Space: Exploration and exploitation in a modern society

Report of a seminar, held on 20 May 2009, that highlighted how space exploration is leading to major scientific discoveries, is essential to the UK economy and how it helps to improve our everyday lives.

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Parliamentary Space Committee

Introduction

The Institute of Physics, the Royal Society of Chemistry and the Parliamentary Space Committee held a joint seminar at the House of Commons on 20 May 2009. The seminar highlighted how space exploration is leading to major scientific discoveries, is essential to the UK economy and how it helps to improve our everyday lives while playing a crucial role in managing global challenges such as climate change.

Curiosity about the Earth, the planets and stars has been the driving force behind human progress since prehistoric times. Today, the exploration of the universe beyond the confines of our home planet remains one of the most inspiring, exciting and fruitful areas of scientific research. Many studies require sending spacecraft into space, mostly unmanned, although humans first reached the Moon 40 years ago and may go to Mars in the future. One of the main advantages of investigating the universe from space is that the details of far-off galaxies, as well as events marking the birth, evolution and death of stars, can be seen unhampered by the blurring effects of the atmosphere, and at wavelengths of light not easily accessible from the ground. Increasingly, scientists and engineers are developing advanced space probes, with robotic components that can operate autonomously, to explore the extraordinarily diverse planets and moons of our solar system.

As well as gazing at the cosmos, many space missions are designed to look back at the Earth, to study its rich complexity and the effects of humans on the terrestrial environment. Satellite services is one of the fastest-growing areas of advanced technology. It is now hard to imagine modern life without satellite communications – for entertainment, information, security and environmental monitoring.

Basic science, Earth observation and the application of technology in everyday life continue to benefit hugely from space exploration. As governments and space agencies plan ever more technically challenging missions to survey the universe, going back to its birth, and even to search for signs of life on planets around other stars, the resulting technologies developed will find use on Earth, in sectors as diverse as health and transport. One day we may even be able to utilise the natural resources, such as water and fuels, that are found on other solar-system bodies, as our own supplies dwindle.

Mr Ian Taylor MP, co-chairman of the Parliamentary Space Committee and a former minister for science and technology, chaired the seminar. He emphasised that space projects inspire everyone and draw young people into studying science. He pointed out that satellite services are playing an increasingly important part in monitoring land use, transport services and the impact of environmental disasters. **Prof. David Southwood**, director of science and robotic exploration at the European Space Agency (ESA), explained how current and future space-science missions will continue to transform our understanding of basic physics and the universe, as well as the Earth itself. **Mr David Williams**, chief executive of the satellite-communications company Avanti Communications, described how space science and technology are generating flourishing and expanding space-based industries and services in the UK. **Dr Maggie Aderin-Pocock**, optical instrumentation group leader of the European aerospace company Astrium and STFC-funded fellow of University College London, gave examples of how recent space missions are impacting on our lives and expanding our perception of our place in the universe.

The UK has a major space programme, which it pursues through membership of ESA and some bilateral collaborations outside Europe. Eighteen European countries participate in ESA, and the number is likely to grow with increasing interest from eastern Europe. ESA's remit covers the exploration of the universe, Earth observation, and the development of underpinning technology for commercial satellite operations and other applications. Although ESA's budget is smaller than that of NASA, its programmes are highly productive, both in terms of the scientific discoveries and economic benefits derived from novel technologies developed to carry them out.

Space discovery and exploration

Prof. Southwood said that looking out into space at the Sun and stars and measuring their progression has been a key part of human progress for thousands of years. He described how reaching out into space during the past 50 years has expanded our knowledge of the universe in an extraordinary way. Space missions enabled galaxies, stars and interstellar space to be observed at wavelengths of electromagnetic radiation not possible from the ground, providing new insights into astrophysical processes. For example, observations of the sky around the familiar constellation of Orion at infrared wavelengths (which are absorbed by atmospheric water) reveal vast clouds of cold, glowing dust, which is condensing into new stars and planetary systems. Our own solar system is constructed from the same building blocks. "We are made of the same stardust," said Prof. Southwood.

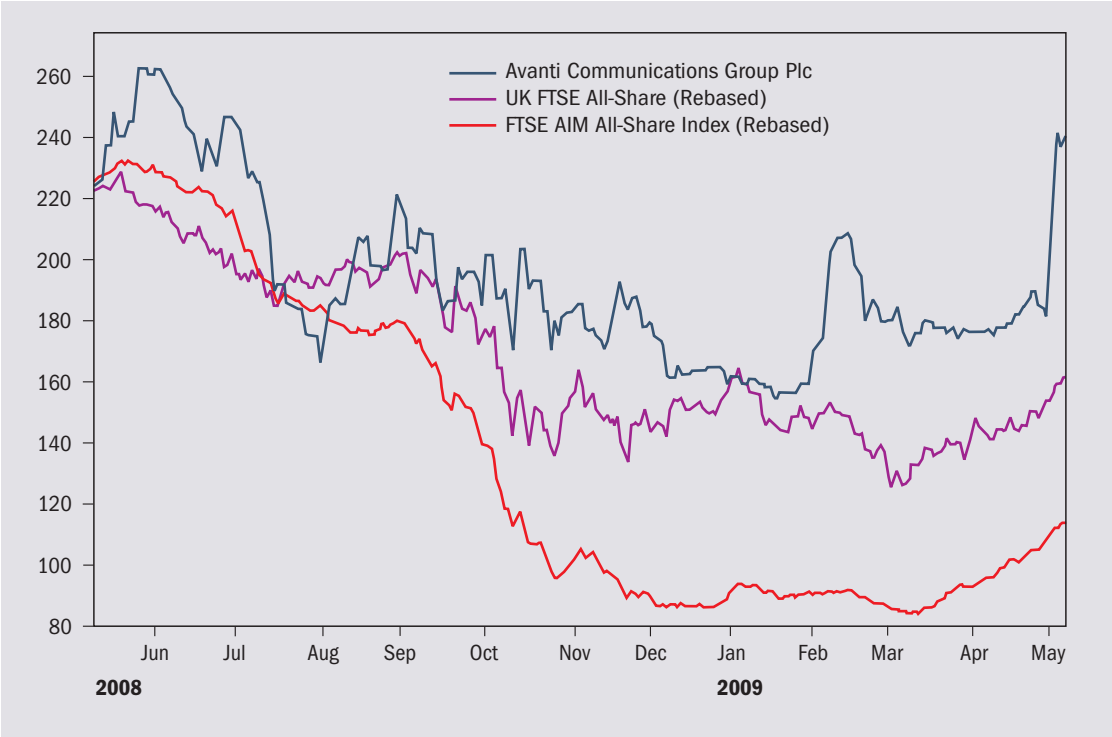
ESA has launched a gamut of space-science missions that make observations at wavelengths covering most of the electromagnetic spectrum, from gamma rays to microwaves. X-ray astronomy provides details of the most violent events in the universe, such as those associated with black holes, while ESA's most recent missions – Herschel and Planck, which were launched together in May 2009 – are surveying the universe at cool infrared and microwave wavelengths. Herschel boasts the biggest telescope ever launched. It is cryogenically cooled and holds the record for the coldest object in space, at 0.05° above absolute zero. Designed to detect radiation from cold, distant parts of the universe, Herschel can peer at young galaxies that formed only a billion years after the Big Bang. The Planck mission looks back even further, at the pervasive longer microwave radiation left over from the decoupling of matter and light 380 000 years after the Big Bang. The microwave background carries imprints of the primordial quantum events that set in motion the formation of the first galactic structures. Both missions are named after scientists who made fundamental discoveries that affect our lives. Sir William Herschel, working in Bath, was the first scientist to identify infrared radiation, while the German physicist Max Planck showed that radiation came in packets of energy called quanta. Both discoveries are vital to the way that we live modern life.

The launch of the Planck and Herschel missions. Courtesy: European Space Agency/D Ducros/ Science Photo Library

Prof. Southwood explained that ESA has an extremely successful programme of solar-system exploration. It includes missions to study the Sun, Moon, Venus, Mars, Jupiter and Saturn, as well as to land on a comet. The missions continue to produce fascinating and unexpected data that provide insights into the Earth's own geology and meteorology, and provide clues on how life evolved. ESA plans to send a mission to Mercury in 2013. "It has been a wonderful decade of discovery for ESA," said Prof. Southwood.

Many of ESA's missions are carried out in partnership with NASA. The most celebrated is the Hubble Space Telescope, which has been sending back spectacular images of the universe for nearly 20 years. Global collaboration will increasingly be needed for the most ambitious projects. "We are trying to forge a joint European/US programme for the exploration of the Red Planet [Mars]," said Prof. Southwood. ESA and NASA recently proposed the creation of the Mars Exploration Joint Initiative (MEJI), which will provide a framework for the two agencies to define and implement their scientific and technological programmes. The UK plans to play an active role in such missions. Prof. Southwood said that the UK's bid to land a robotic explorer Beagle 2 on Mars in 2003 had changed British people's perceptions of space, and had reinforced the UK's capabilities in robotic exploration. As a consequence, a new ESA facility will be set up on the Harwell Science and Innovation Campus in Oxfordshire, to concentrate on space robotics and climate-change science.

Economic impact of funding space research



Avanti Communications' share-price performance illustrating how growth of the UK space industry consistently outstrips broader economic growth. Courtesy: Avanti Communications

Space-science discoveries and technology development will continue to go hand in hand. This was the message from Mr Williams. His company Avanti Communications was founded on basic research and applied science, he said. It is the first European company to launch a satellite-based super-fast broadband service serving customers in rural areas. The underpinning technology stems from ESA's Advanced Research in Telecommunications Systems (ARTES) programme, which enables European industry to explore new ideas for satellite-communications products and services. The new broadband service will contribute towards the implementation of the government's "Digital Britain" policy to secure the UK's position as one of the world's leading digital-knowledge economies.

Mr Williams pointed out that the UK holds a dominant position in the space industry because it has built up a critical mass of knowledge and human resources over a long period that makes it difficult for others to compete. "The UK has a very lean and focused attitude towards space, concentrating on cutting-edge payloads, instrumentation and small platforms. The result is that we have generated a seven-fold return on investment from the ARTES budget," he said.

Some of the world's most successful space companies are based in the UK, supporting 70 000 jobs and a highly skilled workforce. As well as Avanti Communications, they include: Europe's leading space company Astrium; Infoterra, which is a leader in Earth-observation services; Inmarsat, which is the world's most profitable telecommunications company; Paradigm, which provides military satellite-communications services; and Surrey Satellite Telecommunications, which pioneered low-cost satellites. Downstream industries such as Sky TV have also flourished. "We should be very proud of our industry," said Mr Williams.

According to the leading economic forecasting consultancy, Oxford Economics, the global space industry is set to grow by 15% a year. However, Mr Williams warned that the UK must maintain its momentum of developing and exploiting cutting-edge space technologies in the face of growing competition from emerging economies such as China and India. "We need to be continually investing in applied space research and converting it into commercial services. This requires that the science and business sectors work in harmony," he explained.

Space in our lives

As well as stimulating economic growth, space-based systems have made an enormous impact on how we deal with the environment. Dr Aderin-Pocock explained how Earth observations from space can follow weather patterns. They can provide an understanding of hurricane formation, for example, so that early-warning systems can be implemented. Images from space can show the best routes for access into areas cut off by flooding and other environmental disasters.

A growing use of space technology is in studying the effects of climate change. Dr Aderin-Pocock has been working on the design of ESA's Atmospheric Dynamics Mission (ADM-Aeolus), which aims to measure wind-speed profiles. The data obtained will improve the quality of weather forecasts, and advance our understanding of atmospheric dynamics and climate processes. "Wind speed is one of the biggest unknowns in understanding what influences climate," said Dr Aderin-Pocock. The main instrument is a laser that emits pulses of ultraviolet light, which are then back-scattered from atmospheric particles and detected.

Studying the climates of our planetary neighbours also helps us to better understand the Earth's climate, explained Dr Aderin-Pocock. ESA's Venus Express mission, launched in 2005, uncovered our sister planet's extraordinary atmospheric system, revealing, for example, a bizarre giant double-hurricane system at the South Pole. Venus is extremely hot and suffers from a runaway greenhouse effect, so provides an extreme model for studies of global warming. Mars, which is much colder than the Earth, is an example of what happens when a planet loses its atmosphere. ESA's Mars Express spacecraft is mapping the planet, and observations indicate that water was once abundant on the Martian surface. Mars could once have harboured life and may do so again if humans decide to colonise it.

Dr Aderin-Pocock said that there were many practical benefits from planetary exploration. The UK Beagle 2 lander, which was carried by the Mars Express spacecraft, had to incorporate instrumentation that was as compact as possible. One of the main instruments was a miniature mass spectrometer, which is now being developed as part of a portable system for diagnosing tuberculosis in Africa. Similarly, autonomous navigation systems being designed for future Mars expeditions (ExoMars to explore and sample the Martian surface and subsurface for past and current signs of life, and Mars Sample Return, which aims to bring Martian samples back to Earth) will find equally significant applications in terrestrial environments.

Another potentially major impact (literally) on human existence is the threat of near-Earth objects (NEOs) – orbiting comets or meteorites that could collide with the Earth. ESA is working on a mission concept called Don Quijote, which

Top: the Beagle 2 lander leaving the Mars express orbiter. Courtesy: European Space Agency 2001. Illustration by Media Lab. Left: the ExoMars Rover – phase B1 concept. Courtesy: European Space Agency

A wide-field view of the constellation of Indus. Courtesy: A Fujii

involves smashing into a targeted near-Earth asteroid and measuring the deflection resulting from the impact. The aim is to see whether the NEO can be pushed into a new, safe orbit.

A significant benefit of space exploration is its ability to excite young people, who may then go on to pursue a career in science and technology in general – and perhaps in the space industry in particular, which is suffering from a shortage of suitably qualified scientists and engineers.

Dr Aderin-Pocock explained that she had wanted to be a rocket scientist since she was a child and was keen to stimulate interest in others. In addition to working for Astrium, she has a company, Science Innovation Ltd, which presents space science and exploration to schools. The extraordinary images of billions of distant galaxies sent back to Earth by the Hubble Space Telescope, and the possibility of discovering Earth-like planets in other solar systems via future space missions provide a real inspiration.

Further information

1. Beagle mission, www.beagle2.com.
2. The European Space Agency, www.esa.int.
3. Herschel, http://sci.esa.int/herschel.
4. Planck, http://sci.esa.int/planck.
5. The Hubble Space Telescope, http://hubble.nasa.gov.
6. The ESA ARTES project, http://telecom.esa.int.
7. Avanti Communications, www.avantiplc.com.
8. Digital Britain – Final Report, June 2009, www.culture.gov.uk/images/publications/digitalbritain-finalreport-jun09.pdf.
9. Astrium, www.astrium.eads.net.
10. The Atmospheric Dynamics Mission (ADM-Aeolus), www.esa.int/esaLP/aeolus.html.
11. Venus Express, www.esa.int/venusexpress.
12. Mars Express, www.esa.int/marsexpress.
13. ExoMars and Mars Sample Return missions, www.esa.int/esaMI/Aurora.
14. Don Quijote mission, www.esa.int/SPECIALS/NEO.
15. Science Innovation Ltd, www.science-innovation.com.

About the societies

The Institute of Physics (IOP) is a scientific charity devoted to increasing the practice, understanding and application of physics. It has a worldwide membership of more than 36000 and is a leading communicator of physics-related science to all audiences, from specialists through to government and the general public. Its publishing company, IOP Publishing, is a world-leader in scientific publishing and the electronic dissemination of physics.

The Royal Society of Chemistry (RSC) has been the leading society and professional body for chemical scientists since 1841 and is committed to ensuring that an enthusiastic, innovative and thriving scientific community is in place to face the future. The RSC has a global membership of more than 46000 and is actively involved in the spheres of education, qualifications and professional conduct. It runs conferences and meetings for chemical scientists, industrialists and policy makers at both national and local level. It is a major publisher of scientific books and journals, the majority of which are held in the Library and Information Centre. In all of its work, the RSC is objective and impartial, and it is recognised throughout the world as an authoritative voice of chemistry and chemists.

The Parliamentary Space Committee (PSC) exists to raise awareness in Parliament of the benefits to the UK of its world-class space industry. Recent PSC events have covered themes as varied as Africa, space finance, the Olympics, astronauts, and promoting women in science, engineering and technology. The PSC is one of the oldest and most established all-party groups in Parliament with more than 100 members in both houses.

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