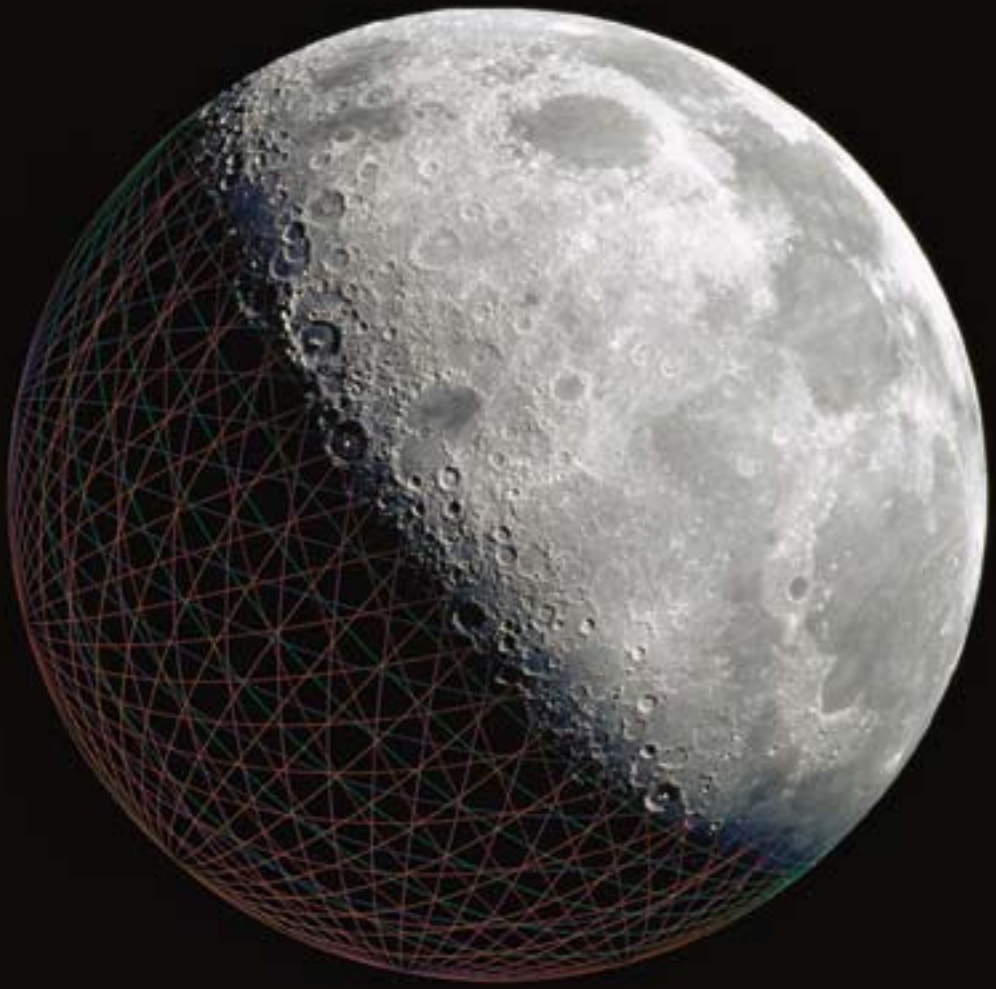
UK in Space 2009



BNSC
BRITISH NATIONAL SPACE CENTRE

Contents

Credit: ESA

Introduction

David Williams, Director General of BNSC

Welcome to the 2009 edition of the British National Space Centre's (BNSC's) annual report covering the achievements of the past year and looking forward to the next 12 months.

This has been another busy year. September 2008 saw Glasgow host the 59th International Astronautical Congress (IAC), the first time in over 20 years that the UK had hosted this prestigious event. The IAC attracted an international audience of over 3,000 visitors to discuss past achievements, current activities and future plans to utilise and explore space. Congratulations to all at the British Interplanetary Society who made this possible.

In October 2008, Lord Drayson was appointed as the new minister for Science and Innovation, and in this role he covers space. One of his first tasks was to represent the UK at the European Space Agency (ESA) Ministerial level meeting in November 2008. This discussed future objectives and priorities for ESA, and the UK committed over €900 million to current and future ESA programmes. A highlight of the meeting for the UK was the signing of an agreement for the establishment of an ESA research facility in Harwell, Oxfordshire.

Artist impression of GOCE over ice
Credit: ESA

The UK has been involved in a number of exciting and varied missions launched this year. These include the advanced space observatories Herschel and Planck, designed to answer fundamental questions about our Universe; the GOCE satellite exploring the Earth's gravity field; and a UK-built instrument is also on board Chandrayaan-1, India's first (unmanned) mission to the Moon.

Existing ESA missions continue to operate successfully. Mars Express, the first European mission to Mars, provided breathtaking images of the surface of the red planet. Venus Express, originally proposed by UK scientists, has provided stunning images and information about Earth's sister planet. Finally, the Cluster mission has performed the best ever investigation of the magnetosphere – the magnetic bubble surrounding our planet. The UK committed funding to seven ESA programmes.

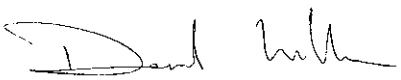
David Williams

This year also saw the launch of the first of a series of new European Earth Observation satellites. With its UK-built electric propulsion system, the GOCE satellite is skimming the atmosphere making precise measurements of the Earth's gravity. Data from this sleek 'space dart' will be used to help scientists better understand ocean circulation and our planet's changing climate. It is a good example of how space is playing a real role in our efforts to tackle global warming.

Following an internal review, BNSC relocated its head office from London to Swindon in January 2009. This means that BNSC is now co-located with three major funding partners of BNSC, namely, the Science and Technology Facilities Council, the Natural Environment Research Council, and the Technology Strategy Board. There was also a significant Government restructuring in June 2009 that has led to changes affecting BNSC. Our previous host department, the Department for Innovation, Universities and Skills (DIUS), merged with the Department for Business, Enterprise and Regulatory Reform to become the Department for Business, Innovation and Skills (BIS). As a result of this, BIS has taken over the hosting of BNSC from DIUS.

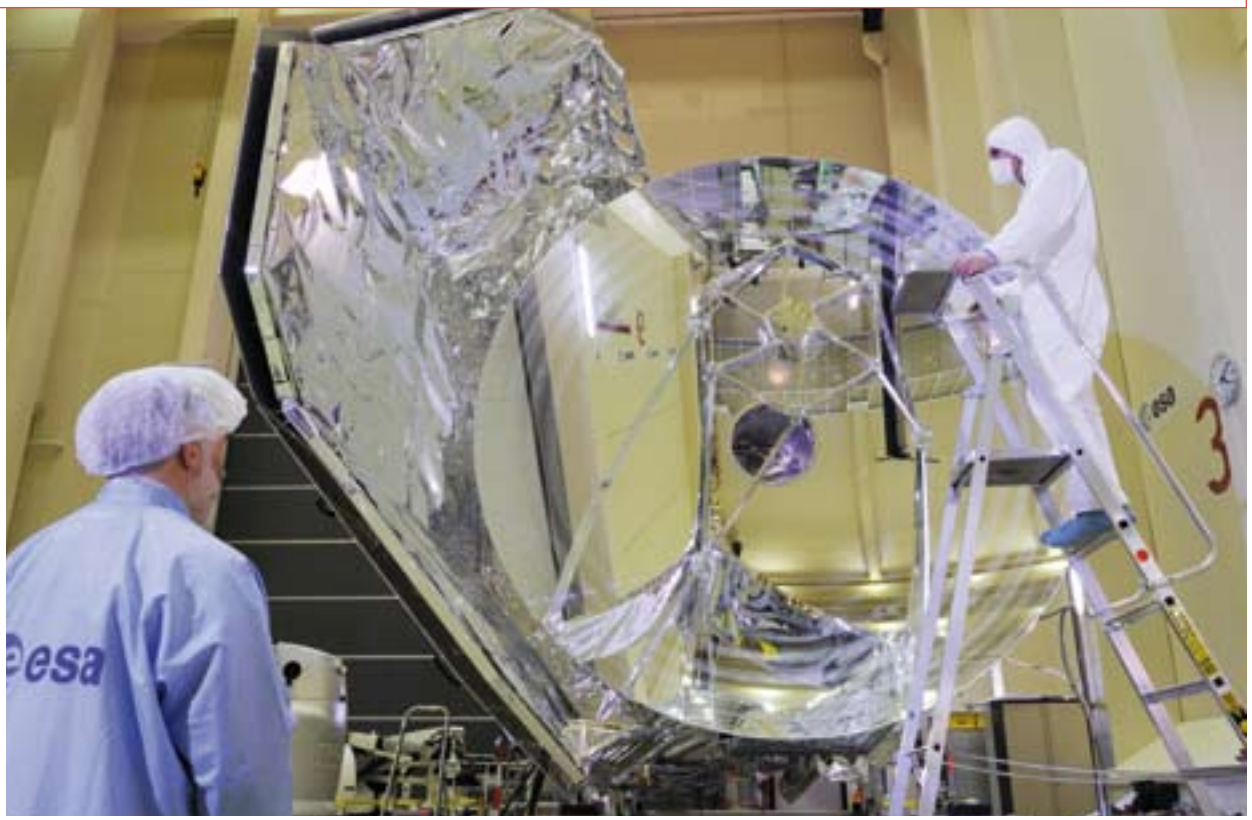
Looking ahead to the next 12 months, the Herschel and Planck space telescopes, whose instruments were designed and built with input from UK scientists, will begin sending back data to scientific teams. There are also a number of launches scheduled for this year which are being prepared with UK involvement. These include the satellites HYLAS – which will provide wider broadband access across Europe – and CryoSat-2, a new mission to measure the polar ice to help advance our understanding of the Earth's changing climate.

So, an exciting year behind us and much more to look forward to in the coming months. I hope you enjoy reading this edition of BNSC's annual report.



David Williams

Highlights 2008–2009



The Herschel space telescope has the largest mirror ever launched into space
Credit: ESA

New ESA facility

An agreement was reached at the European Space Agency (ESA) Ministerial Meeting to establish an ESA facility in the UK, focusing on robotics and the science of climate change.

Launch of Herschel and Planck

The European Herschel Space Observatory and the Planck Surveyor are designed to answer some fundamental questions about the birth and evolution of the Universe and its galaxies. UK scientists and industry made major contributions to these two outstanding space telescopes, which will begin their observations in summer 2009.

Europe's gravity mission

One of the most sophisticated Earth Observation satellites ever launched, GOCE is measuring tiny variations in the Earth's gravity field. Data derived from GOCE will be combined with information from other satellites to track the direction and speed of ocean currents. UK involvement includes scientific contributions and a British-built electric propulsion system.

Return to the Moon

The UK is working with its international partners on current and future missions to the Moon. A UK science and engineering team has a key instrument on India's first lunar orbiter, Chandrayaan-1 and a new UK-led mission to investigate the Moon's surface is being developed.

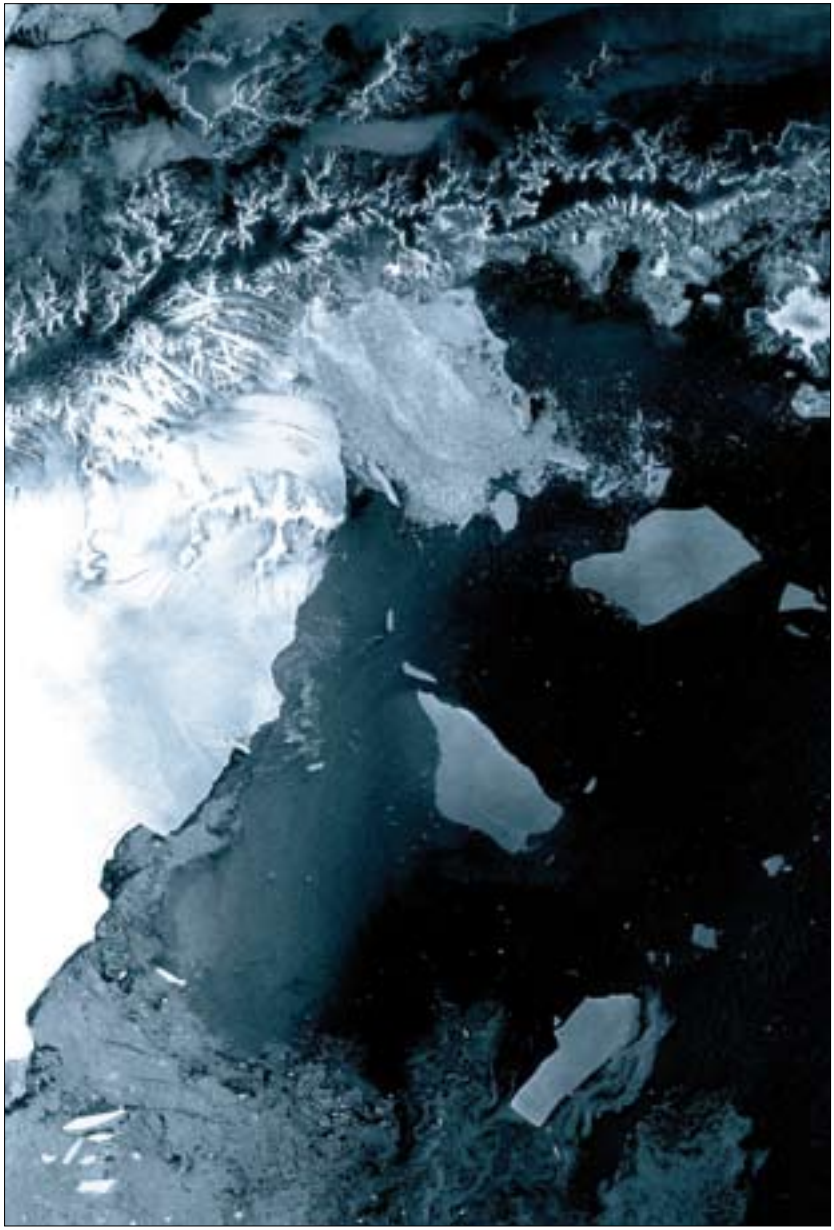
Broadening Broadband

The launch of a new satellite will provide affordable high speed broadband services to rural areas over much of the UK and Europe.

The Highly Adaptable Satellite (HYLAS) has been designed and built in the UK with development support from BNSC.

Climate Research

A new centre has been launched to harness the potential of space technology for environmental research. The National Centre for Earth Observation will support science investigating the environmental challenges facing the World and help place the UK at the forefront of efforts to exploit Earth Observation technology.



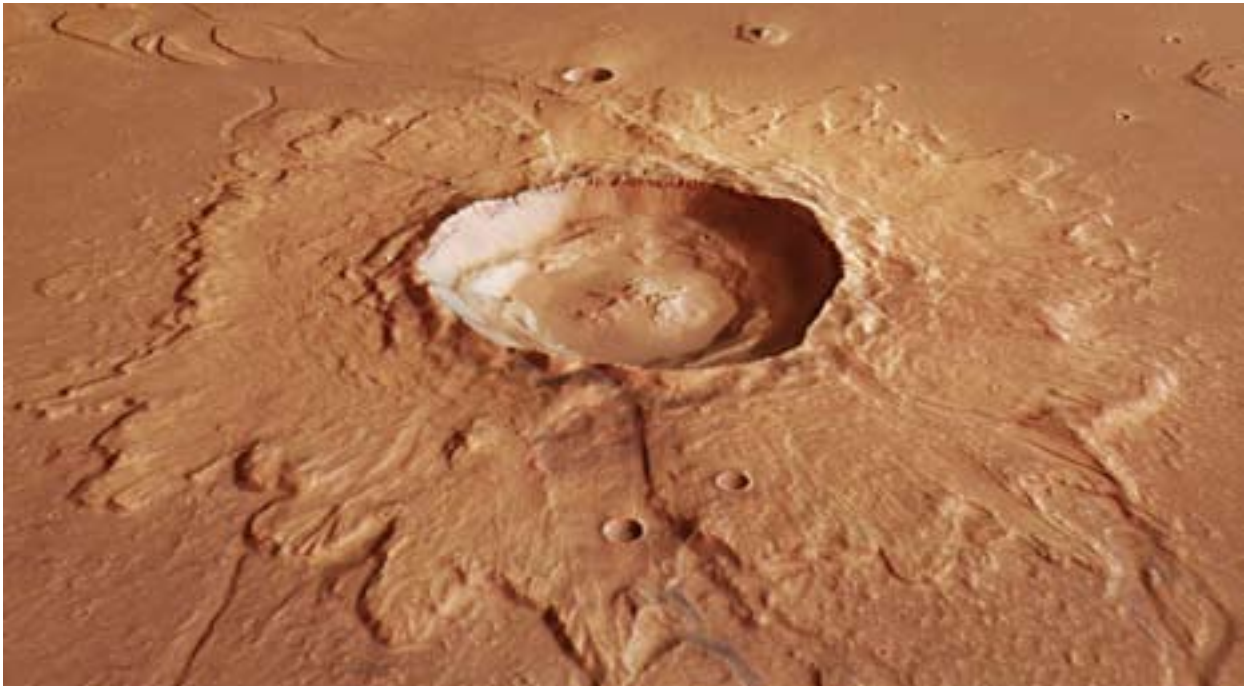
The National Centre for Earth Observation will support science investigating the environmental challenges facing the world
Credit: ESA

Monitoring Disasters

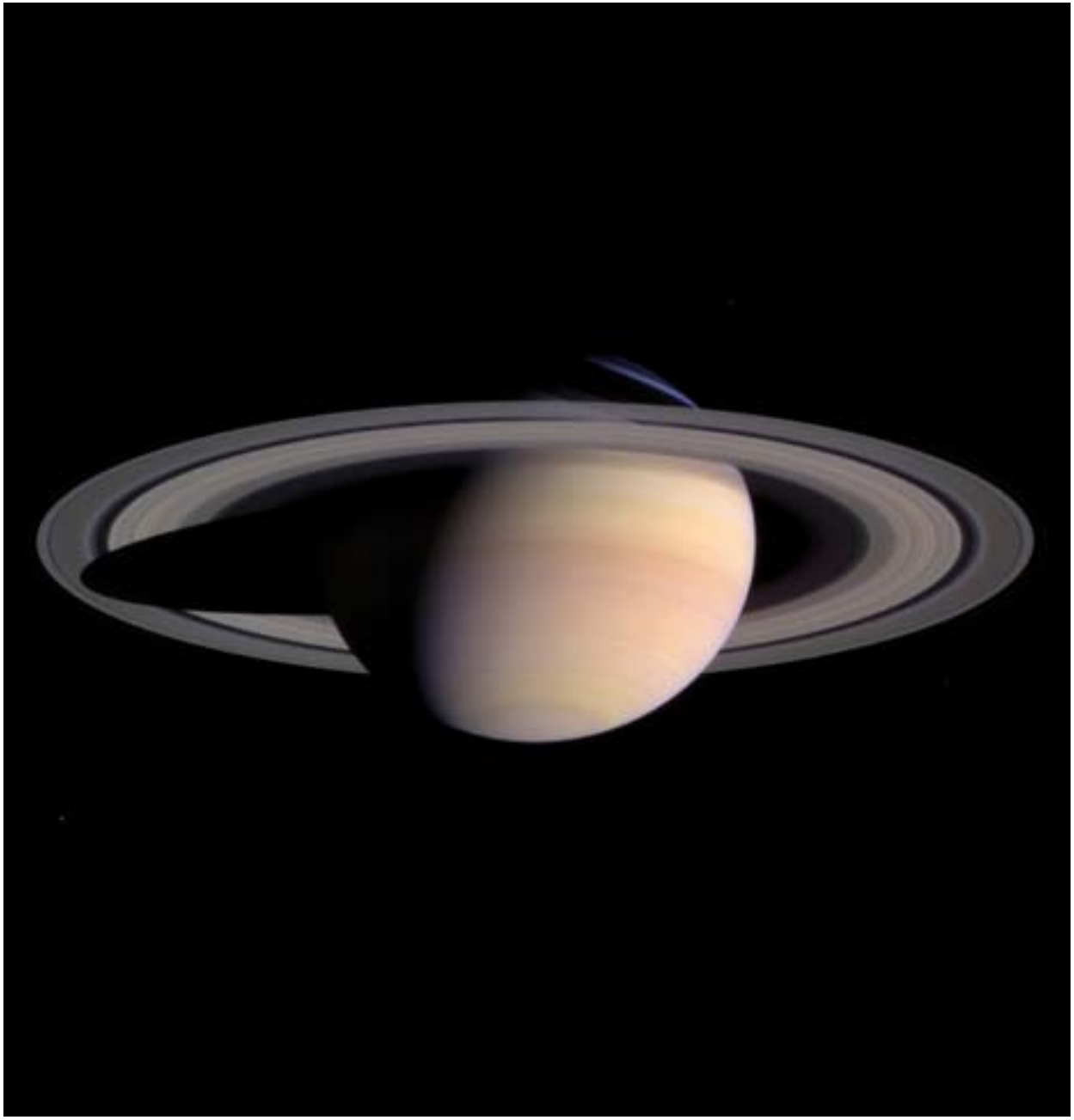
The UK-built Disaster Monitoring Constellation (DMC) continues to prove vital in disaster response. The satellites were used to provide the first images and maps following the devastating tropical cyclone that hit Burma in May 2008. New satellites are nearing completion and are due to be launched later in 2009.

Space Science Missions

European missions exploring Mars, Venus and the magnetosphere – the magnetic 'bubble' surrounding the Earth – have all been extended. Mars Express, Venus Express and Cluster have made enormous contributions to our understanding of the Solar System. UK involvement in each of these missions is considerable.



Mars Express has transformed our understanding of the red planet
Credit: ESA



The international Cassini-Huygens mission has captured remarkable images of Saturn
Credit: NASA

GIOVE-B being prepared for launch – equipment onboard the satellite was built in the UK
Credit: ESA

International Astronautical Congress

This year the UK hosted the successful International Astronautical Congress (IAC) – the leading international annual space congress and exhibition. The 59th IAC provided a forum for discussing new ideas, current and planned projects, and longer-term ambitions in space.

Industry Success

The latest BNSC survey of the size and health of the UK space industry indicates that total turnover increased to £5.8 billion in 2006-07, up from £4.8 billion in 2004/05. The number employed in the space industry increased to 18,800 from 16,200. This year also saw further development of a UK-designed spaceplane.

The BNSC Partnership

One of the clean rooms at Astrium in Portsmouth – the UK is one of the world's leading satellite manufacturers
Credit: Astrium

Space makes a real contribution to our economy and brings direct benefits to all our lives. BNSC is at the heart of Government efforts to explore and exploit space.

BNSC co-ordinates UK civil space activities and brings together representatives from Government, science, industry and education to promote advances in space technology and science. BNSC also supports efforts to use space within the teaching of science, technology, engineering and maths to inspire young people.

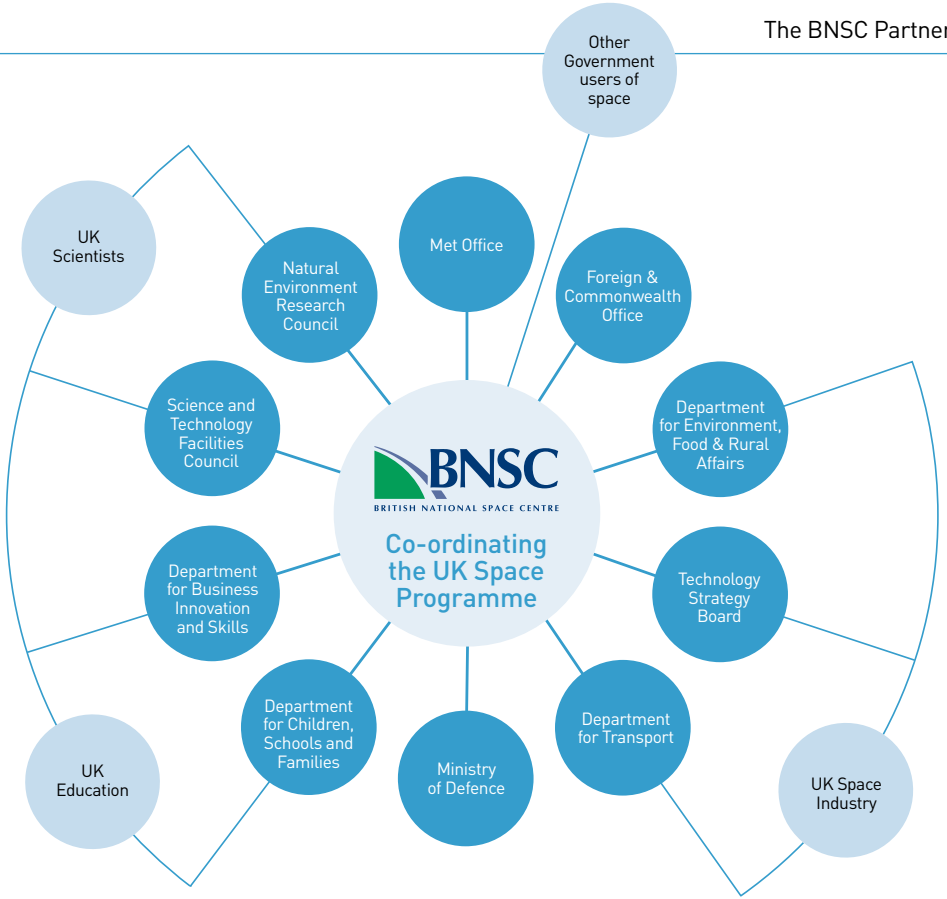
BNSC is a partnership of six government departments, two research councils, the Met Office and the Technology Strategy Board. It reports to the Minister for Science and Innovation in the Department for Business, Innovation and Skills. The BNSC ethos of collaboration applies across Government as well as to external organisations including European and global partners such as the

UK space policy is carried out within the framework of the 'UK Civil Space Strategy 2008-2012 and beyond'. This strategy shapes the direction of UK space policy and is based on five objectives:

- Win an increasing share of the global market in space systems, services and applications in the race to develop tomorrow's economy
- Deliver world-leading exploitation of space systems for managing our changing planet
- Be a partner of choice in global scientific missions to explore the Universe
- Benefit our Society by strengthening innovation from space, and stimulate the creation of new products and services for everyday use
- Develop a major channel for skills development and outreach for a high technology future, and improve public and political recognition of the value of space systems as part of the critical national infrastructure

The full document is available on the BNSC website.

The BNSC partnership



European Space Agency (ESA), the European Union, national space agencies and the United Nations.

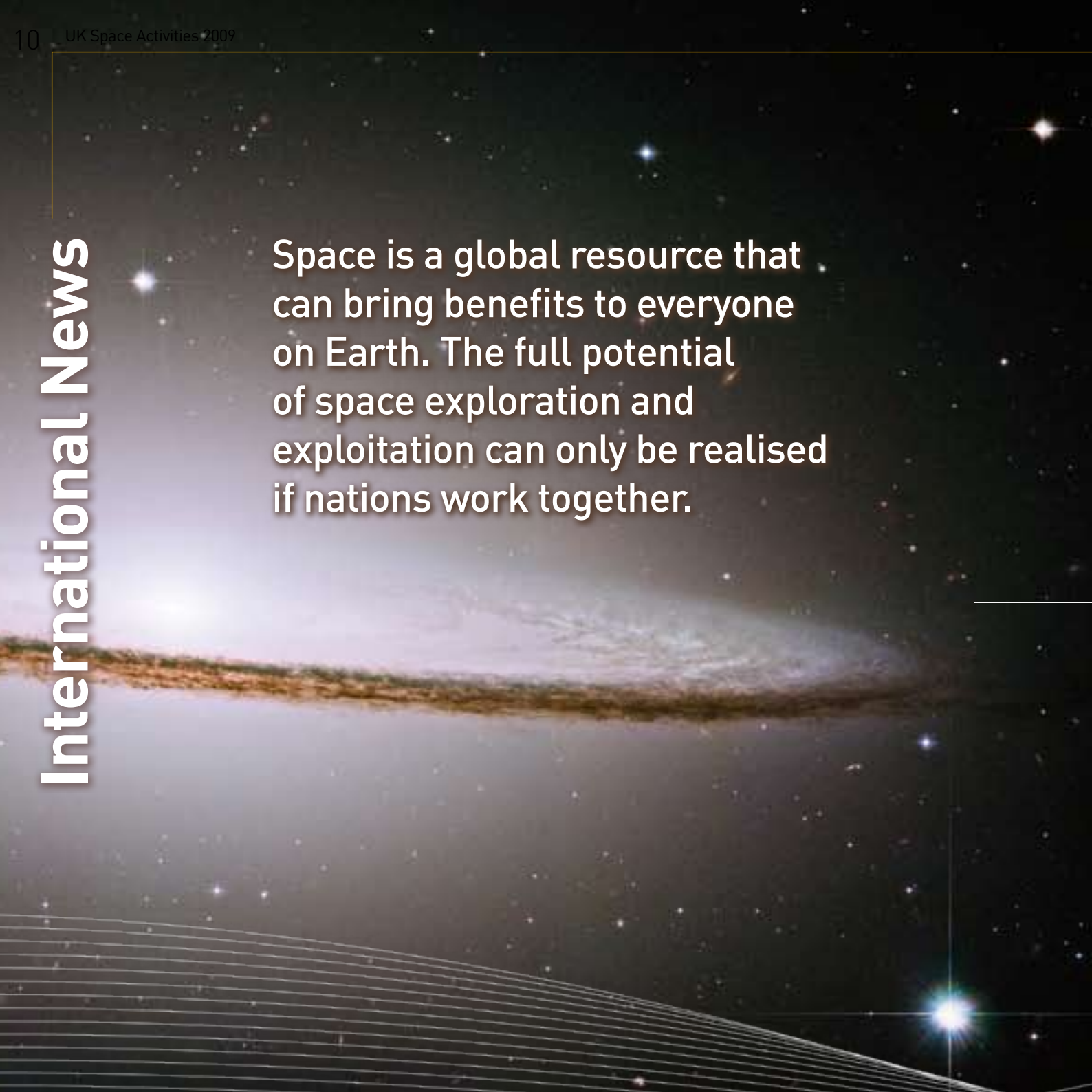
The past 12 months have seen two significant changes at BNSC, both of which will benefit the organisation's long-term future.

The Technology Strategy Board (TSB) is a new addition to the BNSC partnership. TSB was set up by the Government to promote, support and invest in technology research, development and commercialisation. BNSC will be working closely with TSB to ensure that space plays a key role in the UK's future economic prosperity.

This year also saw BNSC move its headquarters from London to join three of its partners in Swindon. The Science and Technology Facilities Council, which funds space science; the Natural Environment Research Council, which funds Earth Observation; as well as TSB are already based in the Wiltshire town. These bodies are responsible for some 85% of the space budget so by relocating, BNSC is able to work closer with its partners to combine space policy and delivery.

International News

Space is a global resource that can bring benefits to everyone on Earth. The full potential of space exploration and exploitation can only be realised if nations work together.



From the smallest Earth

Observation satellite to the most complex planetary science mission, almost everything the UK does in space is in partnership with other countries, agencies or organisations. By working with international partners, the UK can take part in a wide range of space activities that it would never have the resources to carry out alone.

The Sombrero galaxy captured by the Hubble space telescope
Credit: ESA

BNSC co-ordinates the UK's relations with the world's civil space community. This co-operation includes projects with European partners and bilateral agreements with an increasing number of other nations. The UK works with global organisations such as the Committee on Earth Observation Satellites (CEOS), the International Space Exploration Coordination Group, the International Charter Space and Major Disasters and the United Nations.

Delegates at the ESA Ministerial Meeting
Credit: ESA

European Partnerships

Seventy per cent of the investment in civil space by BNSC's partners is channelled through the European Space Agency (ESA). Since 1975, ESA has generated benefits for its member states and their citizens. UK funding for weather forecasting and climate research is also invested in the European Organisation for the Exploitation of Meteorological Satellites.

ESA has 18 member states and is one of the world's leading space agencies. The Agency's programmes include missions to investigate and monitor the Earth, explore the Solar System and understand the Universe. These programmes are featured extensively throughout this publication.

ESA Council meets at Ministerial level to discuss future objectives and priorities. The most recent meeting was held at The

Hague in the Netherlands in November 2008 with the UK represented by the Minister for Science and Innovation, Lord Drayson. At the meeting the UK committed funding to a number of key European space programmes and a deal was struck to establish a new ESA research facility in the UK. Highlights of the meeting are listed below:

ESA Ministerial meeting 2008

- A new ESA research facility will be established in the UK. Based at the Harwell Science and Innovation Campus in Oxfordshire, it will focus on climate change modelling that uses space data and the development of technologies for a new era of planetary exploration. This will include innovative robotics and the design of new power sources.
- The UK committed €121 million to the Advanced Research in Telecommunication Systems (ARTES) programme. This will make the most of the UK's reputation and expertise in satellite communications technology.
- A total of €171.5 million was committed by the UK to the Aurora ExoMars programme. The ExoMars mission is expected to launch in 2016.
- The UK subscribed €102.5 million to the Global Monitoring for Environment and Security (GMES) segment 2 programme. GMES will provide essential observations to monitor climate change. The UK also subscribed €1 million to the Space Situational Awareness programme and €3 million to the General Support Technologies Programme.

The UK also agreed investments in the ESA's mandatory programmes over the next three years:

- The Science Programme, funded by STFC, pays for the design, build and launch of space science missions. The UK's investment will be €234.5 million.
- The General Budget, funded by STFC and NERC, pays for the basic infrastructure and overheads of the ESA programme as well as outreach and education activities. The UK's investment will be €110 million.

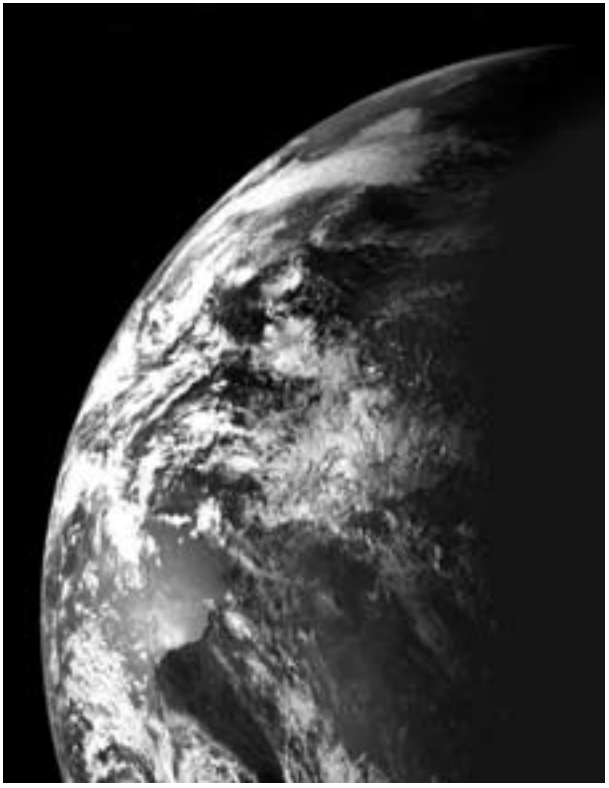
The UK works closely with its international partners on missions such as STEREO
Credit: NASA

Global Partners

The UK space community, with the help of BNSC, continues to forge new international partnerships. BNSC actively promotes UK space interests through international exhibitions, trade delegations, seminars and publicity campaigns.

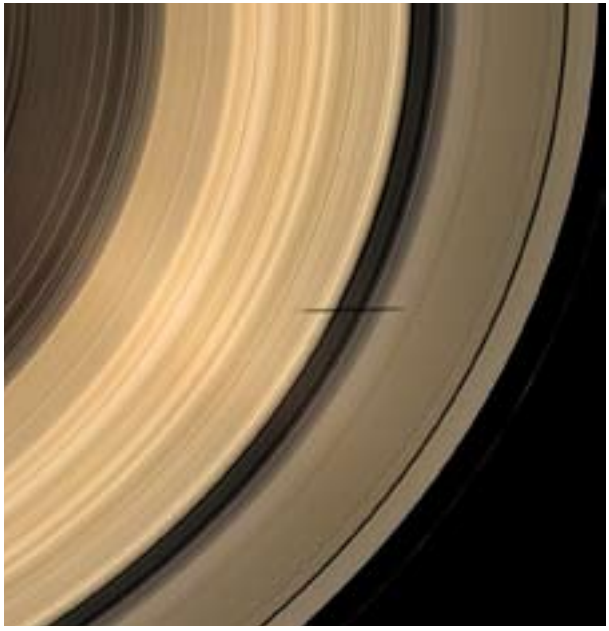
BNSC works closely with UK Trade and Investment, the Government organisation that supports UK companies doing international business. It also liaises with the Science and Innovation Network, set up by the Foreign and Commonwealth Office to encourage exchange between science communities around the world and foster closer links between science and business.

One of the UK's longest standing international partners in space exploration is the United States. The very first space science mission conducted by UK scientists, Ariel 1, in 1962 was in partnership with the American space agency NASA. Today, UK scientists are involved with many NASA missions including Phoenix and STEREO. BNSC is also working closely with NASA to develop future missions to the Moon. NASA collaborates with ESA on international missions including Hubble, Cassini-Huygens and SOHO.

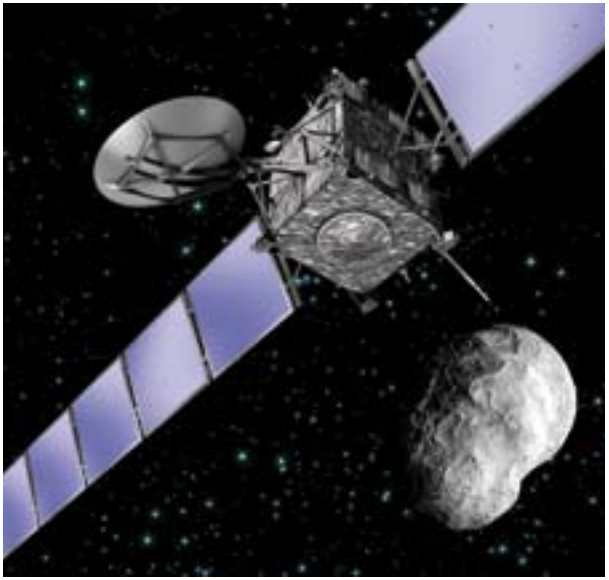


Chandrayaan-1 looks back at the Earth on 29 October 2008
Credit: ISRO

BNSC is also working with other countries. Examples include the significant UK contribution to India's first mission to the Moon and work with the Japanese space agency (JAXA) on Hinode and ESA's mission to Mercury, BepiColombo. Earth Observation missions involving international partnerships include the Disaster Monitoring Constellation – a collaboration between the UK, China, Nigeria and Algeria.



Minas casts a shadow across Saturn's rings
Credit: ESA



Artist image of Rosetta as it flies past asteroid Steins
Credit: ESA

The UK works with the United Nations Office for Outer Space Affairs, responsible for promoting international co-operation in the peaceful uses of outer space. BNSC also takes a leading role in the Inter-Agency Space Debris Co-ordination Committee and international groups concerned with Near Earth Objects. Through its membership of the Committee on Earth Observation Satellites (CEOS), BNSC works to foster closer co-operation in exploratory missions that observe and study the Earth.

The BNSC stand at the IAC

59TH INTERNATIONAL ASTRONAUTICAL CONGRESS

For the first time in more than 20 years, the UK played host in 2008 to the International Astronautical Congress (IAC) – the leading international annual space congress and exhibition. The 59th IAC – which ran from 29 September to 3 October in Glasgow – provided a forum for discussing new ideas, current and planned projects, and longer-term ambitions in space.

Sir Martin Sweeting, Chairperson of the event, said that with over 3,000 visitors it was "the most successful IAC for many years. Not only were there a large number of visitors but all of the heads of the world's major space agencies were present and participated in the panel discussions. The quality of the presentations was excellent."

As well as the kudos that hosting the IAC brings, Sir Martin commented that the UK also benefited through "the ability to showcase UK space activities and to show that the UK is serious about space." A UK Host Nation Welcome Zone gave visitors to the event exhibition an overview of the UK's current space activities and expertise.

The British Interplanetary Society organised the Congress, with help from BNSC. Each day had a theme ranging from Agencies Day, which brought together heads of the world's major space agencies, to Citizen's Day. This included discussions about possible human colonisation of space and outreach events aimed at young people.

Delegates at the IAC discussed future missions to the Moon and beyond
Credit: John Frassanito and Associates

Space Science

UK expertise has enabled spacecraft to reveal the surface of alien moons, the inner workings of the Sun, the origins of galaxies and even the birth of the Universe itself. The UK is involved in more than 20 space science missions and technology developed in the UK is currently in orbit around the Earth, Moon, Venus, Mars and Saturn.

Research teams from institutions

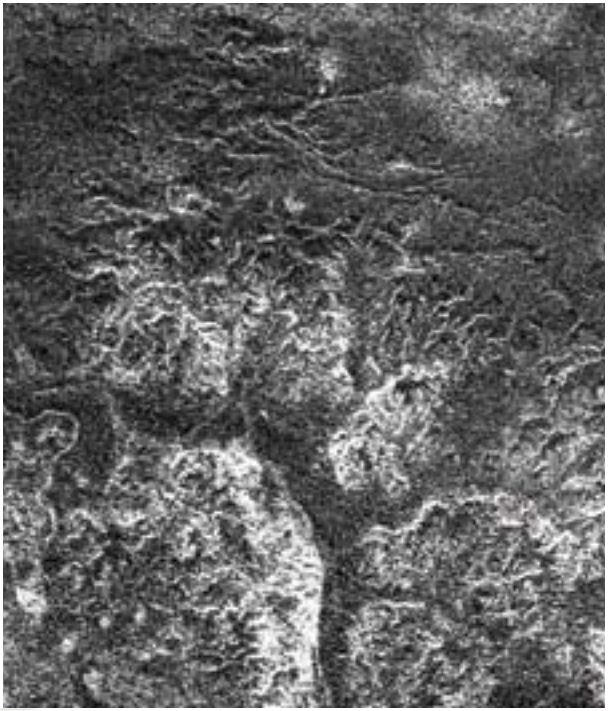
across the UK are working on the most ambitious space science missions ever conceived. With these missions under development, Britain is at the forefront of efforts to explore planets, stars and the wonders and mysteries of the Universe.

The UK's space science effort is funded through BNSC partner, STFC. ESA is leading the majority of space science missions and the UK is the second largest contributor. The UK also collaborates with other international partners including NASA, the Indian Space Research Organisation and the Japanese space agency (JAXA).

As a founder member of the International Space Exploration Co-ordination Group the UK is working towards globally coordinated space exploration. The UK makes a large financial contribution to Aurora: ESA's programme to take Europe to the Moon, Mars and beyond. Support for the UK's contribution to any missions is subject to a rigorous peer-review process conducted by STFC.

Within the UK ESA facility, one focus will be on the development of technologies for planetary exploration such as robots and novel power sources.

A Mars Express image of what appears to be a river delta
Credit: ESA



The southern canyons of Saturn's moon Titan as seen by Cassini in May 2009
Credit: NASA

2009 is the International Year of Astronomy and throughout the year there are events across the UK to celebrate astronomy and its contribution to society and culture. Supported by the Royal Astronomical Society, the Institute of Physics and STFC, the year provides an opportunity to promote space science and astronomy – particularly among children and students. There will be a touring outdoor exhibition of stunning astronomical images, a new show for UK planetariums as well as a wide range of local events.

Understanding the Universe

UK science and engineering teams are working on missions to explore the depths of space. These include the new observatories Herschel and Planck, ongoing missions such as Hubble and XMM-Newton as well as future endeavours including the James Webb Space Telescope (JWST).

Four hundred years ago, Englishman Thomas Harriot turned a telescope on the Moon. The drawings he made that night are the oldest known depiction of a celestial object as seen through a telescope
Credit: Lord Egremont

Hubble received its final service in May 2009
Credit: NASA

The launch of the Herschel and Planck satellites on 14 May 2009 marked the culmination of more than ten years' development. It represents the start of a new era in our investigation of the birth and evolution of the Universe and its galaxies. Launched together on Ariane V they are now on their journey to their operational location some 1.5 million km from Earth.

After 19 years in space, the Hubble Space Telescope received its final servicing mission in 2009. This will extend the telescope's operating life until at least 2013. In the meantime, construction of Hubble's successor the JWST is well underway.

The JWST is a joint mission between NASA, ESA and the Canadian Space Agency and will investigate the origin and evolution of galaxies, stars and planetary systems. The UK is involved in many aspects of the mission from manufacturing instruments to planning scientific programmes. A team led

Removing Planck's protective cover
Credit: ESA

THE BIG QUESTIONS

The Herschel Space Observatory and the Planck Surveyor satellites will give us fundamental insights into the birth and evolution of the Universe.

"Planck's observations will tell us what happened in the first split second of the Big Bang and about the fundamental physics responsible for it," says Professor Matt Griffin from Cardiff University.

Planck's 1.5 metre telescope will examine the radiation left over from the Big Bang using detectors that can operate at only a tenth of a degree above absolute zero (- 273°C).

It will focus the Cosmic Microwave Background – the 'oldest' light in the Universe – onto its High Frequency and Low Frequency instruments. The UK built part of the cooling system and provided and assembled detectors for the units.

Herschel, with its 3.5 metre primary mirror, is the largest space telescope ever constructed. It will view the Universe in the far infrared part of the spectrum with instruments that can penetrate dust clouds and detect the faint glow of particles in regions where stars are formed in our own and other galaxies.

These instruments include SPIRE, the UK led Spectral and Photometric Imaging Receiver, which was assembled and tested at the STFC Rutherford Appleton Laboratory (RAL). Professor Griffin is the international consortium's Principal Investigator.

"Herschel's main scientific goals are to reveal how stars and planetary systems are forming in our own galaxy today," he explains, "and how galaxies like our own Milky Way formed in the past."

"Together, Planck and Herschel will explore the Universe throughout almost its entire history," says Professor Griffin. "This will give us a much better understanding of how our Universe came to be."

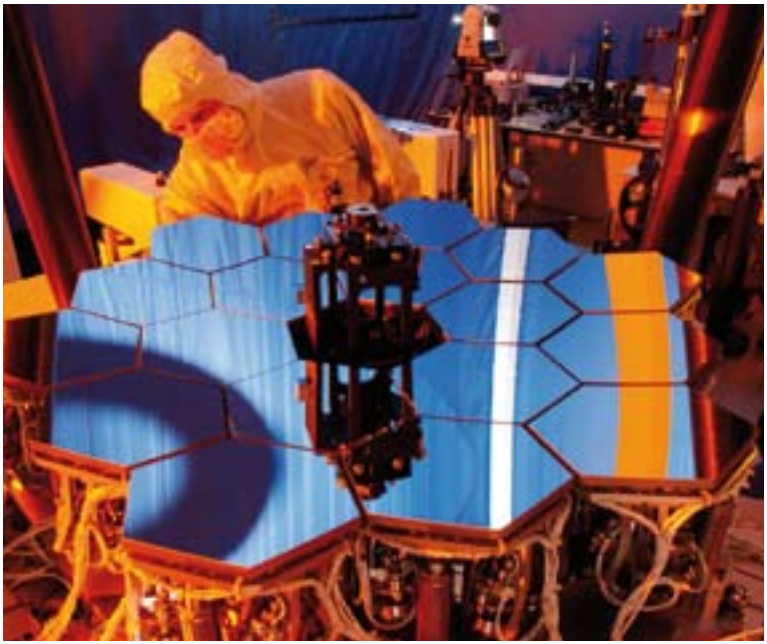
Herschel being tested prior to launch
Credit: ESA

Ariane 5 lifts off from Europe's Spaceport in French Guiana carrying Herschel and Planck
Credit: ESA

in Europe by STFC's Astronomy Technology Centre in Edinburgh is developing one of the telescope's three cameras, MIRI (Mid InfraRed Instrument), and assembly of the flight model is now underway at RAL in Oxfordshire. A Staffordshire-based company, Tekdata Interconnect Systems, is manufacturing a 'cryogenic harness' for the telescope – a crucial component that will link all the JWST's major systems. The harness is being tested in RAL's space test chamber during 2009.

February 2009 saw the publication of the 2,000th scientific paper resulting from data produced by Europe's X-ray telescope, XMM-Newton. Since its launch in 1999, XMM-Newton has been investigating all kinds of astronomical objects – from planets in our Solar System to the most distant quasars. The telescope studies thousands of different X-ray emitting objects and can detect more sources of X-rays than any other satellite.

Results during the year included the discovery, by a team from the University of Durham, of a periodic signal (once per hour)



A test section of the JWST mirror
Credit: NASA

Hubble image of the Eskimo Nebula, 5000 light years away
Credit: NASA, ESA

being emitted from a super-massive black hole lodged at the centre of a galaxy.

The finding will provide scientists with a new insight into the fundamental physical processes taking place within black holes.

Using data from the Swift satellite, UK astronomers captured information from the early stages of a gamma ray burst (GRB). These are powerful cosmic explosions, which astronomers believe are the birth pangs of black holes. Swift is able to locate and point at GRBs far quicker than any other telescope and the team at the Mullard Space Science Laboratory (MSSL) has developed new techniques to improve our understanding of these strange phenomena.

Swift, a NASA mission in collaboration with STFC and the Italian Space Agency, has key UK involvement from the University of Leicester and MSSL with scientists from both institutions 'on-call' to investigate GRBs as they occur.

A UK led ESA mission to test technology aimed at proving one of Einstein's most famous theories has itself been undergoing an extensive programme of testing prior to launch. The Laser Interferometer Space Antenna Pathfinder (LISA Pathfinder) is a spacecraft and propulsion module that will prove the technologies for the future missions designed to detect gravitational waves.

These ripples in time and space are predicted by Einstein's Theory of General Relativity and are thought to be generated by violent astrophysical events. LISA Pathfinder is designed to prove that a test mass can float freely in space so that any effects on its trajectory will only be the result of external gravitational forces.

LISA Pathfinder is the first ESA science spacecraft led from the UK since Giotto, with Astrium Limited as the main contractor and SciSys Limited the software architect. UK scientists from the University of Birmingham, the University of Glasgow and Imperial College London are collaborating on the mission.

Hubble image of the Antennae Galaxies
Credit: NASA, ESA

[EXOPLANETS]

'Are we alone?' is one of mankind's most poignant and fundamental questions.

The UK scientists who study exoplanets – planets orbiting stars outside our Solar System – could one day provide an answer.

So far around 350 exoplanets have been found. "These worlds can be extremely interesting," says Dr Giovanna Tinetti from University College London, "and the idea that some of these worlds might be inhabited is quite amazing."

In March 2009, Dr Tinetti was part of a team that reported discovering a carbon-containing molecule on an exoplanet for the first time. Planet HD189733b orbits a star 63 light years away in the constellation Vulpecula.

The organic compound methane was discovered in the planet's atmosphere, along with water, but in this case scientists believe HD189733b is too hot to support life.

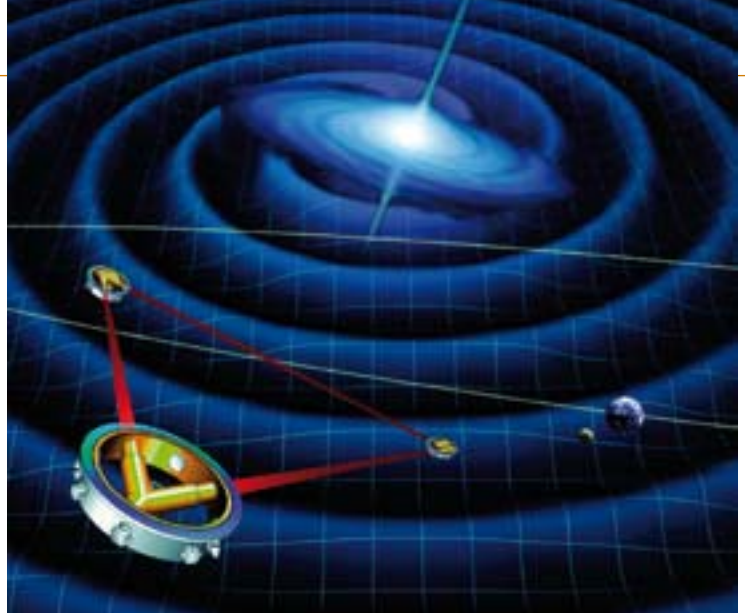
According to the Royal Astronomical Society, the chance of finding Earth-like planets is real. And there is now a new camera called RISE, designed by astronomers at Manchester University and Queen's University Belfast, to detect so-called 'hot Earths'.

"RISE will allow us to observe and time the transits of extrasolar planets very accurately," explains Neale Gibson from Queen's University Belfast. "This gives us the sensitivity required to detect the effect of even small Earth-sized planets."

RISE is attached to the 2 m Liverpool Telescope on La Palma, in the Canary Isles. It can measure how the light reaching the telescope changes as a large Jupiter-like planet crosses its parent star. This technique, called transit timing, can be used to detect any orbital changes that might be produced by the gravitational pull of a smaller, but unseen, nearby planet.

The Liverpool Telescope in La Palma is owned and operated by Liverpool John Moores University with support from STFC
Credit: ARI 2009

Although hot Earths are not thought to harbour life, it is an important step towards finding planets like our own.



LISA will be the first space-based mission to attempt the detection of gravitational waves
Credit: ESA

Exploring the Solar System

Solar System missions include investigations of the Sun, Moon and three very different planets: Venus, Mars and Saturn. The UK is also a leader in the ambitious Rosetta programme which will be the first spacecraft to examine a comet close-up.

The Earth and the Sun

The UK is world-class in solar physics, space plasmas and planetary atmospheres. UK scientists are involved in three major international missions to study the Sun: Hinode, STEREO and SOHO. The UK is also a leader in studies of the magnetosphere – the magnetic 'bubble' surrounding the Earth.

Launched in 1995, the joint NASA/ESA Solar Heliospheric Observatory (SOHO) is a most successful and enduring mission. Its observations have revolutionised knowledge of our Sun. UK scientists at RAL developed SOHO's Coronal Diagnostic Spectrometer experiment, which detects extreme ultraviolet radiation from the Sun. The satellite has also turned out to be an unexpected record-breaking comet spotter and last year celebrated finding its 1500th comet.

The Japanese (JAXA) Hinode mission was launched in 2006 to study the Sun's dynamic atmosphere. Hinode has provided new

The Helix Nebula formed by gas expelled by a dying star
Credit: NASA, ESA

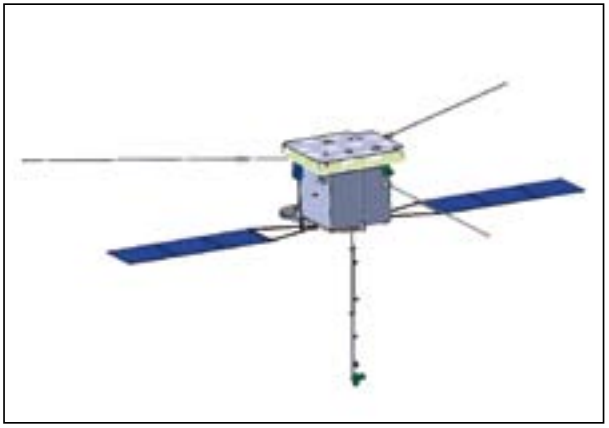
A SOHO image of the Sun taken at three different wavelengths
Credit: ESA

insights into the processes involved in solar flares and coronal mass ejections – explosions of billions of tonnes of particles into space. Results from the UK-built Extreme Ultraviolet Imaging Spectrometer (EIS) on Hinode have also enabled scientists to discover the source of the continuous stream of charged particles emitted from the Sun, known as the solar wind. The UK invested almost £5 million in developing and building the EIS, which was designed and developed by a team led by MSSL.

This year a new variety of sunspot with a completely different type of magnetic field was discovered. Strong magnetic fields on the Sun's surface drive dynamic activity such as solar flares and eruptions. Solar flares are tremendous explosions in the atmosphere of the star and can directly affect the Earth's upper atmosphere, disrupting radio communications.

NASA's Solar Terrestrial Relations Observatory (STEREO) continues to provide remarkable 3-D images of the Sun. A UK consortium, led by RAL and the University of Birmingham, developed the Heliospheric Imager, one of the key instruments on board. The orbital design of the mission means that the twin STEREO spacecraft continue to separate. This allows them to see more of the Sun at the same time. When the two satellites are 180 degrees apart in 2011 we will, for the first time, be able to directly observe the entire Sun simultaneously.

The four spacecraft orbiting the Earth in formation as 'Cluster' are providing a detailed 3-D map of our planet's magnetic field and its interaction with the solar wind. This joint ESA/NASA mission, which is helping



Concept model for the ESA Solar Orbiter
Credit: ESA

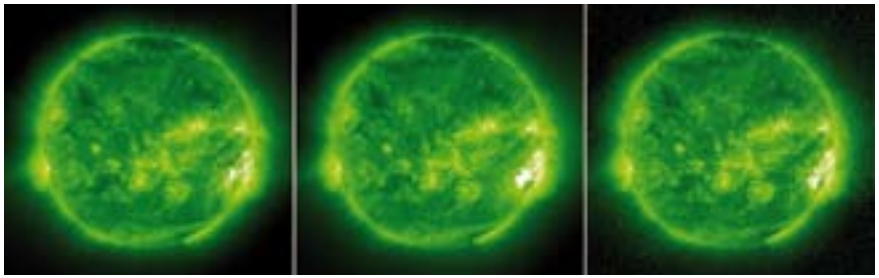
scientists better understand space weather and plasma physics, has been extended until the end of 2009. UK scientists lead three of the 11 instruments on each spacecraft.

The scientific payload has been selected for the ESA Solar Orbiter. Solar Orbiter is being designed to provide new close-up and high-latitude observations of the Sun from an elliptical orbit. It is envisaged that the mission will fly in conjunction with NASA's 'Sentinels' mission to the Sun. Ten instruments have been recommended for the payload, including a magnetometer led by Imperial College London and the Solar Wind Plasma Analyser proposed by MSSL.

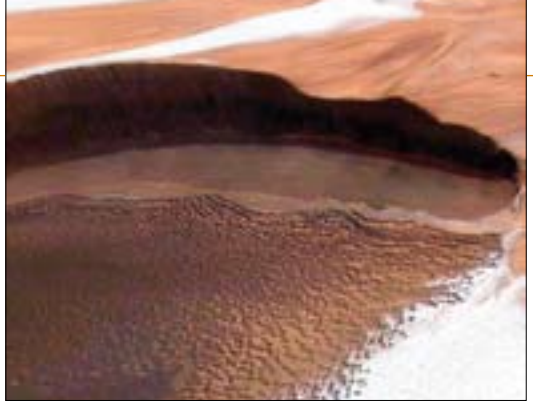
The Moon

For the first time since the 1960s, there is renewed international interest in exploring the Moon. A UK science and engineering team is currently working with the Indian Space Research Organisation on its lunar orbiter, Chandrayaan-1. A new UK-led mission to investigate the Moon's surface is being developed and the UK is investing in future exploration programmes through its international partners.

The UK-built X-ray camera on board Chandrayaan-1 has sent back its first images of the lunar surface. It reached its final lunar orbit in November 2008 and the X-ray Spectrometer (C1XS) instrument on board is now being used to examine the composition of the Moon and the distribution of chemical elements. The aim is to build up a detailed picture of the Moon's mineral resources. RAL designed and built C1XS in collaboration with the Indian Space Research Organisation.



SOHO image of the Sun's corona during an extreme solar event
Credit: ESA

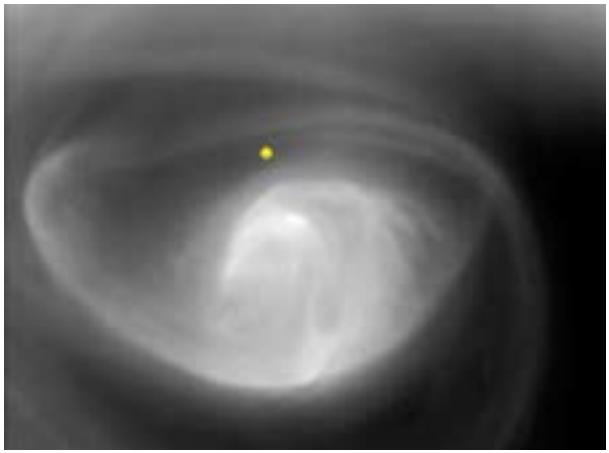


Ice and dust at the Martian North Pole
Credit: ESA

Visiting the Planets

European missions exploring Mars and Venus continue to generate new results and will continue to operate through 2009.

Venus Express is currently mapping Venus's thick, noxious atmosphere, its interaction with the solar wind and has revealed details of the planet's cloud system. The spacecraft has examined the surface and has produced the first clear images of the Venusian South Pole. Because of Venus's extreme greenhouse effect, these observations are helping scientists on Earth better understand climate change.



Venus Express image of the planet's polar vortex
Credit: ESA

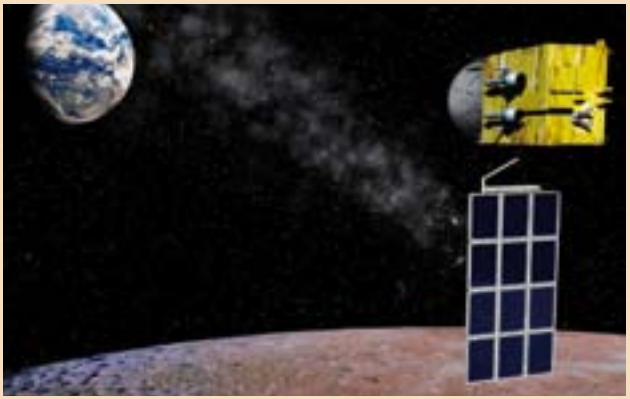
The Venus Express mission was conceived and developed with UK participation. Following a series of orbit correction manoeuvres, the spacecraft is now experiencing the effects of atmospheric drag. A detailed analysis of data from this experiment will shed new light on the planet's atmosphere.

Publications this year based on data from Venus Express include the first detection of hydroxyl in the atmosphere and a study into the planet's global cloud patterns. Data from Venus Express has been delivered to the ESA Planetary System Archive and is now freely available to interested users.

Mars

After six years in space, Mars Express continues to deliver outstanding results, having transformed our understanding of the red planet. Mars Express is mapping Mars's mineral composition, examining its atmosphere, geological and volcanic activity as well as taking high-resolution images of the surface. The spacecraft is also investigating the planet's climate and searching for water.

[MoonLITE]



Artist image of the MoonLITE spacecraft with penetrators attached

BNSC, through STFC, has approved a major 'Phase A' technical study to examine the feasibility of a UK-led mission to the Moon.

MoonLITE (Moon Lightweight Interior and Telecom Experiment), with a planned launch in 2014, aims to place a satellite in orbit around the Moon. It will deploy four 1 metre long 'penetrators' to the Moon, delivering scientific instruments below the lunar surface.

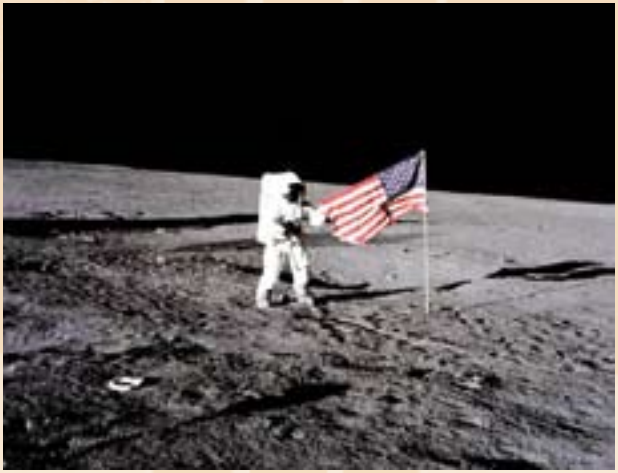
These instruments would be the first experiments since the Apollo era to probe the Moon's interior. The seismometers, sensors and detectors will explore the frequency and origin of moonquakes as well as help answer continuing questions about how the Moon formed and how it has evolved.

"We have world leading expertise in small satellites through Surrey Satellite Technology Limited, impact technologies through QinetiQ and instrument innovation at a range of academic institutions building upon Beagle-2 and other planetary missions," says Professor Alan Smith from MSSL, who's been appointed the Principal Investigator for the study.

The orbiting spacecraft would also act as a telecommunications relay node between the four stations on the lunar surface and the Earth.

"The MoonLITE orbiter could go on to become the main communications link for subsequent lunar exploration missions," says Professor Smith, "opening up the far-side of the Moon to study."

BNSC is coordinating the MoonLITE mission and the MSSL will conduct the feasibility study. If approved, it will be funded by STFC and built by UK industry. The US space agency NASA would work on the communication system between Earth and the satellite.



40 years after the first man landed on the Moon, the UK is involved in international efforts to return
Credit: NASA

UK space scientists contributed to three of the instruments on board Mars Express: the ground-penetrating radar, MARSIS, the High Resolution Stereo Colour Imager and ASPERA, which is studying the Martian atmosphere. UK engineers built the propulsion system that got it safely into orbit and a UK team works alongside its partners at mission control in Germany. In summer 2008, Mars Express made a series of close passes to the planet's largest moon, Phobos. As well as returning remarkable close-up images, the encounter will shed new light on the moon's origins.

Mars Express image of Phobos, one of the planet's moons
Credit: ESA

Scientists from the University of Bristol and Imperial College London have been involved in Phoenix, NASA's latest mission to Mars. The probe landed safely on the northern plains of Mars on 25 May 2008 to begin its search for water and any signs of life. Among early results, it verified the presence of water-ice in the Martian subsurface, returned more than 25,000 images and carried out a microscopic study of the planet's soil.

ExoMars

ExoMars, the first mission under Europe's Aurora programme, has a provisional launch date of 2016. ExoMars will consist of a descent module, a six-wheeled rover and, possibly, an orbiter. The first European rover on Mars

The view of Mars witnessed by the Phoenix lander
Credit: NASA

will carry a drill that can burrow up to 2 m into the Martian surface allowing its scientific instruments to analyse and sample the soil and search for mineral content, composition and traces of past and present life.

The UK is the second largest contributor to the ExoMars mission. At the ESA Ministerial meeting in November, the UK confirmed extra funding bringing its contribution to €165 million for the Enhanced ExoMars mission component and €6.5 million to the Mars Robotic Exploration Preparation Programme Component.

As a result of its support, UK involvement in the mission is considerable: Astrium Limited will build the rover, a team led by the UK is developing the Panoramic Camera System; and instruments, components and software are being provided by academic institutions and companies from across the country.

Saturn

The Cassini-Huygens spacecraft successfully fulfilled its initial four-year mission to Saturn last year but is still going strong. The combined ESA, NASA and Italian Space Agency project is now in extended mission operations and continues to send back stunning images and valuable scientific data. The UK has been at the forefront of the design, engineering and science of Cassini-Huygens, which has transformed our knowledge of the Saturnian system – from the planet, its rings and moons, down to the surface of Titan where the Huygens probe landed in 2005.

In March 2009 Cassini successfully swapped its backup propulsion motors, to maintain performance. Science highlights this year include further fly-bys of Titan and the moon Enceladus. Close views of the southern polar region of Enceladus (from a distance of just 50 km) – where jets of water vapor and icy particles erupt from vents – provide surprising evidence of tectonic plates, similar to those on Earth. The plumes also appear to vary over time and have a far-reaching effect on Saturn's magnetosphere.

Earth Observation

An artist's view of the rear of Proba-2 as it looks towards the Sun
Credit: ESA

The Apollo images revealing the

beauty of the Earth, isolated and seemingly adrift in space, heavily influenced the environmental movement. Today, Earth Observation (EO) satellites enable us to see the retreat of polar ice, the destruction of the rainforests and advance of the deserts. They also allow us to measure pollution, track weather systems and respond to disasters. Over the years, satellites in orbit have allowed us to accurately map the world and monitor changes to patterns of land use.

The Earth seen by the crew of Apollo 17
Credit: NASA

BNSC partner the Natural Environment Research Council (NERC) is responsible for the UK's funding of ESA Earth observation science missions and a number of UK EO facilities and centres. By its very nature, EO is a global endeavour and the UK, through BNSC, works very closely with its international partners to co-ordinate space missions and share results. The UK is also an active member of groups including the Committee on Earth Observation Satellites (CEOS), the Group on Earth Observation (GEO) and the International Charter Space and Major Disasters.

This year, highlights include the start of an ambitious mission to map the Earth's gravity field; the launch of a major new national centre devoted to exploiting EO data and technologies; and the development of new satellites to monitor the environment, track weather and respond to disasters.

The Earth's Changing Climate

Climate change is the greatest environmental challenge facing the world today and tackling climate change is a global priority. The UK Government is currently working towards reaching new agreement on climate change at the forthcoming International Climate Change Conference being held in Copenhagen in December 2009. The UN Framework Convention on Climate Change (UNFCCC) Conference of Parties will agree strategies for the post-2012 period. EO technologies have a vital role in monitoring how the Earth's climate is changing and help ensure that government decisions are based on sound scientific evidence.

This year saw the launch of the National Centre for Earth Observation (NCEO) to support science investigating the environmental challenges facing the world. The NCEO also aims to broaden the use of EO by the scientific and industrial communities to help place the UK at the forefront of efforts to exploit the capabilities of space EO technology.

The NCEO will work alongside the Centre for Earth Observation Instrumentation (CEOI). Jointly funded by NERC, TSB and industry, it is managed by a consortium led by Astrium. The centre aims to harness the UK's scientific expertise and industrial strengths in EO instrumentation. Initial projects will develop new remote-sensing technologies to investigate atmospheric chemistry, pollutants and trace gases.

At the ESA Ministerial, the UK agreed to invest £82 million in ESA's flagship Global Monitoring for Environment and Security (GMES) programmes. GMES will provide essential environmental observations, including for the monitoring of climate change and a mission to measure the chemicals in the atmosphere. It is expected that the UK space industry will play a leading role in developing the satellites for this programme.

Envisat image of the Alps
Credit: ESA

The Ministerial meeting also agreed that a new ESA research facility should be opened at the Harwell Science and Innovation Campus in Oxfordshire in the UK. One of the areas this centre will investigate is climate change modelling that uses data from satellites.

New Missions

This year saw the successful launch of Europe's gravity mission, GOCE (Gravity field and steady-state Ocean Circulation Explorer). This will be followed later this year by the launch of the SMOS (Soil Moisture and Ocean Salinity) satellite and ESA's ice mission, CryoSat-2. These are all Earth Explorer Science missions and form part of ESA's Living Planet programme. UK science and engineering teams continue to work on a number of other established EO missions including Envisat, ERS-2 and Proba.

The small island of San Salvador seen by Proba
Credit: SSTL through ESA

[GLOBAL VIEW]

The National Centre for Earth Observation (NCEO) brings together highly-skilled scientists and researchers. They are using satellite data and imagery of the Earth to investigate and understand some of our biggest environmental challenges: from climate change to atmospheric pollution.

"Earth-observing satellites provide a global view of the interconnected forces that shape our planet," says NCEO Director, Alan O'Neill. "Together with ground-based systems, satellites are a key component of an Earth Management System which will help us to live on Earth in a sustainable manner."

The NCEO combines satellite data with ground-based sensors and computer simulations to monitor and predict climate and environmental changes. And it has plenty of data to draw from, thanks to major investments in satellites by the world's space agencies.

One of the centre's main projects is to investigate the Earth's carbon cycle. Understanding the carbon cycle is key to understanding the planet's environment, and how it might be changing. It's a delicate balance. The land and oceans each remove about a quarter of man-made carbon dioxide emissions. Without them, the climate would change much more quickly than it is already doing. And the cycle isn't just about global warming – through monitoring land and marine plant growth, we can see how much plant life there is and how it's changing.

It's difficult to get a global view of the different processes involved in the carbon cycle. But data from space can provide vital information. Earth Observation satellites can measure atmospheric carbon dioxide and methane, as well as other environmental components that tell scientists how well the carbon cycle is working.

ESA's GOCE satellite was launched on 17 March 2009 from the Plesetsk Cosmodrome in northern Russia. With its dart-shaped design, GOCE is one of the most sophisticated EO satellites ever produced. By measuring tiny variations in the Earth's gravitational field, GOCE will enable scientists to gain a greater insight into how the Earth works; the physics of its interior and changes in sea levels. The data will be combined with information about sea surface height from other satellites to track the direction and speed of ocean currents.

Flying just 250 km above the Earth's surface, GOCE is measuring gravity using highly accurate accelerometers. To do this it has to eliminate other accelerations generated by the force of the air or even the force of photons from the Sun. The designers have overcome these challenges by employing an electric propulsion system, built in the UK by QinetiQ. Instead of burning

fuel, electricity from the spacecraft's solar panels will be used to produce charged particles, or ions, from an inert gas. These ions will be pumped out of the spacecraft to propel it forward.

Scientists at a number of UK academic institutions are involved in the mission alongside industrial partners including SciSys Limited, which developed a satellite simulator to support spacecraft operations.

Final preparations are being made for the launch of SMOS in September 2009. SMOS will study the amount of salt in the oceans, and water in surface soil. These are both linked to the planet's climate and water cycle. Data from the satellite will contribute to improved seasonal climate forecasting and the prediction of extreme weather events.

SciSys UK Limited is a member of the SMOS Payload Module Team and has developed the on-board software that controls one of the instruments. ComDev developed the X-band filter and Chelton Antennas was involved in the manufacture of the antennae. Science teams involved in SMOS include researchers from the National Oceanographic Centre, Southampton and De Montfort University's Earth and Planetary Remote Sensing Laboratory, Leicester.

GOCE encased in its faring prior to launch
Credit: ESA

The third Earth Explorer mission, CryoSat-2, has been undergoing testing prior to launch at the end of 2009. Europe's 'ice mission' will measure the thickness of ice at the Earth's poles to the nearest centimetre. It will also monitor variations in Arctic sea ice and help build up a picture of long-term trends. The CryoSat-2 science team is being led from University College London.

Three UK companies – Astrium, Surrey Satellite Technology Limited (SSTL) and Systems Engineering and Assessment (Group) Limited (SEA) – are working on the development and construction of the ESA EarthCARE (Earth, Clouds, Aerosols and Radiation Explorer) satellite. EarthCARE will focus on clouds and tiny particles in the atmosphere – aerosols – to assess their influence on atmospheric radiation. The EarthCARE platform will be built in the UK by Astrium, the Multi-Spectral Imager by SSTL and the Broadband Radiometer by SEA.

Europe's Envisat continues to capture stunning images of the Earth and generate

Antarctic ice shelves are at risk of collapse – temperatures are rising and our climate is changing

CRYOSAT-2: UNDERSTANDING OUR CHANGING CLIMATE

Arctic sea ice is disappearing and Antarctic ice shelves are at risk of collapse – sure signs, scientists say, that temperatures are rising and our climate is changing. The European Space Agency's (ESA's) CryoSat-2 will take exact measurements of the polar ice for five years to help scientists monitor changes.

Professor Duncan Wingham of University College London leads the mission. "CryoSat-2 is ever more important as the Arctic ice declines," he says. "Mapping changes at the poles is vital if we're to understand our changing climate." Polar ice is a good indicator of what's happening across the world – reflecting rises in global temperatures as it thaws more rapidly in summer, and takes longer to freeze in winter.

It's also central to the Earth's climate system: regulating its temperature by reflecting sunlight back into space, and actually helping parts of the planet stay warm by keeping ocean currents flowing. Without polar ice, some scientists predict that Europe could be plunged into another ice age.

ESA's CryoSat-2 will take exact measurements of the polar ice for five years to help scientists monitor changes

What's more, melting ice could cause rising sea levels and increased flood risks, and have a devastating effect on wildlife. Scientists say the ice isn't just receding – it's also getting thinner. But it's difficult to measure how much is melting and how quickly. Sending teams to check by hand is expensive and can be unreliable. And although other satellites can measure the ice, most have wider-reaching missions and their orbits aren't always compatible. That's why CryoSat-2 is so important. Its twin radar system and two onboard radar receivers will show a 3D view of the ice. Used with data from other satellites, it will give a long-term picture of what's happening.

The first CryoSat mission was launched in 2005 but a failure after lift-off meant it didn't reach orbit. In 2006, ESA approved a second mission: highlighting the value of CryoSat-2 in our search for a better understanding of the impact of climate change.

valuable scientific data. The most sophisticated EO satellite ever launched, Envisat's mission has been extended until 2013.

Other ongoing EO missions include the TopSat and Proba satellites. Funded jointly by BNSC and the Ministry of Defence, TopSat delivers high quality images from around the globe. The satellite was built in the UK by a consortium led by QinetiQ and contains a single powerful camera capable of delivering high quality images from around the globe. The Compact High Resolution Imaging Spectrometer (CHRIS) on board the Proba satellite, built by Sira (now SSTL), has found a wide variety of uses from mapping ancient Roman remains to monitoring pollution in Hong Kong. SSTL has also developed the RapidEYE EO constellation, which was launched in 2008.

Disaster Management

When disaster strikes, images from space are proving vital in aiding relief efforts. Satellites are being used to provide maps and detailed images to assist rescue workers. UK research teams are using satellite data to monitor areas at risk of earthquakes, floods and landslides.

Envisat image of the Balearic islands
Credit: ESA

The UK is a member of the International Charter Space and Major Disasters. The Charter can be triggered by national civil protection agencies and the UN to acquire and deliver space data, for free, to those affected by natural or man-made disasters. The UK's involvement in the Charter is a collaboration between BNSC and UK company DMC International Imaging (DMCii). The UK, working with other Charter members, is working to improve access to the Charter for a wider range of countries, particularly in Africa.

The Disaster Monitoring Constellation (DMC) is a unique network of satellites designed and built by SSTL in the UK, which can provide detailed images of most parts of the world in times of need. The satellites are operated by the UK (DMC-1), Algeria (AlSAT-1), Nigeria (NigeriaSat-1) and China (Beijing-1). The UK-DMC-1 satellite was developed through a jointly funded programme between SSTL and BNSC.

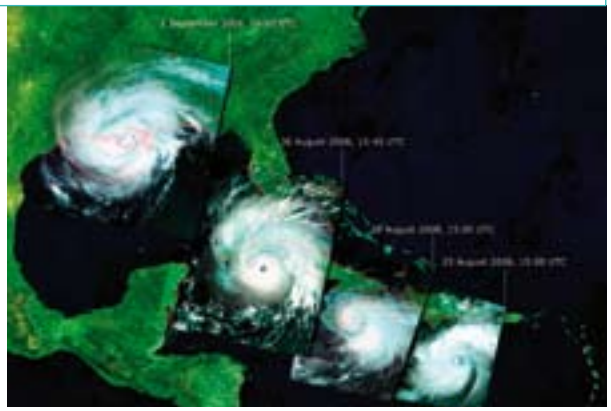
The DMC family of satellites continues to grow and four new satellites will soon be launched. The Spanish Deimos-1 satellite and UK-DMC2 are due for launch in summer 2009. NigeriaSat-2 and a further Nigerian satellite

– being built as part of a training programme for the West African country's future space scientists and engineers – are scheduled for launch in 2009/2010. Each of the new DMC satellites will have improved cameras, enhanced memory capacity and faster communications. They will also be able to take continuous images over thousands of kilometres. The new technology should enable images and maps to be delivered more rapidly to rescue workers on the ground.

DMCii continues to develop new markets for reliable satellite imagery for a growing number of international customers in forestry and agriculture. High profile projects include mapping of the Amazon basin to monitor rainforest loss for the Brazilian government and work on behalf of ESA to produce complete satellite maps of Europe. DMCii has also won an ESA contact for tropical forest monitoring in Indonesia.

Global View

The UK continues to actively support international Earth Observation initiatives – particularly those that contribute to the monitoring of our planet and those that help us to better understand climate change. The UK, led by Defra, supports



Composite images showing the progress of Hurricane Gustav in August 2008
Credit: ESA

the Group on Earth Observation (GEO) – a high level international group headed by Ministers from a growing number of countries (in June 2009 the number stood at 79). GEO helps co-ordinate Earth Observation around the globe. The UK contributes through the Global Earth Observation System of Systems (GEOSS) implementation plan.

The UK also participates in the Committee of Earth Observation Satellites – a group that has positioned itself as a coordinator of space-acquired data, responding to GEO and the GEOSS implementation plan. In Europe the Global Monitoring for Environment and Security (GMES), a joint initiative between the European Commission and ESA, continues to develop. The UK is actively seeking to develop the GMES initiative to meet UK requirements and is working closely with ESA and the UK space community to achieve this.

HELP FROM SPACE

In May 2008 a huge tropical cyclone hit Burma. The nation's worst ever natural disaster, Cyclone Nargis is believed to have killed more than 140,000 people.

Assessing the damage on the ground was difficult: the Burmese authorities restricted access to aid workers and rescue teams. In the past, agencies would have struggled to find out what was happening. Today, the International Charter, using satellites belonging to its international space agency partners, are on hand to help.

Some of the first images of the Burmese disaster came from the British-built satellite, UK-DMC.

"Satellites like UK-DMC make it possible to monitor disasters in remote areas that are difficult to get to from the ground," says Dave Hodgson, Managing Director of DMC International Imaging (DMCii). "The images are compared with others taken before a disaster and are processed into maps to help relief agencies deploy resources."

UK-DMC image of Burma showing the area around Rangoon and southern coastal regions
Credit DMCii

Flood maps of Burma are generated from the UK-DMC satellite image by the United Nations and supplied free to agencies responding to the disaster
Credit: DMCii/UNOSAT

Weather

The combination of satellite observations and powerful computer models has transformed the way we forecast the weather. Satellites are used to monitor weather as it develops, as well as for long-term studies of weather and climate.

The UK exploits the latest satellite technology to put itself at the forefront of modern weather forecasting. The operation of Europe's weather satellites is co-ordinated by EUMETSAT, with the Met Office representing the UK. EUMETSAT has a close working relationship with ESA and the space agency has responsibility for initial satellite development.

EUMETSAT also works closely with other international meteorological agencies to share satellite information. International efforts are co-ordinated by the World Meteorological Organisation (WMO). The WMO facilitates the free and unrestricted exchange of data and information on matters relating to safety and security of society, economic welfare and the protection of the environment.

Meteosat Second Generation (MSG)

Geostationary weather satellites provide a constant view of a large region of the Earth. In order to provide coverage for Europe and Africa, two satellites are located at the 0° longitude position. Meteosat-9 is the prime satellite for European weather services, and provides updated images every

Jason-2 launch
Credit: Carlton Baillie/United Launch Alliance

15 minutes. This allows the monitoring of rapidly developing weather systems such as the deep area of low pressure that brought severe gales and storm force winds to north western parts of the UK during the middle of January 2009.

Meteosat-8 serves as the backup satellite to Meteosat-9, and operates in 'Rapid Scan' mode, sending back images of the European area every five minutes, and further improving our ability to monitor rapidly developing weather systems.

MetOp

Europe's first operational polar-orbiting weather satellite, MetOp-A, carries several new instruments for monitoring the atmosphere and the ocean surface. MetOp-A shares a common set of core instruments with polar-orbiting meteorological satellites operated by US partner the National Oceanic and Atmospheric Administration (NOAA).

MetOp instruments are being used to measure profiles of atmospheric ozone and other trace gases, as well as wind speed and direction over the oceans. This not only improves weather forecasting, in the longer term these instruments will help in monitoring the Earth's changing climate.

Jason-2

Jason-2 was launched in June 2008 and provides us with the capability to measure sea level changes over the world's oceans to a high accuracy. The combination of Jason data with other lower-accuracy altimeters (such as on Envisat) has enhanced our understanding of ocean circulation, the role the oceans play in climate and the interactions between the oceans and atmosphere – important for studying hurricanes.

Future missions

To ensure continuity of coverage and collection of data, there is an ongoing satellite replacement programme. The replacement for the MSG satellite series, Meteosat Third Generation (MTG) will be needed by 2016, and is under development. The follow-on programme for MetOp is in the first discussion stage. A Jason-2 follow-on will also be required beyond 2013 and proposals are currently under consideration.

Satellite Technology

The UK is a world leader in satellite technology for a wide variety of applications. UK companies manufacture sophisticated communications satellites and are developing the next generation of satellite navigation systems. Satellites built in the UK are being used to provide global broadband services, TV broadcasts and secure communications systems. UK technology forms the basis of Europe's new global positioning system, Galileo.

Communications

Satellite communications have made possible the massive growth in digital TV broadcasting, phone and web services. Broadband satellite technology has the potential to bring fast and affordable telecoms to even the remotest communities worldwide. As the demand for services continues to grow, BNSC and its partner the Technology Strategy Board (TSB) are committed to maximising the benefits of this technology for UK citizens and business.

Satellites can bring broadband to even the most remote communities

A key priority for the Government is to make high-speed broadband Internet services available to every home in Britain. The 'Digital Britain' report (published in June 2009) once again emphasises this priority. A cost effective solution to providing broadband access to rural and remote areas is from space and the launch of a new satellite, HYLAS, in 2009 will provide affordable high speed broadband internet to rural areas over much of the UK and Europe.

The Highly Adaptable Satellite (HYLAS) has been designed and built by Astrium UK for Avanti Communications. It is based around a low-cost, low-risk satellite targeted at areas of Western Europe that are unlikely to receive any terrestrial service within the next ten years. The satellite automatically allocates varying amounts of power and bandwidth to the different regions within its 'footprint', reacting to dips and peaks in demand. This means that between 150,000 and 300,000 users can be online via HYLAS at the same time.

Artist's impression of HYLAS in orbit
Credit: Avanti

FROM HYLAS TO HERCULES

Before HYLAS has even been launched, Avanti Communications is already starting work on its successor satellite, to be called Hercules. The project has taken a step forwards thanks to the award of €250,000 from ESA for a preliminary design review.

Hercules was proposed by Avanti following publication of an interim version of the government's Digital Britain consultation in January 2009. The number of UK broadband customers that can be served by HYLAS is well short of the latest estimates of the number that could potentially benefit from its use. Hence the opportunity for Hercules.

"Whilst HYLAS will soon be serving hundreds of thousands of households in the UK, it is clear that the demand now runs into millions, so more capacity will be needed," says David Williams, Chief Executive of Avanti. "This Hercules contract would enable us to respond rapidly."

An Astrium telecommunications satellite under test in Portsmouth
Credit: Astrium

HYLAS will also facilitate the distribution and broadcast of a range of HDTV (High Definition Television) programmes over much of Europe. BNSC has contributed development funds to HYLAS through ESA's ARTES programme.

Global communications

The UK is home to the world's largest global satellite communications provider. Inmarsat provides broadband data connections and 3G phone services to mobile users worldwide via compact terminals that can be used on land, at sea and in the air. Its newest generation satellite system – the Inmarsat-4 series – currently covers 85 per cent of the world's landmass. The satellites have largely been built in the Astrium factories in Stevenage and Portsmouth.

HOT BIRD takes flight
Credit: Arianespace

Inmarsat has signed a €260 million contract with Astrium to design and build Alphasat. This new generation satellite will bring affordable communications to the developing world. It will be more powerful, cheaper and versatile than previous telecommunications satellites and support broadband services that can be received by smaller and more efficient terminals.

Astrium is the prime contractor for the project and the key technology for the satellite payload is being designed and manufactured in Britain. Inmarsat will operate the satellite as part of its global broadband service.

Development work on key components, as well as early stage conceptual studies, was funded through the UK investment in the ARTES programme. Industry estimates suggest that the development and operation of the satellite will secure around 500 highly skilled jobs.

The latest in a series of powerful communications satellites was successfully launched on 12 February 2009. HOT BIRD 10 was largely designed and built by Astrium in the UK and is the company's fifteenth commission for satellite communications provider Eutelsat.

The HOT BIRDs are designed to broadcast digital and new HDTV channels to small antennas on people's houses as well as to cable and community stations. They transmit almost 1,100 channels to 120 million homes in Europe, North Africa and the Middle East.

Secure communications

Satellite communications are essential to support all aspects of modern military operations and provide secure and flexible communications for maritime, air and land forces deployed around the world.

Since the 1970s, the UK has operated its own independent system of military communications satellites called Skynet.

Artist image of GIOVE-A in space
Credit: ESA

The latest generation of satellites, Skynet 5, has been built in the UK by Astrium to provide advanced and flexible communications for UK Armed Forces for the next decade.

The Skynet constellation is operated by Paradigm, a subsidiary of Astrium, under a 17-year Public Finance Initiative agreement with the Ministry of Defence. In addition to providing secure multimedia communications for British and NATO forces, Paradigm also provides phone services for military personnel to speak to their families at home and provide TV services for those deployed abroad or at sea.

The third of this new generation of satellites, Skynet 5C was launched successfully in June 2008. This will operate as an 'in-orbit spare'.

Satellite Navigation

Satellite navigation enables users to find their position accurately anywhere on Earth using signals from orbiting spacecraft. The technology helps drivers, sailors and pilots find their position. It's used for tracking containers or deliveries and for monitoring farming or fishing operations. Rescue crews use satellite navigation to locate people in an emergency.

GPS systems greatly improve farming efficiency
Credit: ESA

Final tests being carried out on GIOVE-B
Credit: ESA

Galileo

Europe is developing a new satellite navigation system called Galileo. This will be much more accurate and reliable than current technology, enabling its use in safety 'critical' environments such as air traffic control. It could even be used to replace signals on railways or allow the automatic control of vehicles on the roads.

When fully operational, Galileo will consist of 30 satellites offering global coverage accurate to within one metre. Galileo is being developed by ESA and the European Union. The UK, through BNSC, is one of the four big contributors to the project along with Germany, France and Italy.

The first two test satellites, GIOVE-A and GIOVE-B, were launched in 2005 and 2008. SSTL built and continues to operate GIOVE-A, while Astrium in the UK developed the payload and the ground control system for GIOVE-B, with a team from Portsmouth designing and building the onboard equipment. The payload for GIOVE-B includes the most accurate clock ever flown in space. During an intensive period of in-orbit testing following its launch, the satellite met all the expectations of its designers.

The next stage of the project is 'In-Orbit Validation' (IOV) when the complete system will be tested. The four IOV satellites will be placed in a circular orbit at an altitude of 23,600 km by the end of 2010. These will be the first fully operational satellites and form part of the final Galileo constellation.

Applications

Satellite navigation has enormous potential to bring benefits to a large number of people. Industry estimates suggest that by 2015, Galileo alone will be generating €10 billion worth of benefits every year (source: Astrium).

SCI-TECH SYSTEMS PERSON OVERBOARD

Inspired by their amateur yachting experience, the founders of Sci-Tech Systems designed Person Overboard (POB) to improve the survival chances of sailors who fall into the sea. The trick? Simply providing an accurate current location to search vessels.

"A fast rescue is important, especially in cold or freezing water when survival time is short," says Peter Hall, Technical Director of Sci-Tech Systems. "The innovation of our system is that it sends the real-time position coordinates back to the ship."

The system is activated automatically when its wearer goes overboard, and uses satellite navigation data to derive an exact location which it transmits, on an open radio frequency, for display on standard maritime GPS receivers. This means that many other boats in the area can potentially pick up distress signals.

POB has won several awards for technical innovation. At the 2008 European Satellite Navigation Competition, the system won the overall Galileo Master prize, along with the European Global Navigation Satellite System Authority (GSA) Special Interest Prize and the UK SatNav Challenge – an award sponsored by the BNSC.

While leisure boating was the designers' original market, there has been considerable interest in the system from people involved in areas such as oil exploration and sport diving. The company expects to go into production in early 2010.

The system consists of crew units, worn on life jackets, and a ship unit. Two-way communication between the crew and ship units enables transmitter power to be modulated in order to extend battery life, and will also give the lost sailor reassuring confirmation that their signal has been picked up. "That psychological element can be vitally important in survival at sea," says Peter Hall.

POB will initially use GPS signals for its location data, with accuracy enhanced by EGNOS. The plan is that it will eventually switch over to Galileo, to benefit from that system's inherently greater accuracy.

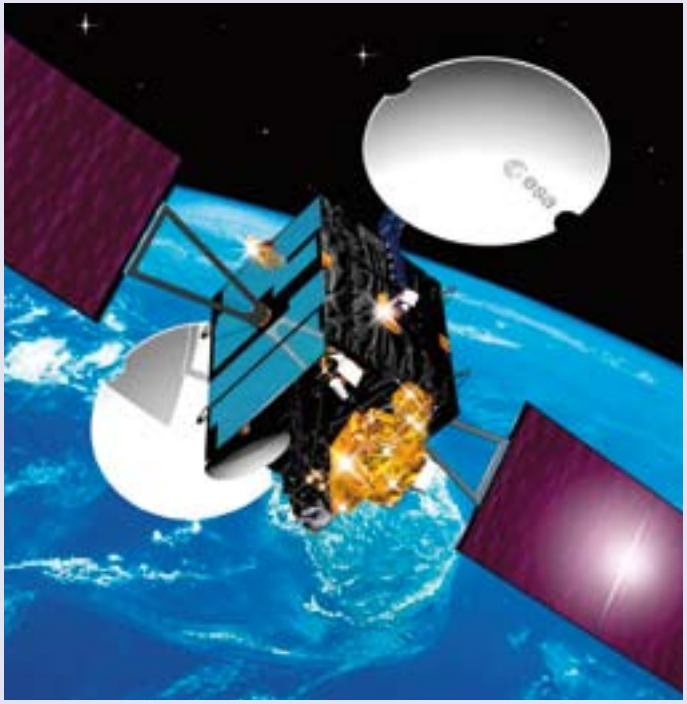
Improving the survival chances of sailors who fall into the sea using GPS technology
Credit: Maritime and Coastguard Agency

EGNOS

As an interim step to Galileo the European Geostationary Navigation Overlay Service (EGNOS) will augment the United States' Global Positioning System (GPS) making it suitable for safety critical applications.

The EGNOS service, which covers the whole of Europe, is broadcast via two Inmarsat communications satellites and a third spacecraft, Artemis. EGNOS transmits a signal containing information on the reliability and accuracy of the positioning signals sent out by GPS and allows users to determine their position to within two metres.

UK companies including BT, Astrium, Logica and Airsys have been involved in developing EGNOS. During the past two years, a series of trials have been carried out involving using test planes and helicopters for air traffic control applications. It is planned that the system will be certified by the end of 2009 for safety critical use in air traffic management.

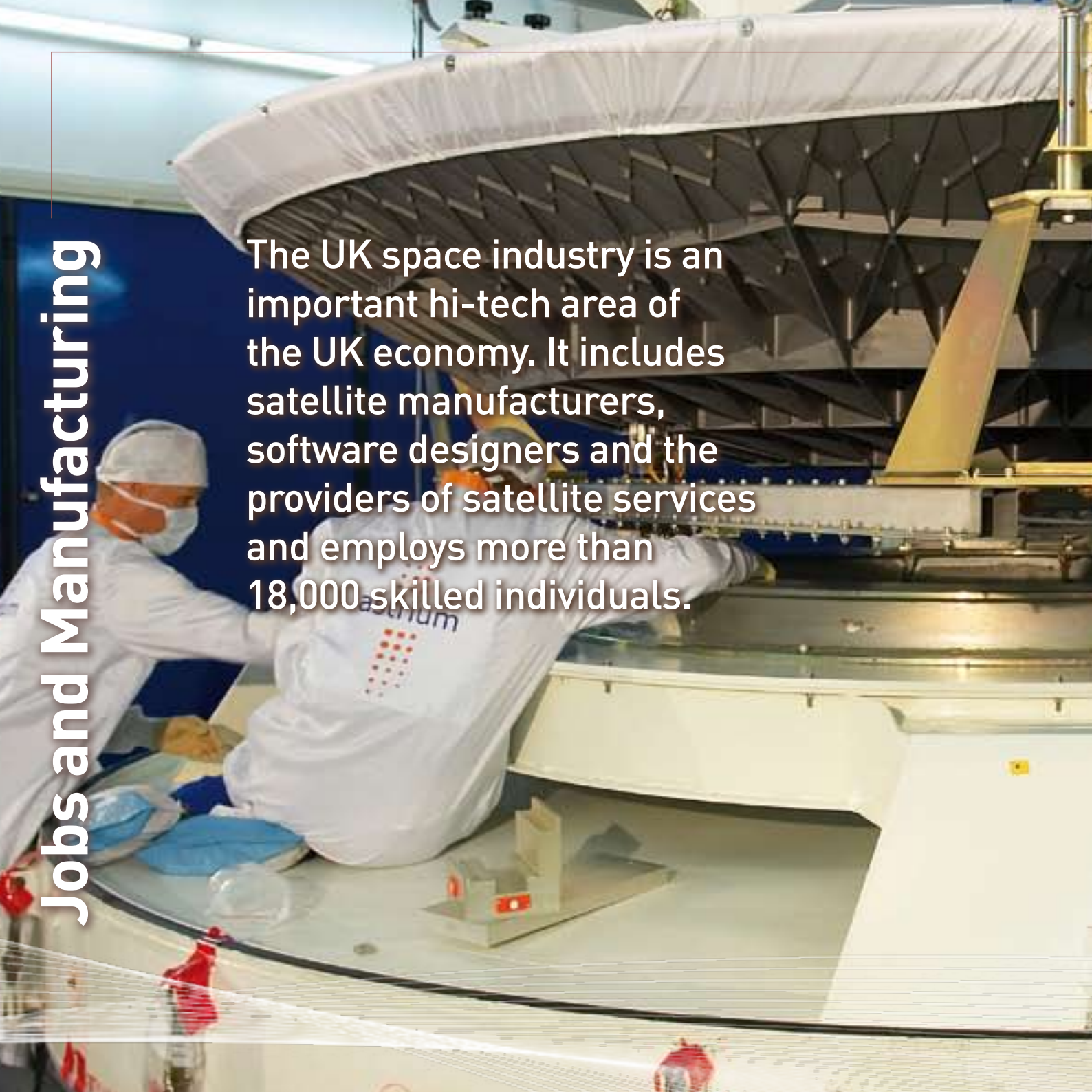


Artist image of Artemis
Credit: ESA

UK companies are already developing new ways to exploit existing satellite technology and BNSC continues to support the UK SatNav challenge to encourage innovation.

The Location and Timing Knowledge Transfer Network, managed by TSB, is fostering efforts to develop new applications and services. A collaboration between academics, industry and government, the network is helping to create new markets and provide support to business.

Jobs and Manufacturing



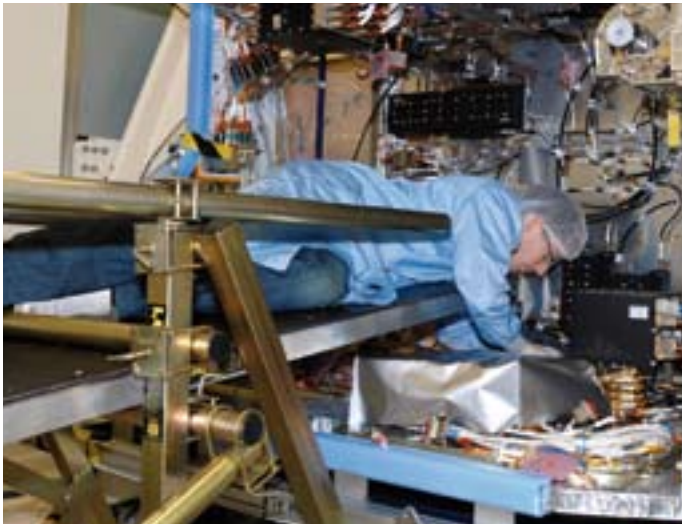
The UK space industry is an important hi-tech area of the UK economy. It includes satellite manufacturers, software designers and the providers of satellite services and employs more than 18,000 skilled individuals.

The UK space industry can be

divided into upstream and downstream sectors. Upstream companies are considered to be those that build the technology, such as satellite or instrument manufacturers. Downstream companies are the technology users and service providers.

Herschel being prepared for launch
Credit: ESA

The latest BNSC survey of the size and health of the UK space industry was published in October 2008. It indicates that total turnover increased to £5.8 billion in 2006-07, up from £4.8 billion in 2004-05. The number employed in the space industry increased from 16,200 million to 18,800 million.



The Payload for one of the new Galileo IOV satellites under construction at Astrium
Credit: Astrium

The study has been undertaken on a regular basis since 1991 by BNSC. More than 200 companies contributed, ranging from small businesses to multinationals. The overall trend since 1999 has been one of continued growth.

The Executive Summary of the report can be downloaded from the BNSC website.

Growing business

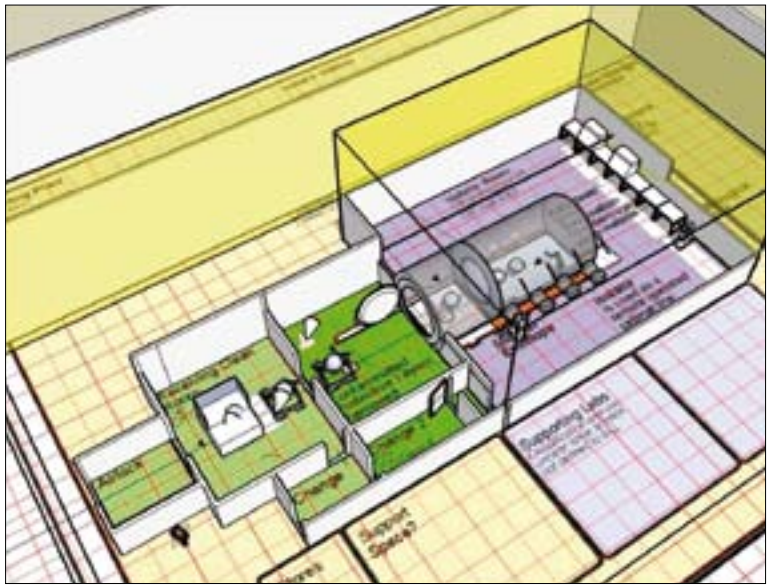
Developments in space technology continue to find new applications and generate new business opportunities. BNSC, in partnership with the TSB, works with industry to seek funds and encourage the future success of the space sector. BNSC also subscribes to ESA programmes that lead to the development of new technologies including GMES and ARTES.

The strength of the UK's satellite industry is reflected throughout this report and UK companies continue to win major contracts and develop innovative products. Below are some examples from the past year. These illustrate the range of products and services being developed:

- The UK's largest satellite manufacturer, Astrium, is currently working on contracts

for ESA, the Government and satellite communications providers. The company is also developing a fully integrated satellite communications system for YahSat (Al Yah Satellite Communications Company) in the United Arab Emirates. The first satellite, YahSat 1A, will be launched in late 2010 followed by YahSat 1B, in 2011.

- EADS Astrium finalised the acquisition of Surrey Satellite Technology Limited (SSTL), a world leader in small and 'micro' satellites. Under the deal, SSTL will remain an independent company with its own individual brand.
- Glasgow-based Clyde Space continues to thrive with 100% year on year growth in its revenues. The company is supplying customers around the world with its range of advanced power supply subsystems particularly targeted at the burgeoning market for small satellites. Its Cubesat product is being deployed on a variety of science, observation and military payloads.
- Orbital Optics Ltd (OOL) develops and sells state-of-the-art, compact and affordable space cameras that are capable of producing high quality images. Its optical payload products are based on technology originally developed at STFC's Rutherford Appleton Laboratory. The company was spun out by STFC in early 2006 and through subsequent investment by MacDonald Dettwiler and Associates Limited has been able to invest further in the development of new camera technology and bid into major international missions.
- Other UK companies are developing Earth-based infrastructure. A team led



Concept image for the biocontainment facility being developed by SEA
Credit: Bovis Lead Lease UK

[SKYLON SPACEPLANE]

Skylon, the UK's innovative spaceplane design, is now a contender as a future European launch vehicle. It would take off and land using a traditional airport runway with the ability to carry over 12 tonnes into orbit.

"Skylon is unique because of the type of engine it uses," says Reaction Engines' managing director Alan Bond, "and with the help of BNSC and private investment we're able to develop the technology."

Reaction Engines, the Oxfordshire-based company behind the project, received a welcome cash boost of 1 million Euros from ESA's technology and development programmes in February 2009. This money will be invested in developing the engine's high performance heat exchangers and other critical engine technologies.

These heat exchangers are essential because Skylon's engines use existing jet and rocket engine technology to utilise air as part of the propulsion system.

"That air is at five times the speed of sound and 1,000 °C when it enters the engine – and that is too hot," explains Bond. "We have to use the hydrogen fuel to cool the air and that has to be done through a heat exchanger."

Artist image of Skylon in orbit
Credit: Reaction Engines

The reusable launcher has enormous potential in the space science market. Skylon, with its unpiloted sleek design and Sabre air-breathing rocket engines, would provide a new approach to access to space compared with today's costly launches.

"It's really taking conventional technology and putting it together in a different way," explains Bond. "It's technology that's a few years away – not a couple of decades."

by SEA has won a €500,000 contract for ESA's Aurora programme to define the requirements for a Martian Sampling Receiving Facility. The facility must protect terrestrial life from any potential risk posed by the samples, while preserving their scientific content. A parallel activity at the National History Museum, funded by STFC, will examine potential methods for sterilising the extra-planetary material.

Space Debris and Near Earth Objects

Space Debris

There are tens of thousands of pieces of space debris orbiting the Earth. This 'space junk' includes fragments from redundant spacecraft and other space systems which can severely damage and even destroy orbiting satellites. The collision between an operational Iridium satellite and a decommissioned Cosmos satellite in 2009 demonstrated how real the risk of space debris is (see below).

There are currently more than 12,000 catalogued objects in orbit. The UK has taken a leading role in efforts to reduce and mitigate space debris and BNSC is working at national, European and International levels to develop effective ways to manage the problem as an active member of the Inter Agency Space Debris Co-ordination Committee (IADC). Within Europe, BNSC is part of the Space Debris Network of Centres and has backed a European Code of Conduct on space debris. The UK is also taking the lead on debris activities at the International Standards Organisation (ISO). The ISO is developing standards for the implementation of measures to combat space debris.

If a satellite explodes, it creates thousands of small debris particles
Credit: ESA

In 2008, the UK subscribed to the European Space Agency's (ESA) space situational awareness programme, which is aimed at reducing the collision hazard in space by monitoring the population of orbital objects.

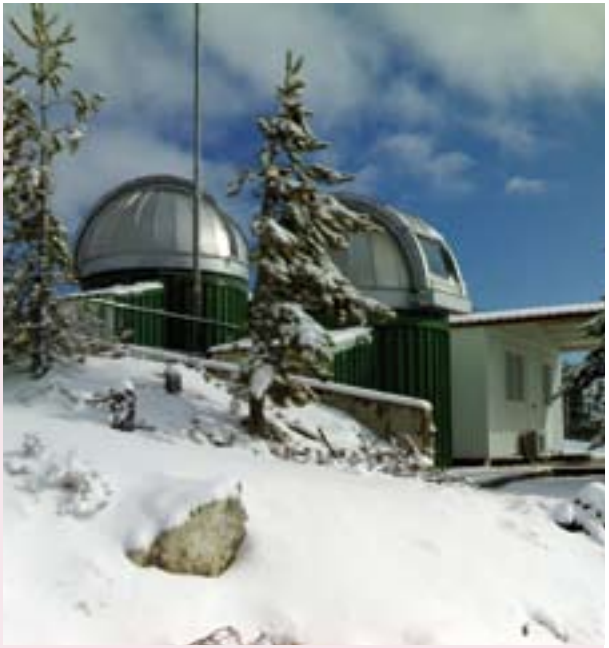
In support of its commitment to the UK Outer Space Act, BNSC funds the operation of the Starbrook space

OUTER SPACE ACT

BNSC regulates UK space activity to ensure it complies with Britain's international obligations. The Outer Space Act (OSA) 1986 requires UK individuals or organisations to apply for a licence from BNSC whenever they launch or procure the launch of a space object, operate a space object or carry out any other activity in outer space.

Before granting a licence, the Secretary of State for Business, Innovation and Skills has to be satisfied the activity will not jeopardise public health or the safety of people or property. The OSA also requires the Government to maintain an up-to-date public register of space objects launched by UK organisations or individuals.

The UK considers it particularly important that satellite operators are able to dispose of their satellites once they have reached the end of their operational life, to avoid contributing to the problem of space debris. To support this goal, BNSC funds the operation of the Starbrook space surveillance sensors. It has also introduced improved safety assessments and procedures to minimise the accidental release of debris.



The Starbrook facility provides space monitoring in support of BNSC's satellite licensing activities
Credit: Space Insight Limited

surveillance sensors developed by UK company Space Insight Limited. The wide field of view of these sensors enables surveys of space debris in the higher Earth orbits to be carried out efficiently. Starbrook's role in debris surveys is being expanded to include surveys of the orbits used by navigation satellites, such as Galileo. Analysis of debris surveys is reported to the IADC.

A science team at the University of Southampton has developed computer models to enable future predictions of space debris to be made. The information will be

[SPACE COLLISION]

A UK radar tracking station played a vital role in tracking space debris when two satellites collided in orbit at 40,000 km per hour.

In February 2009, RAF Fylingdales in North Yorkshire spotted the collision between a defunct Russian Cosmos 2251 and a commercial US Iridium satellite 800 km above the Earth.

RAF Fylingdales, as part of the worldwide Space Surveillance Network, monitored the resulting debris and assessed any possible threat to the International Space Station or a Shuttle launch.

Most of the debris burnt up in the atmosphere but since then Fylingdales has been identifying how many satellite pieces remain and whether they are likely to do any more damage.

STFC space technology expert Professor Richard Crowther warns that unless countries work together, space junk posed a long-term threat to the future of space advances.

RAF Fylingdales in North Yorkshire
Credit: ESA

"We want to ensure Europe is not flying blind in space," says Professor Crowther, "and is able to exploit the satellites on which our lives are increasingly dependent."

used to advise policy makers on how best to manage the orbital environment in a sustainable manner for generations to come.

Near Earth Objects

Our planet is surrounded by cosmic debris – comets, asteroids, ice and rock. Hundreds of tiny fragments bombard the Earth every day but these are usually no more than a few millimetres across.

Occasionally, a larger piece of material will hit the surface. But if a fragment of even a few dozen metres in diameter were to hit the Earth, it would have a catastrophic effect. Comets or asteroids whose orbits come close to our planet are called Near Earth Objects or NEOs.

The UK, through BNSC, has been at the forefront of international scientific efforts to examine the potential threat that future

Artist image of the Don Quijote mission
Credit: ESA

NEOS could pose. The Government set up and supports the NEO Information Centre, based at the National Space Centre in Leicester. The UK is also home to the Spaceguard Centre, located near Knighton in mid-Wales. Both have a well established outreach programme to provide accurate and factual information on NEOs to the public and media. The UK currently chairs the United Nations Working Group addressing the NEO threat.

QinetiQ and the Open University (OU) have been undertaking studies to develop ESA's Don Quijote mission. Don Quijote is a 'precursor' mission, designed to assess the technology that could one day be used to deflect an asteroid threatening our planet.

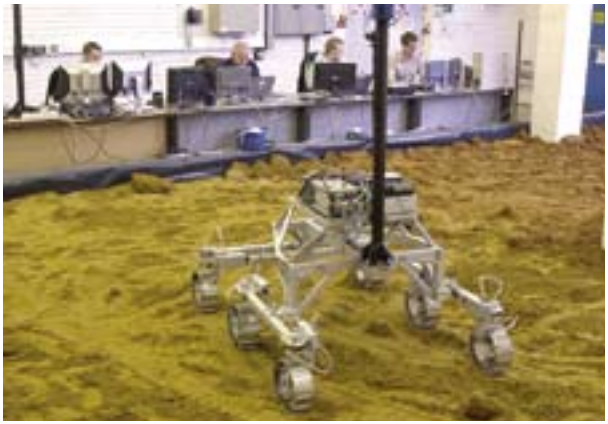
Preparatory studies for the upcoming NEO sample return mission, Marco Polo, are being made by Astrium, together with the OU and Aberystwyth University. The OU, Leicester, Oxford, MSSL and RAL are also developing potential payload instruments. This mission has been selected as a candidate within ESA´s Cosmic Vision programme and would be designed (most likely in cooperation with Japan's space agency JAXA) to return a sample of primitive asteroid material to Earth.

Education and Skills

Space can be used in education to help inspire young people to study science, technology, engineering and mathematics (STEM) subjects. The space sector also needs well-educated and appropriately qualified people to enable it to grow.

BNSC works with educators to use space in delivering the curriculum. This effort is coordinated through a working group involving BNSC partners concerned with education: DCSF, BIS and STFC.

Current examples include the development of interactive teaching materials that use GMES data and the use of space by Department for Children, Schools and Families (DCSF) in promoting careers in STEM subjects. STFC's Leading Space Education Programme (in collaboration with the Specialist Schools and Academies Trust) has worked with 30 schools in its first year and will shortly be adding a second cohort of 20 schools. Each will act as a 'beacon' for local secondary and primary schools and will work with many of the Trust's 1,200 STEM specialism schools.



The UK-built Mars rover undergoing tests
Credit: ESA

As part of the International Year of Astronomy, The Society for Popular Astronomy, Royal Astronomical Society and STFC have teamed up to give free telescopes to 1,000 secondary schools
Credit: RAS

The newly-formed Space Academy, funded by the East Midlands Development Agency and based at the National Space Centre (NSC) in Leicester has begun to make an impact, holding its first space conference for teachers in April 2009.

A series of high-profile competitions was run during 2008 to attract the attention of students. Pupils from Shrewsbury School won a competition run by SSTL and are now

Lord Drayson, Minister of State for Science and Innovation
Credit: DIUS

designing their own instrument to be launched into space with some funding from BNSC. Their experiment will use GPS signals to investigate the ionosphere (the uppermost part of the atmosphere). The runners up, Langton School in Kent, were so good that further funding has been found (from SEEDA and Kent Education Authority) so that their experiment may also fly. This will use instruments from CERN to detect cosmic rays in space. In both cases the pupils will contribute real science results while learning about both the theory and practice of building hardware for space.

A further group of space-related activities was organised around the visit of British-born entrepreneur, Richard Garriott, who flew on the International Space Station in October 2008. A competition for primary school pupils resulted in a large number of proposals for experiments for him to carry out in space. These were filmed and then shown to the winning students at a prize-giving ceremony at the NSC. A competition for secondary pupils invited ideas for new enterprises in space, with the winners spending a week at Space Camp in Turkey. The winners of all of these competitions were also treated to special presentations at the IAC in Glasgow in 2008. Other activities organised to capitalise on Richard's mission included projects with many schools – including one to design a short promotional cartoon about space for seven-year-olds (with Central St Martins, Warner Brothers and others) and a competition for fashion students to design uniforms for future space stewards, with the winning entries presented on the catwalk during London Fashion Week.

A review of the skills needs of the UK space sector was carried out for BNSC in 2008 by the NSC. The focus for BNSC now is to review the range of current space education activities in the UK and to agree a coordinated programme across the Partnership. It is intended that much of the delivery of this programme will be through, or in cooperation with, the new European Space Education Resource Office for the UK, due to be set up at the National Science Learning Centre in York.

Communications

The BNSC communications team works to raise awareness of the UK's space activities, and to show how they benefit all our lives. It aims to reach a wide range of audiences, from industry specialists to students and the general public.

BNSC was heavily involved in organising the International Astronautical Congress and also hosted a stand packed with information, displays and souvenirs to promote space in the UK.

The ESA Ministerial meeting was another key event for BNSC this year. Lord Drayson, Minister of State for Science and Innovation and a keen space enthusiast represented the UK and committed over 900 million Euros to ESA missions. The undoubted highlight came when Lord Drayson and ESA's Director General Jean-Jacques Dordain signed an agreement for the UK to host its first ESA facility – a thrilling new development in the UK's space story and testament to the quality of UK space science and technology. The Ministerial attracted an impressive range of media coverage, with a dedicated section on the BBC News website among the highlights.

The BNSC's headquarters also moved to new offices in Swindon this year, to be closer to BNSC partners STFC, NERC and TSB. This proximity means that we can work more effectively together to promote the interests of the UK space community. To strengthen its existing links and build up new connections in its new home, BNSC hosted a series of events for partner staff including information stands, networking events and presentations.

BNSC's *space:uk* magazine continues to build its readership and reputation. Now available to every secondary school in the

The BNSC stand at the 2008 International Astronautical Congress
Credit: BNSC

UK, recent issues featured an interview with space tourist Richard Garriott, and in-depth features on the ESA Herschel/Planck astronomy missions and HYLAS – the new Astrium-built satellite designed to bring broadband access to remote rural areas. A readership survey will run during 2009 to help in the further development of the magazine. BNSC is also planning a redesign of its website, to keep it up-to-date, accessible and informative. Future plans include the increased use of podcasts on the site to complement features in *space:uk*.

An introduction to the UK Space, published in ten languages is one of a suite of information leaflets

space:uk magazine

Finance

Breakdowns of funds – by spend area (£ million)

Amount accrued during financial year 2008/09	UK Contributors							
	MOD	STFC	NERC	Met Office	Defra	DECC	DIUS	Total
Earth observation								
National			5.56		0.20		0.98	6.74
ESA	0.50		37.13		1.00		3.08	41.71
EUMETSAT				20.00				20.00
AATSR						0.75		0.75
Space science and exploration								
National		34.80						34.80
ESA		71.27						71.27
Telecomms and navigation								
National							0.35	0.35
ESA							57.51	57.51
Technology								
National	0.10						0.40	0.50
ESA								0.00
Transportation								
National								0.00
ESA							6.31	6.31
Other national							0.37	0.37
ESA general budget		12.27	9.99				5.50	27.76
Total	0.60	118.34	52.68	20.00	1.20	0.75	74.50	268.07

Preliminary figures for the first two calls of the EU Framework Programme Space thematic priority indicate the UK is likely to receive €25.23m, a 12.82% share of the total expenditure of €196.78m. The UK nominally contributes 12% to the overall EU budget.

Contacts

British National Space Centre (BNSC)
Polaris House
North Star Avenue
Swindon
Wiltshire SN2 1SZ
Tel: 020 7215 5555
bnscinfo@bnsc.gsi.gov.uk
www.bnsc.gov.uk

Department for Business, Innovation and Skills (BIS)
Castle View House
East Lane
Runcorn WA7 2GJ
Tel: 020 7215 5555
Enquiries sent via the website:
www.bis.gov.uk

Department for Children, Schools and Families (DCSF)
Sanctuary Buildings
Great Smith Street
London SW1P 3BT
Tel: 0870 000 2288
Fax: 01928 794248
info@dcsf.gsi.gov.uk
www.dcsf.gov.uk

The impact of an asteroid or comet several hundred million years ago in the Sahara Desert of northern Chad
Credit: ESA

Department for Environment, Food and Rural Affairs (Defra)
Customer Contact Unit
Eastbury House
30-34 Albert Embankment
London SE1 7TL
Tel: 08459 33 55 77
Fax: 020 7238 2188
helpline@defra.gsi.gov.uk
www.defra.gov.uk

Department for Transport (DfT)
Great Minster House
76 Marsham Street
London SW1P 4DR
Tel: 0300 330 3000
Fax: 020 7944 9643
FAX9643@dft.gsi.gov.uk
www.dft.gov.uk

Foreign & Commonwealth Office (FCO)
King Charles Street
London SW1A 2AH
Tel: 020 7008 1500
Enquiries sent via the website:
www.fco.gov.uk

Met Office
FitzRoy Road
Exeter
Devon EX1 3PB
Tel: 0870 900 0100
Fax: 0870 900 5050
enquiries@metoffice.gov.uk
www.metoffice.gov.uk

Ministry of Defence (MOD)
The Main Building
Whitehall
London SW1A 2HB
Enquiries sent via the website:
www.mod.uk

Natural Environment Research Council (NERC)
Polaris House
North Star Avenue
Swindon
Wiltshire SN2 1EU
Tel: 01793 411500
Fax: 01793 411501
enquiries@stfc.ac.uk
www.scitech.ac.uk

Science & Technology Facilities Council (STFC)
Polaris House
North Star Avenue
Swindon
Wiltshire SN2 1SZ
Tel: 01793 442000
Fax: 01793 442002
enquiries@stfc.ac.uk
www.scitech.ac.uk
Tel: 0300 330 3000

Technology Strategy Board (TSB)
North Star House
North Star Avenue
Swindon
Wiltshire SN2 1UE
Tel: 01793 442700
enquiries@tsb.gov.uk
www.innovateuk.org

British National Space Centre (BNSC)
c/o BIS Public Communications Unit
Castle View House, East Lane, Runcorn WA7 2GJ
Tel: 020 7215 5555 bnscinfo@bnsc.gsi.gov.uk www.bnsc.gov.uk

Printed in the UK on paper with a recycled content of 75% July 2009. URN 09/88