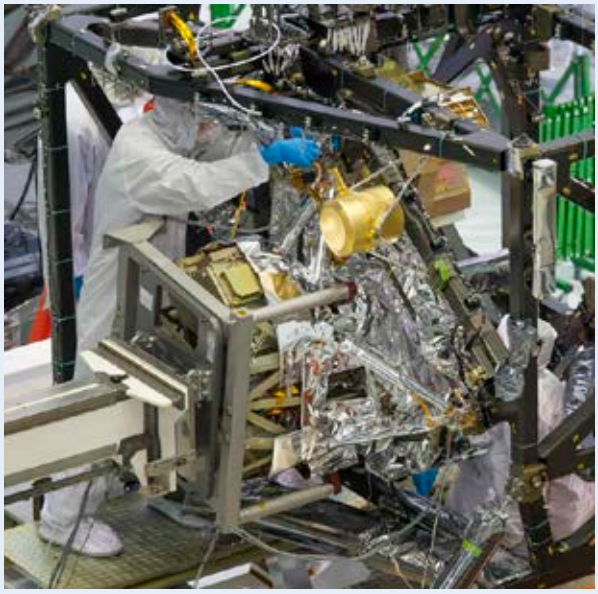
Engineers at Airbus Defence and Space, Stevenage, have provided core systems for the Gaia satellite including video processing unit, satellite electrical platform, and mechanical subsystems, SCISYS UK Ltd is responsible for the spacecraft's operational simulator.

The UK support to the DPAC development is £12 million and ongoing support for post launch operations is at £2 million per annum.

The Gaia spacecraft after the last deployment test of the sun shield. Credit: ESA

Case Study – *The MIRI instrument on the James Webb Space Telescope (JWST)*

MIRI was delivered to NASA in May 2012. The instrument was built by a European Consortium led by the UK with funding from the UK Space Agency and STFC. It is the first of four instruments to be delivered for the James Webb Space Telescope, a NASA/ESA collaborative mission designed to be the successor to the Hubble Telescope. MIRI has been integrated onto the Integrated Science Instrument Module-the JWST ISIM - and is undergoing three ISIM-level cryovac tests as part of the environmental test campaign to be carried out during 2013-2015. As part of the collaboration, the UK team (including the Principal Investigator from the UK-Astronomy Technology Centre, the Project Manager from Airbus Defence and Space and staff from STFC's Rutherford Appleton Laboratory) are supporting this NASA test campaign at Goddard Space Flight Centre in Maryland. This is the first time that MIRI has been at operational temperature for two years, and preliminary functional testing has shown the instrument to be working correctly. The JWST launch date is set for October 2018 from Kourou, French Guiana.



MIRI (wrapped in aluminized thermal shield) integrated into the JWST Integrated Science Instrument Module (ISIM). Credit: NASA/Goddard Space Flight Center/Chris Gunn

UK Space Agency Aurora National Programme

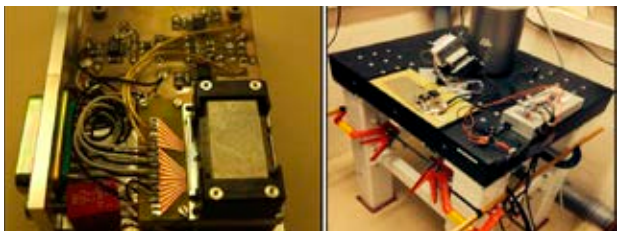
Objectives

Aurora is the European framework for solar system exploration, focusing on Mars and the Moon. It is an optional ESA programme and currently comprises the ExoMars mission and a development programme for future missions (MREP 2 – Mars Robotic Exploration Preparatory Programme 2). The UK's national Aurora Programme complements the investment through ESA and comprises:

- The Collaborative Research in Exploration Systems and Technology (CREST) programme. CREST supports industrial and academic partnerships developing technologies with potential for both exploration and terrestrial applications. Specific Announcements of Opportunities (AOs) for this programme give guidance on priority research areas. Universities are funded via a Research Council grants and industry awards are made directly to the researching company. Awards for CREST 2 were announced over the summer of 2013. Nine proposals were awarded funding to a total of £2 million.

- The instrument delivery funding is currently focused on the 2018 ExoMars mission. Funding is provided to instrument teams via Research Council grants to academia and contracts to industry. The UK's contribution is peer reviewed and prioritised and the potential for technology spin out and science return are key criteria for the UK Space Agency.

- Aurora funding has been used by Imperial College London to develop the short-period sensors (SEIS-SP) and the associated electronics for the seismometer. The seismometer instrument, led by CNES, forms part of the NASA InSight (Interior exploration using Seismology, Geodesy, and Heat Transfer) mission. This mission, scheduled to launch in 2016, will travel to Mars to study the interior of the planet. The seismic activity package will be used to assess the deep interior structure of Mars, including the thickness of the crust, the composition of the mantle, and the size of the core.



Testing the SEIS-SP in a seismically quiet basement in Oxford, an Earthquake in Greece was detected. Credit: University of Oxford/Simon Calcutt

- The Aurora Science Award Programme designed to build the research community by providing studentships, Post Doctoral Research Assistants (PDRAs) and fellowships to promising young researchers, thus maximizing the UK's ability to exploit future science data. There is nominally one call per year and the AO provides guidance on key areas. The call is open to all research institutions and awards are made via Research Council grants. In June 2014, just over £1 million was awarded for 3 studentships and 3 PDRAs. The AO for the 2014/2015 awards was released in June 2014 for up to £1.3 million.

- The Aurora Knowledge Exchange Programme to inject Aurora technology into wider industrial applications to benefit the UK's economy. Nine projects were awarded funding up to £0.5 million in July 2011.

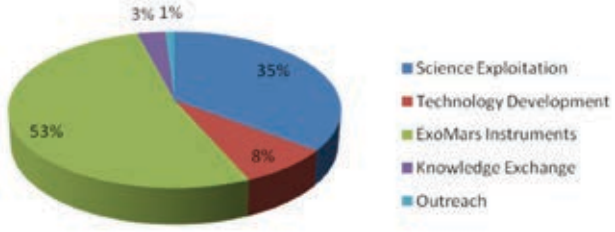
- A Mars Exploration Outreach Programme to fund the development of schools materials and activities. This provides support for outreach officers and cover publications, events and media materials (the latter is via contracts). The AO for Aurora outreach was released in June 2014 for up to £50,000.

Funding and Management

The UK contributes €164 million to ExoMars (16.5% of the total mission cost) and €25 million to the Mars Robotic Exploration Preparatory Programme (MREP 2). The UK is Principal Investigator for the ExoMars Panoramic Camera instrument, 'PanCam', and Co-Investigator on the Raman Laser Spectrometer (RLS). The UK ExoMars instrumentation build is managed via the UK Space Agency and the ExoMars Oversight Committee (EXOC).

The UK Space Agency is responsible for the UK's subscription to ESA as well as the UK national programme. The national programme is managed using community advice provided by the Agency's Space Exploration Advisory Committee (SEAC) and via project-level management committees.

The average spend on the Aurora national programme is £5 million per annum. The planned breakdown of national funding (£57.3 million) to the end of ExoMars operations in 2021 is show below:



Case Study – *PanCam*

The rover vehicle's PanCam instrument, led by a team from the Mullard Space Science Laboratory (UCL-MSSL), has been designed to search for textural information on rocks that can be related to the presence of organisms on Mars. PanCam will also capture other information that will help in revealing the geological characteristics of the Martian surface.

The instrument will play a key role in the Rover's scientific operations, providing stereo and 3D imagery of the terrain around the Rover. In particular, the Panoramic Camera will be used to:

- help locate the landing site and Rover position with respect to local geographical references
- provide the geological context of the sites explored by the Rover
- support the selection of the best sites to carry out exobiology studies
- study properties of the atmosphere and of other variable phenomena

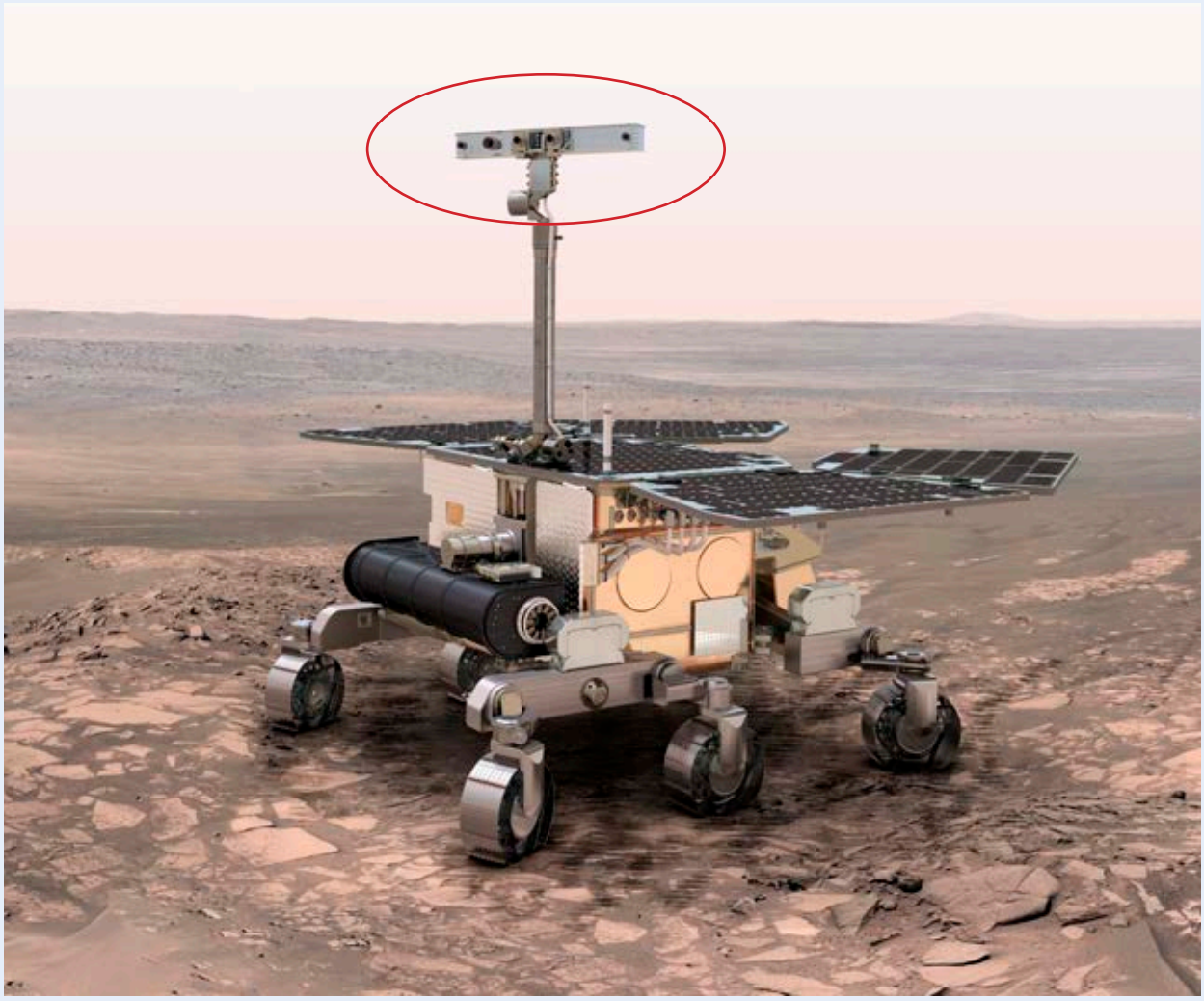
PanCam will also support the scientific measurements of other Rover instruments. It will capture wide angle and high-resolution images of locations that are difficult to access, such as craters or rock walls. Then, it will monitor the sample from the drill before it is ingested and crushed inside the Rover, where the Analytical Laboratory instruments will perform a detailed chemical, physical, and spectral analysis.

PanCam is composed of:

- two Wide Angle Cameras (WACs), for panoramic imaging (38° field of view, fixed focus); both "eyes" are equipped with a 11-position filter wheel each covering a different wavelength, thus enabling multispectral observations
- one High Resolution Camera (HRC), for 'zoom' colour imaging (5° field of view, with an autofocus mechanism)
- the PanCam Interface Unit (PIU), the "brain" of the instrument communicating with the Rover

These three elements are grouped inside an optical bench arranged on the Pan-Tilt Unit on top of the ExoMars rover mast assembly.

PanCam design (Credit: C.Theobald, MSSL)



The PanCam mounted on the Rover mast. Credit: ESA

Case Study – *Raman spectroscopy*

Raman spectroscopy is a well-established and powerful technique that allows fast, non-destructive chemical and structural identification of materials in the solid, liquid or gas state. For the first time, in 2018, a Raman spectrometer will fly on-board a space platform. ESA's ExoMars rover will incorporate a Raman instrument in its suite of analytical instruments, which will used to characterise the mineralogy and geochemistry of the Martian surface. The development of the Raman Laser Spectrometer (RLS) for the ExoMars mission has resulted in significant steps forward in the miniaturisation and robustness of the technologies associated with portable spectrometers, aiding their implementation in many other areas of research and industrial applications.

As part of a collaboration with the National Nuclear Laboratory and Sellafield Ltd, prototype miniaturised Raman instruments developed during the ExoMars programme will be tested to explore their suitability for the identification of isolated nuclear waste material and to investigate how they can be used to aid decommissioning. In addition, a research collaboration has been set up with the pharmaceutical charity, Inter Care Ltd, to explore how various Raman techniques and instruments can be used to characterise the degradation of the active ingredients in certain pharmaceuticals.

Case Study – *The ESA Sample Acquisition Field Experiment with a Rover Project (SAFER)*

The five-day Sample Acquisition Field Experiment with a Rover, or SAFER, field trial concluded on Saturday 12 October 2013, with great success. The SAFER project used an early version of ESA's 2018 ExoMars rover fitted with a trio of prototype ExoMars instruments in the Atacama Desert, Chile and was overseen from a remote control centre at the Satellite Applications Catapult facility in Harwell, UK.

Just as the actual rover will do on Mars, the test rover – supplied by Airbus Defence and Space, dubbed 'Bridget' – hosted a panoramic camera, close-up imager resembling a geologist's lens and ground-penetrating radar to identify promising sites for subsurface excavation. The one item the rover lacked was a working drill, so whenever the control centre ordered an excavation, the local team stepped in to manually dig the site. This obtained samples for 'ground truth' – checking that the radar analysis was accurate as well as enabling close-up analysis.

"At our second simulated drill location the field team found a layer of rock starting at a depth of 60 cm," remarked Dr Sev Gunes-Lasnet, SAFER project manager, from RAL Space. "This comes close to the kind of features the team was looking for: analogues for locations on Mars which could hold traces of past or present life."

The SAFER project was a huge success; the team achieved remote operations with an average of two martian sols per day, acquired valuable instruments data, drilled successfully down to more than a metre and found a significant rock layer which will help cross calibrating the ground penetrating instrument data and support future Mars exploration missions.

SAFER was funded by ESA's Basic Technology Research Programme, with additional co-funding from the UK Space Agency.

The SAFER valley with direct line of sight to ESO, Credit: Gerd Hudepohl, ESO Paranal

National Space Technology Programme

Initial Successes of NSTP Phase 1

In February 2012 the UK Space Agency made an open call for project proposals which would introduce highly innovative technologies with strong enabling potential for future space activities. This programme's aim was to support studies on more speculative, lower Technology Readiness Levels (TRL) that would improve performance and system parameters such as cost, mass and resource requirements on future space missions. A selection panel was drawn from independent representatives from academia, industry, the Space National Technical Committees, UK Space Agency and the Research Council Reviewer College. The successful proposals proved credible benefit to future operational, commercial or scientific mission objectives and demonstrated an alignment to one of the five National Space Technology Roadmap sectors as defined by the first Space Innovation and Growth Strategy and various industry workshops; Access, Position-Navigation-Timing, Robotics-Exploration, Sensing, and Telecommunications.

A central aim was to de-risk technologies sufficiently so they became commercially viable. The NSTP raised the TRL on projects on average by two levels.

Space for Growth

The 'Space for Growth' competition formed the core of the UK Space Agency's National Space Technology Programme. The aim was to support activity that either developed or de-risked the technology needed to build on the UK's share of global high-growth markets. This included the identification of innovative new areas to exploit.

Following an open call for proposals in October 2011, four large 'Flagship' projects received funding up to £2 million each, and 25 'Fast track' projects were funded between £50,000 and £100,000. This funding was largely provided on the basis of 50% of project cost, with a total of £6 million provided by the UK Space Agency, £2 million plus administration and assessment costs by the Technology Strategy Board and an additional £500,000 by the South East England Development Agency (SEEDA) for projects based in that region.

All projects were business-led and were chosen to clearly focus on collaborative R&D activity between small and medium-sized businesses, academia and larger established members of the space industry.

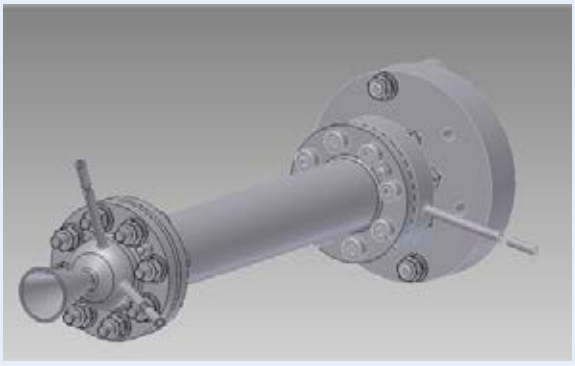
Further information on the completed Space for Growth projects can be found in the TSB Space for Growth Directory.

Flagship Case Study – *High Resolution System for Commercial Carbon Stock and Flux Measurement*

DMC International Imaging Ltd (DMCii), Carbon Auditors Ltd (CAL) and University College London (UCL) proposed to jointly develop a system for measuring land carbon stocks and fluxes from Earth observation (EO) satellite data. The resulting carbon-market intelligence products would address segments of a total market today estimated at £16 billion. The project applied the developing science of carbon stock and flux measurement techniques to deliver global high resolution products at regional and local scales (sub hectare). The system would be automated for online processing and delivery through established routes to market. The project built on existing investment by the partners in this area and the resources and expertise of the TSB to position UK industry through the partners to exploit new services in this high growth emerging market.

Fast track Case Study – *Innovative "Green" Propulsion Systems*

All UK Propulsion Systems produced for telecoms, earth observation, navigation and science missions currently follow the global propulsion industry trend and utilise hydrazine or monomethyl hydrazine as a fuel. Due to toxicity the European Chemicals Agency (ECHA) has put hydrazine on the "substance of very high concern" list which will lead to obsolescence in 2016. A consortium was assembled of; Airbus Defence and Space and Surrey Satellite Technology Ltd (SSTL) (Primes), Ampac-Isp (thruster entity), MTSP (tank entity), University of Southampton and Deltacat (propellant specialists) to build on existing IP to work on an alternative propellant and propulsion system to hydrazine as current alternatives were not industrialised or cost effective. The export market is global and this team was well placed to enable the UK to take a technical and strategic lead in low toxicity propulsion technology.



Future Technology Pathfinder Programme

The UK Space Agency granted £500,000 to industry and academia to fund 10 Pathfinder projects under the National Space Technology Programme (NSTP) in preparation for future space missions. The projects were selected following an open call to the space community in February 2012 and the projects commenced in May 2012.

In total, 19 academic and industrial organisations carried out the work, which was managed on behalf of the Agency by the Centre for EO Instrumentation (CEOI). The organisations leading the projects were: Reaction Engines Ltd, Magna Parva Ltd, Archer Technicoat Ltd (ATL), Airbus Defence and Space, TISICS Ltd, EADS Innovation Works, The Open University, COM DEV Europe Ltd and Selex ES Ltd.

All of these Pathfinder projects achieved a great deal in a limited time, using minimal resources. Most of the Pathfinders built or tested new hardware or implemented a new manufacturing technique or process; a challenging achievement for a six month project. A number of new common areas of interest were discovered at the final review, leading to the potential for future collaborative projects. This suggested that an earlier interaction in future rounds between Pathfinder (and other NSTP) projects could be beneficial.

Two projects pursued a total of six patent applications, directly as a result of the Pathfinder work.

Future Technology Pathfinder Case Study – *Evaluation of Reduced Hazard Clean Combustion Propellants*

The UK Space Agency awarded funding to Reaction Engines Ltd, partnered with Airborne Engineering Ltd to demonstrate carbon monoxide as a viable propellant with a non-contaminating exhaust free of water and hydrocarbons, thus enabling a Mars landing mission which would avoid contamination of the surface.

Initial analysis identified methane and carbon monoxide as the most promising propellants, as 'clean' alternatives to hydrazine. Test results show that a stable reliable combustion with good pressure and thrust stability can be achieved for both propellants. For carbon monoxide overall combustion is very efficient, with 90 – 94% of the theoretical vacuum exhaust velocity being realised. For a high aspect ratio nozzle vacuum exhaust specific impulses of 275 – 290 seconds, can be achieved and the thrust can be throttled in the range from 1500 – 3700 N over the total mass flow range investigated. For methane, efficient combustion was not achieved and further work is required to characterise the limits of performance.

Future Technology Pathfinder Case Study – *Titanium Matrix Composite Arm*

TISICS Ltd was awarded funding for a titanium matrix composite (TMC) arm. Silicon carbide fibre reinforced titanium composites, structures were shown to be viable alternatives to standard CFRP units and offer superior performance for selected niche space components such as robotic arms with complex metal joints.

Fabrication of three representative silicon carbide fibre reinforced titanium composites, structures, consisting of two full arms with end pieces (760 mm, 640 mm long) and a 400 mm tube section, was completed successfully by TISICS Ltd. One arm was tested under deflection showing agreement to the FEA model to within 5%. FEA modelling was also used to compare the performance of TMC with comparative CFRP robot arms. FEA analysis predicted superior bend, torsion and compression stiffness for TMC compared to CFRP per unit mass in all configurations.

Space CITI Pilot Programme

The Space Collaborative Innovation Team Initiative (Space CITI) funding programme was developed in order to provide rapid prototyping of new technologies more quickly than has been possible using conventional development techniques.

The programme funded four projects totalling £700,000 in funding. These four projects covered a diverse set of areas including the provision of information to maritime customers, a general purpose avionic testbed for future small spacecraft, developing a multi-instrument payload data handling system and a study of options for launching spacecraft from the UK. The individual projects were:

- SeaSpace – led by SeaZone Group at Wallingford
- FlatSat – led by SSBV
- Integrated Payload Data Handling System (I-PDHS) – led by Airbus Defence and Space
- Towards a UK Space Launch Capability – led by Surrey Satellite Technology Ltd

The programme ran from 2011-2013. The management of the Space CITI programme was conducted by staff from the International Space Innovation Centre (ISIC). The work of ISIC was incorporated into the Satellite Applications Catapult Centre in April 2013.

Case Study – *Towards a UK Space Launch Capability*

SSTL conducted a study into the different options for developing the capability of launching spacecraft from the UK in order to fulfil the demand from the UK for access to space in a manner that provides the UK with control over launch dates, something that is essential in order to deliver a complete service to customers. The study covered a variety of launch vehicles, whether it would make sense to import launch vehicles from other countries or to build them in the UK, and the economic case for a launch site within the UK. The economic case was conducted by London Economics, to provide an independent and unbiased advice on how to judge the economic case.

The UK now has more information about the key components that would be part of any UK launch capability. The study made a compelling case that a UK launch capability would benefit the UK, both in terms of the services that it would offer industry and in terms of it being a viable financial proposition in its own right. The next step would be to actively consider whether, and if so, how, to develop a UK launch capability in the light of this and previous related studies.

Case Study – *Integrated Payload Data Handling System (I-PDHS)*

The Integrated Payload Data Handling System (I-PDHS) project developed the hardware and software tools that would be needed in order to reduce the power and mass requirements in multi-instrument missions by having one processor with the ability to control and process the data from multiple payloads. Each instrument had its own specific requirements, so rather than use a single processor with multiple processes as is commonly the case with ground-based computers, I-PDHS would provide the ability to reconfigure the on-board system and so provide an optimal configuration for each instrument.

The aim of the project was for the UK to be better placed to offer competitive payloads to a wide range of international missions through the reduction in mass and power that the I-PDHS methodology would provide.

The project demonstrated that central provision of the processor and its core system services would free the instrument teams to concentrate their resources on sensors and the science.

Horizon Scanning

The aim of this activity was to examine emerging trends, including threats and opportunities that would affect the UK space sector and respond to these identified trends. Led by the University of Strathclyde, with a team from across the community, the activity examined scientific, industrial and commercial factors both within and beyond the space sector to ensure both technical and socioeconomic drivers were identified as well as framework, regulatory and governmental issues that would influence the future of the space sector. Due to its combined technical and socioeconomic approach, this was an important aspect of the NSTP that will be carried forward into Phase 2.

The National Space Technology Horizon Scanning activity should always be considering a timeframe beyond that of the National Space Technology Roadmaps. Therefore, the earliest valid period for consideration of technology realisation within the context of this activity would be ten years hence, with no upper time limit. The targeted technology horizon timescale was 15 – 25 years.

National Space Technology Programme Phase 2

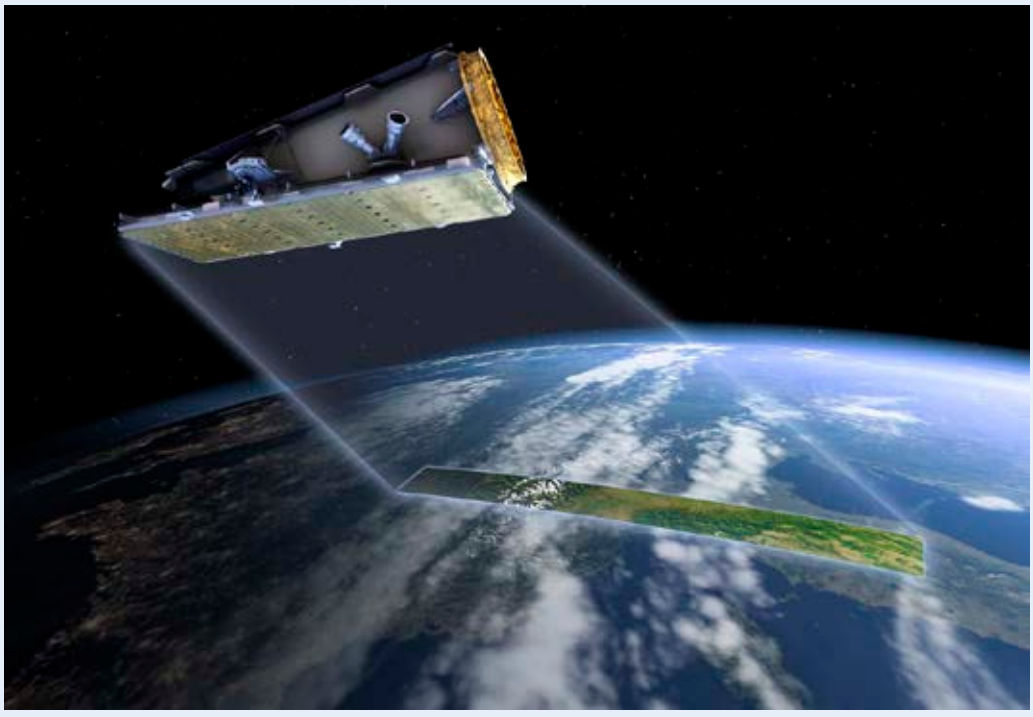
In January 2013, £25 million was announced for the National Space Technology Programme Phase 2 (NSTP 2), to support a two year model of technology funding. This second phase will allow a new programme to be delivered with aligned funding elements over multiannual activities. NSTP 2 will continue the established structure of the first phase allocation model as well as introducing new elements of funding over the next two years. The first allocation of £5 million was used to support the development of a highly secure navigation system technology. The next call for NSTP 2 was released in July 2014 and was announced on the UK Space Agency website.

NSTP2		Allocation NSTP2 Year 1 £k
Flagship		N/A
CORE PROGRAMME	Technology Fast Track	2,000
	Pathfinder	800
	"Mini"	200
Collaborative Projects with other public sector agencies		500
Horizon Scanning Studies		100
Other Studies		150
Small Project Support		250
Capital Projects		(in year 2)
CEOI		2,000
Highly Secure Navigation Technology (PRS)		2,000
Total		**8,000**

*Note: These are indicative figures for planning purposes for NSTP 2 and are not yet finalised.

Case Study – *Flagship Project: NovaSAR innovative imaging chain-critical element qualification*

This collaborative project between Surrey Satellite Technology Ltd (SSTL) and Airbus Defence and Space combines recent technological advances with proprietary and highly flexible algorithms to accelerate the technology development of an innovative S-Band synthetic aperture radar (SAR) instrument. This low-cost, yet extremely capable instrument design combines commercial techniques and processes with significant space hardware experience. It is the key enabler for a new lower cost satellite constellation, called NovaSAR, currently in development by SSTL. Making all-weather, day and night imaging more affordable will change the economics of radar remote sensing and help place the UK at the forefront of a new and exploitable global market. Economic benefit to the country will result not only from jobs in the industry building the space infrastructure and the associated supply chain, but also from the creation of business opportunities in downstream service sectors and across the wider economy.



Credit: SSTL

Highly Secure Satellite Navigation

Galileo is the satellite navigation system currently being built by the European Union. Galileo is a constellation of navigation satellites and a set of ground facilities to control and monitor the performance of the navigation signals provided by the satellites. It is a civil system under civil control (albeit with military application). This contrasts with GPS and other satellite navigation systems which are primarily military in nature. The Public Regulated Service (PRS) is Galileo's highly encrypted navigation and timing service which will provide increased integrity and resilience to a range of government authorised functions. PRS could include applications in civil/military government and critical national infrastructure. Market analysis from the UK and EU authorities indicates the PRS market to be worth £4-7 billion in the next 10 years. UK industry reasonably expects to secure close to 50% of this opportunity.

Given the potential of PRS to be used in a wide range of security sensitive applications and taking account of the UK's industrial capability in this space, it is prudent to secure a strong sovereign supply chain for this technology. Recognising this opportunity, the Agency launched a programme to engage UK industrial capability in 2011-2012. Phase 1 saw joint UK Space Agency/TSB investment of £1 million in 12 months to develop 'proof of concept' for a number of PRS platforms. This technology incubation has generated four patents and brought four additional companies into the PRS field in the UK.

Credit: ESA, P. Carril

Phase 2 of this programme has joint UK Space Agency/TSB funding of £6 million over two years. UK Space Agency funding for Phase 2 comes from the National Space Technology Programme (NSTP) and will demonstrate the best of UK industrial capability for this technology. This phase will develop the Phase 1 platforms into prototypes for demonstration and integration at the Satellite Applications Catapult which will host the demonstrators for a period of two years after the programme completes in early 2015. This level of development will create a unique shop window to demonstrate the value that PRS will add to a broad range of future user communities.

Space Applications and Services

Space applications are key to delivering the growth that is at the heart of the UK Civil Space Strategy, the Space Innovation and Growth Strategy 2014-2030, and the associated Space Growth Action Plan.

For applications to be successful, many elements need to be in place;

a. The satellites need to fly with instruments that capture the data users want

b. The data/signal is transmitted to a ground station

c. The data is quality checked and archived

d. The data is retrieved and accessed by a user (or service provider)

e. The data is manipulated/combined with other information to become the information source used in an application or service that the end user wants.

In the UK, responsibilities for this application development chain are shared. The UK Space Agency works with the Technology Strategy Board, the Satellite Applications Catapult, academia, industry and of course the users. The UK Space Agency is responsible for (a) ensuring the right space infrastructure is in place to meet UK needs for space-based applications. We work with our international partners such as the European Space Agency, as well as supporting national initiatives such as the NovaSAR mission to provide radar-based maritime security applications. We also ensure the right ground infrastructure is in place so (b) data and signals can be shared widely to get maximum value from the investments we make in space. The UK Space Agency leads on space policy and this often impacts applications development. We work in Europe and globally to ensure that data policies (c and d) are adopted which promote maximum exploitation of data without compromising

security or commercial business models. The UK Space Agency also leads on driving public sector uptake of data (e). To this end, we are developing the Space for Smarter Government Programme (see below) and are members of Eurysy.

In summary there are many organisations in the UK and abroad supporting applications work and the UK Space Agency can play a key and neutral role advising our broad stakeholder community on where to go for help.

Space for Smarter Government Programme

The UK Space Agency and the Technology Strategy Board are currently developing the Space for Smarter Government Programme (SSGP). This was previously referred to as the National Space Applications Programme (NSAP). It builds on but is a departure from the now closed GIFTTS programme.

The main objectives of the Space for Smarter Government programme are to;

- inspire and enable Government itself to use space for smarter, more efficient operations
- to use UK Government as an anchor tenant to drive growth through export of UK space products and services

The programme will be run in cooperation with, and to complement, the Satellite Applications Catapult and ESA programmes such as the Integrated Application Programme.

The public sector is already a major user of data and information acquired via space; communications, navigation information, and earth observation images and data. The rapidly increasing quantity and types of data, information and images being created and delivered through programmes such as Copernicus and Galileo have the potential to enable new applications to help manage the challenges faced by central and local government, and other public bodies.

The SSGP will enable identification of public sector requirements and the team will become a neutral brokerage of ideas between users and suppliers of space products and services. It will also enable those not usually in the space sector to identify appropriate funding routes. Whilst identifying potential public sector users and requirements, the programme is likely to set priority areas for SSGP funded projects which will enable growth for smarter government.

Once operational, the SSGP will act as a trusted first port of call for advice on the use of information acquired via space. The programme could take a number of routes to achieving its aims such as education and awareness raising, communications, policy changes and funding. We will work with other government departments to ensure their policy development and delivery cycles use space data and services to drive efficiencies in the public sector.

UK Space Agency Centre for Earth Observation Instrumentation (CEOI) Programme

Objectives

The CEOI aims to bring together the UK's academic and industrial Earth Observation (EO) communities in identifying key scientific questions to be addressed through the development of instrumentation and new technologies. Projects are advanced through the earliest technology readiness levels (TRLs) aiming to strategically position the UK Community to benefit from future national, ESA and other international opportunities.

Funding and management

The CEOI's budget has been increased to £2 million for 2014/15, allocated annually from government, with an additional 20–50% achieved from industrial support.

The CEOI is managed by the UK Space Agency. The consortium is led by Airbus Defence and Space along with QinetiQ, STFC-RAL and the University of Leicester. Over the years, nearly 40 projects have been funded following open calls to the community.

The 12 projects selected in the CEOI 5th Technology Call are complete. The largest of the projects – to prove the integration of highly sensitive receivers for future climate and meteorology missions – builds on existing CEOI work on passive microwave technologies, and two projects developed technologies for the next generation of the Eumetsat meteorology mission - MetOp Second Generation (MetOp-SG). Since completion of these latter projects, a UK-led team has secured the prime contractor role for the microwave sounder (MWS) on MetOp-SG. Other funded projects have conducted investigations into areas such as low weight mirror fabrication techniques, radar developments and other mission critical technologies.

An additional six projects were funded in autumn 2012 to investigate a diverse range of novel future EO mission and instrument concepts.

Case Study – *High Resolution Radiometry in the Infra-Red*

The Laser Heterodyne Radiometer uses a low power, highly stable quantum cascade laser to down-convert the spectral analysis into the radio-frequency domain, providing high spectral resolution, sensitivity and spatial resolution. Miniaturisation of the system using hollow wave guides has made the technology suitable for a wide range of terrestrial remote sensing applications for industrial pollution monitoring, defence, and security.

Breadboard of the first generation LHR. Credit: CEOI

The CEOI also managed the Pathfinder element of the National Space Technology Programme, overseeing 10 novel projects carried out by teams from academia and industry. The projects investigated a broad set of topics, including innovative propulsion systems, advanced detector technologies and miniature nuclear power systems for Martian rovers.

The future

Building on the continued success of the CEOI and the development of early stage technologies, in the autumn of 2013 the UK Space Agency initiated an expanded programme for CEOI to allow it to take EO technologies to an increased technology readiness level. The partnership will also take on increased responsibility in management of the NSTP projects. A planned series of calls for both EO and ST will be launched in 2014 and 2015 which will include technology demonstration projects, technology miniaturisation and disruptive technologies.

Technology Strategy Board Programmes

TechDemoSat

TechDemoSat-1 is a satellite platform, derived from heritage technology, which functions as an 'in-orbit test facility' for innovative UK payloads and software. UK industry and academia are working together with Surrey Satellite Technology Ltd (SSTL) to trial UK space technologies and hopefully win substantial international business for the companies collaborating on the project.

The project is part-funded through the Technology Strategy Board (TSB). TechDemoSat-1 plays host to a number of payloads separated into 4 suites: the Maritime suite, the Space Environment suite, The Air and Land Monitoring suite and the Platform Technology suite.

The Maritime Suite consists of SSTL's Sea State Payload (SSP). An evolution of SSTL's SGR-RESI payload, the SSP uses an enhanced GPS receiver to monitor reflected signals to determine ocean roughness. By utilising components from Airbus Defence and Space's Synthetic Aperture Radar (SAR) to operate as a coarse altimeter, the SSP pulses radio waves onto the ocean. The echo waveforms that return give an independent measurement of the sea state and the information gathered can then be applied to meteorology, oceanography, climate science and ice monitoring.

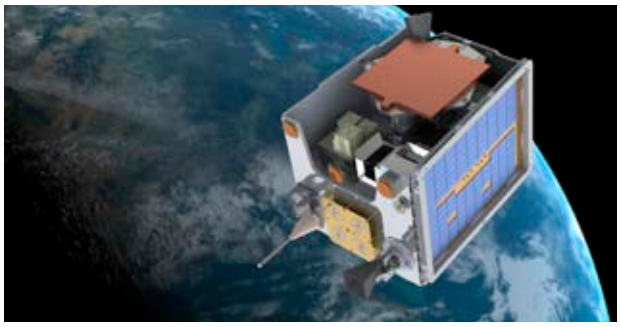
The Space Environment suite consists of the MuREM, ChaPS, HMRM and the LUCID payloads. MuREM, supplied by the Surrey Space Centre, provides a flexible, miniature radiation environment and effects monitor which can be flown as a standard radiation alarm and diagnostic package, enhancing the security of future space missions.

The Charged Particle Spectrometer (ChaPS), supplied by the Mullard Space Science Laboroatory (MSSL), is the first prototype of a new class of compact instruments to detect electrons and ions, building on 40 years of experience at UCL-MSSL. ChaPS will demonstrate the principles in-orbit and open the way to use the techniques on other missions where mass and power are at a premium, for example space

weather constellations. ChaPS will operate in three modes, to measure electrons in the auroral regions, electrons and ions in other regions and also to measure the spacecraft potential.

The Highly Miniaturised Radiation Monitor (HMRM), supplied by Rutherford Appleton Laboratory (RAL) and Imperial College London, is a lightweight, ultra compact radiation monitor designed to measure total radiation dose, particle flux rate and identify particle species (electrons, protons and ions). The instrument is designed to provide housekeeping data on the radiation environment to spacecraft operators to correlate the performance of spacecraft subsystems, raise alerts during periods of enhanced radiation flux and to assist in diagnosing spacecraft system malfunctions. TechDemoSat-1 also reaches beyond the UK space industry to incorporate the UK scientists of the future.

As the winning entry of a UK space competition for sixth form colleges, The Langton Star Centre, the LUCID (Langton Ultimate Cosmic ray Intensity Detector) payload will also fly on the space environment suite. LUCID allows characterisation of the energy, type, intensity and directionality of high energy particles. The data obtained from LUCID is of interest to NASA in terms of radiation monitoring but also provides inspiration to the next generation of physicists and engineers by giving school students the opportunity to work alongside research scientists and take part in authentic research.



Artist's impression of TDS-1 in orbit. Credit: SSTL

The Air and Land Monitoring Suite consists of a single Compact Modular Sounder (CMS) system being provided by Oxford University's Planetary Group and Rutherford Appleton Laboratory. The CMS is a modular infrared remote sensing radiometer unit, designed to easily mix and match sub-systems and fly multiple versions on multiple platforms at low cost by tailoring it to specific customer requirements once flight heritage has been proven.

While the companies and academia organisations flying payloads on the other three suites will make full use of the three year mission on board TDS-1 to prove their technology, Cranfield University must wait until the end of life decommissioning activity to prove theirs. One of two technologies within the Platform Technology Suite, the 'de-orbit sail' will safely bring TDS-1 back into Earth's atmosphere to burn up at the end of the mission. The other payload in the Platform Technology Suite is the CubeSAT ACS payload, supplied by SSBV, which is a complete 3-axes attitude determination and control subsystem designed for cubesats.

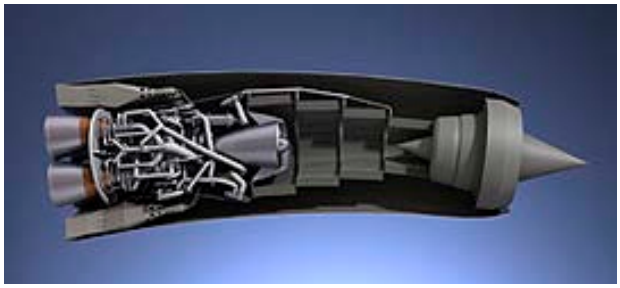
The satellite itself and all the payloads were fully assembled and integrated as a system at SSTL. The launch was in July 2014.

SABRE

SABRE (Synergetic Air-Breathing Rocket Engine) is a new engine class being developed by Reaction Engines Ltd to operate in both air-breathing and rocket modes. SABRE engines have the potential to transform access to space by providing a cheaper and more reliable way to power space planes. The advanced combined cycle air-breathing SABRE rocket engine will enable space planes to operate easily at speeds of up to five times the speed of sound or fly directly into Earth orbit. With the pre-cooler heat exchanger and other SABRE engine advanced technology development programmes nearing completion, the next stage of the SABRE programme is the construction of a full engine demonstrator.

A total of £60 million has been earmarked from the UK Government and will part-fund the production of the SABRE engine design by de-risking the development of engine components and also fund the completion of SABRE's final designs. Together with supporting subsystem tests and establishment of manufacturing capabilities, this project is the key enabler for the subsequent phases of prototype development, full engine testing and development.

The Agency expects to start initial funding of the next phase of SABRE development in 2014 through the ESA General Support Technology Programme (GSTP), subject to an agreed business case. The first tranche of funding of £10 million will be used to undertake further technology development and to complete SABRE's preliminary design phase.



Synergetic Air-Breathing Rocket Engine. Credit: Reaction Engines Limited

UK Space Agency's Education, Skills and Outreach Programme

The Agency's Education, Skills and Outreach Strategy addresses two distinct, although related, issues:

1. **Space for Education** - Space has demonstrated a remarkable power to inspire widespread interest in science, technology, engineering and mathematics (STEM) and provides exciting contexts for the teaching of a range of subjects.

2. **Education for Space** - Growth of the space sector is hampered by the scarcity of graduates and technicians with relevant qualifications and action is required to increase the number of skilled workers.

These aspects are mutually supportive and actions may address one or both themes in varying measure. In order to address these issues the Agency works with its partners in government, industry and elsewhere to:

- Continue to review and monitor the skills needed by the UK space sector and develop plans to address these needs
- Work with those responsible for the development of information, advice and guidance for all ages to ensure that support and materials on careers in the space industry are easily accessible, including role models, work experience, internships and information on jobs
- Encourage and support the use of space as an inspiring context for learning across all age groups, but with emphasis on:
    - supporting non-specialist primary teachers in the use of space in teaching
    - improving the quality and availability of teaching materials using space across the curriculum for primary and secondary schools and for colleges (mainly through ESERO-UK)
    - engaging pupils in STEM through the use of space, and maintaining and developing the interest of the most enthusiastic students by providing suitable opportunities
- Develop and implement wider outreach programmes to improve awareness and engagement with the UK's space programme, in particular by organising the UK Space Conference

Examples of ongoing programme elements include:

- The 'Space for All' outreach grants programme, which is about to enter its sixth round of awards
- The Agency's scholarships for UK students to attend the International Space University (ISU)
- The Mission X Train like an Astronaut international challenge (see case study)
- Support for the National Space Academy (see below)
- Support for the space education office (ESERO-UK) (see below)
- Support for the annual 'Space School UK' programme at the University of Leicester
- Support for the UK Space Settlement Design Competition for schools run by the Space Science and Engineering Foundation
- Sponsorship and learning resources for The Scout Association Astronautics Activity Badge
- Activity and career advice provider at the UK's largest annual STEM event, the Big Bang Fair

The Agency's budget for the Education, Skills and Outreach programme for Financial Year 2014-15 is £400,000, the bulk of which will be spent on Space for Education theme. However, the Agency also supports schemes such as the Space Internship Network (SpIN) run by the Satellite Applications Catapult.

The Agency's education activities are closely integrated with the work of ESERO-UK (the space education office, based within the National STEM Centre at York). ESERO-UK is used wherever possible to reach educators by providing access to high-quality teaching resources that use space as an inspiring context for a range of subjects across the curriculum.

The Agency also helps fund the National Space Academy, which offers continued professional development for teachers, master classes in physics and other STEM subjects for GCSE and A-level students, and a post-16 space engineering course. In September 2013, the Academy welcomed its first intake of students for the new Higher Apprenticeships in Space Engineering, aimed at 19 to 24-year-olds.

The Agency led in organising the UK Space Conference 2013. This was held in Glasgow and included, as well as strong delegate representation from across the space sector, an outreach programme, attended by over 500 people, and an ESERO Conference for teachers and educators.

Tim Peake Activities

The Agency's planned budget for Tim Peake activities in 2014/15 is £400,000. The UK Space Agency has put together a programme of activities that uses space as a context and hook for learning, that encompasses not

just STEM subjects, but those across the curriculum, such as food, exercise, music and literacy. This will be a celebration of the mission across the age ranges, reaching tens of thousands of people around the UK.

The Great British Space Dinner project is already underway; Tim has asked the children of the UK to design a menu for him to eat during his mission. The competition attracted over 500 entries from teams and individuals, engaging over 2000 children from across the UK. The winning entrants will work with Heston Blumenthal to turn their ideas into real meals that will be flown to the ISS in 2015.

Other projects planned will be related to, amongst other topics, biology, physics, chemistry, coding, music and literacy.

Credit: Max Alexander, UK Space Agency

Case Study – *Mission X: Train like an Astronaut*

In 2014, 9,000 pupils nationwide took part in the international Mission X programme – the UK being one of 24 countries taking part. This programme uses the example of health and fitness in astronauts to inspire understanding of the science behind diet and exercise, as well as a change in habits among upper-primary and lower-secondary school pupils. At the same time it introduces school pupils to space through the exciting field of human space exploration. The wide range of subjects covered and the international aspects of the challenge were especially valued by the teachers.

The plan for 2015 is to continue to increase the number of school registrations for the programme and to link the activities to the Tim Peake Education Programme. A national teaching guide has been developed to supplement the programme and help UK teachers deliver the activities.

UK students taking part in Mission X with British ESA astronaut Tim Peake Credit: Heather MacRae

Further Information

More information on the UK Space Agency can be found at:

Web http://www.gov.uk/ukspaceagency

Twitter http://twitter.com/spacegovuk

Youtube http://www.youtube.com/user/spacegovuk

For further information, visit:

European Space Agency
www.esa.int

Catapult - Satellite Applications Catapult
www.catapult.org.uk

Centre for Earth Observation Instrumentation and Space Technology
www.ceoi.ac.uk

Engineering and Physical Sciences Research Council
www.epsrc.ac.uk

European Space Education Resource Office – UK
www.esero.org.uk

Japan Aerospace Exploration Agency
global.jaxa.jp

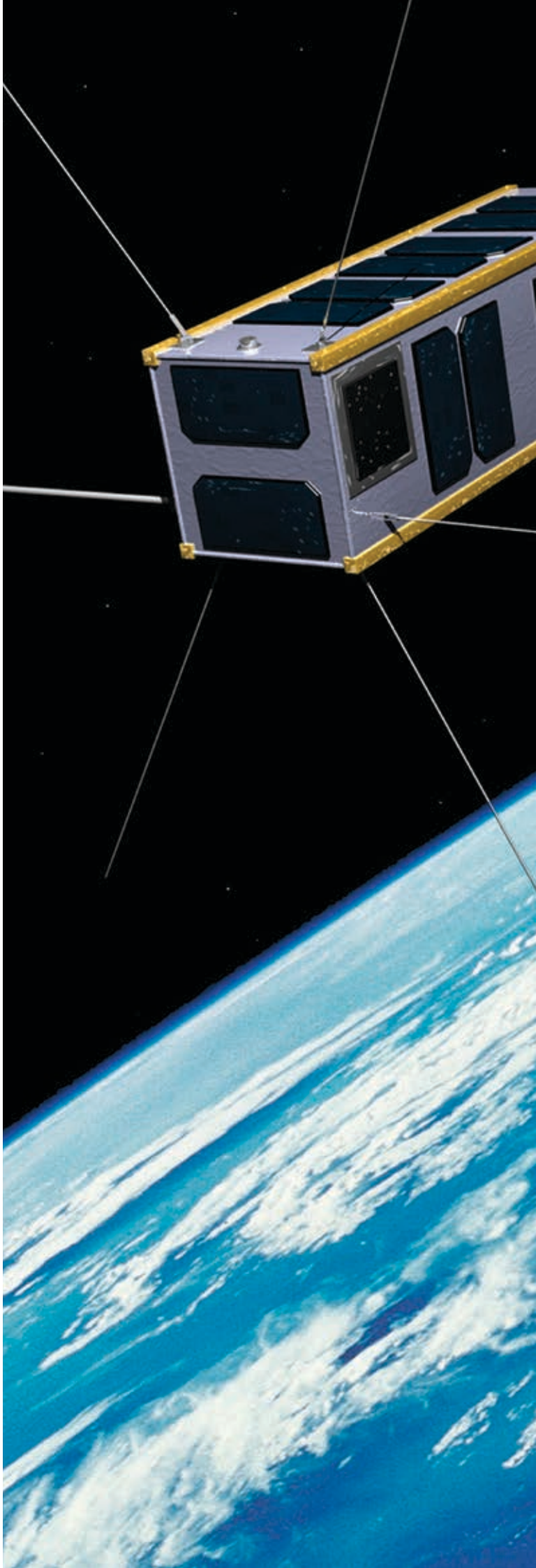
Knowledge Transfer Network
www.innovateuk.org/-/knowledge-transfer-networks

NASA
www.nasa.gov

Natural Environment Research Council
www.nerc.ac.uk

Science and Technology Funding Council
www.stfc.ac.uk

Technology Strategy Board
www.innovateuk.org



UKube-1. Credit: Clyde Space

An executive agency of the Department for Business, Innovation and Skills

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