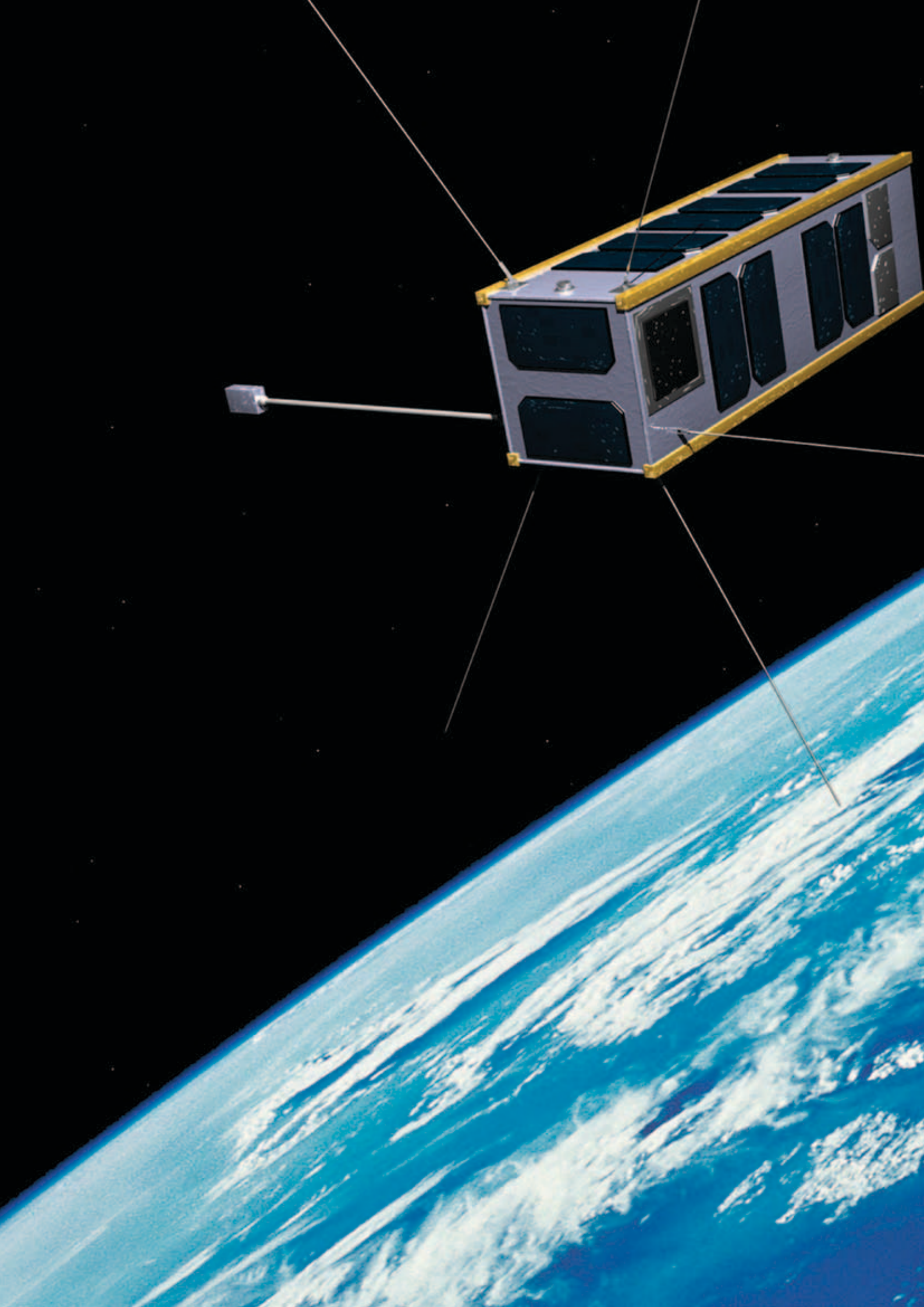




UK SPACE
AGENCY

National Space Programmes

2012 - 2013



Introduction

Welcome to the second edition of the UK Space Agency's National Space Programmes brochure. This document contains financial and management information about our suite of National Space Programmes, provided in order to give you an insight into the wide range of investment we are making in the UK's space sector.

It is now approaching two years since the Agency's full establishment. During this time the UK space sector has continued to grow, as has its contribution to the economy as a whole, currently thought to be £9.1 billion a year and directly employing 28,900 people. The average growth rate of the UK space sector is almost 7.5%; the National Space Programmes are in place to complement our investments in a range of European Space Agency, European Commission and bilateral projects in order to further this growth in line with the six themes of our civil space strategy:

- Growth through exports
- Growth through innovation
- Growth through exploiting new opportunities
- Growth through smarter government
- Science as an enabler of growth
- Education for growth

The national programme has seen dramatic progress. In the past year, we launched the National Space Technology Programme with £10M of fresh funding from central government. By working with industry, TSB and the Research Councils, this has turned into a £27 million programme of about fifty different

projects – a massive injection of innovation into the blood stream of the UK's space sector. Meanwhile, the programme of scientific instruments has reached a milestone with the delivery of MIRI for the James Webb Space Telescope, the result of over a decade's hard work by the UK-led European consortium. The national exploration and the Earth observation technology programmes have also made good progress, while both UKube-1 and TechDemoSat-1 are preparing for launch in 2013. It is going to be another exciting year.

We hope you find the brochure valuable. It's hard to capture the huge range of projects that the UK Space Agency has underway in a few pages. For further information and also to download our other publications, please see our website:

<http://www.bis.gov.uk/ukspaceagency>

And don't forget to sign up for our monthly newsletter and follow us on Twitter - [@spacegovuk](https://twitter.com/spacegovuk)!

Dr. David Parker
Director of Technology, Science and Exploration,
UK Space Agency

National Space Technology Programme

The creation of a National Space Technology Programme was identified as a priority for the UK space sector by the Space Innovation and Growth Strategy (IGS) in 2009. As part of the 2011 Government Growth Review, the UK Space Agency was given £10M to create the first National Space Technology Programme (NSTP).

Figure 1: NSTP – Current Allocation

	Allocation £k	TSB/SEEDA Support £k	Intervention Rate
1. Core Programme – Space for Growth	6,000	Support £k	50%
2. Future Technology Pathfinder Programmes	500	2,500	90%
3. Demonstration Programmes	500		100%
4. GSTP Additional Funds	1,000		50% or 100%
5. Collaboration with other Public Funding Providers	1,000		as required
6. Focused co-located team projects at ISIC ('Space CITI')	500		65-80%
7. Horizon Scanning Studies / Management	500		n/a
TOTAL	10,000	2,500	

Over the two years since its foundation, the UK Space Agency has designed and implemented a UK Civil Space Strategy to shape the future of this national programme. The current award is specifically targeted at the Government's growth agenda, and is supported by funding from UK Space Agency partners.

Working hand-in-hand with other UK Space Agency programmes, as well as academic, industry and public sector partners, the goal of NSTP is to advance UK technologies to higher technology readiness levels (TRLs). This will support UK industry's ability to accelerate innovation, expand sales in the commercial space market and reinforce the UK position as a stronger player in future international space programmes, including those of ESA.

Space for growth

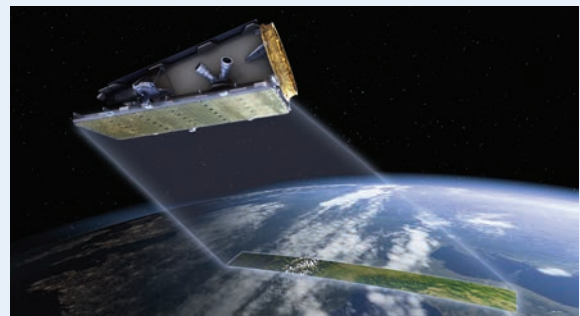
'Space for Growth' competition forms the core of the UK Space Agency's National Space Technology Programme. The aim is to support activity that either develops or de-risks the technology needed to build on the UK's share of global high-growth markets. This includes the identification of innovative new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

Following an open call for proposals in October 2011, selections have now been made and funding allocated. There are currently four large 'Flagship' projects in the competition receiving funding of up to £2 million each, and 25 'Fast track' projects with funding between £50,000 and £100,000. This funding is largely being provided on the basis of 50% of project cost, with a total of £6 million provided by the UK Space Agency, £2m plus administration and assessment costs by the Technology Strategy Board (TSB) and an additional £0.5 million by the South East England Development Agency (SEEDA) for projects based in that region.

All projects are business-led and have been chosen to clearly focus on collaborative R&D activity between small and medium-sized businesses, academia and larger established members of the space industry. These relationships will help accelerate the commercial exploitation of space technology and will lead to new applications and services based on space-derived data. A number of them will use the facilities at the International Space Innovation Centre (ISIC) in Harwell and will benefit from the UK Space Agency's strategic funding commitments in existing ESA programmes for flight demonstration.

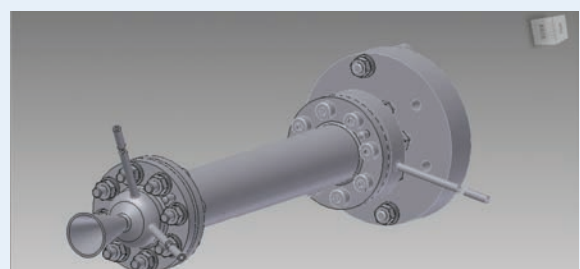
Case Study – Flagship Project: NovaSAR innovative imaging chain - critical element qualification

This collaborative project between SSTL and Astrium will combine recent technological advances with proprietary and highly flexible algorithms to accelerate the technology development of an innovative S-Band radar instrument (SAR). 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 satellite constellation, called NovaSAR, currently in development by SSTL and Astrium. Making synthetic aperture radar more affordable would change the economics of radar remote sensing and would 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.



Case Study – Fast-Track Project: Innovative 'Green' Propulsion Systems

All UK propulsion systems produced for telecoms, Earth observation, navigation and science missions currently follow the global propulsion industry trends, utilising hydrazine or its derivatives as fuel. Due to its toxicity, the European Chemicals Agency (ECHA) has put hydrazine on a list of substances of very high concern, which ultimately leads to enforced obsolescence in 5 years. A consortium of UK industry – including Astrium and SSTL as prime contractors, Ampac-ISP as a thruster manufacturer, MTSP as a fuel-tank manufacturer, the University of Southampton and Deltacat as a propulsion specialist – are to build on existing work on an alternative propellant to hydrazine and the necessary propulsion systems. Current alternatives are not industrialised or cost-effective. The export market for this research is global and this group is well placed to enable the UK to take a technical and strategic lead in low-toxicity propulsion technology.



Future Technology Pathfinder Programme

While the core programme of NSTP will address projects expected to deliver short term economic impact and job creation, it is also vital that the Agency identifies and explores future technology needs with blue-sky research. The Future Technology Pathfinder Programme (FTPP) is aimed at more speculative projects which could yield benefits in the medium-to-longer term. Funding is capped at £50,000 from the NSTP for these activities.

In February 2012, the UK Space Agency made an open call for project proposals which introduce highly-innovative technologies with strong enabling potential for future space activities. The aim of the FTPP is to support studies on more speculative, lower

Technology Readiness Levels (TRL) that will improve technological performance and/or system parameters such as cost, mass and resource requirements on future space missions.

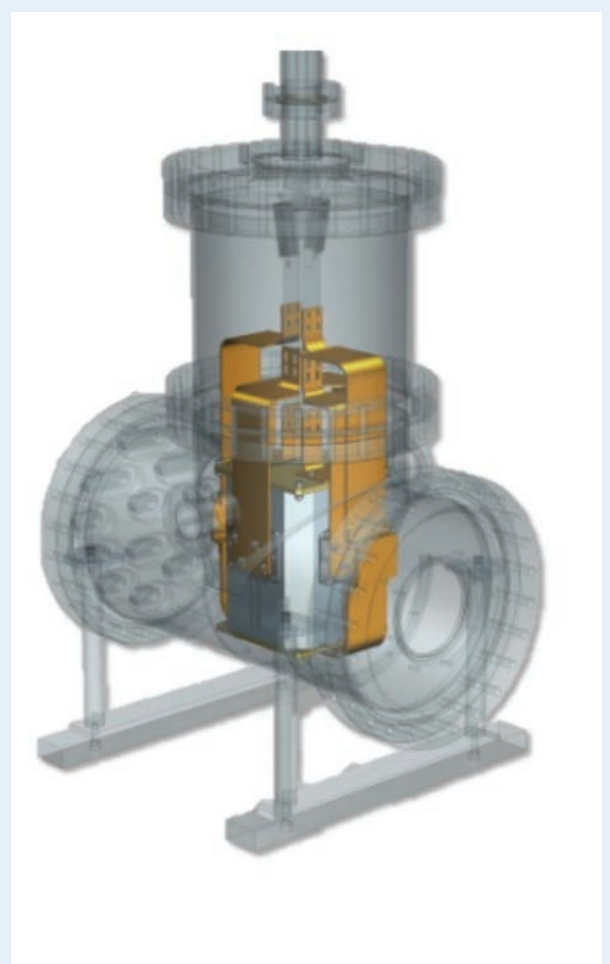
The successful proposals had to show a credible benefit to future operational, commercial or scientific mission objectives. They also had to demonstrate an alignment to one of the five National Space Technology Roadmap sectors as defined by the Space Innovation and Growth Strategy; Access, Position-Navigation-Timing, Robotics-Exploration, Sensing, and Telecommunications. The programme is managed by Centre for Earth Observation Instrumentation (CEOI), on behalf of the UK Space Agency. Of the 49 proposals received, 10 have been selected and are currently under study with completion dates in November 2012.

Case Study – FTPP: Science and Exploration Mission Opportunities and Requirements for Nuclear Power Systems (NPS)

Nuclear Power Systems (NPS) are a mission-enabling technology for spacecraft. The use of NPS results in longer lifetimes and more stable missions, capable of surviving cold, inhospitable environments as well as providing more value for money compared to solar power sources. Traditionally only used by American and Russian missions, ESA is now preparing a European programme with the aim of realizing a coherent approach to the use of NPS.

The purpose of this study is to fill that gap by gaining an improved understanding of the end to end system requirements for a general purpose space nuclear power system and to develop a realistic mission roadmap for a European nuclear power system. The method relies on the analysis of multi-mission nuclear power systems, including those utilising Radioisotope Heater Units (RHU), Radioisotope Thermal Generators (RTG) and Stirling Radioisotope Generators (SRG) on future science missions.

The study builds on the already deep UK involvement (Astrium Ltd, SEA Ltd and Leicester University) in the ESA programme, which is assured due to the National Nuclear Laboratory, Sellafield, providing the radio-isotope source. It also contributes to the wider Mars Robotic Exploration Programme which aims to develop the technology necessary for future robotic Mars missions. Currently assessed at TRL 3/4, the aim of NSTP funding is to bring the RTG and SRG technology to around TRL 5/6 by 2016.



Space CITI Pilot Programme

On behalf of the UK Space Agency, the International Space Innovation Centre (ISIC) invited proposals in response to an Open Call for space technology and applications research and development projects related to the National Space Technology Roadmaps. Space CITI stands for Space Collaborative Innovation

Team Initiative and, through the entry guidelines, proposals were encouraged that were multi-disciplinary, multi-organisational and which plan to exploit the unique environment of ISIC.

Space CITI was allocated a total of £500,000, with the aim of funding between one and five projects (each receiving £100k-£500k). As the central aim of NSTP is

to drive economic growth through the development of space technology, Space CITI proposals had to demonstrate their ability to develop new space-related businesses or services. Although projects which addressed purely scientific outcomes were not eligible, those which planned to exploit technology or data from scientific missions were welcomed. In particular, projects which would lead to the transfer of expertise from academia and national laboratories into commerce and establish new business relationships were encouraged. Consequently, the successful proposals have a legacy far beyond their

3-6 month timeframes. This relatively short window demanded full-time dedication from applicants over the timeframe, achieving results which could normally take much longer, in a matter of weeks.

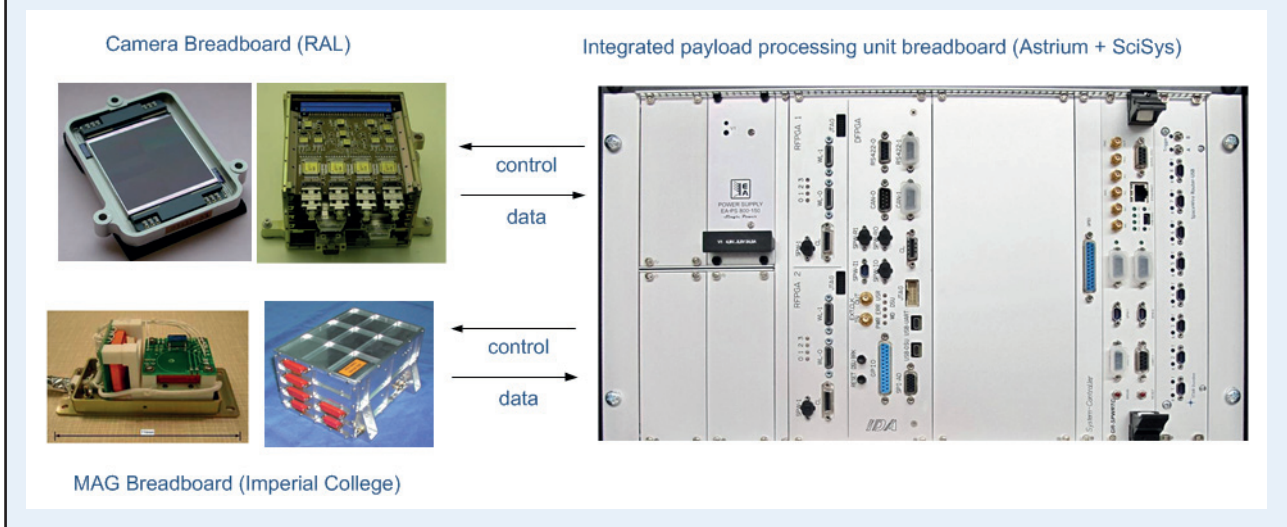
Winning proposals will have access to a wealth of project facilities at ISIC and the Science and Technology Facilities Council's Rutherford Appleton Laboratory as well as from ISIC member universities, companies and other government bodies. Four projects are to be funded at between £50K and £270K.

Case Study – Space CITI: Integrated Payload Data Handling System IPDH-S

A key challenge for any space mission is the management, integration and operation of multiple payloads. Usually each such payload carries its own processor, resulting in duplicated systems across a platform. This cautious approach is accepted by mission sponsors and project managers for its built-in redundancy, but is an inefficient use of mass and power, increasing the cost of the mission and reducing the opportunity to host additional payloads. ESA have long sought to develop 'highly integrated payload data systems', especially for space science where severe limits on mission resources are particularly challenging. More recently other missions face similar issues (nanosats; unmanned rovers) and

even terrestrial systems such as agile autonomous vehicles and unmanned aerial vehicles are establishing a need for similar, mission-critical solutions.

The UK has taken the lead in developing many of the key elements for a solution. The proposed project will provide a timely step forward in UK technology and demonstrate a functioning integrated payload data handling system (I-PDHS) with a realistic set of instruments. The project consortium led by Astrium Ltd draws on key expertise from a unique combination of academic and industrial partners; SciSys Ltd, RAL Space and Imperial College London.



Horizon Scanning

NSTP has allocated a budget to Horizon Scanning, a programme designed to examine emerging technological and socioeconomic trends, including threats and opportunities, that will affect the UK space sector in the 10-20+ year timeframe. This shall be achieved not only on a technical level by looking at what space-related technologies are being studied at basic research level, but also by examining the wider scientific, social and security, industrial and commercial landscape beyond the space sector. For example, what are the trends in global telecommunications that may affect the satellite communications industry?

How might advances in computing and materials technology affect spacecraft design? What would be the impact of a reusable launch vehicle upon the economics of satellite manufacturing? How will space help mitigate threats to civil security?

The first development of Horizon Scanning has been the award of a £50k contract to the University of Strathclyde's Advanced Space Concepts Laboratory. The laboratory has strong links to wider institutional spacecraft capabilities and is delivering radically new approaches underpinning new space-derived products and services for space science, telecommunications, Earth observation and navigation. The Advanced

Space Concepts Laboratory will carry out a nine month project to produce an extensive 'Trends and Developments' report for use in the creation of a programmatic plan for UK space technology futures studies activities. The project will look to establish a UK Space Agency 'Technology Futures Group' from experts in the space community and wider social and economic circles.

Collaborative funding

NSTP supports a very broad spectrum of technologies. It is therefore of considerable relevance to other UK Space Agency stakeholders. In addition, to emphasize this as one of the aims of the programme, it includes a measure with the specific aim of co-funding projects with these stakeholders.

- £250k Agency contribution to £6M EPSRC + industry autonomy technology project – agreement signed and project started
- £250k addition to £250k DSTL space technology activities
- £300k addition to £300k STFC project for STEAM-R and other EO instrument technologies
- £335k TDS-1 mission planning system, in support of technology demonstrator satellite initiative funded by TSB

Initial successes of NSTP

The first calls were held in the autumn of 2011 and have continued to May 2012. To date 95% of funds have been allocated and most projects will have been completed by the end of FY12/13. Despite the need for private co-funding, all calls were oversubscribed, sometimes by a factor of five or more. Due to this co-funding with industry, EPSRC, DSTL, TSB and STFC, the £10M programme has directly created a programme of total volume £27M.

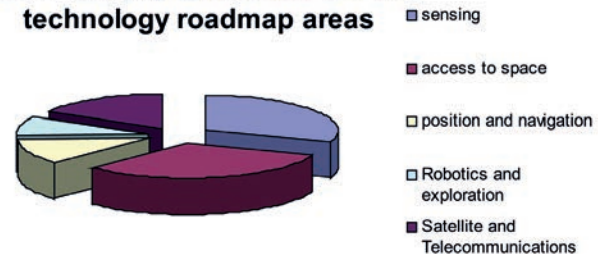
At the start of the UK Space Technology roadmapping exercise, Sir Keith O'Nions as the first chair of the National Space Technology Strategy Group defined the need for a 'balanced portfolio' of measures to ensure UK takes full economic benefit from its many and varied space technology capabilities. In response, the Agency carried out a consultation with the community to define the shape of the programme resulting in an agreed delivery plan issued in June 2011:

<http://www.bis.gov.uk/assets/ukspaceagency/docs/national-space-technology-programme.pdf>

The distribution of funded projects across the roadmap areas in all four open call funding

programmes under NSTP (Flagship, Fastracks, FTTP and Space CITI) provides an immediate indication of the strength and capabilities of the UK Space community. The chart shows a relative even distribution as defined by the independent assessment nature of each programme and agreeing with the consultation in 2011.

NSTP funding across the IGT's 5 technology roadmap areas



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.

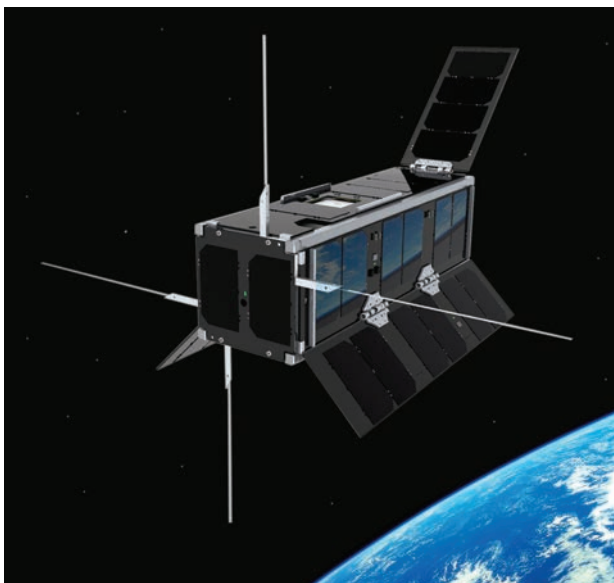
Cubesats are miniaturised satellites that weigh less than 10kg and exploit off the shelf components where possible. As vehicles to carry scientific and commercial payloads they present an exciting opportunity for those seeking rapid access to space for relatively low costs. The aim of a National Cubesat 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 UK Space Agency, the Technology Strategy Board, and STFC. The Cubesat is being built by Clyde Space and the University of Strathclyde through a Knowledge Transfer Partnership, supported with internal funding from Clyde Space. From 21 payload proposals four were selected, of which the following three are ready to fly: a CMOS Imager Demonstrator from the Open University and E2V Technologies, Janus from Astrium and TOPCAT from the University of Bath, Chronos Technology, RAL and MSSL. In addition, UKube-1 will fly FunCube, an educational payload provided by AMSAT-UK, with the goal of enthusing and education young people about space, electronics, physics and radio. More information on these payloads is available on the Agency website. A launch for UKube-1 has been agreed with the Russian space agency (ROSCOSMOS) for March 2013.

The payloads have been chosen for the programme's pilot, U-Kube1 and its construction is taking place at

innovative Scottish company Clyde Space through a Transfer Partnership with and the University of Strathclyde, supported with internal funding from Clyde Space. A launch date of early 2013 is currently hoped for.

Meanwhile, following on from the original call for U-Kube1 payloads, 30 proposals have been evaluated and 11 grants allocated totaling £310k since the UK Space Agency ran mission concepts studies competition in December 2011 for research into further exploitation of cubesats, indicating the desire in the space community for a National Cubesat Programme.



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 – Mars Robotic Exploration Programme). 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 grant. Industry awards are made directly to the researching company. Sometimes with collaborative projects, the funding may be routed through one of the partners.

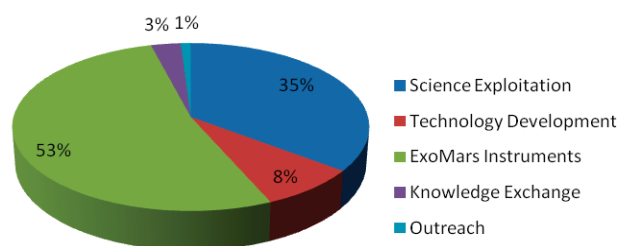
- Instrument delivery funding, currently focused on ExoMars. Funding is provided to instrument teams via grants to academia and contracts to industry. The UK's contribution is peer reviewed and prioritised. Potential for technology spin out and science return are key criteria.
- An award programme designed to build the research community by providing studentships and fellowships to promising researchers, thus maximizing the UK's ability to exploit future science data. There is nominally one call per year and the announcement of opportunity provides guidance on key areas. The call is open to all UK research organisations and awards are made via grants.
- The Aurora Knowledge Exchange Programme to inject Aurora technology into wider industrial applications to benefit the UK's economy. About £0.5M was awarded to a set of promising projects 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.

Funding and Management

The UK contributes 164M€ to ExoMars (16.5% of the total mission cost) and 6.5M€ to the Mars Robotic Exploration Programme. The UK is Principal Investigator for the ExoMars Panoramic Camera instrument, 'PanCam', and Co-Investigator on the Raman Laser Spectrometer (RLS).

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 Aurora Advisory Committee (AurAC) and via project-level management committees.

Aurora national programme budget for 2012/13 is £4.9 million. The planned breakdown of national funding (£57.3 million) to the end of ExoMars operations in 2021 is show below:



Case Study: PanCam

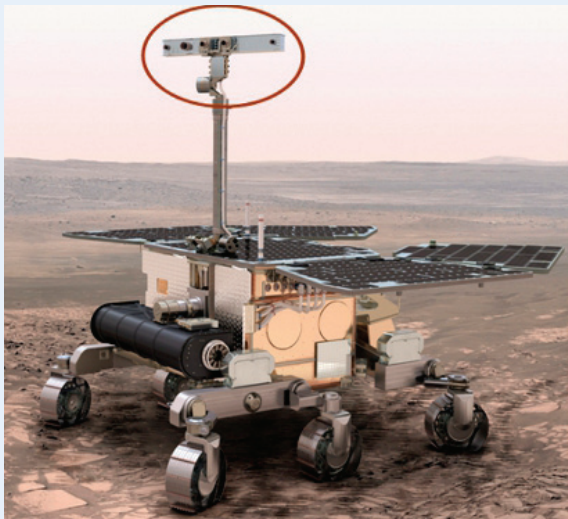
The ExoMars rover vehicle's PanCam instrument, led by a team from the Mullard Space Science Laboratory (MSSL), has been designed to search for textural information on rocks that can be related to the presence of organisms on Mars. PanCam will also capture other information that will help in revealing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

The instrument will play a key role in the Rover's operations, providing stereo and 3D imagery of the terrain around the Rover. In particular, PanCam 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 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 (34° field of view, fixed focus); both "eyes" are equipped with a 12-position filter wheel each covering a different wavelength, thus enabling multispectral observations; One High Resolution Camera (HRC), for high-resolution 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 on an optical bench arranged on the Pan-Tilt Unit on top of the ExoMars rover mast assembly.



The PanCam mounted on the Rover mast. Credit: ESA

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 (TRL) 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 approximately £1 million yearly, 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 Astrium along with QinetiQ, STFC-RAL and the University of Leicester. Over the years, more than 30 projects have been selected following open calls to the community for technology projects.

The CEOI recently ran its 5th open call from which 12 proposals were selected. 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 are developing technologies for the next generation of the Eumetsat meteorology mission - MetOp Second Generation (MetOp-SG). Other funded projects will be conducting investigations into areas such as an assessment of a low weight mirror fabrication technique, radar developments and other mission critical technologies.

The future

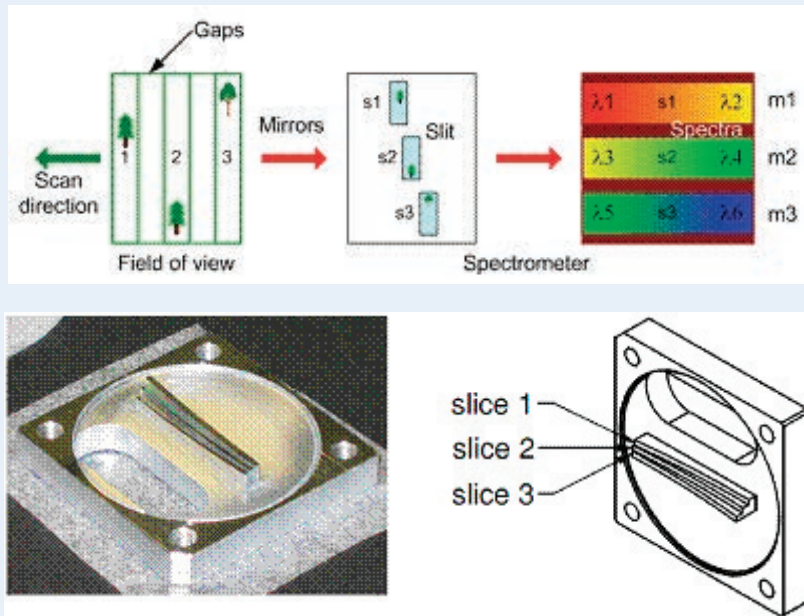
Six of the CEOI projects are now sufficiently mature, having reached Technology Readiness Level 4 (TRL-4), that they require further funding to maximize future opportunities and build on the UK's investment to date. Other technologies, outside CEOI, have been identified which require support to secure ESA return on noble instrumentation roles for future ESA programmes.

The Agency is currently reflecting on the future approach for taking forward EO instrumentation and technologies to higher TRL, in the context of a cross Agency national space technology programme.

Case Study – Prototype Earth observing system using image slicing technology

Using techniques developed for the MIRI instrument for the James Webb Space Telescope, the UK ATC have designed and built prototype core elements of a novel hyper-spectral imager, aimed at measurement of atmospheric CO₂

concentration from Earth orbit. The technique allows a more compact and lightweight design than conventional optical systems, and exploits image slicing techniques using a multi-faceted focussing mirror. The design allows the imaging of spectra from 3 separate wavebands onto a single detector array.



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 (STFC) 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 of £14M in 2012-13, of which approximately £800,000 is used for early-phase studies. The remainder funds development and mission operations (sometimes called 'post launch support'). Under current Research Council rules, the Agency provides 80% of full economic costs for agreed proposals from academia, the remainder being 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 assess its potential role within any consortium and focus on maximizing scientific return, leadership and technical capability.

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.

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 IGS 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 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 have progressed through their assessment phase and are now in development, with launches targeted for 2017 and 2019 respectively.

Following Agency funding of four candidate payloads, the UK is in line to make a significant contribution to ESA's first Large-Class mission, JUICE, pending payload selection in 2013. Once formally adopted by ESA in 2014, JUICE is planned to be launched in 2022.

The Agency has also awarded initial studies funding for UK participation in all five of ESA's M3 mission candidates. In 2013 ESA will decide which should proceed to the competitive definition phase, with a formal selection taking place in 2015 and launch by 2024. These are EChO, LOFT, PLATO, STE-QUEST and Marco-PoloR.

The Agency also hopes to support ESA's planned programme of new Small-Class missions, initially through utilising previous investment in the International Space Innovation Centre (ISIC) at Harwell by using it to provide ground segment support for the first of these missions CHEOPS, an exoplanet space telescope.

Phase	Project	Summary
Under Study	EChO	EChO – The Exoplanet Characterisation Observatory – seeks to investigate the physical and chemical atmospheric conditions of planets discovered beyond our Solar system. Through this it is hoped that fundamental questions can be answered such as what are the conditions for planetary formations and the emergence of life? Dr Giovanni Tinetti of University College London is the UK Co-Primary Investigator along with others from six countries.
Under study	STE-QUEST	The Space-Time Explorer and Quantum Equivalence Principle Space Test will search for new fundamental constituents and interactions in the Universe, using an atomic clock and atom interferometer to test Einstein's Equivalence Principle to high precision. A UK study team is led by Professor Kai Bongs of Birmingham University and includes RAL, the National Physical Laboratory, SEA Ltd and Astrium UK.
Under study	LOFT	LOFT (Large Observatory For X-ray Timing) will provide high time resolution X-ray observations of compact objects providing direct access to strong gravity, black hole masses and spins, and the equation of state of ultra-dense matter. It will reveal general relativistic effects and gain information on strongly curved space time and matter at supra-nuclear densities and in supercritical magnetic fields. There are possibilities for UK leadership of the Large Area Detector (LAD) instrument through MSSL and Leicester and interest in the science team from the Universities of Southampton and Durham.
Under Study	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. Professor Pollacco of Queens University Belfast is the Principal Investigator of the international PLATO Science Consortium, and Queens University Belfast, along with six other UK institutions, has involvement in PLATO.
Under Study	Marco-PoloR	Marco-PoloR is a sample return mission to a primitive near-Earth asteroid for laboratory analysis. Its aim is to provide samples not currently available for the study of early solar system formation and origins of life. There is UK interest in sample analysis and initial development support has been provided to the Open University and Oxford University
Under Study	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. In support of their applications to be selected as JUICE payloads by ESA in early 2013, the Agency has provided initial study phase funding for four UK instrument teams lead by Imperial College London, Oxford University, MSSL, and University of Leicester.
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). EADS Astrium Limited is the spacecraft's main contractor. SciSys Ltd develops the satellite's on-board software.
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 has completed testing at RALSpace, Harwell, and is the first of four JWST instruments to be delivered, arriving at NASA's Goddard Space Centre for integration in May 2012.
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 Solar Wind Analyser (SWA) suite and contributing towards the Extreme UV Imager (EUI), ICL with the Magnetometer and RAL Space the Spectral Imager (SPICE). In addition, Astrium UK is the Prime contractor for the mission.

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.
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 in mid 2015.
In Development	Gaia DPAC	Due for launch in August 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 £10M contribution to the development of the pan-European Data Processing and Analysis Consortium project led from Cambridge University.
In Operation	Herschel	ESA's Herschel Space Observatory is the largest ever infrared space observatory. It collects 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.
In Operation	Planck	The UK has provided instrument technology to the Planck mission which is examining the ancient radiation released shortly after the Universe was formed, known as the cosmic microwave background radiation. Operations and scientific exploitation involves multiple UK groups led by Cambridge University.
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 RALSpace.
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 is due to rendezvous with Comet 67P Churyumov-Gerasimenko in 2014. Rosetta has significant UK involvement from industry and science including the Ptolemy chemical analyser on the lander.
In Operation	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.

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

Due for launch in 2018, JWST is a joint mission between NASA, ESA and the Canadian Space Agency. It is a space-based observatory optimised for infrared wavelengths that will study a wide range of celestial objects. As the successor to the Hubble Space Telescope, it will be almost three times the size, with a six metre mirror, and operate at much colder temperatures than any previous telescopes, allowing for unprecedented sensitivity.

JWST will observe objects at a variety of distances using four instruments. MIRI (Mid InfraRed Instrument) is the tool that will enable the study of the Universe's most distant, first generation of stars, with the aim of clarifying the processes at work during their formation and lifecycles. MIRI is essential for studying all four of the JWST science themes: Detection of the First Light, Assembly of Galaxies, Birth of Stars and Protoplanetary Systems, and Evolution of Planetary Systems and Conditions for Life.

The UK Astronomy Centre's (UK ATC) Professor Gillian Wright is the MIRI European Principle Investigator and leads the MIRI European Consortium of over 20 participating organisations, which are responsible for the instrument's design, build, integration and testing. Through ESA the UK Space Agency has invested around £20M into MIRI over the last ten years and on 28th May 2012 the instrument was formally delivered to NASA's Goddard Space Flight Centre from STFC's Rutherford Appleton Laboratory (RAL). MIRI is the first of the four JWST instruments to have been completed and is currently undergoing integration at NASA.



MIRI undergoing alignment testing at RAL before delivery to NASA
Credit: STFC/RAL

Government Information from the Space Sector (GIFTSS)

Objectives

The GIFTSS programme (Government Information from the Space Sector) supports delivery of government policy objectives. It has four high level objectives:

- Increase routine uptake of appropriate space information into routine operational processes;
- More effective users where this can be made possible through the use of appropriate information derived from space assets;

- Increased involvement of other appropriate areas of support from academia, institutes and industry;
- Increase the 'critical mass of innovation' in UK industry in these areas.

Funding and management

The programme is jointly funded by the UK Space Agency together with end-users. Its budget varies depending on the extent and nature of projects under development. The Agency works in partnership with end-users to develop projects. It uses sector facilitators, who work with end-users to develop project ideas and with user support experts who assess the technical feasibility of the projects.

The future

The GIFTSS programme is expected to become part of a broader end-user service currently being developed to respond to the Innovation and Growth Strategy Recommendations. The review of the GIFTSS programme found end-users valued the neutrality and the access to experts that the programme offered and would like the UK Space Agency to extend the range and flexibility of services it facilitates in partnership with end-users. The new service will need to be strategic and a new governance structure will enable identification of key priority areas.

ESA – General Support Technology Programme (GSTP)

Objectives

ESA's General Support Technology Programme (GSTP) exists to convert promising engineering concepts into a broad spectrum of mature products. It bridges the gap between pre-commercial early stage ideas and their exploitation commercially or through ESA missions. The aim is to de-risk technology developments sufficiently to allow them to become commercially attractive propositions. GSTP covers all technology areas apart from telecoms (covered by the ARTES programme). Importantly, it enables UK companies, particularly smaller and medium companies, to build partnerships across Europe to position them to take a role in future large projects; this can not be achieved through a national technology programme alone.

Funding and management

The programme is funded by the UK Space Agency through its subscription to ESA. ESA project manage the programme and are responsible for all operational aspects. The current three year programme now coming to an end is GSTP 5, although some UK

projects are still running from the previous GSTP 4 programme. The UK contributed a total of €4.1 million to GSTP 5, which is now totally committed with a total of nineteen individual projects having been funded (or in the process of being funded). Most are in the range of €100,000 to €200,000, the highest being €500,000. Projects are spread across the main GSTP themes, though most are in the programme's generic technology area. Individual technology areas include EO data management, atomic clocks, MEMS (chromatography and sunseekers), supersonic parachutes, fuel analysis, ground system and spacecraft software, propulsion (both chemical and electric), semiconductor materials, advanced RF sensing and magnetometers.

The future

An ambitious case has been made for increased funding for ESA's proposed GSTP 6 programme. This broadly continues the themes developed in previous GSTP periods. Initial planning has started in a few areas where UK projects might be developed – including new hypersonic testing infrastructure and support for cubesat related technologies.

Case Study – MEMS based Gas Chromatograph/Mass Spectrometer

The objective of this project is to achieve a fully functional breadboard of a miniaturised Gas Chromatograph and Mass Spectrometer system for in-situ chemical analysis in harsh environments based on MEMS technology.

Gas chromatographs, in conjunction with spectral mass analyser technology for the identification of organic and inorganic compounds, has been flown or is flying on several space missions, e.g. Huygens and Rosetta, and is in the process of being built and qualified for applications such as the Mars Science Lab (NASA) and for ExoMars. These instruments are already highly miniaturised and optimised in terms of mass and power consumption, but MEMS based technology offers a potential for a new generation with further radical reductions in resource consumption and cost.

This would enable a range of exciting new possibilities - for instance environmental monitoring using a swarm type of mission, applications in human spaceflight, and cheap gas analysis applications in consumer markets – such as even perhaps maintaining a constant health check on the contents of your domestic refrigerator.

Education, Skills and Outreach Programme

The Agency's Education, Skills and Outreach strategy, issued in 2011, 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:
 - o supporting non-specialist primary teachers in the use of space in teaching
 - o 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)
 - o 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 a National Space Conference.

Examples of ongoing programme elements include::

- The 'Space for All' outreach grants programme, now in its fourth round of awards
- Scholarships for UK students to attend the International Space University
- The Mission X: Train like an Astronaut international challenge (see box)
- Support for the National Space Academy (see below)
- Support for the annual 'UK Space School' programme at University of Leicester
- Support for UK involvement in the international Space Settlement Design Competition for schools run by Imperial College London

The Agency's planned budget for the Education, Skills and Outreach programme in 2012-13 is £245,000, the bulk of which is spent on the Space for Education theme, although an increasing emphasis will be placed on supporting the space sector to address the skills gap.

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 is a strong supporter also of the National Space Academy – which has recently been rolled out from the successful pilot in the East Midlands and now offers continued professional development for teachers, master classes in physics and other STEM subjects for GCSE and A-level students, and a new post-16 space engineering course. It has recently been selected to develop the framework for higher apprenticeships in space engineering with the first intake of students planned for 19 to 24-year-olds.

The Agency will also take the lead in organising the next UK Space Conference to be held in Glasgow in July 2013.

Case Study – Mission X

During the first half of 2012, the Agency expanded its involvement in the Mission X: Train like an Astronaut programme to use the example of health and fitness in astronauts to inspire 40 schools across the UK. The programme aimed to encourage an understanding of the science behind diet and exercise as well as promote change in habits among upper-primary and lower-secondary school pupils.

Nearly 4000 pupils took part in the physical and learning exercises. The wide range of subjects covered and the international aspects of the challenge were especially valued by the teachers.

In the spring of 2012 over 100 international visitors, including pupils, teachers, parents and agency staff, were welcomed to a three-day international conference, based mainly in East London to link with the London Olympics. The children met and trained with astronauts and Olympic athletes, while the international partners were able to compare their experiences and share best practices.

A wider rollout of the next phase is planned in 2013, using the materials developed by the 17 international partners (led by NASA, and including ESA and other agencies), and updated in the light of our joint experiences. The goal for 2013 is to double the number of students taking part to around 8000 across the UK.



UK students taking part in Mission X Credit: Michael Cockerham

Technology Strategy Board (TSB) programmes

TechDemoSat

TechDemoSat -1 is a satellite platform, derived from heritage technology, which will function 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 and South East England Development Agency (SEEDA). TechDemoSat-1 plays host to a number of payloads separated into four

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 Astrium'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.

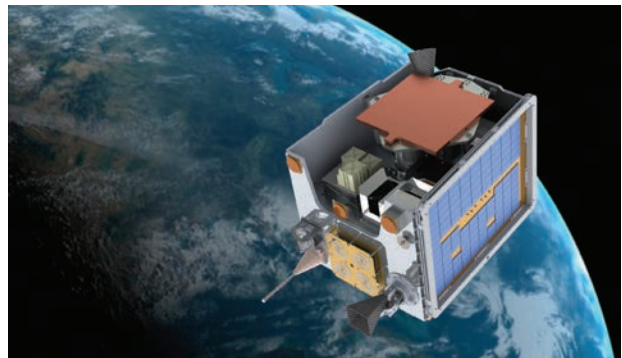
The Space Environment suite consists of the MuREM, ChaPS, HMRRM and the LUCID payloads. MuREM, supplied by the Surrey Space Centre, provides a flexible, miniature radiation environment and effects monitor which can be flown as a standard radiation alarm and diagnostic package, enhancing the security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

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



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, Cranfield is working on a 'de-orbit sail' that 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 have now been fully assembled and integrated as a system at SSTL, and has undergone its system checks and thermal cycling as a complete spacecraft. After a successful test readiness review, TechDemoSat-1 is currently in its environmental and verification testing (EVT) and has just completed vibration testing. The EVT campaign (including thermal vacuum testing and EMC) will continue into the New Year when it will then be boxed up and shipped out to the launch site in Q1 2013. It is anticipated that the launch will be Q2 2013.

Feasibility Studies

The Technology Strategy Board Feasibility Studies aim to help companies, either singly or in collaboration with others, assess the potential of new product and

service ideas in specific thematic areas. For the UK Space sector the last Feasibility Study, 'Innovation in Space', took place in 2011. Funding and support was provided for companies to explore the development of innovative commercial technologies for space or to look at new services which exploit data gained from space-based systems. The study culminated in the Collaboration Nation conference in which the total 77 projects were presented and given the opportunity to engage with a wider space industry audience.

The Innovation in Space call funding was approximately £2m, primarily funded by the Technology Strategy Board, while SEEDA provided additional funding for projects within their region. All grants were co-funded by the participating companies. Each three-month project received up to £25,000, some were conducted by single companies whilst others were carried out by collaborative consortia, including universities. A good mix of small and medium-sized enterprises (SMEs) and larger companies participated in the competition. The Technology Strategy Board managed the programme, based on the National Space Technology Strategy and Roadmaps.

In the Technology Strategy Board's Space Applications Action Plan for 2012-13 there are preparations for similar projects in the future. Funding by other regional and interested agencies is also in discussion for 2013. A report into the impact of Innovation in Space is being undertaken with the view to help improve future process and identify what additional support may be needed for the successful applicants in future. A number of projects have led to full Collaborative R&D projects under the NSTP "Space for Growth" call but other follow-on support mechanisms are considered such as making use of varying Technology Strategy Board support mechanisms including Launchpads, Collaborative R&D and Knowledge Transfer Partnerships, or external mechanisms such as the ESA IAP and BIC programmes.

Innovation Vouchers

As part of its Innovation and Research strategy, the Government has allocated funding of £75 million to be targeted at small and medium sized enterprises (SMEs) to foster and support growth. Some of this funding is to be spent by the Technology Strategy Board through its Innovation Vouchers scheme. Ring fenced funds have been allocated to support the cluster of activity around ISIC at Harwell and associated member organisations. The Innovation programme is designed to support collaboration between SMEs and external knowledge providers such as universities and in future the catapult centres. The programme partnership between Technology Strategy Board and ISIC demonstrates the joint approach needed to make the Satellite Applications Catapult a success.

Satellite Applications Catapult Centre

The Satellite Applications Catapult Centre is one of seven new technology and innovation centres in the UK being established by the Technology Strategy Board. The aim of this Catapult Centre is to support the Government's 2010 Space Innovation and Growth Strategy, in which an increase from 6% to 10% of the UK's share in the global space sector, with a market value of £40 billion, is targeted to be achieved by 2030. Initially focusing on supporting SMEs, the Catapult's vision is to be the centre where the best businesses, researchers and end users come together to develop new satellite and space based products, services and applications.

Recent negotiations, led by UK Space Agency, have agreed a way forward to combine the goals of the ISIC and the Catapult Centre into a single organisation, thereby maximising the use of facilities and communities' engagement through a common platform. This is on track for initial operations in early 2013.

UK Space Agency

The UK Space Agency is at the heart of UK efforts to explore and benefit from space. It is responsible for all strategic decisions on the UK civil space programme and provides a clear, single voice for UK space ambitions.

Second only to the USA in space science, the UK's thriving space sector contributes £7.5bn a year to the UK economy, directly employs 24,900 and supports a further 60,000 jobs across a variety of industries.

The UK Space Agency:

- Co-ordinates UK civil space activity
- Encourages academic research
- Supports the UK space industry
- Raises the profile of UK space activities at home and abroad
- Increases understanding of space science and its practical benefits
- Inspires our next generation of UK scientists and engineers
- Licences the launch and operation of UK spacecraft
- Promotes co-operation and participation in the European Space programme

The UK Space Agency is an executive agency of the Department for Business, Innovation and Skills (BIS).





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

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