THE UK IN SPACE

The Rt Hon David Willetts MP
Minister for Science and Universities

I was delighted to introduce this year's annual National Science & Engineering Week seminar for the Parliamentary and Scientific Committee. The theme *'Space – How Can We Use It?'* and the subjects covered by the other contributors, were a reminder of how we are using space in more ways than ever before and how the UK is at the forefront of innovation.

UK EXCELLENCE IN SPACE

In my introductory remarks, I highlighted the UK's areas of expertise in telecommunications, particularly satellite navigation and broadband. I highlighted the launch last November of Europe's first dedicated Ka-band broadband satellite – HYLAS-1 – as an example of our technological prowess and of the strength of the public-private partnership business model. We invested some £40 million of funding into advanced telecommuni-cations technology by the UK Space Agency through the European Space Agency's ARTES programme. That initial investment was then commercial-ised by Avanti Communications, raising more than £525 million in capital for their first satellite, and creating jobs and revenue for the country.

This is an excellent example of how strategic investment in space technology can yield benefits for the wider economy. As a technical application, HYLAS-1 can provide the same high-speed broadband to a farmer in the Highlands that it can provide to a banker in the City. As a growing UK industry, the space sector as a whole already provides an estimated £7.5 billion a year to our economy.

But the value of UK involvement in space became apparent in other ways with the tragic events in Japan on 11 March. Less than two hours after the Tohoku earthquake and tsunami struck Japan, the International Charter on Space and major disasters was activated. This international network of satellites provided free images of the affected area to assist disaster response efforts and the Charter members' earth observation satellites continue to provide essential imagery to assist Japan's recovery.

The response to this disaster highlights the international nature of space and marks the first time that multiple space agencies – European Space Agency, the German Aerospace Centre and the Japan Aerospace Exploration Agency – are freely sharing data for understanding tectonic processes. The UK will also chair this initiative from May this year.

The UK has excellent earth observation capabilities. The radar instrument aboard the European Space Agency satellite ENVISAT was designed and built in the UK. ENVISAT itself, launched in 2002, was delivered by Astrium UK and remains the largest and most complex earth observation satellite ever built.

The UK is also building partnerships around the world. In the past year, we have signed agreements with Russia and the United States. In February I opened the UK-Russia Year of Space 2011 to commemorate the 50th anniversary of Yuri Gagarin's space flight, one of the iconic moments of the 20th century.

POSITIVE POST-SCRIPT

In the Budget on 23 March, the Government ear-marked £10 million to start a national space technology programme with industry aimed at promoting economic growth and self sustainability. Funding will be channelled through the UK Space Agency.

We have committed to reforming the Outer Space Act – which will introduce an upper limit on the third-party liability of UK satellite operators, making the industry more internationally competitive.

We are also committed to working with the international regulatory authorities to enable space tourism operations in the UK and to define regulations for novel space vehicles that offer low cost access to space.

On 1 April the UK Space Agency became an executive agency of the Department for Business, Innovation and Skills, taking over responsibility for the majority of the UK's commitment to space exploration and science. Its efforts will be targeted at areas that have the greatest potential for delivering economic benefits, scientific excellence and national security. Priority areas include developing scientific advancements in space technologies, gaining a better understanding of our planet through earth observation spacecraft, and nurturing our next generation of space scientists and researchers. The organisation's strategy for 2011-2015 has been published for consultation and we invited comments on the Agency's draft strategy before 8 July 2011.

http://www.bis.gov.uk/ukspaceagency/who-we-are/strategy

COMING UP….

The economy and education continue to be major areas of focus for the Government's involvement in space over the coming months and will be at the core of the inaugural UK Space Conference which takes place in July.

Recently, Jodrell Bank Observatory was selected to host the project office for the Square Kilometre Array (SKA) radio telescope project, a global initiative to develop one of the largest science facilities in the world by the early 2020s.

SPACE FOR SCIENCE

John Zarnecki
Professor of Space Science,
The Open University

Yesterday we had a wonderful day at the Royal Aeronautical Society celebrating the 50th anniversary of Gagarin's flight. Twenty-five years ago the Giotto spacecraft flew 594 kilometres past Halley's comet and this typifies the sort of thing I wish to talk about. These comments are very much my own and the first may be a form of political suicide! I'd like to start by saying that we don't primarily do Space Science because of a desire to generate either money or economic activity. We do Space Science because it is "Blue Skies" research and it might even lead to Nobel Prizes for some!

Paul Gauguin's 1898 painting, entitled "D'où venons-nous? Que sommes-nous? Où allons-nous?" encapsulates all the drivers for space science: Where do we come from? Who are we? Where are we going? Or to translate these into Space Science terms – "How did our Earth, our Solar System, our Universe originate and evolve?"; "Where are we in the Universe?"; "Where are we going?"; "Where did life come from, and are we alone?".

Methods for "doing" Space Science either involve "going there" for example, to Mars, Saturn, or the Sun, or it simply requires putting our telescopes above the Earth's atmosphere. The atmosphere is like a dirty window and obscures radiation coming to us from our universe.

80% of our space science is done through the European Space Agency (ESA), though there are also important missions done with other agencies. Some ESA Missions go to places, such as Cluster for example, which placed spacecraft in the Earth's magnetosphere; Mars Express which is a spacecraft in orbit around Mars; on the other hand, the Hubble Space Telescope remains in low Earth orbit and is sometimes closer to London than is Edinburgh! Some are purely European Missions with the UK playing a large part such as XMM Newton. Hubble is 20% European with a NASA lead. Double Star is a Chinese Mission with British and European involvement, Akari is a Japanese led Mission, together illustrating that there are many different modes for doing space science in terms of international collaboration.

Examples of "going there" include Mars Express, a purely European Mission, which has been in orbit around Mars very successfully for several years. It provides wonderful resolution images of the surface of Mars. Data like these are an absolute goldmine for interpreting Martian processes in great detail. A fly-by Mars Express photo of Phobos, one of the two Moons of Mars, shows the best detail yet of this small body and in particular of potential landing sites for a Russian mission which is due to be launched later this year.

The Cassini-Huygens mission is one of the most sophisticated, and has been operating since 2004 and will operate until 2017. The Huygens Probe landed on Titan, the largest Moon of Saturn, in 2005, while Cassini performed fly-bys of the moons of Saturn and of Titan, thereby providing a wealth of data that will be analysed for decades to come with UK involvement in many of the instruments on board.

Rosetta is a purely European Mission, launched in 2004, and is due to arrive at a comet in 2014. Europe has a very strong tradition in cometary research. This mission will attempt to put a lander, the first ever on a comet surface, on 10 November, 2014. Comets are important as they represent the most pristine material within our Solar System, so put the date in your diaries!

Turning now to the other type of space science that we do. Galileo Galilei, in August 1609, was the first to turn his telescope to the heavens. Well now we do something similar, but we put our telescopes above the atmosphere, escaping its absorbing and blurring effects. The most famous is the Hubble Space Telescope, which started work in 1990. One of the most interesting results is the Hubble Deep Field, the result of staring for ten days at an apparently blank piece of sky. This produced an array of previously unseen objects, almost all of them being very distant galaxies. By looking into space we are effectively looking back in time to early epochs, see Figure 1. Many of the galaxies visible from Hubble are extremely young in

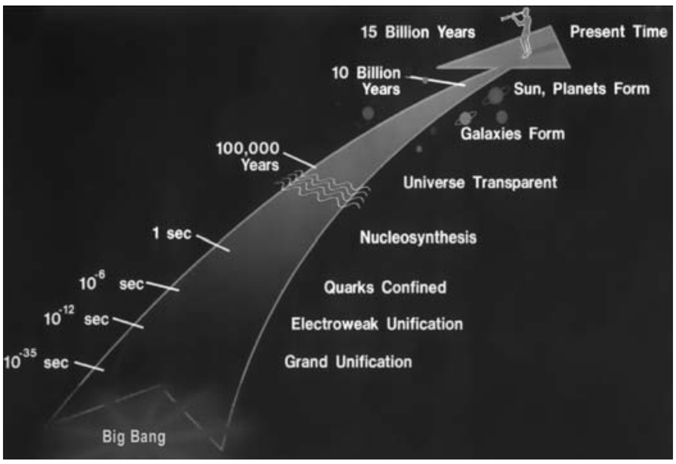


Figure 1 Look out in Space – Look back in time

cosmological terms.

The electromagnetic spectrum can be represented by a rainbow of which visible light is only a tiny part. This includes Gamma Rays, X-Rays, Ultraviolet, Infrared, and Sub-mm rays which are mostly absorbed in our atmosphere. That is not very helpful for astronomers, but probably lethal for us if they were not absorbed by the atmosphere! The space age has however enabled satellites to carry telescopes sensitive to these different radiations. A couple of these are worth mentioning here, namely Herschel and Planck, both European Space Agency missions and covering the infrared and microwave part of the spectrum which are essentially inaccessible from the ground. Herschel is the largest telescope ever put into space. Planck looks at microwaves and therefore measures the cosmic microwave background. If we want to go back more than the first 400 million years, we cannot see any light, and the microwave spectrum thus enables us to go back even further than the galaxies we can see with visible light and probe even earlier epochs in a scientific manner, see Figure 2.

Those are a few of the examples of space science. The spacecraft we use carry technological wonders usually built in universities and research institutes, whereas the spacecraft are built by industry. An analysis of contractors for the Huygens probe shows companies throughout the world, but mainly based in European countries, who contributed towards the construction of that wonderful probe. The main UK contributions included flight software, descent subsystems, parts procurement and parachutes.

Some recent examples of "spin out" from the technology of Space Science include medical imaging detectors, security applications, air quality monitoring in submarines and in-situ disease detection. Apart from the specialised technology developed through Space Science missions such as these, we produce a cohort of highly skilled graduates and technicians, many of whom go on to use their skills in the wider world.

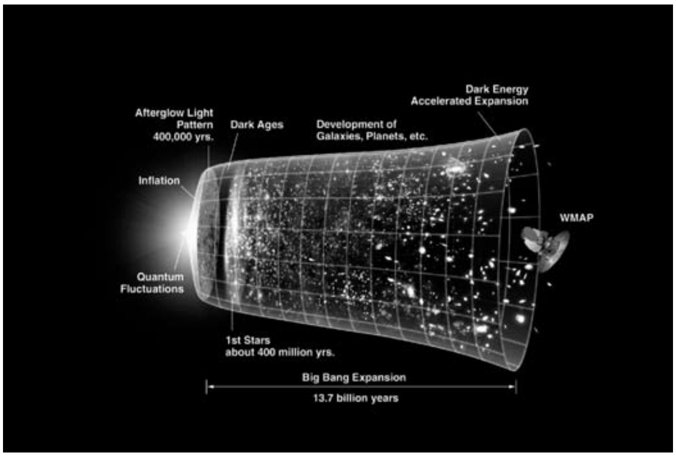


Figure 2. Herschel/Planck (ESA, 2008)

SPACE – HOW CAN WE USE IT?

EARTH OBSERVATION FOR SCIENCE, SOCIETY AND SERVICES

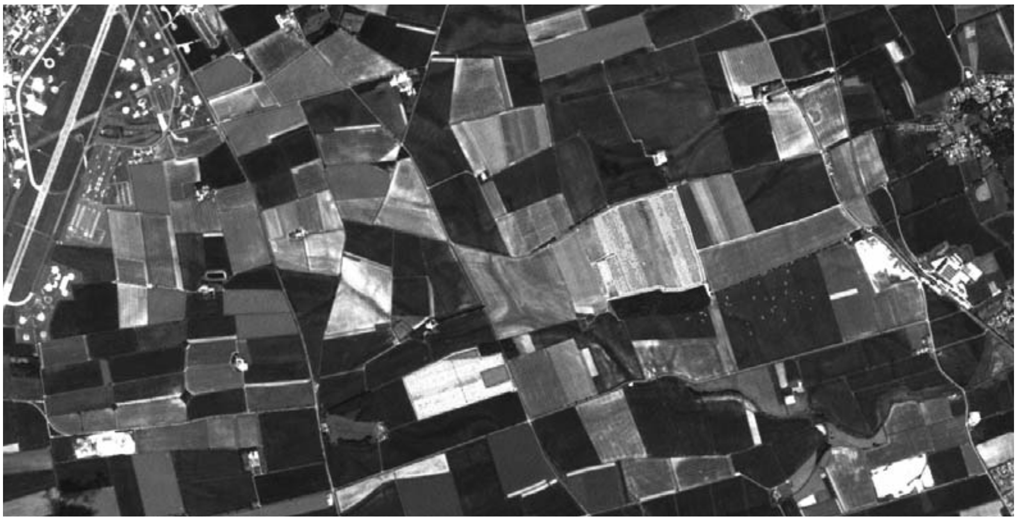
Professor Paul S Monks
Professor Earth Observation Science, University of Leicester

What is Earth Observation from space and how can it make a difference? Satellites impinge on many people's daily existence but without them realising, from the use of your "Sat" Nav to the weather forecast. Earth Observation is essentially looking at the earth from space using instruments on satellites; the application and exploitation of data from such instruments drives the three S's – science, society and service.

The first S is Science. Earth Observation Science is important as satellite data can tell us all about the different parts of the earth system from the cryosphere to the tropical regions, from the ocean to the atmosphere. The challenge of monitoring change in the earth system should not be underestimated from the rate of deforestation of rainforests, hazardous weather, flooding to dynamic changes in the ice-caps. In a way earth observation science allows us to give the earth a "health check".

You can observe earth in many different ways but satellites give us a unique view because they are accurate, they are global and they are independent. These properties make satellites a very important part of our global observing system.

The second S is society. Society faces a number of challenges moving forward such as food security, natural resource security, climate change, public health and environmental security. In many natural disasters Earth Observation acts as a first responder delivering maps and detailed impact assessments of the devastation to allow aid teams to target their efforts. Earth observation is integral to monitoring climate change be it by measurements of sea-surface temperature, a thermometer of change, or the emissions and concentrations of carbon dioxide in our atmosphere.



The third S is service. With all this data coming from satellites are there commercial benefits to be had? The pieces of the jigsaw are falling into place. In a European programme called GMES (Global Monitoring for Environment and Security) science will be put into service for the benefit of society by flying essentially uninterrupted missions to give us a continuous high quality data stream. This is important as it gives us the backbone on which to build services. Future services can help, for example, farmers to be more efficient in use of fertilisers, the insurance industry assess risk, local government control air quality in their towns or cities. As satellites can provide data in near real time decision makers will have access to an unheralded view of the earth from the local to the global.

Earth observation – 'What can we do with it?' The answer is really only limited by our imagination. Earth observation does change our life and make a difference, from observations over the scientific bridge to societal impact and finally commercial service. In the future we face the challenge of making this seamless. The UK is a world leader in all areas of Earth observation. Science, society and services in a seamless way is going to be the clarion call for earth observation moving forward.

SPACE – HOW CAN WE USE IT?

DRIVING INNOVATION IN SPACE

Michael Lawrence
Head of Special Projects, Technology Strategy Board

The Technology Strategy Board is working with the space industry, academia and the UK Space Agency to enable the development, commercialisation and exploitation of space technologies and applications.

The Technology Strategy Board is the UK's innovation agency and is based in Swindon. It is a national body supporting innovation to support business, to drive economic growth and to improve quality of life. The title of the Technology Stratgey Board's original strategy, 'Connect and Catalyse', describes how the organisation has worked since it was established three years ago. A new strategy, 'Concept to Commercialisation', was published in May 2011 and defines how the organisation will move forward in the next three years.

Most of the Technology Strategy Board's activity supports companies who have moved beyond the blue sky research and have technology that needs to be developed and demonstrated prior to being launched into the commercial market. Resources are focused on areas where innovative UK businesses can thrive and exploit large global markets. Support through public funding for research and development makes a difference, it helps companies take risks, build new collaborations and open new markets.

Space is clearly a growth area, the Space Innovation and Growth Strategy published last year takes a twenty year view of how the industry could develop in the UK and defines how the UK can take a 10% share of a global market forecast to be worth £400 billion by 2030. The creation of the UK Space Agency in April 2011 confirms the importance of Space and the Technology Strategy Board supports the Space Agency in five areas.

1. Managing the UK involvement in telecommunications and navigation programmes run

by the European Space Agency.

2. Promoting business opportunities for UK space companies across all the growth areas that the Technology Strategy Board works in such as energy, transport, digital and healthcare.

3. Providing technology demonstration opportunities for UK organisations to prove their technology in orbit and remove a barrier to market.

4. Encouraging knowledge transfer between the academic base and industry as a driver of economic growth.

5. Promoting open innovation to accelerate the commercialisation of R&D activity.

The Technology Strategy Board ran its first Space R&D competition this year. Over 200 applications were received, 76 projects were successful and received small grants of around £25,000 towards projects which will run from May to July 2011. Some of these projects will take advantage of the facilities available at the newly opened International Space Innovation Centre at Harwell. The idea of these feasibility studies is to allow early work to assess the technical or business feasibility of innovative ideas for Space technology or applications of data from Space. The Technology Strategy Board put £1.2 million into this competition, with SEEDA contributing a further £0.6 million, and industry contributing £0.6m

The Technology Strategy Board is currently establishing a small number of elite Technology and Innovation Centres across the UK. The idea is that business focused research centres can fill a critical gap between excellent research and commercial exploitation. Space is one of ten potential areas for the next three TICs and the Space industry is building a case for a technology innovation centre in Space that can help deliver the ambitious growth objectives it has set itself.

The Space sector in the UK is changing with the UK Space Agency providing a single focal point for Space policy and the Technology Strategy Board providing its innovation expertise to the sector. This approach to innovation and growth bodes well for the future and makes the UK target of 10% share of the market by 2030 look achievable.

The Technology Strategy Board (www.innovateuk.org) is a business-led government body which works to create economic growth by ensuring that the UK is a global leader in innovation. Sponsored by the Department for Business, Innovation and Skills (BIS), the Technology Strategy Board brings together business, research and the public sector, supporting and accelerating the development of innovative products and services to meet market needs, tackle major societal challenges and help build the future economy.

SPACE – HOW CAN WE USE IT?

GALILEO, THE EUROPEAN GLOBAL SATELLITE NAVIGATION SYSTEM

Philip Davies
Surrey Satellite Technology Ltd

Galileo is a joint initiative of the European Commission (EC) and the European Space Agency (ESA). Galileo will be Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be inter-operable with GPS and GLONASS, the two other global satellite navigation systems.

The Galileo system is a major undertaking consisting of a space segment of 30 satellites in the Medium Earth Orbit (23,000 km altitude), the launch of these satellites, a global network of 30-40 sensor stations, 9 navigation command stations, 5 satellite control stations and 2 European control centres plus the network to interconnect these facilities. The system also includes the equipment used by the system's end users to receive Galileo's signals.

Galileo offers 5 services to its users:

- An open signal, broadcast at two frequencies for mass market use,
- A commercial signal with better accuracy and service guarantees,
- A safety-of-life signal for high integrity services capable of being certified for use in safety related applications,
- A search & rescue service allowing emergency services to locate users "in distress",
- A public regulated signal for use by government approved users.

Compared with the situation today Galileo will improve navigation for anyone who makes use of one or more of the services offered. Galileo is

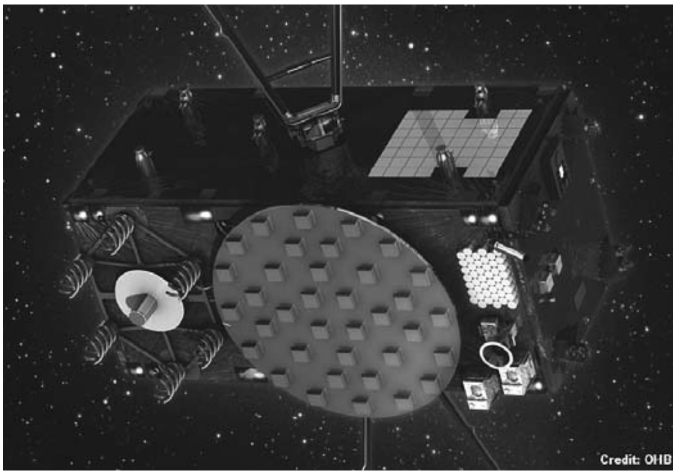


Image: Galileo FOC Satellite Credit: OHB

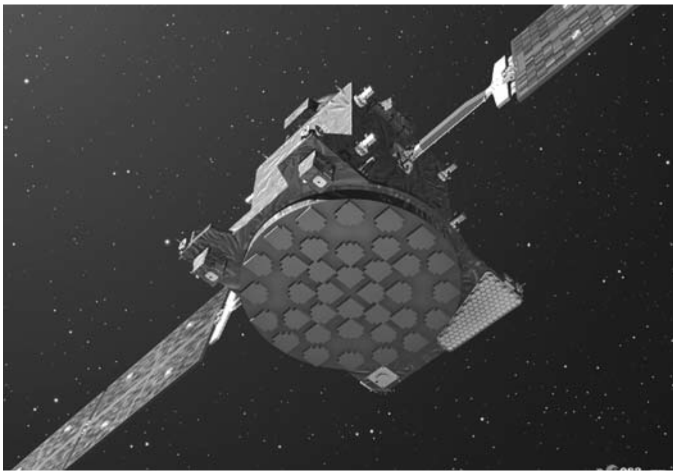


Image: GIOVE-A Credit: ESA

easily interoperable with GPS and the combination of Galileo with one of the existing systems such as GPS will double the number of satellites being received giving much improved availability in areas with marginal view of the sky such as city centres and valleys in mountainous regions. Galileo brings technical innovation such as better atomic clocks and broadcast on multiple frequencies which will improve the accuracy of satellite navigation and Galileo will be more resilient to effects such as multipath interference and jamming. Finally, an additional global system brings better residence to systematic (common mode) failures which could, in theory, make all of the satellites from one system inoperable due to a common cause.

Industrially, the UK has played a major role in developing the system. Surrey Satellite Technology Limited (SSTL) built the first test satellite called GIOVE-A and is now under contract to supply 14 navigation payloads for the next batch of "fully operational" (FOC) satellites being procured by the EC through ESA. Astrium built the navigation payload for the second test satellite GIOVE-B and for the earlier batch of 4 "In Orbit Validation" (IOV) satellites being procured by ESA. UK space segment companies such as COM DEV and ABSL are supplying equipment for the satellites. UK ground segment companies such as Astrium, Qinetiq, Scisys, Logica, Vega, NSL and NPL are involved in the building of the ground system.

The system development is now well advanced. The system has been validated by the two GIOVE test satellites and the ground systems built to support those missions. SSTL's GIOVE-A was launched in 2005 and continues to operate after more than 5 years. In 2008 ESA declared this mission a "100% success". GIOVE-B was launched in 2008 and continues to operate after more than 3 years. The next 4 IOV satellites will be launched starting in the second half of 2011 and the next batch of 14 satellites will be available for launch in 2013 and 2014. The batch of 14 satellites will be very efficiently produced and will roll off a production line at the rate of one satellite every 6 weeks. Given that the full system is 30 satellites and that only 18 are currently contracted there are still 12 satellites yet to be procured before the system can be fully operational.

The production line for the building of the payloads for the batch of 14 satellites will be based at SSTL's new technical facility, the Kepler building, which is due for opening in May 2011.

In conclusion, the development of the Galileo System is well advanced. The complete ground segment is under development and there are 18 satellites under contract – the initial 4 IOV satellites and the first batch of 14 FOC satellites. The 4 IOV and the first 10 FOC satellites also have launches booked – using Soyuz from French Guyana. The 14 FOC satellites are currently being designed and the production line will soon be up and running delivering a pair of satellites every 3 months.

Legal disclaimer: SSTL's work on Galileo FOC is funded under a programme of the European Union and executed under a contract with the European Space Agency. The views of the author expressed herein can in no way be taken to reflect the official opinion of the European Union and/or ESA. The OHB project is funded by, and part of, the Galileo programme which is an initiative by the European Union (EU), and where the European Space Agency (ESA) acts in the name of, and on behalf of, the EU. "Galileo" is a trademark subject to OHIM application number 002742237 by EU and ESA.

Image: SSTL's Kepler Building Credit: SSTL

THE FUTURE OF SPACE – PUBLIC PRIVATE PARTNERSHIPS?

Bill Simpson
Trident Sensors Ltd

In 2010 Eric Lindstrom of NASA and his co-authors from many other agencies [1] summarised the problem of research satellite missions. *"Satellites are expensive to design, build, and launch, hence the time from mission concept to launch is measured in years. This characteristic can leave data gaps in time with negative consequences for the essential inter-calibration between successive satellites that is critical to producing consistent time series suitable for climate research (especially decadal variability)."*

Public Private Partnerships (PPP) are joint projects that are to the Partners' mutual benefit, in this instance where government agencies wish to fly sensors and companies are willing to host the payloads. In order to maintain their businesses, satellite communications companies need to build, launch and operate satellites and constellations and this means that governments can benefit from rides into space at a fraction of the cost of conventional agency practices. In return, the companies can offset high capital costs by charging fees for payload hosting, sensor integration and data delivery in real-time to anywhere in the world. Between now and 2030 there will be well over 300 communications satellites launched – that's potentially 300 hosted payloads. So first, PPP's can drive down costs for both parties; second, heritage sensors can be flown with short time scales, ie 2 years rather than 7 to 15 years typical of Agency projects; third, many of the commercial satellites have long design lives (10 to 15 years) thus mission continuity is less of an issue; fourth, duplication of sensors in constellations means that launch or satellite failures are not catastrophic.

An essential requirement from the private sector is that the company is commercially viable. The communication sector is very buoyant with the total Mobile Satellite Services market turnover increasing from $0.6B in 2001 to $1.8B in 2010. Constellations operate both in geosynchronous (eg Inmarsat) and low earth orbits (eg Iridium). Both companies are in PPP's, Inmarsat with ESA on the Inmarsat XL/Alphasat project where Inmarsat gets an extended L-band payload to augment its BGAN service and ESA flies the Alphabus, an experimental communications payload. The launch is scheduled for 2012. Likewise Iridium Communications Inc needs to replace its LEO constellation of 66 satellites between 2015 and 2017, and hosted payload space has been designed into the satellites. Many of these slots have been reserved – ADS-B tracking of aircraft outside of land based radar range, GPS radio occultation, defence and other payloads. Earth observation missions are being encouraged by the Group on Earth Observations and these include ocean and land imaging, altimetry, cloud motion wind vector and Earth's radiation budget, the last two led by UK consortia. The total cost of integration, launch and 10 years operation is approximately $1M to $2M per year per Iridium satellite.

This low cost opens up the possibility for both research and business investment in single sensor constellations. Professor Monks (this issue) suggests that missions should fulfil the requirements of science, society and security. Altimetry, to monitor sea surface height and wind speed, fits these requirements. The research community has asked again for consideration to be given to such a constellation to resolve meso-scales eddies[2] and there are good business reasons for mariners to pay for a reliable service relating to real-time sea state. $3B of shipping losses per annum can be attributed to bad weather, often inadequately predicted by standard Met practices. Other factors make a polar orbiting altimeter constellation timely, such as the risks of oil and gas exploration in the Arctic and the opening of the North East and North West passages to shipping in the summer months. With respect to security, the Navy is an obvious beneficiary but so are regions prone to flooding due to storm surges or rising sea level. There are precedents for private companies operating profitable Earth observation operations (GeoEye, RapidEye and Astrium GEO Information Services), and often a public partner had the foresight to invest.

We can expect the private sector to play a greater role in all space activities. Entrepreneur Elon Musk serves as inspiration to youth during NSEW in that he founded SpaceX in 2002 and already has achieved great things, including the first commercial company in history to recover a spacecraft from orbit (see the video on www.spacex.com). SpaceX has won several $B contracts, including the support of the International Space Station and the launch of Iridium NEXT. The aim is to *"ultimately reduce the cost and increase the reliability of space access by a factor of ten".*

Lastly, on March 16, 2011, Charles Baker of NOAA gave a presentation at Satellite 2011 in Washington entitled *"Hosted Payloads, Thinking Outside the Box"* which acknowledges the maturity of commercial enterprises in space and the new opportunities offered. The UK is well placed to play its part in the exploitation of PPP's

[1] Lindstrom, E., et al. (2010), *'Research Satellite Mission',* Proceedings of OceanObs 2009, Venice

[2] Bonekamp, H., et al. (2010), *'Transitions towards operational space-based ocean observations: from single research missions into series and constellations',* Proceedings of OceanObs 2009, Venice