# The Space Innovation and Growth Strategy
# Main Report

An Innovation and Growth Team report

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# 1.0 Introduction

## The UK Presence in the Space Economy

Space has been one of the hidden success stories of British industry in recent years.  It is a medium-sized industry with revenues of £5.9 billion in 2007 and directly employs around 19,100 people. It is also a sector where productivity is more than four times the national average - contributing some £145,000 per worker to UK GDP – perhaps not surprisingly given the large capital investments and high skilled nature of the industry where nearly two-thirds of workers have degrees. But this is an industry that punches above its weight in the UK economy. Oxford Economics, the highly respected forecasting agency, estimates that the UK Space sector overall contributes around £5.6 billion in value added to the UK's GDP and supports around 68,000 jobs in the UK directly and through its spending.

Science provides a very strong and vital part of our success in Space with the UK being the second-largest publisher of major Space Science papers in the World, providing a knowledge base for many other developments. The technology spin-offs from Space affect industries from medicine to manufacturing. The end user applications affect our lives in every way, from communications at home and work to security, safety, entertainment and travel.

The Space Industry covers not just spacecraft but also the manufacturing of the launchers and the ground equipment. Satellites perform many functions autonomously but need to be operated (supervised and controlled) from the ground. Satellites are also insured. These are termed Upstream industries. There is also the much larger Downstream market place. The downstream business sectors include the manufacture of mass market user equipment such as satellite TV dishes and set top boxes and devices for navigation and precision timing. Applications and software development using the in orbit infrastructure are of great importance in securing benefits from space. The Space Foundation estimated that in 2008 the Space Business was a $257B industry.

The UK currently enjoys a 6.5% share of this market despite its public investment being only 0.014% of national GDP (compared with 0.1% in India, 0.05% in Germany and 0.025% in Canada). However, the most striking attribute of the UK's Space sector over the last decade is that it continues its relentless growth on average at 9% per year.

Space has proven to be one of only a very few sectors where growth has remained resilient through the world-wide recession This has been possible because of the diverse range of customers for Space-enabled services from commercial telecommunications to institutional surveillance. As well as increasing market demand, this growth is built on strong UK industrial capabilities in satellite manufacturing, operation, exploration sensing and in downstream applications.  The UK does well in export markets, an already important factor for this sector but also an increasingly important one given international demand far outstrips domestic needs.  The UK (and everyone else) is weaker than the US in consumer applications and it is not involved in rocket launchers or a significant player in human spaceflight.

Space is perceived differently by different people. To some, Space is about astronauts and robotic craft exploring the universe. To others, it is all about satellites and football. In fact Space covers a wide range of activities from commercial communications satellites, through location-based services to Science and exploration. Any Space-based infrastructure will support a myriad of applications and services.

It seems, like ICT, to stimulate (through its disruptive influence) pervasive and continuing improvements in diverse sectors. All of these contribute to and benefit from the Space economy.

Most people are unaware of the technology which supports their services – so long as it works well. Television is watched an average of 3.5 hours per day by every person in the UK. Unknown to most viewers almost all TV content passes through a satellite at least once on its way to the home even if it is not the "satellite TV" that we associate with Sky and Premier League football. Satellites are normally used to distribute programmes to the digital terrestrial transmission network. Meteorological satellites are vital to weather forecasters providing data as well as pictures. Satellite navigation is a standard feature for many vehicles and phones.

Access and use of Space is fundamental to defence forces. Wherever these forces are deployed, they benefit from high-capacity secure communications, precision navigation, surveillance, missile launch identification, weapons delivery and intelligence gathering. It is no coincidence that developing nations – India, China and Brazil are obvious examples - have active Space programmes. Space is needed to access the premier league in more than one sense!

## How did the UK achieve this?

The vast majority of Space activity in the UK now lies in the private commercial sector. However the origins of the Space industry stem from government initiatives made in the past. In particular rocket technology is needed to install any Space infrastructure.

Rockets (alongside microwave radar) were developed as a product of 20th century conflicts. Rocket research for access to orbit and for weapons delivery rapidly became a key technical aspect of the Cold War period. In a twenty year period the von Braun-led team took the US forward to the Saturn 5 moon rocket. Parallel developments led to a substantial Soviet capability in rocketry in the same period. The world had entered the era where nuclear weapons could be launched on intercontinental ballistic missiles (rockets) sitting in silos or submarines.

Whilst the British could not afford the vast rocket research programmes of the US and USSR, R&D did continue on both missiles and launchers. The Blue Streak launch vehicle was developed and tested but by the 1970s the UK decided to buy its weapon delivery systems from the US and to continue launcher development at a European level. Initial European launcher efforts – effectively bolting together different parts from the various national developments – achieved limited success. The Europeans then adopted a "clean start" approach very much under French leadership resulting in the Ariane launchers we know today.

The satellite launchers available commercially today remain almost exclusively a direct result of R&D undertaken by national governments primarily for reasons of national security. The UK currently makes a small subscription to ESA towards EGAS: European Guaranteed Access to Space, whereas involvement of the UK in the industrial side of Ariane has declined to almost nothing today. At the same time the UK also avoided the pitfalls of investment in manned spaceflight races and other white elephant prestige projects, instead focussing on commercial applications.

At about the same time as von Braun was developing the rocket to the point that it could launch an object into orbit, an Englishman, Arthur C Clarke, proposed the concept of the geostationary communications satellite. The UK strategically changed its emphasis from launchers to satellites. By this time the military and commercial importance of satellites was apparent.

Communications satellites (which use microwaves for communications rather than for their first application in radar) came onto the stage. Government Space funding led to the development of the technology and skills necessary for satellite manufacturing. This has enabled UK industry to play an important part in the manufacture of commercial and military communications satellites.

The 1960's saw the creation of the European Satellite Research Organization (ESRO) with active UK participation. Satellite know-how developed steadily. Four launches of UK-led satellite projects occurred before the end of the 1970's. Two were Skynet II military satellites (Marconi, Portsmouth) and two were civil communications satellites (Hawker Siddeley, Stevenage); unfortunately and frustratingly two of these suffered launcher failures and did not reach orbit.

In 1975 several Western European governments agreed to set up the European Space Agency (ESA) and the UK participated enthusiastically. UK government funding, through ESA, developed the ability to build communications satellites with a new design superior to that used in the US. The platform was used for trunk telephony, mobile maritime services and military communications and the design was copied in the US where its growth potential was recognised. This European innovation has now been adopted as the standard approach around the world.

Three InterGovernmental Organizations (IGOs) were formed to purchase and operate satellites- Intelsat, based in the US, for worldwide international communications, Eutelsat, in Paris, for European communications and Inmarsat, based in London for maritime and aeronautical communications. The UK government interest was managed though the GPO, later British Telecom. Since then Intelsat, Inmarsat and Eutelsat have lost their monopoly status and have become successful commercial businesses. BT has now sold its stakes in all three companies and also its satellite service businesses.

The Royal Aerospace Establishment was the public body responsible for UK military Space interests. It acted as a research laboratory and a project management agency. Eventually, after evolving into DRA and DERA, much of its activities have been privatised as QinetiQ.

In the 1990s European manufacturing consolidation intensified to try to create an Airbus-like competitor to the US giants of Hughes (now Boeing) and Lockheed Martin. The sale of UK interests in satellite manufacturing and operating companies in the 90s broadly coincided with a shift in UK Space policy. It was considered that communications satellites were a 'mature' sector, able to reinvest in technology from profits. This decision now looks premature but enabled a shift in UK funding towards Earth Observation. These decisions have resulted in a significant manufacturing and service activity in the UK and the construction of spacecraft for navigation and Earth Observation as well as Science missions.

**The sale of UK interests in satellite manufacturing and operating companies in the 90s broadly coincided with a shift in UK Space policy**

To date the customer for EO satellites has almost always been the public sector, most usually ESA. The capability has developed steadily. In many cases the spacecraft are one-off custom builds for a unique set of mission requirements. ESA's Earth Observation missions have been very successful and clearly benefit from rapidly rising interest in environmental issues such as climate change and pollution.

A fairly early success in Europe was the establishment of EUMETSAT as an operator of meteorological satellites and a disseminator of the measurement data to the participating European nations of which the UK is one. Unfortunately the UK has failed to secure a balanced involvement of its Space industry in the build of such satellites.

The European navigation programme, Galileo, was initiated by the European Commission in the late 1990s. It will be a 30 satellite constellation broadcasting positioning signals independent from but complementary to GPS. Fairly recently the proposed European PPP failed and the Galileo project is to be a public procurement of the infrastructure and a public owner/operator. Progress is now being made with the announcement of the award of the construction contract for the first 14 satellites to an international consortium of OHB and Surrey Satellites technology Limited.

Europe has now learnt the art of spacecraft engineering and rocketry and its Space products compete in world markets. Standard communications satellites no longer require direct government R&D support. There has been, and continues to be, UK public investment injected into new satellite technology and also for some specialized missions – most notably the Mobile Satellite Services (MSS) satellites used by the UK operator Inmarsat.

The current generation of Inmarsat satellite is amongst the largest and most complex built so far. Public investment de-risked new complex technology permitting Inmarsat to step up to a more capable service that is now exporting services and earning revenue worldwide. Inmarsat provides vital services to mariners, first responders at disaster scenes and aircraft. This includes the facility for making distress calls.

The UK Government is itself now a major user and procurer of satellite services. The current generation of Skynet military satellite communications services is provided under a PFI. This venture has been one of the most successful PFIs to date. The satellite technology needed for Skynet stems from the UK's earlier funding of technology and some of the advanced military features of the satellite's communications payload stem from the skills accumulated during the development of Inmarsat payloads, supplemented by direct investment by MOD for specific military features.

**The current generation of Skynet military satellite communications services is provided under a PFI... one of the most successful PFIs to date.**

The current situation is that the UK government's principal Space spend is the purchase of services that it needs – military communications, meteorology, navigation signals, Earth observation and the contribution to Space science. This service-side funding helps drive the whole satellite manufacturing capability forward through synergies in the technology. This role as a consumer of satellite services is combined with a modest annual technology development budget to encourage a healthy satellite manufacturing base. This represents a clear evolution from 30 years ago where government was the sole customer of the Space industry.

## What do Satellites do well?

Satellites come into their own for five important applications. All of these result from the fact that the satellite provides a very high vantage point from which to see or be seen. In geostationary orbit – as used by most communications satellites – the satellite appears stationary in the sky above its coverage area. Typically satellites are spaced at orbital slots (often several sharing bandwidth in one slot) which are spaced by international agreement every 2 or 3 degrees around the geostationary circle. A service provider in the UK can choose to point his users' antennas to select any satellite from about 60 slots visible along the geostationary arc. In other lower orbits successive satellites appear over one horizon, pass overhead and then disappear over the opposite horizon. With a constellation such as Galileo a minimum number of satellites are guaranteed to be in view at any one time. It is useful to summarize the situations where a satellite is the best and most cost effective solution. This helps to understand where new applications of satellites will arise.

**Broadcast:** A satellite is the most efficient means of broadcasting signals over a wide area such as the UK or a continent. This is true for low data rate services such as radio as well as high data rate services like HDTV. An equivalent terrestrial transmission network requires many transmitter stations and invariably works out more expensive as well as being slower to deploy. The successes of satellite TV were not foreseen at the outset. From early introduction with a handful of analogue channels, improvements have come rapidly and without direct taxpayer support. Increased bandwidth and the satellite version of digital switchover have improved choice and HDTV and 3DTV are improving quality.

**Service Extension:** The best way to extend most communications services, such as mobile telephony and broadband access, out to remote areas is to use satellites. For example, Inmarsat, a London-based operator, provides a variety of communications services to ships, aircraft and land users in remote regions. Inmarsat saw a surge in use immediately following the 2004 Boxing Day tsunami often because terrestrial systems had been destroyed by the waves.

**Securely Controlling National Infrastructure:** Satellite communications is one way to provide low-data rate 2-way data services over a wide area such as the UK. One satellite can cover the entire country compared to a need for thousands of base stations in an equivalent terrestrial system. Improvements in user equipment may make this one of the biggest growth areas over the next 20 years. Applications cover transport and the built environment and include Smart Metering communications, Smart Grid control and monitoring as well as a range of transport-related services.

**Navigation Signal Broadcast:** Satellites are well recognized for providing the best way to transmit navigation signals for outdoor positioning.

'Satnav' is already widely accepted for consumer devices such as Tom Tom and iPhone; before long it will be standard in all vehicles and mobile phones.

**Observation:** Earth orbit is ideal for a wide range of observation functions from environmental sensing, meteorology and military surveillance, especially where world-wide coverage is required. Its role has steadily increased as concern over climate change and military needs have grown. It is not an exaggeration that our early warning of climate change came from these satellites.

The above five satellite strong points show where satellite services provide the best solution either to a public or to a private sector requirement. All five are concerned with the application of Space technology and do not consider Space Science which is part of research into fundamental Science or Space exploration. A sixth strong point should be added.

**Science:** Spacecraft provide the obvious means of exploring the solar system and beyond the reach of ground-based techniques. Spacecraft have successfully taken men to the Moon and back. Astronomers can use spacecraft to raise their telescopes above the distorting effect of the Earth's atmosphere when making observations and measurements. The spectacular pictures of the universe from the Hubble Space Telescope have been seen by all. There are many other missions with a lesser public profile that help to advance our knowledge of Science and the 13 billion year-old universe, our Solar System and planet Earth.

The UK's participation in science, most often through its contributions into ESA's institutional Space Science and earth observation programme, has been delivering world-class science, innovative instrumentation and related satellite technologies, and associated industrial activity since the 1980s.

Today, our industry, universities and research establishments are active on technology and Science developments for climate change, deep Space astronomy, solar physics and the exploration of other planets.

Most Space Science can be done using robotic technology at which the UK excels, but it is important to recognise that manned missions have provided inspiration for a generation and that the Apollo missions and the moon landings and the iconic images relayed back to Earth will be remembered for the rest of human history. Whilst Apollo (and the Soviet Soyuz programme) was an entirely public-funded venture, a new generation of wealthy Space tourists has shown a willingness to spend millions of dollars to experience the sights from Space. Virgin Galactic is demonstrating that Space as a tourist destination has commercial potential. Even Stephen Hawking has publicly declared an interest in travelling into Space.

## What is the UK capability in Space?

The Space industry can generally be divided into two broad categories – the 'upstream' sector and the 'downstream' sector (as shown in the following figure). Upstream represents companies (often linked with academia) involved with the development, build and launch of Space hardware and the associated ground segment. Downstream sectors represent companies (again linked with academia) in the business of exploiting satellite capabilities and selling commercial products and services directly to end users. Serving these two communities are satellite operators (who operate satellites in service) and earth station operators (who manage satellite communication links while not operating the whole satellite system).

BNSC (British National Space Centre) regularly surveys the UK Space Industry. Its 2008 Size and Health study identified a UK Space industry with a value of around £6 billion in 2007 of which £827m was in the upstream (manufacturing) and over £5 billion was in the downstream (applications and services). This gives a ratio of nearly six to one between the upstream and downstream. The study identified 123 'Pure Play' upstream companies with a total turnover of £710m, the top 17 of which account for 96% of the total. This indicates that the industry has a very large number of SMEs (more than 100 have a turnover of less than £1m).

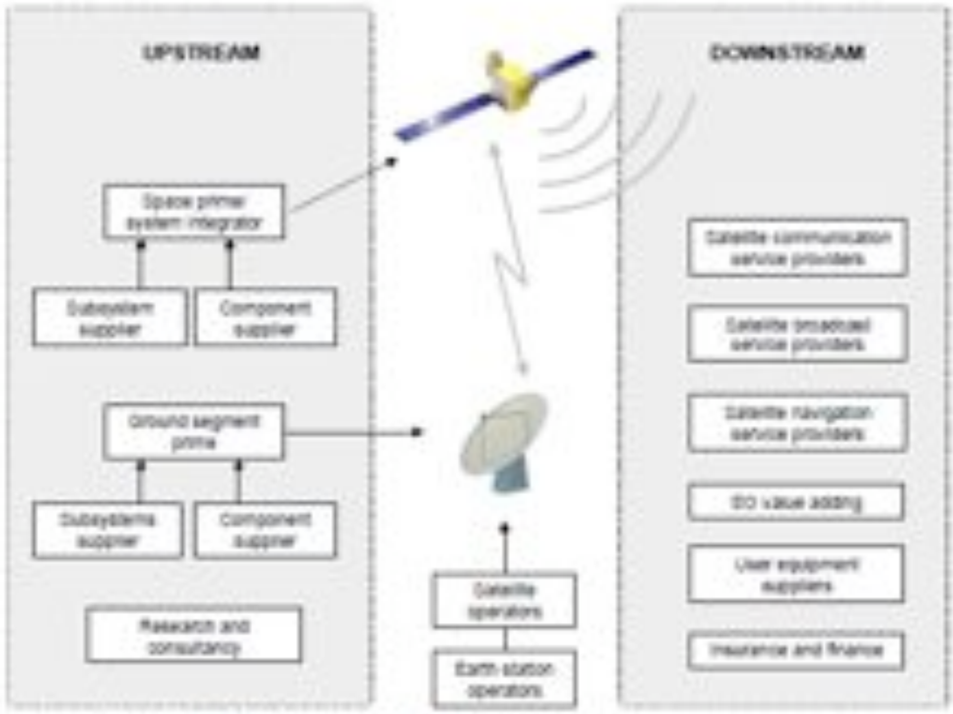
The only large Space company in the upstream totally dedicated to the Space business is Astrium. It used to be accompanied by Surrey Satellites but in 2008 this too become an independently operated part of the Astrium organisation.

The next largest Space companies are those that are neither pure Space or pure upstream and include Logica, QinetiQ, Rutherford and Appleton Laboratory, VEGA (now part of SELEX Systems Integration), Spirent, Thales, Vislink, SciSys, E2V and Comdev. This group accounts for 87% of the upstream turnover.

There are currently three satellite operators based in the UK: Inmarsat, Paradigm and Avanti. Inmarsat's history is included in history of satellite manufacturing above and here we shall add that the basic reasons that Inmarsat is London-based are that the IMO (International Maritime Organization) is London-based as a result of the UK's past lead in the maritime world and that the UK has actively encouraged Inmarsat to have its HQ in the UK.

Paradigm is a fairly new operator. It was formed to bid for the (PFI) service contract for the fifth generation (UK) Skynet military satellite communications system. This PFI was pioneering. A private company was to bid for the job of financing, procuring and operating a fleet of satellites. The UK Armed Forces would pay for satellite communications services just as if Skynet were a commercial satellite system.

The operator was permitted to sell unused capacity on the satellite commercially to the mutual benefit of both the MoD and Paradigm.



Source: Size and health of the UK space industry 2008

Paradigm is now becoming a casebook example of a successful PFI. It is financial model that could be easily copied in other areas of the Space market.

Avanti is an entrepreneurial SME making the transition to medium-sized company. From origins of delivering specialized services over leased satellite capacity, the company has succeeded in raising private finance to complement a small amount of ESA funding for advanced payload development. The company is now expecting to be an important provider of rural broadband services to the UK.

The downstream, although much larger in volume, has relatively fewer companies although it also has more large companies. The total turnover in 2007 was £4.8 billion of which one company, Sky, made up 71% by turnover and the top 10 companies made up 92%. The top 15 downstream players made up 99% of the turnover, the smallest of the 15 having a turnover of greater than £5 million, meaning that the downstream has a higher percentage of medium and large companies than the upstream. It is clear that the downstream is dominated by satellite communications, although with a growing role for the navigation-based downstream companies.

A new addition here that emerged in 2009 is Cambridge Silicon Radio, with their recent acquisition of US GPS chip designer SiRF Technologies (navigation-related turnover could exceed £200m in 2010). Earth observation currently trails telecommunications and navigation in significance. The first companies in the top 15 with an EO element are Infoterra in the commercial sector and Raytheon in the defence sector. The EO sector is currently at the bottom of the top 15 downstream companies but has significant growth prospects.

There is a significant trend of consolidation in the industry at all levels. Changes between the studies in 2006 and 2008 clearly show that although consolidation in the upstream was already well advanced, consolidation of service providers and operators is now also significant, with a number of UK companies passing into foreign hands.

Small companies with a turnover of less than £1 million (many of them with a turnover of less than £250K) are by far the most numerous but do not have a huge impact on the total figures for turnover or employment.

This portion of the sector is always difficult to characterise, including as it does many 'one-man bands' working as contractors in the industry, generally on long-term assignments with the major companies. However, there are also a number of start-up companies – some with high growth potential – actively seeking to commercialise new opportunities enabled by Space.

Image supplied by Astrium

Scientific excellence coupled with outstanding technical expertise means that UK institutes are "partners of choice" for missions developed in Europe, USA and Japan. We have major scientific and technical leadership roles on key forthcoming missions – the successor to Hubble (JWST), Gaia and ExoMars. A significant fraction of mission proposals to ESA Cosmic Visions Programme had either a UK Principle or co-Principal Investigator (PI). This current high standing is based upon investments over the past 20-30 years. Current investment is deemed to be below "critical mass" for the UK to retain its current position, particularly given investments being made in other countries.

This description of the Space industry in the UK begins to highlight some of its unique characteristics – even its major activities cross the boundaries of conventional industrial sectors. It certainly combines major activities in and around aerospace with those in the ICT sector. Indeed, no system of standard industrial classification – even the US system – provides fine enough detail to allow adequate economic characterisation of the Space industry. Moreover, as the inclusion of a publicly funded research centre like the Rutherford Appleton Laboratory in the list of major Space companies above clearly illustrates, the relationship between the academic and industry communities in Space is much more complicated than in other sectors. As in other sectors universities are a major source of new ideas, knowledge and highly skilled people for the Space industry. But, particularly where it depends on major investment in satellites, academic research is also a market for the industry, and - in many areas such as the production of new instruments and payloads – a competitor. The UK's most successful university spin-out in any sector – Surrey Satellites, now a part of Astrium – is eloquent token to this.

Currently, commercial communications satellite manufacturing and the non-commercial spacecraft manufacturing complement each other in a very desirable positive way. The satellite engineering skill base broadens its experience and opportunities by being active in both fields.

## Which Technologies Support Space Infrastructure?

The energy required to propel a body into orbit is so high that most of the mass of the launcher has to be propellant. Unlike aeroplanes, which are air breathing, a rocket carries its own oxygen. It took many years to develop the efficient engines to get a reasonably useful spacecraft into orbit. Even now, with mature expendable launcher technology little more than 2 to 3% percent of the mass of the vehicle on the launch pad reaches low earth orbit and around 1% into the higher transfer orbit where communications satellites begin their self propulsion using onboard fuel and small rocket engines to climb to geostationary height around

25,000 miles from the UK. For those spacecraft which travel into deep Space and visit other planets the journey can take many months.

This leads the industry to be very careful of its resources, operating very efficiently, pushing technologies and manufacturing capabilities to their limits to minimise mass and keep within the constraints of launch volume.

With no physical access for maintenance during operational life Space products and systems need to be rugged and reliable. Communications satellites in geostationary orbit are guaranteed to survive a life of 15 years. Space standard design and test approaches allow us to deliver highly reliable products by ensuring the capability of the product before it enters service. These tests include aspects like vibration and thermal environment and payload performance (including spares and flexibility to ensure planned and calculated graceful degradation over lifetime).

The manufacture of Space products is challenged by what most would consider extreme product requirements. Many issues like resource management, alternative energy sources and extreme environmental conditions (which are becoming important to our everyday life on earth) are already normal operating conditions for the Space industry. There are no plug sockets in Space so renewable energy sources are a necessity. Engineers had to learn how to construct batteries and fuel tanks that involve moving liquids in a state of weightlessness. The temperature of deep Space is -270 °C. Instruments on scientific missions are often kept constantly below -271°C. The Sun shield on the BepiColombo mission to Mercury will reach 350°C.

Spacecraft hardware is designed to be tolerant of the effects of radiation by using radiation hardened technology. Such severe radiation environments have affected us on earth and could be more prevalent in the future. In 1989 a solar flare brought down the power network for 6 million people in Quebec. Our power grids are not designed to resist such surges and will need to be strengthened.

For missions closer to the sun than Mercury conditions are simply too hot for solar arrays. Beyond Mars there is not enough solar flux to use solar arrays. Alternative ways of generating energy are constantly being explored for different missions.

One important fact about satellites is only just starting to command attention. In fact some of the first work on the subject by expert consultants has been performed during this Innovation and Growth report activity. Satellites provide low-carbon solutions to terrestrial problems! Once in orbit satellites need very little electrical power and since that is solar power this significantly reduces emissions of greenhouse gases here on Earth. The manufacture and launch of a satellite have only a modest carbon impact. Indeed the satellite launch produces less $CO_2$ than a transatlantic flight. Once in position the satellite does use a small amount of fuel but typically averages around 3 million miles to the gallon!

Many Space products are bespoke and specialist which is the case of many relatively young industrial sectors (when compared to aeronautics and automotive industries).
As business grows on the commercial applications higher production rates will cause the Space industry to push the boundaries of manufacturing capability. There are a number of disruptive manufacturing technologies which are likely to have strong application in the Space industry perhaps in advance of other industries. Multifunctional smart structures with embedded sensors for through-life monitoring, in orbit servicing requiring no human contact, additive layer manufacturing techniques where a simple component or a complex bespoke multifunction component can be made with the push of a button, are examples. Such technologies may also be major disruptors to current thinking on manufacturing costs and labour costs may no longer be a driving factor.

## How do we Organise Use of Space in the UK?

Since WWII there has been a strong and dependent relationship for the UK with the US. This has not been a one-sided relationship but Space, for the UK defence community, has been relegated in recent years to a matter of primary dependence on the US. The exception during the 80s and 90s has been continuing investment by both UK civil and Defence Departments in Satellite Telecommunications. UK MOD investment in direct R&D support underpinned the Defence-specific aspects of the Skynet IV Defence GEO Satellite Communications Capability, but by the early 90s the development of core antenna and payload capabilities had shifted to ESA where UK funding has been provided by DTI, now DBIS. However, along with the decision by MOD to pursue a PPP approach to Skynet V, UK satellite telecommunications support from government now lacks any R&D funding from MOD. DTI/DIUS/DBIS officials have sought in successive Comprehensive Spending Reviews to concentrate available funding purely on civil requirements.

For over twenty years, the UK has followed a philosophy of user-led partnership in its approach to Space. It was assumed that end results can be directly linked to individual groups of end users and ultimately single Departments, and that these should be responsible for the specification and funding of Space solutions. In this way, only the aspects of Space that were deemed by end users (those with the funds) as important to their goals would be supported, and technology push or prestige projects (launchers, manned spaceflight) would fall by the wayside. In practice, a degree of overlap has always been recognised, and the BNSC partnership exists to further consensus building for the betterment of exploitation of Space opportunities.

It has been shown in the Delivery of Public Policy from Space working group that space-derived data and services have the potential to contribute across many areas of the public sector. It is not surprising therefore that there is interaction among many stakeholders. This results in multiple interdependencies.

Centrally, the British National Space Centre is a partnership that co-ordinates UK civil Space interests. However the Devolved Administrations also have Space interests that are not particularly impacted by BNSC (or vice versa). Examples are the Welsh Assembly's use of satellite imagery for land-cover mapping (via the Countryside Council for Wales), and the Scottish Government's interest in satellite broadband for rural areas, and the potential of satellite measurements for environment monitoring.

At the regional level, some areas have set up initiatives that relate to space. Yorkshire Forward uses Space as one entry point for education in STEM (Science, Technology, Engineering and Maths) skills, while The East Midlands Development Agency (EMDA) has set up collaborative centres in satellite navigation (GRACE) and GMES (G-STEP). Some of the other RDAs (Regional Development Agencies) also have Space interests, partly due to industrial presence in their regions (SEEDA, EEDA and LDA).

Local government has no direct relationship with Space policy interests, but does nevertheless use space-derived data (GPS for buses, bins, and emergency services; weather data; imagery for urban planning and heat loss; air pollution warning etc.)

The main national Agencies that are users of Space in the UK are those associated with the MoD (Ministry of Defence) and Defra (Department for Environment, Food and Rural Affairs), plus some others like Ordnance Survey. However, for many activities, actual implementation at the local level is through a slightly different agency function – for instance, the separation between Highways Agency and District Council responsibilities for roads.

Both Galileo and GMES are European programmes of interest to more than one Department, with slightly different priorities: Galileo for DfT (Department for Transport), BIS (Business Innovation and Skills) and MoD and GMES for Defra, BIS, DECC (Department of Energy and Climate Change) and DfT. There are also new initiatives that are relevant to more than one Department: Space Situational Awareness (SSA) for MoD, BIS and HO (Home Office) and the satellite contribution to Digital Britain for BIS and DCMS (Department for Culture, Media and Sport).

The user-led model requires pull-through at the downstream level (which due to scale factors happens to be where the highest value to UK wealth resides). The upstream is an important enabler of the downstream but also can be the promoter of innovative ideas & applications on behalf of both. Sometimes this is perceived as pushing technology when in fact the whole sector is working together to provide solutions to delivery policy problems.

Government sets policy which requires evidence behind its creation. Some of this evidence can be best or only supplied by Space-derived data, and this may require investment in satellite infrastructure in order to deliver it. Delivery of policy creates requirements for services - some of which can be delivered by satellite applications. Policy may be directed at industry, to meet a Government need, or to optimise the wealth and standing of the UK.

Conversely, industry has commercial interests that may or may not be aligned with those of Government – R&D priorities, export licences, and the regulatory regime (launch licensing etc.) may all be affected.

Overall these multilayered interactions lead to interdependencies that are not always recognised; local government has to convert the aspirations of central government into actions and achievements, or to put it another way, the juggernaut of central policy often has to be interpreted and implemented at the smallest, local level.

Therefore, Space as a provider of data and services is not only cross-cutting, but is important at all levels and scales. However, the question of how the services are to be provided (back-end infrastructure) is rarely, if ever, feasible to deal with at the local level, but is handled at the national or international level. It then follows that there is the potential for a significant disconnect between understanding (and procurement, and funding) of the infrastructure and understanding (and adoption) of its daily use through data and services.

Overall, a direct consequence of the UK's approach to Space is that the set of capabilities in the hands of UK and other firms operating in the UK is fragmented.

## The Global Context

Space is international in many aspects and the UK has important opportunities through its membership of the European Space Agency (ESA). The UK routes most of its civil Space spend through ESA to achieve the scale benefits of aggregation at the European level; it is doubtful that major Space infrastructure such as Galileo or GMES would be approved by any European national Government acting alone. The UK is therefore engaged with ESA for proper oversight of setting priorities and of how the money is spent. Broadly speaking, most of ESA's work programme has historically been aimed at technology and the establishment of new Space capabilities - not all of which (launchers, manned spaceflight) the UK participates in.

The main core of ESA's programme is in Space Science and related under-pinning technologies where Member States contribute to a Mandatory budget at a level dependent upon their GDP.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The residual part of ESA's mission endeavours are organised as 'Optional' programmes where Member States may select whether or not to participate in major domains and individual projects. Whereas it must participate in the 'Mandatory' programme at a level of approx 16.5%, the UK's overall participation in ESA is approximately 9.5% as a consequence of its small (4.5%) contribution to ESA Optional programmes. This situation has remained steady for the last 20 years with the exception of a small increase last year. Since HMG decided not to enter the Ariane V launcher programme it has appeared to many European partners to be close to withdrawing altogether from Space. This common perception has created an atmosphere of uncertainty and encouraged ESA not to rely too heavily on the UK for important roles.

Enthusiasm for ESA's Mandatory programme has come – not surprisingly – from UK Space scientists, i.e. those supported by the UK's Science Technology and Facilities Research Council STFC.  As European, US and other International Science missions have become more ambitious, no government argues that Space Science can be pursued on a National basis. Typically, an ESA Space Science mission will require a budget of between 300m and 1Bn Euros over a period of 6 to 8 years. The ESA Space Science process is based on a broad collaboration between ESA – whose Member States fund the mission platform and ground segment - and lead Member States that fund the payload and instruments.

This can lead to perverse effects if a Member State funds through ESA one of its firms to act as the prime contractor, but does not fund on average sufficient national R&D to ensure that its firms are involved in the more noble work that is inherent in the challenging Science instruments.

The UK also is a member and contributor to the EU, which is taking on an increasing interest and role in Space programmes, both as procurer of infrastructure and incubator of applications to serve its own policy goals. The Lisbon Treaty gives the EU a much stronger mandate in Space and its spend will be on a par with ESA within 5 years, providing important competitive procurement opportunities for which UK industry needs to be prepared. Also of potential importance is the role of EDA (European Defence Agency) in developing European-level security solutions.

The UK has also taken part in bilateral projects with nations outside ESA / EC; mainly these have been related to Science programmes and they have dwindled to become a minor element in recent years due to available funding levels. At the international working level, there are agency to agency interactions, e.g. Interpol, UK and EU Environment Agencies, NATO, the UN, the ITU (International Telecommunication Union), ICAO (International Civil Aviation Organization), IMO (International Maritime Organization) etc.

As a superpower, the US strives for military dominance from Space and has publicly declared goals to achieve dominance in commercial markets. US Defence expenditure on Space plus that of NASA (approx $40Bn) is about 7 times that invested by European governments in ESA and Nationally.  The large home market created by Defence has for example underpinned the growth of US Telecommunication prime contractors (Boeing, Lockheed Martin and Loral), whose competitiveness in supply of satellite platform and payload to international satellite operators has resulted from access to Defence-funded equipments and platforms.

This National strength for the US would be a matter of serious market failure for European suppliers, were it not mitigated to some degree by the investment of France, Germany, Italy and the UK in ESA's Advanced Research and Telecommunications Systems Programme.

Russia is the dominant launch service provider today. Due to its insistence on a foreign policy initiative with ISS and a post Kennedy insistence on Shuttle, the US has diverted large amounts of its budget into areas that are costly and have helped Europe to compete elsewhere. Now that Shuttle is close to termination and ISS is past its spending peak, the UK needs to be aware that the US is likely to be a bigger competitive threat in the next 20 years that it has been in the last 20 years. Russia can continue to offer launch services, additional to Ariane and independent of the US and its obsession with ITAR.

Just before the release of this Innovation and Growth Report it has been acknowledged that the US National Geospatial-Intelligence Agency have contracted to buy data from all three commercial Earth Observation radar systems, with a cap of $85m on each. This can be seen as an intergovernmental arrangement with likely exchange of intelligence and favours as well as dollars. The UK dependency on the US in this area means that it is excluded from this deal and any political as well as economic benefits that ensue.

## UK Strengths and Weaknesses

It has been established that the UK Space Business is now wealth-creating and that this currently stems primarily from commercial satellite communications interests – both upstream and downstream. The industry is competitive globally. Why is this important? Well, as in many other technology areas, commercial markets have no constraints to buy from a particular country or region. Satellite operators will buy the cheapest credible compliant spacecraft.

Similar considerations apply for user equipment and ground station equipment. Customers of satellite operators, such as broadcasters, are mostly private companies. The supply chain is exposed to global competition and must be world class to survive.

Twenty years ago it was common to hear the opinion that European satellite manufacturers could not compete in the commercial satellite manufacturing market because US manufacturers such as Hughes (now Boeing) had the advantage of huge contracts with the DoD. The US taxpayer not only paid for the development of the technology but also placed multiple satellite contracts to kick start production. This view proved pessimistic as Europe made inroads into the commercial export market. At satellite manufacturing level UK success is achieved through European collaboration, a situation common in other high cost high-technology areas such as aircraft and missile manufacture. The approach remains at risk as evidenced by the US military satellite procurements such as Wide Band Gapfiller which have pushed advanced satellite technology including digital processed payloads into production products.

Astrium has developed, in collaboration with ESA, advanced payload technology recognised around the world. Its own digital processed payloads (developed without the benefits of a Wide Band Gapfiller order) provide Inmarsat with the ability to provide oil companies, broadcasters and others with global broadband capability from small terminals. Another of these advanced payloads will soon fly on a satellite named Hylas operated by a small start-up operator of rural broadband services, Avanti, also based in London.

In the past decade both Boeing and Lockheed Martin have chosen to concentrate their capacity on their considerable government work and are only now reactivating seriously their commercial interests.

In fact the strongest US competition for commercial satellites comes from Loral Space

Systems which has less DoD work but has benefited from debt restructuring after entering Chapter 11. OSC has emerged as a market leader at the small to medium class spacecraft.

### ... as in many other technology areas, commercial markets have no constraints to buy from a particular country or region

Surrey Satellite Technology Limited (SSTL) is pretty well unique in the world. It has its origins in Space research at Surrey University and developed small satellites that could be launched cheaply in spare capacity in launch vehicles like Ariane. SSTL found a steady market for these satellites for experiments and Space technology learning projects. Customers were often countries wishing to develop a Space capability. Since then SSTL has matured into an established manufacturer of small inexpensive satellites for navigation, Earth Observation, Science or communications. It was spun off from the University as a limited company and was recently bought by Astrium, part of EADS group.

The performance of the UK Space industry is similar to those of other Nations involved in ESA. Italy, for example, is a country of similar size to the UK with a similar size of Space upstream, around 950 million euros per annum. From this they generate a similar size of downstream. There are no exact figures for the downstream as the national Space agency surveys tend to focus on the upstream. However, in UK terms, they have a single DTH (Direct to Home) provider of similar size (also owned by Sky), a major teleport operator, a national military satellite system but no major satellite operator. They have been the leading proponent in Europe for satellite-delivered broadband and have a larger downstream EO activity. This indicates that the upstream to downstream multiplier is of the same order as the UK. The industry includes around 180 Space-related companies most of which are SMEs.

France has a much larger upstream sector, three times that of the UK, the increase being partly due to the significant launcher business based on Arianespace. Although the upstream is well characterised by CNES, the downstream is not so well understood. There are 221 SMEs that claim a connection with the Space business, both up and downstream. Beyond that, like the UK and Italy France has a single large DTH provider in CanalSat, it is home to a major satellite operator with Eutelsat, it has a much larger EO downstream and a larger navigation downstream through companies such as Thales. Satellite-delivered broadband is still developing. The overall indication is that the downstream in France is bigger than in the UK, but the ratio of upstream to downstream is lower in view of the larger Space upstream in France.

### Space is an industry which needs a long term view. It is based on risky early R&D and a high skilled workforce.

The Canadian Space Agency provides an annual survey of the Canadian Space Industry which indicates an upstream of £560m and a downstream of around £1.4 billion, a ratio under three to one. However, the downstream figures do not include DTH revenues. In 2008 there were two main DTH providers, Bell and Shaw Communications. DTH revenues for the two were around £1.5 billion, lifting the downstream to around six times the upstream figure, similar to the UK. A major difference is in the export performance of the Space industry, where Canadian exports a much higher proportion of its upstream manufacturing. MDA is a supplier and potential competitor to Astrium UK and already supplies antennas to spacecraft manufacturers including Astrium and has now sold its first payloads to Russia.

The European and Canadian industries are similar to the UK in the ratio of upstream and downstream performance, at around five or six to one.

North America and Europe enjoy improving communications based on a legacy fixed communications infrastructure but this is not typical of most of the world where such luxuries are reserved for major cities. In most countries the bulk of the population relies on terrestrial and satellite wireless infrastructure to connect islands of population far from the nearest core network. As a result the global Space market is on the verge of seeing several more applications markets go mainstream and global, just as TV and satellite navigation did in the 90s and in the previous decade. These include broadband direct to the user, cellular and internet backhaul, machine to machine communications, and surveillance and Earth observation. The UK plays a remarkable role in these super-high growth markets, quite disproportionate to the relative size of its economy. The reasons for this success can be laid squarely at the feet of the UK government which, over the last 20 years, made certain key decisions to concentrate its limited Optional ESA spend on ESA programmes with good return on investment.

Space is an industry which needs a long term view. It is based on risky early R&D and a high skilled workforce. The Case for Space (2007) showed that by government making strategic interventions in blue sky technology development, the UK industry can gain a crucial speed to market advantage which it then leverages with its commitment to technology commercialisation and its sophisticated finance industry. The world is changing, new Space nations are commoditising elements of Space with their low costs (India and China) but we are maintaining our lead by getting hi-tech developments to market early by marrying government hi-tech R&D funding with commercial and financial entrepreneurialism.

This is a successful model. But Space is a highly geopolitical industry, and without strong government support in regulation, national interest promotion, international co-operation and R&D it will wither under the onslaught of the developing Space nations.

The other advanced space-enabled economies are also hungry for non-financial industry growth and Space fits the bill. A little more focus, co-ordination and championship of industry from Government are required. An increase of the support for the blue sky R&D which industry finds difficult to finance can turn the UK's advantages into massive global leadership. Export earnings and taxation will ensue from Space and Space-enabled sectors which promise exponential growth in the near term.

The flow of wealth from manufacturing is complex. If one buys, in the UK, a mass-produced product for £100 that was "Made in China" then some money flows to the retailer, the UK tax man, the importer, the transporters, the product assembler, the components manufacturers, owners of Intellectual Property and others. The Chinese economy may see £5 or less of the £100 retail price.

Ownership of all forms of Intellectual Property is important for wealth generation.

In the case of satellite manufacturing the main "value" components are labour, parts and profit. The labour component is predominantly highly skilled labour (mostly university graduates). The "parts" are procured from all over the world but predominantly Europe and thus with a UK component. Space-qualified parts are made of high quality special materials and there is as yet no mass production whatsoever.

Satellites, satellite sub-systems, equipment, components and materials are produced in very small quantities and require much high-value labour time thus the industry makes a very high value-added contribution to the UK economy whenever work is carried out in the country. Unlike most mass-produced products there is a relatively small IPR-related component. Thus if a satellite costs $100M then the percentage of this attributable to patent royalties, franchises, brand ownership etc is very small.

In the downstream market then we find mass-produced products – such as set top boxes and satnav devices. UK industry is involved in many different aspects of the process thus seeing a slice of the value from a wide range of "space goods" manufacturing.

Improving wealth creation by the satellite industry is one of the principal concerns of this IGT. It should be increased by an overall growth in the turnover and also, particularly by increasing efforts in the downstream component, by improving the UK value-added return from IP and other high-value involvement in the value chain.

# 2.0 Market and Technology Directions

## Looking Forward from the 1980's

Some 20 to 30 years ago the home PC was starting to appear, the internet was largely unknown as indeed were Microsoft and Bill Gates. Word Processors had appeared for document preparation but there were several incompatible proprietary types and some clever software was needed to translate from one to another. Typing pools still had a few years of life left. The fax machine was rapidly making telex extinct. CDs had recently appeared and VHS tapes were popular but needed rewinding. The mobile phone was a large heavy unreliable device used by a few reluctant field workers. The UK fixed telephone revolution was starting: previously BT owned the phone in the home and enjoyed a monopoly. Mercury Communications had just appeared as a competitor. Cordless phones were virtually unheard of. TV consisted of 4 channels. The roads of towns and cities were about to be dug up to lay cable TV. High Street outlets were offering to develop photographs within the same day. The DARPANET (precursor to the world wide web) was used by a handful of specialists in academia and government to keep in touch with international collaborators, exchange emails, data and software.

A great deal has happened over the last twenty years, with a relentless swing from analogue to digital communications. Many of the advances are a consequence of the incredible improvements in semiconductor technology and mass production techniques. The real costs of digital processing and digital storage have plummeted.

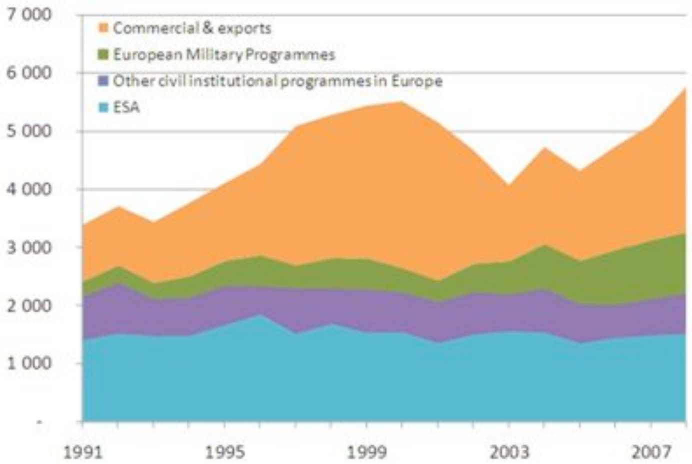
Most satellites were use to provide international communications for telephony and data exchange. They operated between very large earth stations such as Goonhilly and were supplanted in developed nations by fibre optic connections. Islands and less developed nations far from the fibre network still rely on this type of satellite link for their international communications today. The broadcast satellites of that period could carry a handful of analogue TV channels compared with hundreds of digital channels today. Those who suggested that every country would use satellite TV and that the world would need hundreds of TV satellites were ridiculed and quickly forgotten. Inmarsat offered a few tens of analogue channels for large ships compared with hundreds today. The earth station antennas were several metres in diameter compared with a 50cm TV dish or satellite handheld phone today.

Equally significant changes can be expected to appear over the next 20 years and some of these will not appear in today's market projections. It is important that we scan carefully for applications with potential even if they seem fanciful today.

## Overview of Published Market Projections

The Space market is a global business which is dominated by the Communications, Earth Observation, Space Science and navigation sectors and which, prior to the global recession grew in the UK at around 9 % per year, more than three times faster than the UK economy as a whole. The value of the global Space industry varies between analysts depending on how it is categorised. The World Space Report 2008 (from the independently funded Space Foundation) provides figures of international repute. The 2007 revenue figures are quoted as £25.72 billion for the upstream and £78.06 billion for the downstream. This would give a UK share of the market of 3.2% for the smaller upstream and just under 6.5% for the dominant downstream.

Within Europe the Space industry can also be viewed across the markets segments of Commercial, Institutional and Security and Defence (termed Military in the attributed source):




Space industry manufacturing sector sales by main programme customer (M€)
Source: ASD-Eurospace: Facts and figures: The European Space industry in 2008

The Eurospace figures show the strength of Europe especially in the commercial market, where a 40% share has been retained despite adverse exchange rate movements and increased competition for emerging powers such as China and India.


Industry sales for Institutional and commercial programmes (M€)
Source: ASD-Eurospace: Facts and figures: The European Space industry in 2008

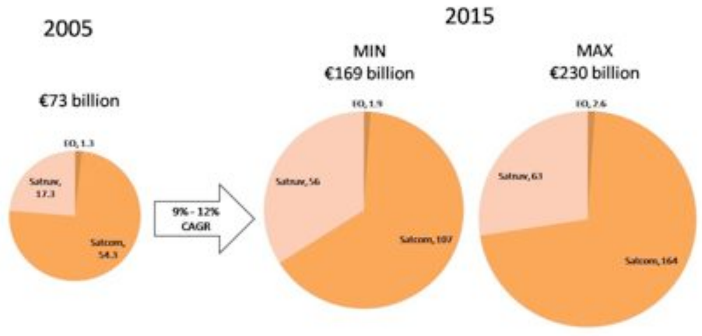
The Euroconsult Report from 2005 presents the further segregation of the three key downstream Space markets into a large number of Space derived services and applications.

The Eurospace figures show the sales against programme type and the current dominance in Europe of the telecoms and broadcasting industries is obvious.

However the growth in Earth Observation and Navigation derived services is also visible in this data and further highlighted in the forecasted global revenues in each sector growth presented by Euroconsult.

These three traditional Space services formed the basis for the downstream market growth projections in the Space economy and as such are useful to set the scene for the follow on sections which focus on special key future market growth areas.

Whilst not considered accessible here, one of the biggest Space markets is the US military satellite business. This includes not only communications satellites but also navigation satellites, spy satellites and monitoring satellites (such as those searching for signs of missile firings). The military satellite business does carry market access restrictions for reasons of national security.




**Space industry forecast global revenue by main programme type (M€)**
**Source: The downstream value-adding sectors of Space-based applications Industry Workshop 2007**

It should be noted that there are signs of the military market, including the US, beginning to be accessible to UK companies at equipment supplier level. This healthy trend is likely to continue.

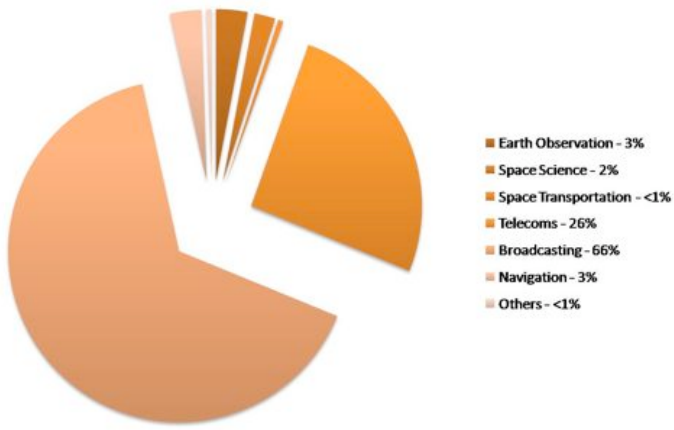
## Satellite Telecommunications

The Satellite Telecommunications market is the most mature of the downstream Space services and is expected to continue to deliver limited increased growth in the short to medium term based on existing services. The current market is dominated by video and split between programme contribution, programme distribution and programme broadcast. Satellite communications are essential to a functioning economy and are key in areas and for activities where terrestrial communications are sub-optimal. The offshore and aviation industries are key markets that will continue to require these services for the foreseeable future. In 2007 alone, the UK offshore industry spent £1.3 billion on exploration services which have satellite communications and for that matter Satellite navigation at the heart of their systems.

In the security and defence sector the requirement for efficient, reliable and secure satellite communications is imperative. Fixed communication satellite services contribute 95% of the downstream market with direct broadcast accounting for the majority of the revenue streams of the major operators.

In 2003 for example the leading 54 broadcast companies' revenues rose to $33 billion (Space 2030: Exploring the future of Space Applications. OECD 2004).

The UK is dominated by the Telecom and Broadcast sectors in terms of Space-related application focus as is illustrated below.




**UK Space turnover breakdown by application**
**Source: BNSC - Size and Health of the UK Space Industry**

The global market view presented by Euroconsult further shows the extent to which telecoms and broadcast revenues dominate the segment.

Direct boadcast services to mobile platforms (land, sea and air) and satellite broadband services are viewed as strong emerging applications. Increasing mobility in society and immediate needs for content and communication will drive these market areas in the future as transport costs increase and new flexible working models are employed to maximise company revenues.

Smart infrastructure and a hybrid use of terrestrial and satellite communications to provide a myriad of smart services to the home will also become prevalent in the next 10 years.

## Transponder Supply Trends

Global transponder demand continues to be dominated by pay-TV with more countries introducing their own satellite TV platforms and existing platforms contemplating new services based on digital PVRs (Personal Video Recorders) and HDTV. Growth in DTH transponder usage is supplemented by further broadcaster requirements for transponder leasing to support programme contribution and DTT (Digital Terrestrial Television) distribution networks.

Demand for satellite capacity for network services is fuelled both by high growth in military demand and also by rapid expansion in corporate networks. This growth does not increase transponder demand but offsets continuing decline in satellite use for PSTN (Public Switched Telephone Network) trunking.

The long-heralded direct to consumer growth is also now being realised based on pioneering US and Asian systems using dedicated multi spot beam satellites. These have achieved volumes of sales which have driven down User Terminal costs to appeal to consumer and corporate users alike. Whilst most often associated with broadband access, multiple spot beams are also used (especially in North America) for broadcast of local TV channels in high definition.

Investment in satellite capacity at a particular orbital location has to be complemented by installation of a large number of user terminals pointed at the chosen satellite. Once a user base has been established the video transponder market is then very stable. The broadcast service provider becomes a captive of the satellite operator with little opportunity to switch to an alternative platform. Fortunately, once large numbers of subscribers have been enrolled revenues should be sufficient to maintain priority and continuity of supply from the satellite operator.

In marked contrast the business plans of telecom customers are more sensitive to transponder costs and with a lower installed user base they can and do switch satellite operators.

Transponders are available for commercial use primarily in C band and Ku band but now increasingly in Ka band. Broadly Ku band is dominant in Europe and for video applications. C band has historical pre-eminence for trunking applications. The decline of voice trunking has led to a steady erosion of the C-band transponder market, though it remains strong in high precipitation regions such as SE Asia.

With a few historical exceptions and some transponders aimed at bringing the new spectrum into use to satisfy the ITU, Ka band is now being exploited for broadband primarily through multi spot beam systems.

Transponder fill rates have averaged around 70% over the past few years. There is some evidence that fill rates will continue to increase, creating local shortages depending on world events. Operators and their owners will continue to seek economies through more efficient usage of their fleets.

Transponder prices are determined by supply and demand, but not all transponders are valued equally. Operators continue to add value to their own transponders through service provision and wholesale prices depend on lease term and coverage or performance parameters. The average annual transponder price is about 1.65M$. Strong regional variability is observed with Western European prices double the average and SE Asia just over two thirds of the average. This probably reflects the high share of video (and restricted number of operators) in Western Europe and smaller share (with larger supply base) in SE Asia.

Contracts with broadcasters (who need stability, availability and capacity for growth at a particular orbital location) tend to be longer term than with telcos. As a result a satellite operator's backlog may be completely dominated by video applications.

Looking forward, several drivers for future growth can be identified. New TV platforms will continue to be introduced and existing ones will increase the number of their channels. HDTV by satellite will grow to differentiate the satellite offer from bandwidth restricted Digital Terrestrial Television (DTT). This on its own could double the global demand for satellite transponders. Terrestrial broadcast networks will increasingly demand satellite distribution to head ends. US' military and government demand for commercial satellite capacity around the globe will likely be mimicked at smaller scale by other nations. The low affordability and availability of terrestrial backbone in areas such as sub-Saharan Africa will continue to grow demand for IP and cellular backhaul by satellite.

Whilst Ka band will provide an alternative where deployed, it is likely that corporate and government networks will continue to make use of available slots and ground networks in C band. Since moisture in the atmosphere attenuates higher (Ka band) frequencies much more than lower (C band) frequencies C Band is especially important for reliable networks for developing countries in high rainfall regions. To take advantage of low costs associated with DOCSIS (Data Over Cable Service Interface Specification) and DVB-S/DVB RCS (Digital Video Broadcasting – Satellite/Digital Video Broadcasting Return Channel via Satellite) standards this may well require upgrade of satellite C band capacity to include multi spot beam systems. Continued resolve will be necessary to counter C band spectral pressures from the terrestrial wireless community.

Approximately 70% of transponder revenues are in the hands of five large operators. The regional strategies of these operators (including Merger & Acquisition) will have a strong influence on local transponder supply and price. Intelsat is the largest Fixed Satellite Service (FSS) supplier around the globe but will have its infrastructure investment concentrated on the most lucrative areas by its owners. This raises questions as to the availability and price of transponders to meet future demands for high added value (societal as well as commercial) government and corporate networks.

The five large operators have good economies of scale and are able to rationalise sparing and procurement strategies. They are greatly outnumbered by smaller niche service, regional or even national operators, especially in Asia and the Middle East, all of whom form potential targets for further acquisitions by the big five. New entrants continue to join the ranks of the small players.

Satellite operators have high Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) at around 70% because of their low operational costs which are not strongly dependent on size. Depreciation is high, leaving Earnings Before Interest and Taxes (EBIT) at 30% or so. Increasingly the large operators have high debt, leaving profit margin in the 10 to 20% region depending on size and debt burden.

The main operator trends over the last 5 years have been a reduction in capital expenditure, increase in fill factors and stabilisation or local increase in lease costs. These trends encourage continuing horizontal integration and consolidation.

The search for new revenues has stimulated some vertical integration with services a minor but growing feature of the operator portfolio. The EBITDA of the satellite service sector is at the high end of the wider service market, but significantly lower than traditional operators' wholesale business.

The United States remains the world's largest market for direct to user satellite services with not only TV but also radio broadcast exceeding 10 million subscribers.

The new success of the Ka band multi spot beam satellites using DOCSIS proprietary standards through vertically integrated operators (most recently Viasat) heralds a significant new growth factor which will be closely monitored by the larger satellite operators. With large capital demands, both on the ground in order to establish a user base and in dedicated Space assets, these ventures require many years to reach break even.

The use of multi spot beam technology enables the service provider to dramatically reduce costs and increase capacity compared to the traditional wholesale transponder suppliers. The Viasat 1 satellite will have around 70Gbps capacity. This single satellite will increase the in orbit data capacity of the entire world FSS and BSS (Broadcast satellite Service) fleets by approximately 10%.

As user numbers grow for the multi spot beam systems small user terminals will fall in price and outperform today's legacy Very Small Aperture Terminals (VSATs). This will have dramatic consequences for services provided over traditional transponders in C and Ku band as some corporate and government users are attracted to the low costs of the user equipment and the low lease costs where this alternative capacity is available.

A large capex investment is required to make multi spot beam capacity available over a wide area. In different parts of the world the selection of frequency for provision of this capacity direct may vary. The obvious exception to the Ka band trend is iPStar which operates Ku band spot beams over Asia. This reflects the perceived high sensitivity to rainfall of Ka band systems and importance of availability to Asian customers.

## Positioning, Navigation and Timing

Growth in positioning and navigation services has increased rapidly from 2001 onwards. This can be directly linked to the US DOD decision to disable the GPS selective availability feature in 2000, hence allowing users access to more accurate location information. GPS has established a strong downstream market with a predicted market in hardware and services of $41 Billion by 2010 (Space 2030: Exploring the future of Space Applications (OECD 2004)).

The DfT has recently (June 2009) released a comprehensive report 'Galileo Downstream Service Applications' by Helios and PA Group. Whilst GNSS is used for a multitude of applications that grow in complexity and diversity on a daily basis, DfT identified eight target areas, as listed below. These represented either the largest existing GNSS markets or those with the potential for largest growth markets, and were also the subject of potential regulatory interest by the European Commission (EC):

- Location-based Services (LBS)
- Road Pricing/Road User Charging (RUC)
- Emergency Services
- Regulatory Enforcement
- Freight and Logistics
- Rail
- Maritime
- Advanced Driver Assistance Systems (ADAS).

Positioning information will be pervasive in every mobile device.  There will be a demand for greater accuracy and extension to use indoors and in transport network and logistics. There will be miniature tracking devices in

various sizes and forms on most items, assets, people and animals (domestic or wild) throughout the world either in transit or in warehouse or naturally mobile.  There will be a proliferation of services associated with locating and tracking items, people and animals of interest.

There will important applications to improve safety in the transport networks for collision avoidance and closer running of assets leading to improved fuel efficiency and reduced delays. Greater use of vehicle automation and control, and high accuracy, high integrity safety critical guidance will be required in real time - necessitating very fast relay and position processing capability.

There will be greater automation of personal guidance and navigation solutions integrated into a wide range of applications to improve public life.  Health care will be improved, persons can be tracked and security improved by the ability to know where things are at any point in time.

In Western Europe 14.4 million Personal Navigation Devices (PNDs) were sold in 2007, up from 7.8 million in 2006, although analysts are predicting that this rate of growth is not sustainable and will reduce to a few percent over the next four years.

## Earth Observation

It is generally agreed that there is an increasing market for Earth Observation (EO) data, and that the sector will start to achieve commercial viability as the costs of the collection systems decrease and the number of applications for the data increase. Multiple-use systems supplied under direct commercial or PPP (Public Private Partnership) service provision arrangements are expected to become increasingly common.

Globally, the public investment in EO equated to $6.7B in 2008, with GMES alone representing a greater than €2B investment in Europe. There are expected to be 250 EO-related launches between 2009 and 2018, up from 128 during the previous decade. These are divided between the institutional systems at 36%, private satellite operators at 19% and export nation satellites at 34% with 17% being for Space ‘emerging’ nations. The Institutional market share over the same period will halve, from 77% (1997-2006) to 36%. Nevertheless, the launch of ~60 new Institutional EO satellites globally between 2007 and 2016 is seen as providing a large and stable market rather than a growth market.

The trends in the EO market to 2017 are likely to be for greatest growth in data sales at 15% CAGR (Compound Annual Growth Rate), the lowest growth in satellite manufacture and launch revenues (despite 250 new satellites) at 1.2% CAGR and modest growth in EO value-added services at 8% CAGR. Data sales globally are expected to have jumped 33% in 2009 alone, to $1.2B (up from ~$200M in 2000).

An assessment undertaken by the UKspace Earth observation group in 2008 identified the likely top markets for EO in the UK over the next 10 years to be: Value-Added Services, particularly in Security (civil & environmental);export, for niche  satellites and emerging Space nations; and commercial operators, for the mass market, e.g. ‘Google’ satellites & new services based on location-based services.

## Technology Directions

Example Technology Road Maps have been prepared within this IGT and their overall visions are available in Volume 3 along with draft and illustrative roadmaps in Volume 4 of this report. The objective of technology road mapping is to provide a clear and concise means to capture the strategic requirements identifying threats, opportunities, drivers, priorities and providing a uniform method to communicate these to a wider stakeholder community. Roadmaps are living documents and will evolve to take into account the influence of factors such as disruptive technologies and changes to the market.

The road mapping activities identified within this document can only be considered as a starting point based on UK capabilities and are hence draft and illustrative in nature. It is essential that a process commences post IGT to create and maintain a series of roadmaps which are aligned to a National Space Technology Strategy and are acknowledged by the UK Space community. The road-mapping exercise should involve Government, Industry, Research Councils and the Science Community. It is considered that the process adopted by the National Aerospace Technology Strategy (NATS) Technology Roadmaps provides a good model through which to start the mapping activity.

Derived from the Technology Strategy, the objective of the technology roadmaps is to show the key linkages between technology investment, products and the high level UK objectives or "market pull", demonstrating the exploitation paths and economic return to the UK. In a conventional commercial market these linkages provide a direct path to exploitation and economic return.

The technology strategy and roadmaps together will provide a focus for UK investment in infrastructure technologies and achieving the significant economic and public good benefits within this complex framework.

The technology base for exploiting Space is very broad and it is likely that the UK does not have the resources available to undertake all the developments for which it has the capability and for which there are commercial and scientific opportunities; choices are necessary to avoid a piecemeal approach and to establish a cohesive strategy that responds to the identified drivers and achieving the UK Vision. Key technology themes have been selected within this IGT activity which can be considered as a starting point for the creation of a set of strategic roadmaps for the Space industry.

In support of ever increasing consumer expectations for Super Fast Broadband and in support of the Digital Britain implementation phase there is a need for ongoing improvements in the cost of capacity. To make satellite-based services a core component of the UK's broadband offering and to keep pace with these expectations, this will demand implementation of improved technology to increase the capacity of the most capable telecom satellites by a factor of 10 every 10 years with a corresponding fall in capacity unit cost by a factor of 10 in each decade. This will be achieved through technology developments in payload, antennas and platforms to increase the available capacity and thus enabling innovative new services. The costs can also be expected to fall in line with the volume effect on both satellites and user modems.

These developments would need to be demonstrated through telecom flight programmes with a nationally supported T&D flight mission every five years either as a national development program or through ESA providing satellites or payloads for technology demonstration or at pre-operational or operational level. Missions could be funded through a PPP approach with very attractive lever effects, or be purely institutional.

## Telecommunications - High Throughput Satellites:

We have seen in the market discussion that the price of satellite capacity needs to continue to reduce rapidly with time, and we envision that this will be achieved through very high capacity satellites for NGA broadband, broadcast and fixed-satellite applications. Key performance measures are monthly costs (per bit or Hz) and lowering these will be a significant step forward in creating new services and applications of societal as well as economic benefit. Since satellites are solar powered they create an environmentally friendly solution with reliability of service achieved through on-orbit constellations and dual- or triple-feed dishes.

The UK is well placed through its background and experience in processed multi spot beam payloads as demonstrated in the Ka-Sat large multi spot beam payload nearing completion for Eutelsat, its generic Flexible Payload technology, advanced antennas and spacecraft platform heritage.

The initial target should be a 2015 Flight Mission with a flexible 100Gb/s capacity telecom satellite payload. This would allow flight demonstration of broadband next generation processor technology for channelisation, routeing and beam hopping (currently being developed in the UK with ARTES support). This would also allow the first flight of a large UK Ka-Band multi spot beam antenna and would use flexible payload frequency converter technology.

A demonstration mission either as a dedicated small-sat or a piggy-back payload on a large commercial communications satellite would prepare the way for a 2020 Flight Mission offering an even higher capacity (1 Terabit/s) satellite platform with regenerative on-board processing, routeing and caching and active array-fed large reflector antennas for high performance to small and mobile terminals.

This would allow a 2025 Flight Mission of a Very High Throughput (1Petabit/s) Satellite platform and a flight opportunity for a new high capability telecommunications satellite platform mechanically, electrically and thermally optimised for very high capacity payloads.

## Telecommunications - Mobile Satellites:

The aim is to implement a multispectral mobile satellite and system infrastructure for commercial, institutional and aeronautical applications (geomobile, security, broadband, ATM).

The UK's background and experience is centred on its London-based World-leading mobile satellite operator and the UK-based World-leading manufacturer of geomobile communications satellites and processed multi spot beam payloads.

The target would be the Next Generation Mobile Communications services requiring a very large platform and extremely large deployable antennas and feed structures. The services are required in the aeronautical sector for air traffic management, broadband communications to aircraft and real-time streaming of flight recorder data.

Image supplied by Inmarsat

Land-based services would include future high frequency mobile and multimedia services in multiple bands (UHF, L- Band, S-Band, C-Band and beyond). An auxiliary terrestrial overlay network would ensure connectivity and provide seamless reliable communications to handsets in cluttered environments.

Disaster and emergency support would include an overlay service that provides connections to essential users and services through their normal handsets in event of the failure of the terrestrial infrastructure.

## Telecommunications - small satellites

ESA has published historical data on trends in launch mass of commercial GEO satellites. The distribution is shown in Figure 3.1.

This shows clearly a trend to medium and large satellites as technology and launch-vehicle performance has improved. It has been argued [Dunbar] that this trend is dependent on competition in the launcher market as it follows the capability of the second or third most capable launch vehicle.

A large platform is able to support a wider range of mission types enabling new services requiring very high power (such as radio broadcast) or large antennas to increase bandwidth through frequency reuse. For standard missions the advantages of a large platform are primarily economic. The cost of some important elements of a platform is only slightly sensitive to its size. A small propellant tank cost much the same as a large one. The avionics and data handling is broadly common to all sizes. Project management and test costs are also insensitive to platform size. The main exceptions to this are the payload and power subsystems, both of which grow with size but both of these contribute to the revenue earning capacity of the satellite. Therefore, the capital cost per transponder normally decreases with platform size.

Consolidation through acquisition and merger has been the major growth vehicle of the more ambitious satellite operators such as SES. With large fleets and steady replacement needs the major operators have found it to be more cost effective to combine capacity from multiple older satellites onto a single, larger replacement satellite.

It will be noticed, however, that the smallest spacecraft launched year has remained fairly flat at just over 1 tonne. There are a number of different explanations for this persistent market for small spacecraft which point to a continuing demand into the future.

Smaller spacecraft are fundamentally lower cost than large ones and new technology and methods maintains. Provided that they have the capability to support the mission they can be attractive to existing operators entering a new market or frequency band or to new operators starting from scratch. In both of these cases the business plan is dependent on growing a subscriber base on an owned asset as an alternative to leasing capacity on the open market.

Civilian and military government agencies procure small satellites because of limited mission requirements and budget constraints. They may also be encouraging domestic capabilities and training which are more compatible with small satellites.

## Opportunities Identified for Accelerated Growth

A key development in the coming decades will be the ever increasing degree of organization of information by knowledge-based industries. This applies to information aimed at or wanted by an individual. More importantly, it applies also to the use of information gathered from many (millions of) sources across the nation to try to make our infrastructure operate more efficiently even when it is under stress.

It is in the latter that Space solutions have an important role to play as they provide ubiquitous coverage allowing information from any fixed or mobile asset to be collected centrally, processed and then forwarded to those that need it. Examples range across the natural and built environment.

The weather forecasting is an example as it requires complex software to model the evolution of the atmosphere but depends on access to previous and current data to define the starting point of the model. Another example might be the collection of rainfall data to feed a model of a river basin to predict flooding and marshal resources to prevent or mitigate the effects of flooding. A further example might be the collection of traffic data (and perhaps route requests from a satnav) to predict the build up of traffic on the road network and suggest alternatives to some drivers to mitigate the effects of congestion and minimise journey times.

Reducing peak electricity demand in a post-carbon economy is another example where the system to do this is useful nationally but also high in added value and exportable to other countries.

The present deluge of information will slowly evolve to a more organized approach using intelligent (smart) systems to personalize and filter information for an individual. The development of the smart software/hardware solutions for the individual and for the optimisation of the performance of our national infrastructures will become a key source of Intellectual Property Rights (IPR) and a generator of wealth on top of the UK societal benefits which will accrue.

Another important factor will be the electronic delivery of public services, so we must ensure that all UK citizens have access to them. Satellites can provide the universal coverage immediately and nationwide rather than have citizens waiting for 10 to 15 years for fibre to reach them.

Satellites' wide-area coverage and flexibility make them ideal for delivering these types of services, which add huge value but use only a little satellite capacity, and so represent little interest to large operators. They require major investment in ground infrastructure, central processing and software, which typically and generally needs to be provided by a large, trusted system integrator and service provider.

In 2030 satellite signals will be communicating with everything of value. That includes homes, mobile phones and vehicles - not to mention critical infrastructures such as the National Grid. The satellites are safely located, thousands of miles away, out of sight and out of mind. The signals are invisible but deliver TV content, navigation signals or collect data from millions of terminals around the country. Modern satellite antennas are small and inconspicuous. The aerial used by a satnav device is small and hidden away inside a small box or phone. The user equipment is mass produced and affordable to all. The ordinary man in the street will make use of satellite signals throughout the day without noticing.

## Extending High Speed Broadband to Rural Communities

Satellite communications are already providing high-speed broadband. A typical customer is someone unable to get the DSL (Digital Subscriber Line) service promised because the house is too far from the exchange.

It must be stressed that satellite communications do not currently have the capacity to be a platform for broadband for all UK homes in major towns and cities. However, extending wired, mobile or fibre optic based solutions out to all rural areas in the country is prohibitively expensive. Having satellite pick up the most rural areas with terrestrial technologies serving the majority provides the lowest cost solution for the UK overall and ensures that those living in rural areas do not have to lag behind their urban counterparts.

## Delivering TV

Satellite TV is well established. Everyone is familiar with the sight of a dish.

We all expect this to remain true in 20 years time. Importantly, Satellite TV broadcast to the home is the greenest (lowest carbon) means of delivery. Furthermore satellites can deliver the range of HD programmes that a population that has invested in HD-ready sets deserves. Terrestrial broadcast has insufficient spectrum to deliver consumers' current expectations let alone provide them with 3DTV (as planned by Sky) or Super High Vision at 300 frames per second to 100 inch screens (to be demonstrated by the BBC during the London Olympics).

It is relatively easy to use green satellite broadcast to deliver a service very close to unrestricted VoD (Video on Demand). The envisaged satellite approach is low carbon in nature. If ten million households were to watch VoD in High Definition over DSL Analysys Mason has shown (study for Ofcom) that this will drive the size of the country's core telecommunications networks. This IGT calculates that the increased power requirement to drive this enhanced internet exceeds 1GW. In carbon terms the family decision to adopt HDTV viewing over the internet would be worse than running an extra BMW X6 diesel automatic.

## M2M Communications

One new area that will burst onto the scene in this timeframe is that of two-way low data rate wide area secure communications. This involves data exchange between machines (computers, if you prefer). This type of communications is usually given the name "M2M" for "Machine to Machine". Satellite M2M comes into its own when the area to be covered is large - the whole UK for instance – and the data rates are typically a few bits per second. It is expected that several nationwide M2M systems will appear in the coming years – driven primarily by the need for energy efficiency. M2M communications are essential to allow effective monitoring and control of large energy-using systems.

In the shorter term the most obvious M2M application is 'Smart Metering'. A small fraction of the capacity of a single satellite can provide the communications needed to and from every electricity and gas meter in the UK. Short-range radio communications connect the meter – typically buried in a cupboard - to a small outdoor box which provides the link with the satellite. The outdoor unit even runs on solar power with no connection to the mains. The satellite is already in orbit. With a single Smart Meter communications system for the whole country, the satellite approach is the cheapest overall solution.

In the mid term (10 years) the same system will be used to monitor the future Smart Grid - the evolution of the National Grid. To minimize energy losses – currently substantial – an advanced monitoring and control system is needed. Its nationwide and low data rate so the Smart Meter system is a perfect solution. The same is true of other wide area networks or transmission systems such as gas distribution and water supplies.

## Smart Transport Systems

Transport constitutes about 9% of the UK's total energy usage. It is a prime sector for improvement in carbon footprint. Our vision is one where greener (ideally electric) fuels and smarter control can improve efficiency with little or no reduction in personal mobility.

The EU is sponsoring R&D towards a new Air Traffic Management (ATM) system. ATM frequently suffers delays which often result in aircraft having to fly further and therefore use more fuel. The fact that ATM routes are not always the most direct also leads to increased fuel burn. The new concept envisages satellite communications playing an important role in the provision of voice and data services when terrestrial communications links are unavailable (as was the case for the Air France Airbus 330 which crashed on 1 June 2009 en route from Rio de Janeiro to Paris). In addition, the use of satellite navigation will be much more robust in future as the GPS constellation is supplemented by additional independent satellites such as Galileo. This improved positional awareness combined with the automatic reporting of the plane's position to the ATM centre, will further improve an already excellent safety record and allow more efficient and safer spacing of aircraft right up to approach and landing with minimal holding time. The cautious nature of progress in safety critical applications such as ATM cannot be an excuse for delay where real safety improvements are now feasible by taking advantage of satellite capabilities. In order to prepare the UK for Phase 2 and 3 of the SESAR project DfT will need to ensure that the privatised NATS has access to sufficient revenue to implement the required systems.

The use of satellite navigation and satellite data services will lead to improved maritime safety, less congestion in narrow waterways and better security through better knowledge of the movement of people and goods at sea. There is current funding available to support terrestrial navigation aids such as Loran C and light houses, light ships and buoys.

As Galileo becomes operational and supplements GPS there is an opportunity to review the overall funding for maritime navigation aids including the deployment of Galileo pseudolights (acting as additional reference points for the receivers) around key coastal infrastructure including ports.

Satellite navigation and satellite data services can form a useful component of the future rail infrastructure. It is evident that increased use of electric rail services is desirable to reduce the carbon footprint; it is also evident that the current capacity of the rail network is difficult to increase unless trains run closer together at approximately the same speed.

Satellite services (navigation and M2M data) will have a major impact on road users over the next two decades. Car design can be expected to be dominated by energy concerns. The number of electric cars is expected to increase leading to needs for sophisticated systems to optimize the charging and discharging of batteries.

The use of satellite M2M together with satellite navigation provides the core of an excellent Traffic Information System (TIS). The beauty of a satellite TIS lies firstly in its ease of collecting detailed real time data of traffic movements and secondly in its ease at broadcasting traffic flow rate deviations nationwide. It is all done M2M – no spoken messages needed.

The advantages are many. Fuel savings help the green agenda; the reduction of time lost to jams improves national productivity. Advanced in-car navigation reduces the number of lost drivers. The satellite M2M approach can also be applicable as a simple extension of the TIS described above. In fact the desirable TIS could be used as a sweetener to the less popular road charging scheme and could facilitate privatisation of the road network.

The DfT strategy to reduce congestion on the roads is split into local and national initiatives. At local level Local Authorities are being encouraged to introduce demonstrator or operational systems to charge drivers who wish to enter congested areas. At national level the Highways Agency faces the biggest projected growth of traffic on its motorway and trunk road network.  Current plans consist of a continuation of increasingly expensive road widening at major safety and congestion black spots, an increased use of hard shoulders for traffic and an increasing use of data on junction-to-junction traffic speed. Data is collected anonymously from terrestrial detectors and conveyed to processing centres to analyse the performance of the network in terms of minutes of delay per ten mile section. This data is collected slowly and it appears that no attempt has been made to use the data to provide real-time control. It is used to provide information to electronic displays. There has been no attempt to utilise satellite capacity for the M2M network but substantial investment has occurred in fibre links, which mix data and video.

## High Profile Exploration of Near Space

A Vision of the next 20 years in “Space” would be incomplete without further exploration of the Moon, Mars and beyond.

2009 saw the 40th anniversary of the US Apollo mission to the moon. It attracted a lot of attention. The world was nearly unanimous in acclaiming the project as one of man’s finest technical achievements.

In the current economic climate and with the challenge to provide clean abundant energy on earth, the circumstances are not right in 2010 for major manned missions and efforts need to concentrate on paving the way through robotic missions, studies and technology development. There are many such opportunities within the ESA programme and for the UK to develop novel and complementary missions outside of ESA either as national missions or in partnership with other agencies.  Such national missions would enable the UK to perform world-class Science and develop new technologies and capabilities for use in future markets and provide inspiration for both STEM and the public. An example here is the UK is one of the leaders of the ESA Aurora programme and has developed a high degree of competency and leadership in many areas of exploration technology especially autonomous robotics, instrumentation and sensors which has been shown via the recent BNSC study to offer a potential large economic return given further investment. Another area is of course Earth Observation where Science missions could enable the UK to increase the accuracy of climate change models by monitoring key model parameters and lead to operational and commercial systems in the mid-term.

Circumstances can change dramatically over 20 years and such manned missions might be initiated. The Space industry in the UK could play a major role in a suitable partnership and the world’s Space technology and other required capability should be prepared and up to the job.

## Reusable Launch Vehicle Opportunities

Since all Space systems require access to Space this section addresses the status, outlook and trends of the launch market for commercial Geo-synchronous (GEO) communication satellites and to a lesser extent the market for Low Earth Orbit (LEO), Medium Earth Orbit (MEO) and military and government satellites.

The launch market for commercial communications satellites can be divided in four segments according to the satellite separation mass which can be injected into a standard Geo-synchronous Transfer Orbit (GTO): below 2500 Kg (Light Lift Capability), between 2500 Kg and 4200 Kg (Medium Lift Capability), between 4200 Kg and 5400 K (Medium/Heavy Lift Capability) and above 5400 Kg (Heavy Lift Capability). Each of these segments is served by a number of established Launch Services Providers using launch vehicles with differing heritage and track records. As one would expect, new entrants are currently focusing on the Light Lift and Medium Lift segments of the market, but with aspirations and plans to serve the a wider range of the market.

Data from sources including the 2009 Commercial Space Transportation Forecast, the FAA Commercial Space Transportation (AST), the Commercial Space Transportation Committee (COMSTAC), May 2009, and from the Euroconsult 2009 World Market survey, show that the market for commercial satellites has remained steady over the last two decades. From 1994 to 2008, an average of 20 commercial GEO satellites across all segments, has been deployed in orbit per year. The market is expected to remain steady at the same level with around 20 commercial launches per year for the next 10 years.

Deployment in orbit of relatively large commercial satellites with separation mass in excess of 5400 Kg, requiring heavy lift capability, is a relatively new market, which started around the year 2000 and has seen an average of five satellites launched each year in the period 2004 to 2009.

Satellites in this class are based on large platforms and particularly suited for Mobile Satellite Services (MSS) such as those delivered by Inmarsat. A few commercial launches requiring very high lifting capabilities such as those provided by Ariane 5 single launches have also occurred.

As of end 2009, the international commercial launch services market is served by several players, International Launch Services (ILS), Arianespace, Sea Launch, Lockheed Martin Commercial Launch Services (LMCLS), Boeing Launch Services (BLS), China Great Wall Industry Corporation (CGWIC) and Mitsubishi Heavy Industries (MHI).

ILS provides launch services capabilities on a Proton launch vehicle from the Baikonur Cosmodrome in Kazakhstan. Proton is ideally suited for the "heavy" segment of the market. Arianespace provides launch capabilities on Ariane 5 (Heavy Lift), Soyuz (Medium Lift) and Vega (Light Lift) launch vehicles, from the Kourou Space Centre in French Guiana. Arianespace's line up of launch vehicles can serve effectively the entire spectrum of GTO injection mass from below 2500 Kg up nearly 9 metric tonnes with dedicated Ariane 5 ECA launches.

Sea Launch provides launch services from a converted oil rig platform from the equator in the Pacific Ocean and from Baikonur in Kazakhstan using a Ukrainian/Russian built Zenit launch vehicle. Sea Launch filed for bankruptcy protection in 2009 and is currently undergoing reorganization. LMCLS and Boeing Launch Services provide launch capabilities on the Atlas and Delta launch vehicles from both Cape Canaveral Air Force Base and Vandenberg Air Force Base in the United States.

Partnership between European and Russian companies, STARSEM and EUROCKOT, are alternatives for the light- and medium-lift capabilities of the expendable market by offering services with the long-established Soyuz and Rockot - based on a Long-Range Ballistic Missile launch vehicle.

The latest and most interesting entrant to the launch service market is undoubtedly SpaceX, a California based company set to take the market by storm by providing low price, high-reliability, expendable launch vehicles. Their line up of vehicles includes Falcon 1 for light lift into GTO to Falcon 9 for injecting up to 4000 kg into GTO. SpaceX is the only company brave enough to advertise their prices on an internet site. They are selling their Falcon 9, still in development phase, at around $50 million, which is significantly less than their competitors. SpaceX have ambitions for a heavy-lift vehicle based on three Falcon 9s strapped together. SpaceX has an impressive launch manifest of 21 launches in the 2010 to 2015 period for their Falcon 9 mostly based on NASA launches but including three commercial launches.

Antrix, the commercial wing of the Indian Space Research Organisation, offers the expendable Geosynchronous Space Launch Vehicle (GSLV), which is an improved version of their earlier less powerful Polar Satellite Launch Vehicle (PSLV). GSLV can deliver up to 2500 kg into GTO. ISRO/Antrix is developing a Mark 3 expendable version capable of delivering up to 5000 kg into GTO.

With Virgin Galactic developing a reusable vehicle for Space Tourism, it is likely that the same vehicle can be adapted to deliver small satellites to the edge of space. This should be much lower cost than expendable vehicles which could foster a new wave of satellite projects, technologies and techniques.

Euroconsult World Market Surveys puts the demand for GEO/HEO over the next 10 years to slightly above 200 satellites while the number of LEO/MEO satellite launches over the same period of time are estimated at around 180, thus making a total number of satellites to be deployed over the next 10 years to be close to 400. No market survey is available for the period 2020 to 2030. However, the need to replace existing constellations, the deregulation of telecommunications, the advances in Space technology and the need from new applications are likely to drive the expected number of satellites to be launched upwards.

In the long term, the demand for launch vehicles and launch services is expected to grow substantially with the demand likely to approach 900 spacecraft to be deployed in orbit over the next 20 years.

An approximate estimate of the launch demand over the next 20 years for each class of lifting capability appears to show consistency between supply and demand when new entrants to the market are considered. Despite the apparent balance between likely demand and supply of launch services, prices are likely to hedge up rather than down due to the premium required to get a timely deployment.

Space-based services for mobile users will drive the mass of satellites well above the lifting capabilities of most suppliers, restricting the market for commercial launches to possibly a single supplier with a significant upward drive on prices.

With the need to deploy from 400 to 500 satellites for each decade in the near future, and with the associated launcher services total cost estimated by Euroconsult analysts at $27 billion for the next decade, there is clearly scope for a more cost efficient method of launching and this logically could include a re-useable vehicle.

A further advantage of the reusability of launch vehicles is the ability to provide timely deployments in orbit to the benefit of commercial customers and government's institutions.

In the next decade governments, Space agencies and launcher manufacturers are expected to consolidate plans to develop reusable launch vehicles which are likely to be offered for commercial use by the end of the second decade.

# 3.0 UK Future Position

## Our Collective Vision

In section 1, we have outlined a success story for the UK Space industry in a sector which is not only rapidly expanding but also one that is at a crossroads in terms of a strategic direction for the UK. The UK share of this world market in 2007 was around 6%. This is above the average world-market share for many UK industry sectors but behind our leading industrial segments. If we take a positive decision to go for growth we believe that we can make this a star in the UK economy. The alternative, to continue with the current approach to Space industrial policy, is likely to result in the industry and its Science base to sliding back from its current level. This would be a waste of the UK's intellectual capital and existing strengths.

We have, therefore, set ourselves a major challenge, to grow the UK's share of this market to 10% over the next 20 years, and firmly establish the UK as one of the World's leading Space nations.


This is an enormous task and we fully acknowledge the scale of future investment and effort needed to achieve this.

We will not achieve this overnight. But what we can do now is set a trajectory to start this growth path: the business environment that will be needed; the market opportunities; the national benefits we should see and how we ensure this is implemented.

## Trends and drivers

Whilst the current financial crisis may be largely forgotten in 20 years, the potential impacts of climate change have taken centre stage on the political agenda and look set to dominate many investment decisions. Britain faces a prolonged period of investment to upgrade or replace infrastructure for water, energy, transport and communications amongst others in a way that is sustainable. A new green industrial revolution is required to end current dependence on fossil fuels and to provide instead sustainable infrastructure to support health, peace and prosperity.

The ICT sector as a whole is making a big play on its future role in helping other sectors to manage their resources in a 'smart' manner to reduce environmental impact. Energy and transport are two important areas where carbon needs to be reduced whilst maintaining the benefits of energy and transportation available on demand. The ICT sector expects to be allowed to grow its electricity demand (doubling every four or five years) in order to achieve these greater benefits. Space can deliver many of these benefits, including rural broadband and the bulk of TV and radio entertainment with the key advantage over terrestrial alternatives that it produces virtually no carbon here on Earth. It also provides a platform for universal climate change monitoring and assurance to the data to turn climate change modelling into reliable predictions.

We must incorporate Space solutions to make best-value investment decisions for national infrastructure. We need to export what we are good at and trade to acquire the things other people do better than us or that which we cannot provide in sufficient quantity for ourselves. Fortunately, we do now have some extraordinary technology and know-how at our disposal. We need to make the best use of our resources and even out peaks and troughs in supply and demand as well as reduce the total investment required.

**We must incorporate Space solutions to make best-value investment decisions for national infrastructure. We need to export what we are good at and trade to acquire the things other people do better than us**

With more highly educated people alive than ever before there will be great competition and the pace of green technology development will not be slow. This will provide opportunities for Britain which we must seize collectively with great vigour to ensure that we are not left behind. We need to develop attractive and useful knowledge-based products and bring these to the market faster than we have done before and faster than our competitors. Space has a global presence and new solutions developed in the UK can be exported almost instantaneously over the existing satellite infrastructure. If new infrastructure is required to support a strongly signalled demand for a new service then satellite operators can raise the necessary capital.

In Section 1 we have seen that the UK has achieved a comparative advantage in some important areas of the fast growing Space economy, notably manufacturing, operations, exploration and sensing.

The US dominates the Space economy and has achieved greater economic leverage than anyone else in developing the downstream businesses which provide Space dependent applications and services. Its upstream downstream ratio is around 25% of that of the UK and other leading Space economies showing that it is better than others at turning upstream technology (e.g. radio broadcast satellites) into consumer products (50% of new cars in the US come fitted with satellite radio and 19 million US (and Canadian) drivers are now subscribing to satellite radio services). The US is benefiting above Europe in deploying these systems because it is a true single market able to aggregate demand across a continent in just two languages and also because of its financial environment. Risk taking is encouraged in funding new ventures such as radio broadcast, but Chapter 11 also allows new owners (typically banks and bond holders) to salvage value after business failure and continue the business to the benefit of customers and lenders at the expense of the original investors. Aggregation of demand (both nationally and at European level) and improved financial environment are important recommendations of this IGT.

These applications and services are the fastest growing area of the market. In areas such as TV, radio and navigation, Space services have become popular consumer products with user-equipment mass produced and achieving economies of scale comparable to any other sector. As other applications (currently produced in small quantities for professional applications) progress down the learning curve they too have the potential to achieve similar success and make a global impact. Important new improvements will be needed in railway signalling, smart transport, tolls and aircraft routeing. All of these are areas where Space can provide simplification and a bigger footprint than alternative technologies.

## Key UK Growth Opportunities

The Space sector has been researched during the IGT across three broad market areas (Institutional markets, Commercial markets and Security and Defence markets) to identify future opportunities for increased growth.

Despite current concerns about the recession, this IGT anticipates a regular stream of new services which underpin the Space industry's growth prospects throughout the next 20 years. These cut across a wide range of sectors, including rural broadband, smart homes, land, sea and air transport, high-speed digital delivery of media, integrated communications for outdoor events, resilient integrated mobile/satellite Position Related Services, compliance with Climate Change commitments, energy from Space, selective interoperable European and US public services and military services.

Many of these opportunities will need urgent attention in the next decade and others (with more emerging all the time) may fall into the subsequent decade. Examples, such as beaming energy or even street lighting from Space are being researched in countries like Japan and the US. These may well become practicable within 20 years and we should not leave others to develop such IPR uncontested. It is important that the UK retains a broad interest at research level and is ready to seize the moment as such concepts become feasible and economic.

## Delivering Digital Britain

The socio economic benefits of telecommunications investment are enormous. It is estimated that one third of economic growth in OECD countries can be attributed to telecommunications. The World Bank estimates that a 10% increase in broadband penetration can boost GDP growth by nearly 1.4% - meaning nearly £20 billion extra GDP a year in the case of the UK.

In the UK this area has been the focus of government study and consultation, initially through the Office of the e-envoy, subsequently through the Caio Report and more recently through the Digital Britain work culminating in legislation. Approval has been given for rapid provision of improved equality of access to broadband networks through a Universal Service Commitment (c2Mbps) and higher network speeds through Next Generation Access (c10-50 Mbps). The former is to be paid for through a DMCS surplus in relation to Digital Switchover and the latter is to be paid for through a new duty to be levied on fixed telephone lines. A procurement organisation is currently being set up by BIS to define and procure the required access infrastructure and satellite solutions are recognised as one potential technology with a role particularly in rural and remote areas. Since satellite solutions are currently based on Ku band VSAT technology urgent work is required to show how more appropriate Ka band technology can meet cost per bit targets in the short, medium and longer term.

For the most part, fixed broadband has been provided through copper telephone lines into the home using a technology called Digital Subscriber Line (DSL). DSL performance is limited by the distance between the user and the enabled exchange. Users beyond 2km from the exchange suffer from significantly reduced speeds. New variants of DSL, still using the same copper wires into the home, support increased speeds within a 2km range but suffer even greater performance degradation with distance. It is an unfortunate fact that the user has to buy before he tries the DSL offer and the price bears no relation to the performance (if any) actually achieved. There are no Pay as you Go options available to ease the decision.

Whilst USC is an important, immediate objective, increasing attention is now being placed on Next Generation Access (NGA) – the ability of citizens to connect to the Internet at speeds of tens of Mbps. NGA services “will become an essential digital utility for the country” according to the Caio report on “The Next Phase of Broadband UK”.

Various technologies are being considered for NGA, but the leading contender at the moment is “Fibre to the Cabinet” (FTTC). This technology deploys fibre optic cable to the telephone street cabinets and then connects to the home using the existing copper telephone wires providing speeds of up to 20 Mbps. BT is planning a £1.5bn investment in FTTC, but this will only reach about 10 million households by 2012 (about 40% of the UK population) and many of these will ineffectively duplicate the cable broadband offer already available.

Cable networks based on fibre to the home (FTTH) can also be used to deliver NGA services. Virgin Media plan to offer such services using their existing cable TV network. However, this again only covers about 40% of the UK population and the company is not expected to deploy significant infrastructure to new areas.

Thus, with both FTTC and cable not expected to deploy to beyond 40% of the UK population, a significant proportion of households are unlikely to benefit from NGA in the near to medium term. In fact, Lord Currie, whilst Chairman of Ofcom, foresaw problems with NGA of much greater magnitude than the ADSL "Not Spots". Referring to "Not Blotches" he suggested early public intervention might avoid the likely market failure associated with the deployment of next-generation services to rural and remote regions. For rural communities, inequality of access to broadband services is a significant issue, with those who live and work in rural communities being at a severe disadvantage. This has resulted in numerous complaints by rural constituents from around the UK which consumes a considerable amount of political energy for central and devolved governments. As more and more public services are delivered electronically it is essential that all homes and businesses have access to them at the same time. This would also increase government savings by removing the need to maintain multiple delivery systems.

It is now accepted that delivery of the USC and NGA will require a mix of technologies. Fibre and ADSL technologies will undoubtedly form a significant part of the solution. However, their deployment is driven by population density and therefore the market will roll out services from the most economically viable areas outwards, leaving rural communities at a major disadvantage in terms of their connectivity. An important question is how rapidly and to how many people these fixed networks will eventually be deployed due to the requirements for planning consent and civil works.

Satellite can very effectively fill the significant gaps in the terrestrial networks to bring about social and economic equality to remote and rural locations. It is entirely realistic for the BIS Department to plan for a situation where 20% of the population relies happily on satellite delivery of its broadband services and without any disadvantage compared to their town-dwelling counterparts.

Satellite broadband technology provides one of the biggest opportunities for satellite since the dawn of Pay TV. The UK has established an early European leadership in satellite broadband technology and services through government, industry and finance working in tandem.

The progressive deployment of higher bandwidth satellite modems is a key part of this strategy. Satellite modems are able to support a few Mbps cost effectively today but this needs to be pushed to 50-100Mbps within 5 years. Satellite solutions already are capable of 50Mbps on the forward link as they are based on DVB-S broadcast standards and this advantage needs to be capitalised on through extension of Sky+ and similar services to HDTV on demand. NHK and the BBC are already working on demonstration of Super High Vision with 16 times the resolution of HDTV. This is intended to be fully commercial technology by 2025 when 100 inch screens are expected to support cinema-like quality at domestic level. Demonstration of such capabilities at national level supported by ARTES technology demonstrations through ESA is key.

If we can get it right in our home market, satellite broadband has huge export potential with a possible global market of £29 billion by 2030.

The Space Internet is the next phase of development in human communications as ubiquitous data becomes necessary for all of mankind in navigation, Earth Observation and telecommunications. As a result the annual global space market is expected to experience explosive growth to perhaps £100 billion per annum since most countries cannot afford the investment necessary for universal deployment of fibre and will rely on satellite and terrestrial wireless outside of the cities. Space is highly geopolitical and to compete with US, Russia, China, France, India and seize a 10% share we must continue to fund early stage research and national deployment, on the basis that industry leverages this government contribution and uses the City of London to get innovation to market fast, as we have done so in the last decade.

## Delivering ubiquitous mobile services

While there are several terrestrial networks capable of providing mobile broadband connectivity – for example, 3G or WiMAX services – they fail to provide ubiquity for consumers in rural areas. This negatively impacts not only on the rural inhabitants and businesses but also on those who visit these areas for work or leisure.

It also inhibits many consumers from dropping the fixed voice network to save money as they cannot be sure to have effective mobile broadband indoors.

It is difficult to comprehend why the performance of a network to serve a device whose main feature is mobility should be measured by Ofcom on the basis of its performance at a fixed location. Consumers cannot make a 999 call after an accident if the network to which they subscribe is unavailable. Ofcom currently allows operators to claim that an entire cell is covered provided that a call can be made at 75% of outdoor locations within the cell.

There are two main solutions to enable mobile coverage through a combination of satellite and terrestrial technologies. In areas of the world such as Canada WIMAX or GSM is used to serve a small isolated town and this is backhauled using currently standard (C and Ku Band) satellites to a more suitable location like, for example, Toronto, for interconnection to the terrestrial network.

Typically, the satellite service provider becomes a terrestrial mobile service provider and

negotiates roaming agreements with terrestrial operators on behalf of users spread amongst many such WIMAX or GSM islands. As Ka band satellites are deployed the costs of these cells will be substantially reduced to allow cost-effective local solutions to quite small local communities. The second alternative is an integrated terrestrial/satellite solution as typified by Terrestar in the United States. Here the terrestrial cell uses satellite frequencies to provide extra frequency reuse in towns and cities. The satellite concentrates its capacity on areas outside the terrestrial coverage. As Inmarsat and Solaris roll out similar S band satellite systems with complementary terrestrial component all mobile operators will have the opportunity to take it up in the interests of rural consumers and for the safety of travellers and those engaged in outdoor work and leisure pursuits.

There remain many more situations in which a satellite-based solution is the best or only option for accessing broadband services in areas beyond reach of terrestrial infrastructure. Many organisations currently rely on Mobile Satellite Services (MSS) for voice and broadband data communications. These communities are and are likely to continue to rely on MSS for the next two decades.

## Delivering a sustainable transport infrastructure

Satellite navigation has already become a core component of the UK's critical national infrastructure, insofar as it underpins many of the enabling applications in today's transport networks that we, as consumers, take for granted. As these satellite navigation services become more robust, the number of applications depending upon these space assets will accelerate rapidly, as well as numerous downstream capabilities and related technologies. Satellite communications already complement terrestrial services in markets such as rail and aviation, where users demand a level of continuity and robustness that cannot be met outside of space.

## Road and rail

Space, and in particular satellite navigation, is a critical enabler to sustainable growth on our road and rail networks:

- Enhanced capacity, reduced congestion and improved multi-modal support for passengers
- Enabling continued growth in use of public transport and achieving appropriate balance of capacity/carbon on the road network
- Reduction in carbon footprint through energy optimised driving – applicable to both rail & road
- New transport and passenger applications contribute directly to 'Digital Britain' objectives
- Enhanced passenger experience for an ageing population through improved security, up to date information and demand based pricing
- Facilitating the Connected Vehicle concept and enabling new media and entertainment services.

The rationale for road pricing starts with the recognition that management of demand, as well as capacity enhancement, can be an effective way of tackling congestion. There are significant congestion benefits in trying to change people's use of the road network, for example through encouraging them to use public transport, using the roads at different times of the day or alternative routes. Direct charging for road use (or 'road pricing') on the basis of distance or even time and place of travel, provides one such mechanism for doing this. A variety of techniques and approaches can be adopted for raising the charge, and satellite navigation has emerged as the only interoperable solution that meets the needs of a global supply industry.

The DfT's 2007 Rail Technical Strategy (RTS) describes a number of key policy domains that are directly relevant to the potential application of onboard positioning and communications systems. Current work being undertaken by the UK railway community clearly shows the dependency upon satellite navigation and (to a lesser extent) satellite communications to deliver these policies.

- Simple, flexible, precise control system: Communication-based cab signalling to reduce infrastructure complexity and cost and allow energy efficiency to be improved and full potential capacity to be realised

- Improved passenger focus: Exploitation of ticketing, passenger flow, train movement and train load data to give high-quality information to passengers throughout their journey.
- Rationalisation and standardisation of assets: A rationalised approach to asset specification, with greater use of modular and commercial off-the-shelf (COTS) equipment, covering industry-specific assets such as rolling stock based on a whole-life, whole-system cost approach across all industry partners.

The development of 3G and wireless networks have created an expectation for continuous broadband connectivity, irrespective of location, and this is particularly evident in the automotive and rail sectors. Whilst this is a relatively new market, it is already clear that there will be some areas that will not be covered by the terrestrial networks, more so in export markets than in the UK. Mobile satellite broadband offers a viable and complementary solution within these markets or where sustained connection is needed for customer satisfaction or operational demand, such as for emergency response vehicles.

## Aeronautical and maritime

Most aircraft, including military and government planes, business jets and the majority of the world's airliners, have access to satellite communications for their operational communications. Satellite communications deliver enhanced safety and have begun to meet the increasing demand for in-flight passenger connectivity. Demand for Mobile Satellite Services on board aircraft is expected to grow, driven by anticipated growth in air transportation and also by increasing demand for media and business connectivity in the air.

British shipping has been growing in turnover at around 15% per annum since 2002. Most vessels use satellite communications, for fuel efficiency and finding and landing fish. Seafarers literally trust their lives to satellite communications through the Global Maritime Distress & Safety Services (GMDSS). There is an expectation of continuing growth, not only in line with the maritime industry growth (expected to be at least 3% per annum), but also through increased demand for new services throughout the IGT period. These new services include security, e-navigation and electronic chart systems as well as email and internet for the management of vessels as a link to the family and community.

## Remote Land-Based Users

For any business operating beyond the reach of terrestrial networks, such as the news, media, oil and gas exploration and extraction, mining, and construction sectors, satellite networks represent the only reliable and secure means of accessing broadband data and this is a market that continues to see significant growth.

## Public Sector

Commercial MSS provide an essential capability to national and regional governmental organisations and other international bodies like the UN in supporting communications in remote areas often where the local communications infrastructure has been lost or is non-existent. Commercial MSS augments the governmental and military-specific systems, bringing strong advantages in terms of portability and data rate capability driven by the requirements of the commercial sector. Challenges being faced by terrestrial network equivalents in supporting users' capacity requirements potentially drive significant future demand for MSS, especially handheld and vehicular capability, within this sector.

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## Delivering Smarter Homes….. And More

Because the Department of Business Innovation and Skills sees satellites as the solution only for a few remote or rural dwellings when it comes to broadband services there is a strong tendency - even within the Space industry - to dismiss satellites as a potential complete solution for both rural AND urban areas for other service needs.

However, for many M2M applications, a ubiquitous low data rate control network is all that is required and existing or planned satellite capacity is sufficient to deliver the complete services with major benefits in integrating multiple mobile as well as fixed applications on a single satellite on a common infrastructure.

Smart Home is a term used to indicate the use of technology and techniques to increase the efficiency of energy consumption in domestic premises. The vision is of a future in which we achieve more than we do presently but expending less energy. Implementing such a vision involves many threads – for example, improving insulation – but the use of communications systems is a critical enabling infrastructure for stabilizing demand at the lowest possible level. Of immediate importance in the smart home is the smart meter which stimulates home owners to be more economical in energy use (by up to 30% according to trials) by giving homes visibility of their electricity and gas use via a conveniently positioned in-home display. All UK homes and businesses are to have a smart meter with roll out commencing by 2012. The meter communicates with both the energy supplier, so avoiding the need for manual meter readings, and with the consumer allowing the creation of attractive tariffs that help balance demand peaks.

It is our firm belief that low data rate 2-way satellite communications offer the ideal (and cheapest) solution to the communications network needed to connect all of the 26 million UK properties with a meter to the energy suppliers' control centre. One satellite – already available in orbit – provides more than enough capacity to cover all the UK's meters.

Terrestrial alternatives either need huge investment in their base station infrastructure or use non-optimal existing communications protocols which carry a significant cost premium as well as not having full UK coverage.

Existing fixed networks would require the current owner of each property to have a contract with a telephony supplier. Over 10% of the population has already chosen not to have such a contract let alone agreed to allow their utility company to use it freely.

The satellite communications approach uses one system for the whole country. The satellite solution is certainly the greenest of the possible communications systems and it is immediately exportable over the existing mobile satellite infrastructure. Europe has signaled the importance of smart meters but national solutions are the norm here and much industry is in government hands. In France the proposed solution is one way reflecting an absence of the concept of customer service. EDF plans to use OFDM (Orthogonal Frequency Division Multiplexing) transmission over the power network to periodically upload meter readings. The UK is advanced in Europe with its market structure and if DECC and OFGEM can organize quickly, there is an opportunity to promote a pure downstream business of immense potential for meters alone.

The satellite technology proposed for the Smart Meters communications system is also applicable to a number of other important applications. This type of totally secure and reliable M2M communications is perfect for wide area monitoring and control functions. It has applications in the future Smart National Grid as well as several transport systems. The export potential for the UK for satellite M2M is substantial.

## Monitoring the Planet …….Live

Earth Observation has advanced greatly over the last 30 years, with greater levels of detail than ever before, and it has been able to deliver on government policy at relatively low investment, whilst at the same time being a generator of wealth for the nation.

During that time, EO data and analysis techniques have revolutionised many areas of earth, geophysical and environmental and climate sciences and the UK has become world class in several of these. The market for EO data is expected to grow, driven by the public demand for the data to be more widely available, and the sector will become increasingly commercially viable as the costs of the collection systems decrease and the number of applications for the data increase.

UK based EO data service organisations have access to a variety of data-collection systems including aeronautical as well as satellite-based sources. Much of this comes through the ESA route, but this has been supplemented in recent years through the establishment and subsequent expansion of the Disaster Monitoring Constellation.

There is clearly a case for greater investment in the CEOI (Centre for Earth Observation Instrumentation) to prepare for opportunities in Living Planet and GMES. The IGT team believes that there is a wide spectrum of strategic niches for data that are academically, politically or commercially needed by NERC (Natural Environment Research Council), the EOPB (Earth Observation Programme Board), and various Government Departments and industry. These go beyond what can be achieved through current or planned shared resources. What is missing is a UK-owned and controlled asset which could be built into a global real-time constellation.

Multiple-use systems supplied under direct commercial or PPP service provision arrangements will become increasingly common, so UK investment in a national EO system would have widespread cross-cutting benefits, between the institutional, private and military markets at the same time as stimulating the upstream, downstream and academic sectors.

A specific theme in which the UK could establish a leading capability and that is expected to emerge in the decade from 2010-2020 is the use of constellations – groupings of satellites operating together to provide significantly enhanced area coverage rates and timeliness of data delivery. These systems will be expected to open up significant markets. They will also help governments to deliver on the grand challenges imposed on society by changes such as climate, environmental stress and national & international security.

Space-derived data will be readily available and the regular appearance of space-derived information in news bulletins will help to raise levels of awareness in both the public and the government concerning space's contribution to society.

**There is a wide spectrum of strategic niches for data that are academically, politically or commercially needed by NERC, the EOPB and various Government Departments and industry**

Investment in EO clearly shows benefits to policy objectives and wealth generation (including the grand challenges) and also a clear link between that investment, user needs and technology/application development programmes. It is also worth building on technologies which are common to EO and communications to build capability quickly and reduce costs.

Investment in EO needs to engage with the Earth Science community to both exploit and generate world-class Science and help break down barriers between research communities and the private sector. There is a need to develop UK strengths using 'open innovation' techniques to drive wealth generation and inspire the next generation of scientists and technologists. For business and industry, investment will deliver economic impact through capability in both the upstream and downstream sectors with the capacity to deliver EO-based solutions. This will build on UK engineering strengths, encouraging SME's and large companies alike. There are many synergies between Science and EO and both will benefit from a co-ordinated approach.

Thus, this vision for EO over the next ten years is to place the UK in a position to drive and benefit from the anticipated market growth. This will require the engagement of the investment community and non-space players and partners to unlock new markets. This can be achieved through a national demonstrator programme building on DMC together with an EO Hub at the ISIC (International Space Innovation Centre), Harwell as the major focus for coordination and delivery. The national programme and EO Hub would help the generation of new technologies and capability giving fresh impetus to market development through lower cost missions, more and better sensors and more capacity to handle and process ever increasing data volumes.

A Climate Model Validation Facility is required to act as a climate hub and to ensure that future management of the planet is based on data which has been rigorously calibrated and scrutinized before being fed into climate models. The climate modeling paradigm is changing with the move towards decadal and regional models now that global trends are largely understood. The facility must reliably and carefully evaluate observational evidence. The models used to interpret the observations will constantly improve so the facility must rigorously record the modifications made to the raw data in order to update the data as new interpretation models emerge.

Such Hubs should utilise the existing centres of excellence that exist within the UK such as ECMWF (European Centre for Medium-Range Weather Forecasts) and the Met Office's Hadley Centre and build upon their work and not seek to replace them.

ESA is establishing at Harwell a centre for satellite climate-related data which will produce information from satellite data needed by climate modelers. The facility outlined previously will complement the ESA centre by assimilating data from other sources, many of them non-satellite, cross-calibrating observations to ensure their validity and accuracy, and providing data to climate modelers, for example at ECMWF and the Met Office's Hadley Centre, that meets the rigorous quality standards necessary for national decisions concerning climate policy – transparently and reliably.

As a part of the CPNI, Space is an infrastructure which is protected from events on Earth but which is exposed to the harsh Space environment. Further understanding of the variations of this environment would be helpful in assessing the vulnerabilities of this infrastructure. Terrestrial infrastructure such as the electricity grid is clearly exposed to Terrestrial events but is protected from the Space environment by the atmosphere. It is still potentially vulnerable to the extremes of the Space environment. Space infrastructure can help to protect terrestrial assets. Understanding of the Space environment is an important activity which could sensibly also be centred at Harwell.

## Securing access to space

Access to Space is critical to all other functions of the Space industry. Without affordable, timely (or convenient), and reliable access, most commercial Space projects become unviable. Because lead times are long supply-side changes do not necessarily respond to increased demand. Prices have risen in the last year following the problems suffered by Sea Launch, though this is likely to be partially corrected as Sea Launch emerges from Chapter 11 protection. Since demand sits currently in the 20-30 satellites per year region and the main commercial launchers have a combined capacity to launch 35-40 satellites per year there is no structural supply shortage. In many countries the civil Space transportation sector provides a means of smoothing workload, skill retention and G&A contribution for companies providing other delivery systems. These countries should be keen to raise extra revenue through this means in response to any sign of increased demand. This IGT concludes that there is no sign of a lack of access to space.

There are a number of potential new applications such as energy from Space and tourism which would be facilitated by reduced launcher costs. This IGT considers that technologies able to provide a step change in launcher price over time do merit encouragement.

The access to Space market for infrastructure can be segmented , into low orbits (up to roughly 1000km above the Earth), geostationary transfer GTO orbits or geostationary GEO (36000km above the Earth) and escaping from the Earth, termed interplanetary. Where the market to put satellites into higher Earth orbits is concerned, for example, GTO, GEO and Earth escape, payload masses reduce and many small vehicles cannot offer a service since they are unable to deliver enough energy.

This situation would change if installation of even larger satellites than today were to be based in future on techniques for in-orbit assembly. Major subsystems could be provisioned through the smaller launchers and assembly completed under supervision from the ground based Assembly Integration and Testing (AIT) team. This is an important area for research and demonstration which would ease the environmental loads during launch and help reduce costs. This could be a significant opportunity in the second decade of this vision and one where earlier work through the Science community developing robotic techniques might reap reward later on. In the long term geostationary satellites might then become permanent fixtures with a planned upgrade and refurbishment programme at periodic intervals.

This IGT has evaluated commercial opportunities in providing reusable launch vehicles as a manufacturer or as a service. The development and eventual production of these vehicles also represents a market to subsystem and component suppliers in its own right. There are three companies with a UK footprint who are evolving business in these potential markets, Virgin Galactic, Reaction Engines and Bristol Spaceplanes. These companies have unique innovative approaches to vehicle technology and the provision of public access services. ESA is enthusiastic to make further assessment of the dual engine cycle inherent in Reaction Engines' Sabre engine and this is an area meriting careful build up of UK IPR and technology capability.

## Exploring Near Space

Developments in long-term strategies for Human Space Flight in the USA and the European Union are opening up a new window of opportunity for the UK to engage in manned international Space exploration, as a partner in the Global Exploration Strategy.

In the US, the Augustine investigation is concerned with a $3bn black hole in NASA's budget. Its remit is to decide whether NASA should go to Mars via the moon, or go straight to Mars. Extension of the ISS seems to be no more than a holding pattern, until new programmes can commence. The UK's recent reviews of Space exploration have identified potential for substantial returns in economic impact and public benefit from both robotic and human exploration. If these potential returns can be used to justify additional funding, from, for example, medical research funds, like those of The Wellcome Trust, then this opportunity could be interesting.

Post Lisbon Treaty, the EU will provide increasing opportunities for funds in support or R&D, pilot services and eventually some operations at European level. The UK will have some bid-winning capabilities resulting from activities at ESA but will increasingly need some pre-cursor national stimulus to position its firms for leadership roles in priority areas to be agreed in the pan-Departmental UK Space Policy/Strategy. This contrasts with the current position where the UK has been a non-participant, and has, therefore, been excluded from ESA's Human Spaceflight programmes.

## Deriving Benefits as a Committed Partner in the ESA Science Programme

Space is clearly the best place for most experiments to observe and test theories of planetary science. It is also a good place to observe the universe and the Earth, competing experiment by experiment with terrestrially based alternatives. Science is a downstream user of space. Scientists also provide instruments as payloads for Space vehicles just as they provide detectors into the LHC (Large Hadron Collider) collision chambers at CERN. Industry can help them to engineer their experiments and also provides the Space vehicle, launch and operations to support their scientific endeavours.

In an ESA Science programme Member States fund platforms and integration of mission instruments. National Science programmes fund those instruments. This distinction is less precise where the instrument design impacts on the design of the platform (bus): In those circumstances Member States/ESA may well contribute to the cost of the instrument. The model for Earth Science is less rigid, usually resulting in manufacture of instruments by industry. The long-term nature of the ESA Space Science programme ensures that industry has good visibility of future requirements but the consequence of limited National Science funding to pay for the necessary instruments in the UK does limit the likelihood that the UK can achieve industrial leadership roles.

As mentioned above, the UK's participation in ESA through the mandatory Science programme has been delivering world-class science, novel instrumentation and satellite technologies, and industrial activity since the 1980s. UK industry, universities and research establishments are currently active on developments for astronomy, solar physics and planetary science. In 2008/9 the UK spent £84M through ESA, plus £35M nationally – the latter mainly on instruments for ESA missions, delivered primarily by academic communities. There is a need to improve the National/ESA Space Science expenditure ratio and this may need to be funded by increasing the proportion of UK Science expenditure which supports Space science.

## Security and Defence

For the Space industry, Security and Defence should be considered as a single market. There are many common underpinning technologies and an overlap of civilian and military requirements. In other European countries the post-Lisbon Mandate provides an opportunity for synergy. In the UK, the MOD has preferences which mean that this is not the case and this has had undesirable consequences, presenting barriers for the UK Space industry. The UK dependency on the US hasn't changed and for its Space industry the consequential indifference of MOD is most undesirable. The UK has not always pursued an active policy of engagement with Europe, for example setting aside UK leadership in radar technology, in favour of Italy and Germany.

The 21st century concept of 'Homeland Security' and the increasing need for all nations to counter terrorism, to assure their legitimate international trade activity and borders, to protect critical national infrastructure and to support domestic and international disaster relief efforts have broadened the governmental applications of Space well beyond the confines of military use. The Lisbon Treaty is expected to accelerate this process at a European level. It is no longer an option for the UK to ignore European initiatives that will provide benefits to UK citizens for fear of losing US favour.

Classic Defence exploitation of Space has continued unabated over the last 20 years - a significant stimulus being the impetus that started with the 1st Gulf War – the 1st Space War - and the lessons that were learnt.

Where MOD has been involved, UK industry has been able to develop major international military and civil (telecommunication) capabilities. Where UK has relied on US assets for surveillance, reconnaissance and navigation and reduced R&D expenditure to zero, France, Germany and Italy have taken the lead.

This is a unique and undesirable situation by comparison with other European Space governments that have significant Defence capabilities and associated export potential. Some small progress has been made in integrating surveillance information from diverse imagery sources to support UK operations, especially overseas, but this should not draw attention away from the fundamental problem

It is therefore appropriate to take stock of the nature and degree to which global trends and emerging threats impact on the status quo. It is time to ensure access to supplementary or alternative sources which will enhance our assurance and resilience. Space-based assets can provide global access to communications coverage for example with reduced reliance on terrestrial infrastructure. Important elements of persistent surveillance can only be achieved from orbiting assets.

Furthermore the civil world, as well as the military domain, has, become increasingly dependent on GPS technology. This has given rise to the decision of Europe and others to complement the US constellation with its own supplementary infrastructure to increase the resilience and robustness that can be achieved in systems and services which rely on such collective assets. The MOD's stance on Galileo has not facilitated the greatest opportunity for other departments to offer financial support. It is now clear that all users will see the benefits of a more robust navigation constellation with contributions from Europe and other nations above and beyond the US (DoD-financed) GPS constellation.

UK industry has world-class strength in a number of Space capabilities directly relevant to the evolving international Security and Defence market place.

This includes military and para-military satellite communications, ground segment, small satellite technology, advanced imaging sensors (including Synthetic Aperture Radar and multi-spectral sensors), electric propulsion, measurement technology, exploitation of Space systems, integration of complex systems and delivering value-added services derived from Space assets.

The future potential for growth in this sector is dependent on exploitation of the industrial and technological strengths, in order to secure operational benefits in the Security and Defence domain. We stress the need for closer government/industry co-operation in order to help sustain and further develop the UK's current industrial strengths. This would allow the UK to meet future domestic Security and Defence needs and also to remain a significant player in the international export market.

## The Size of the Prize

The commercial communications satellite sector is generally viewed as the most mature part of the Space market. The following section will show the exceptional growth potential even in this mature area!

## Space Infrastructure as part of Next Generation Access

It is clear that compliance with NGA will require at least 50Mbps downlink and 10Mbps uplink as its premium service. Although the existing broadband offering (2Mbps) is suitable for many, we believe there will be an increasing desire to upgrade to a faster service driven by new video based applications and content written for that faster service. It will follow the same trajectory as computer RAM and hard disk memory - once hardware is available the ensuing content drives the new hardware to become an essential requirement.

All households will require a broadband connection in the future in order to facilitate reduced government spend in delivering services as well as for communication and entertainment. It is likely that BT will roll out FTTC (Fibre to the Cabinet) to as many households as possible for its allocated funding - £1.5bn. But it is expected that this will be less than 60 % of households and could be as low as 40% with the majority of these already having access to NGA capability over Virgin's cable network.

It is also likely that Mobile 4G and later generations will have difficulty above speeds of 10Mbps and will not increase coverage beyond 80%. A Satellite offering utilising the latest Ka band technology can deliver up to 100 GHz of spectrum with 50Mbps available to a user at its upper end. If there is a spread of users it could offer a broadband service to 500,000 users. Since many users will not require high data rate uploads but will require the satellite delivery of video, it is likely that some urban households would opt for an all-satellite solution.

The Broadband Stakeholder Group (BSG) has undertaken an assessment of the cost of deploying fibre to the cabinet (FTTC) and fibre to the home (FTTH) for the UK as a function of % of population covered. From an assessment of satellite costs performed in this IGT we can see the same result for satellite solutions which could be made available based on current technology from 2015. We can anticipate that the sector for satellite delivery of the infrastructure will be AT LEAST 15% of households. With 30 million households in the UK, this % equates to 4.5 million households requiring 10 satellites including one spare if based on current technology.

It is assumed that by the next decade we should plan for all households to have access to at least one infrastructure which is capable of delivering 'triple play' – that is, broadband, TV and Voice/video communications simultaneously. Once the whole country is covered by infrastructure offering triple play, it is probable that the terrestrial broadcast systems can be turned off to give another UHF spectrum dividend.

In order to offer triple play it will be necessary to offer broadband and TV a single transmit/receive dish with dual feeds. It is probable that the UK will not want to rely on a single source so a second provider at a second orbit slot will be viewed as essential. From the UK around 60 orbital slots are visible with spectrum in Ku band and Ka band. Whilst this in principle provides enough resource when used with small spot beam technology, there are a number of issues which need attention at the regulatory level. This includes increasing the amount of spectrum available on an unlicensed basis for UK-based satellite terminals, increasing the slots available by removing paper filings from the ITU register (including those from the UK and its dependencies) and moving some broadcast to Ka band to facilitate wider band transponders. Note that if a densely populated country like the UK needs 10 satellites, then the export potential for satellites for more sparsely populated countries is many orders of magnitude higher.

By 2011 the World population will be 7 Billion which we here equate to 1750 million homes, with 4 people on average per household. Within 50 years all people will want and need internet access. Assuming that the final 20% must be served by space access whilst the actual market will be between 5% and 15% since not all will be able to afford to pay, then between 87 and 263 million people will be using satellite based internet. Assuming further that a large satellite will serve 500,000 users then this suggests that we will require between 175 and 525 satellites. At £200M per satellite this is worth £35B to £105B without the cost of dishes, modems, installation, etc.

The revenues from services on each satellite are many times this. If we make the assumption that each home pays £100 per year - that's around 175 million homes giving £17 billion revenues. An extra £50 per year for each home served from TV and cellular backhaul gives revenues of £29 billion per annum.

The question is how fast the market will develop to this size, where broadband communication is as essential as electricity?

## Use of Satellites to Reduce the Carbon Impact of Super Fast Broadband

There is a consensus emerging that the growth of the speed and capacity of the internet will be driven by new video rich applications such as video on demand and catch up TV. The IGT has studied a case where the use of internet i-player has grown such that with advanced compression techniques it is possible to deliver HD content on demand with minimal delay at a minimum data rate of about 10Mbps. There is much research taking place into the power consumption of the internet and it is a complex subject but networks are conveniently characterised by the energy required to transfer 1 bit of useful information. From the work of Tucker a reasonable assumption is that the future internet will improve by a factor of ten from today to transfer 1 bit for 10μJoules. Taking the UK as an example, if 10 million homes decided to watch such content at any one time then the power consumption would be 10million x 106bps x 10μJoules per bit or 1 GigaWatt. This is half of the electricity consumption a large power station such as DRAX and would release an extra 40 megatonnes of CO2 over a year. Including the power consumption of an increased number of data centres necessary to provide the Quality of Service requirements for real time video this could easily increase to as much as 100 megatonnes

The internet is not designed for power efficient broadcast but for multiple one to one sessions where content is requested individually on demand. Satellite broadcast could lighten the load on the terrestrial internet that results from such repetitive and inefficient transmission of popular media requested by many people at about the same time.

The UK already has an efficient satellite and terrestrial video broadcast system but this system is locked into a 'linear' model where it is assumed that all viewers watch content as it is broadcast. In practice the broadcasters already offer the VoD functionality of i-player with their Freeview+ and Sky+ boxes. Such technology has the added advantage of freeing the broadcasters from linear scheduling, enabling them to deliver content to the viewer at any time over the full 24-hour period. This could require an extra two satellites for the UK, but this would grow dependant on the speed of the move to HD, 3D and SHV (Super Hi-Vision) content. Note that there is a similar case in all countries with their own TV and video content so again the export potential will dominate.

Currently, all of the major satellite manufacturing players produce between three to eight commercial satellites per year totalling 25 annually. This will need to go through a paradigm shift over the next two decades with the world demand growing to around 200 per year as satellite comes to dominate broadband and TV in most of the world which has little legacy fixed infrastructure! In terms of value this will increase the upstream market from £2.5bn to £20bn. For the UK, Astrium will need to move to manufacturing one satellite per week and more if it were to establish a technology lead.

With a prize of this size, national strategy will play a major role with many nations wanting a slice. The UK is home to one of the world leaders in this field and currently the UK produces not only the mechanical structure but also the highest technology part of the satellite - the payload. The paradigm shift in quantities will mean application of many new production-oriented technologies and the purchase of significant new capital facilities. It is known that many countries utilise mechanisms to support industry moving through such enormous change. The UK Government will need to be prepared to support its industry with additional matched R&T funds and capital support if we are to avoid losing this prize to competitors.

In conclusion, this market will emerge over the next five years and take off within the next 10 years. The UK Government and industry will need to ensure they are prepared to invest to support the technology roadmaps in this area.

In addition to this fast, but evolutionary, growth in the satellite telecommunications sector, we can confidently expect that some other applications (navigation, imaging, and personal security) will follow similar growth paths leading to a succession of opportunities and sustained high growth, out to the 20-year horizon of this IGT.

# 4.0 Seizing Opportunities and Removing Barriers

## The Importance of Exports

For the UK, the challenge is to find the way to develop new Space-enabled services which satisfy our own or a partner's needs and can be instantly exported over the global Space infrastructure. The key is to drive down the cost and hence introduce attractive new services into UK, European and International markets through a mix of private investment and smart public procurement.

**"The UK has strength in depth in Space technology and a strong record of innovation and of ground-breaking Space systems exploitation. But the UK is at its very best when government and industry work together as partners, combining the best of the UK's technological expertise, a single vision, a mature approach to risk sharing and an innovative commercial business model to deliver world-class Space-derived services. An outstanding example of this is the UK Skynet 5 satellite communications programme, which although originally predicated on UK national defence needs has been delivered by UK industry using an innovative service-based approach. I strongly believe there is scope for this kind of business model to be applied in other areas of Space technology and where the costs of acquiring a national capability for many international customers are prohibitively high. I am excited by the idea that a Skynet-like business model could be applied in the UK to reconnaissance from Space and I see many applications and significant demand for the latter around the world - in areas well beyond the strict confines of Defence - and as diverse as anti-piracy, disaster relief and illegal fishing. I very much hope that the UK can rise to the challenge."**

*Richard Paraguin UKTI DSO*

Due to its wide-ranging trade interests and the wide footprint of satellites, the UK has ample opportunity to introduce new pilot applications into its home and other selected pilot markets. If supported by joint industrial and government action, UK firms can be first to market, reach the leading edge for the introduction of lucrative new services, and gain long-term sustained benefits. Exports will be the major driver in capturing this exceptional growth. Since satellite infrastructure is available globally, early domestic success can translate into immediate export opportunity for the service and for the consumer equipment. HMG active support to development of MOUs with overseas partners would be extremely helpful. An initial procurement in the home market speaks volumes to the export community, more so if done by a cost-conscious UK Government.

There are alternative locations for service pilots and demonstration at EU level providing greater scale - both in terms of market and in terms of geographic variety and extent. This flexibility of satellites for providing instant infrastructure is unmatched by any other technology and consequently provides greater export opportunities.

Below we will define the strategic approach to allow us to increase the UK's market share from 6% to 10% of the addressable Space market.

Success in the business of Space has to be based on exploiting the key benefits of Space where its solutions have no equal. These are:

- ubiquity of service (across the UK)
- low-carbon delivery of broadcast/broadband compared to terrestrial
- affordable deployment to remote and rural communities
- increased resilience as a second, quite separate infrastructure
- export potential of services or whole systems

As for any other technology, deployment in small numbers leads to high unit cost. This is the case for many Space applications today and this will only change by commitment to large-scale deployment and manufacturing in quantity. This has already been proven in numerous examples such as TV broadcast and GPS positioning where consumer level pricing has been achieved.

It is important to recognise the long lead times in building the foundations for commercially successful satellite operators. It is often forgotten that almost all of these companies required significant government investment in their formative years and have only recently emerged from their Inter Governmental Organisation (IGO) shells. Inmarsat and Eutelsat fall into this category but more indirect support from the Luxembourg government helped companies like SES.

The hugely successful GPS industry which has spawned household names like Tom Tom and Garmin, was made possible by the US Government's full financial responsibility for the GPS satellites, GPS chip sets and receivers for military vehicles. It is worth taking note that Galileo is now going down the same path. Now that an EU-funded complementary system will improve accuracy and offer assurance of service in urban areas, a second wave of applications will arrive. The UK is well placed to ride this wave but faces intense competition. Even the satellite broadcast sector, which likes to represent itself as fully commercial, was made possible to a large extent by very large government (or agency) R&D investments in satellites, launchers, and ground segment and user devices. There is a common perception that other European governments understand this and are willing to more actively support their domestic champions, while the UK tends to rely on the market and the commercial sector itself to make most R&D investments on a purely short-term commercial perspective.

## Opportunities for Concerted Action

It is imperative that we highlight and support areas where the UK has some inherent or easily-leveraged competitive advantage over other nations in the commercial domain, such as in the aerospace and maritime industries but also in the services and applications markets. The more we can tie the potential future developments in the Space sector to more mainstream and accepted policy drivers and the broader industrial base, the easier it will be to integrate our requirements into a broader context.

## Delivering Digital Britain

The present plan on Digital Britain is in danger of unwittingly producing a major increase in UK electricity consumption.

The ICT sector is growing rapidly in both the work and the domestic environment. There is no universally agreed figure for the amount of electric power ICT uses operationally but it is agreed that it is large and this is the only sector with a rapidly growing energy usage. Figures of over 150GW worldwide are commonly quoted for 2007. This amounts to more than 8% of all electricity consumption or 2.5% of all total energy usage. As more and more countries look to ICT to boost their developing economies this sector's future electricity demand could soon exceed current global electricity generation capacity.

Energy usage of ICT systems and equipment – and its consequent CO2 emissions – should now be accepted to be a major factor of concern.

Arguments that ICT enables an overall fall in energy demand may be true in future as we develop smart infrastructures but these arguments are not supported by hard data. It is true that communications can prevent travel – through video and teleconferencing, home working and internet shopping – but there is little sign of travel declining. Moreover, home working might save on travel but it tends to increase use of heating.

It would be foolish to dismiss ICT energy usage as unimportant or inevitable.

If a video-rich Digital Britain can be implemented in a greener way, then surely this alternative deserves serious consideration. Satellite technology. Operationally, consuming almost no power at all. Satellite broadcasting is wonderfully green – a single relay high in Space transmits hundreds of TV channels to the whole country.

On the other hand, use of the terrestrial telephony and internet networks for TV transmission carries a huge energy demand. There is much enthusiasm for internet Video on Demand in the near future using new high speed broadband connections. Since such VoD services can be delivered virtually as well by efficient use of satellite broadcast it makes no sense to allow the UK (or other countries) to make policy decisions that encourage a drift towards an exceedingly energy inefficient way of delivering TV content.

Allowing the UK to drift towards an unnecessary usage of perhaps over 1GW of electric power – effectively the output of a modest power station – to achieve a very minor improvement in TV viewing without careful consideration would be highly irresponsible.

If the internet becomes a standard TV viewing infrastructure it is not only the operational power that is important. Should 10 million households view TV via the internet at peak times, then the expansion of the UK's core telecommunications networks would need to be significantly expanded - because most of the bits flying around the network at any time are peoples' TV pictures.

The Oxford-based Best Foot Forward, carbon foot printing consultancy, is conducting a study of these issues with Helios for ESA. ESA believes that the issues involved are potentially of serious concern and that the results of their study, when available, will provide policy makers with useful input.

We fully endorse that delivering the Universal Service and superfast broadband set out in Digital Britain is critical for growing the UK's economy and productivity. However delivering Digital Britain (DB) requires an approach that tackles the problem both from urban to rural and also from rural to urban. Broadband satellites will always be a part of the solution as they can provide ubiquitous coverage across the whole UK land mass instantly and are therefore ideally suited to connecting users in rural areas.

Rather than waiting 10 years to discover how many people in rural areas are unable to get services from fixed technologies, our proposition for DB Implementation Policy is that satellite broadband is used to quickly deliver services from the outside inwards while giving time for fixed networks to catch up.

As the lead Government Department, it is also time for Business, Innovation and Skills (BIS) to be less tolerant and more demanding with Mobile Network Operators and to insist that they meet there emergency response commitment by completing their coverage by use of the satellite-based technology which Inmarsat and Solaris can make available. This will be a far cheaper and a lower carbon solution to extended coverage than rolling out more masts with local subsidy, no matter which frequency band is made available.

If as a nation we are serious in our commitment to reducing carbon and increasing capacity on our transport networks, then a commitment to a low data rate supporting communications infrastructure is required. Space can play a critical role in this, by providing part of this underlying infrastructure in the form of both satellite communications and navigation.

Government plays a significant role in enabling these smart infrastructure markets, setting policy and long-term funding. If government sets requirements that are truly technology neutral, in for example, the smart metering context, then Space services will find their natural role within a portfolio of complementary solutions. This also requires government policy not to be set within an assumed context of terrestrial and cellular communications or be overly influenced by the protestations of the incumbent operators.

Space has a role for example in strengthening infrastructure support to government policy on transport congestion and environment. Satellite navigation and communications technologies are also critical enablers for other government-planned strategic applications, such as the DfT rail technical strategy.

In order to prepare the UK for Phase 2 and 3 of the SESAR aviation ATM project, DfT will need to ensure that the privatised NATS has access to sufficient revenue to implement the required ATM systems.

## Environment Monitoring

To fully grasp the opportunity in Earth Observations the UK should:

- Maintain ESA budgets at current levels and when possible increase budgets to maximise returns and UK leadership opportunities.
- Specifically, ensure funding for the ESA Post EPS (EUMETSAT Polar System) programme so as to benefit from the mandatory EUMETSAT contribution, and ensure NERC funding for Explorer missions is fully supported to at least GNI.

Additionally there is a need for the UK to play an increasing role in the GMES programme. GMES has many features: ESA, EU and potentially EDA are all players offering opportunities for the UK community. GMES is also looked upon by the EU as a bridge from EO to security and the needs of its military staffs.

All of these European players will take actions which will impact across UK Government Departments. This will bring opportunities at least the size of Galileo and it is essential for the UK to exhibit enthusiasm and purpose to become an effective partner and beneficiary of the programme. We call on the UK to subscribe to the new GMES Missions (from the Long Term Scenario budgets) and ensure UK influence so as to make the programme more effective in reducing the level of UK parallel expenditure and also to maximise industrial and scientific return specifically in the areas of new observing systems and security including both core and downstream services.

In technology we support the establishment of a National Space Technology Programme (NSTP) and to use Harwell to enable the UK services and applications market to benefit as early as possible from any technology developments. There is an opportunity for example to develop Space assets to produce useable $CO_2$ emissions mapping to increase carbon monitoring and to meet UK obligations.

This should be one application to be commissioned within a new UK EO Application Programme. This should be initiated now and should be designed to position UK players for new commercial and institutional opportunities. Based within the UK EO Hub at ISIC, the Application Programme will maintain long term links with customer communities. It will seek to respond to their requirements and provide prototype products and services for market testing.

These programmes would work in tandem and provide the underpinning market intelligence to support the National Space Technology Programme. They would use the community facilities of the ESA Centre and international nature of the ISIC to engage global customers and partners, assessing and delivering against future opportunities.

## Access to Space, Space Science and Exploration

We recognise that the UK might benefit from direct knowledge of one or more of the launch technologies that will be required for next-generation rapid launch for small payloads into LEO. We will need to appraise progress of the ongoing assessment of technology underpinning the Sabre engine concept, in conjunction with ESA. There could be both civil and military applications if sufficient HMG or commercial interest emerges.

Likewise, it is important that the UK should seek to identify and pursue the potential return for the UK from support for Virgin Galactica or similar future ventures. It is an important study topic post IGT to secure IPR if possible and to see how the proposed competition amongst potential operators from a Spaceport in the US might be extended to include launch from a UK-based site such as proposed by MOD in Scotland. Licences for one or more of the five US operators are unlikely to be issued before 2012 or 2013 but the complexity of this proposed business requires careful assessment in the run up to that decision.

This IGT advises that the 20 year strategy will necessitate regular examination of priorities to determine which niches and or more major topics to pursue as part of the agreed pan-Departmental Space policy. For example, the question of how best to participate in future exploration – when emphasis changes somewhat from remote robotic missions to a more significant mix with manned activity - remains to be decided.

For the moment, the UK is well placed to pursue robotic capabilities and non-manned equipment developments that can contribute directly to robotic missions in the short term and manned missions in the long term.

The new opportunities opening up both for the Space industry and the research sector can only be realised if the appropriate sectors are well positioned beforehand and this means laying some early foundations with nationally funded preparatory work.

As an example, the discovery of totally different immunological responses to viral strains, when propagated in a Space environment, with the implications for production of new vaccines, suggests fostering Space technology within one or more of the UK's world leading university research environments in this field to develop a new space-aware bio-medical workforce to support the research and the pharmaceutical exploitation. If this research were to show early promise and attract investing parties then this might merit consideration as an application to be associated with the recently selected British astronaut, Tim Peake.

In the present circumstances, the proposed strategy for human spaceflight is a two step process.

The first seeks to explore new funding mechanisms that justify early opportunities for engagement in operational use of ISS (by providing meaningful and high profile roles for UK astronauts) in new research fields such as Space medicine. The academic links would be found in existing world-leading bio-medical research institutes and where industry would forge new technologies by space-rating mature ground-based equipment. This approach can be secured through a combination of seed corn funding and academic start-up funding from the UK to leverage parallel funding from the European Commission.

A slow build-up of candidate technologies in industry, fostered through the ISIC, would require investment funding that would need to ramp up in step with the international schedules that will determine when Moon bases or missions to Mars and beyond could feasibly occur.

A continuing ESA programme will create opportunities in Science and technology; these can be clearly mapped out between now and 2025. However, history shows us that UK can lose out to European competitors if its capacity or competitiveness in key opportunities is insufficient. An optimisation of UK preparatory activity is needed, both to position to win noble roles and to effect leadership in Science and industry. Leadership within ESA programmes is a key capability that enables industry and scientists to secure new market opportunities through national or other non-ESA routes.

To benefit fully from the existing market and to influence and position effectively within the strongly developing market, the UK should invest strategically, invest early, and offer flexibility of routes to achieve its ends. National spend should be matched better to the provision of mature technologies and to achieving leadership. Both goals imply a strategic programme that can enable on-ground and in-space developments, both national and bi-lateral, prior to participation in demanding ESA missions or securing international exploration roles. To enhance competitiveness, UK should access technologies both from within and outside the Space sector.

**To influence and position effectively within the strongly developing market, the UK should invest strategically, invest early, and offer flexibility of routes to achieve its ends**

## Providing Resilience

The UK is reliant on Space systems. This reliance is positive and increasing. The UK is not unique in this, and like other nations, the full details of dependencies need to be researched and understood. The UK is however unique amongst key groupings of states, like the G8 and G20, for the extent of its military dependence on another single nation. Resilience may be achieved through appropriate national capabilities and collaboration. A National Space Policy should identify and update accordingly the best mix of these two approaches.

By its very distant nature Space provides a less vulnerable domain for the communication and reconnaissance assets needed to deal with periods of disaster or major upheaval. Space-based systems, either for communication or surveillance are not physically connected to an area of operation and such capabilities can be deployed anywhere in the world at very short notice.

As such the Home Office has already selected satellite (Skynet 5) as the preferred means for high integrity communications. Surrey Satellites and the DMC (Disaster Monitoring Constellation) provide timely and detailed EO data in times of international disaster to the global community. Whereas the DMC 1 constellation equated to multiple US LandSats and provided a good basis for UK's contribution to the International Charter for Disaster Relief, the next generation of DMC 2 and 3 satellites will provide much greater capacity and resolution. We need to consider this UK strength as a potential response to our recommendation that common requirements are assessed across Departments and aggregated in the form of a government EO data procurement service.

The UK needs to consider its requirements on satellite operators who carry its traffic just as has been done in the US, with, for example, Intelsat.

Intelsat has agreed to increase the security features of its satellites and has reserved auxiliary payload Space for piggy-back payloads of national importance such as additional UHF capacity, and for technology demonstrators. The US DOD has a much greater demand for commercial satellite capacity than the UK MOD, but the benefits are clear to both parties, provided that it is organised in advance and does not jeopardise commercial schedules. The same principle should proportionately apply in the UK for the government relationship with UK-based operators and could result in a greater and more resilient infrastructure with opportunities for operational and experimental payload demonstration via the NSTP for example.

The UK is internationally respected in the security arena. Downstream services are a clear opportunity to build on an existing UK strength. Our present contribution to tracking debris is little more than a token involvement. Even here we track and avoid rather than lead in proposing means to minimise or reduce debris. The current opportunities for extending involvement in the ESA SSA (Space Situational Awareness) programme should be grasped firmly and a strategy developed for more substantial involvement at the next phase starting in 2013. SSA may well become a flagship European project and presents the UK with an opportunity or leadership in European Space Security programmes. Downstream services should be developed in support of broadband TETRA developments as proposed by Inmarsat, as these could both lead to wider security exports.

In the past the UK has relied on a collaborative approach to gain both surveillance and reconnaissance Space data which has been almost totally focused on exploiting the UK-US 'Special Relationship' to the detriment of the UK Space industry. This relationship works well in coalition operations and for many years there was little viable alternative.

By focusing purely on the applications, the UK has ceded market leadership in satellite development in this area and lost any of the potential spin-off gains from an active EO Space business. This whole market area has now changed significantly. The Europeans have become major players in EO and there is a burgeoning commercial sector. This could leave the UK isolated and lagging behind in a major Space business sector and also clearly takes away much of our national negotiating power in several forums.

There is probably little to be gained now in trying to come to market as a late entrant in the 'big space' EO business. Indeed, major gains in this area may still come in the downstream business areas involving the creation of actionable information from the collected data. However, the UK does have a world-beating niche small satellite business in which it excels. The DMC created by SSTL offers an upstream capability which can cover both the wider security market as well as defence. Clearly the resolution and collection capabilities of small satellites will never match those of larger dedicated intelligence gathering systems, but the wide swath, improved revisit time and the ability to gather large areas of contemporaneous data are all important factors in producing part of the answer when creating actionable information. The UK still retains the necessary Space proven radar capability and this capability is a national asset which could disappear if sidelined by MOD any longer.

Moreover, the ability to launch quickly on demand together with the ability to rapidly react to improvements in technology offers clear advantages over systems requiring lengthy times on orbit to pay back their investment.

Small satellites offer the capability to build constellations with multiple sensors at affordable cost which would make the development of fused information achievable and cost effective. Small satellites from SSTL include LEO, MEO, GEO and interplanetary opportunities. They have a wide spectrum of potential use, including rapid augmentation of partially failed commercial comms/nav/EO satellites, rollout of pilot services, augmentation of services in a slot, imaging, rapid deployment of battlefield integrated sensor systems, technology demonstration for all classes of satellite, the claiming of frequency fillings and school Satellites as well as constellations like RapidEye, Iridium, DMC2/3 and RadarSat. It is time for MOD to put some funds into developing and using this unique UK capability.

The failure to exploit the small sat potential in the UK has resulted in a significant loss of MOD flexibility and loss of opportunities for UK industry to benefit from any form of Home market. The US has encouraged Canada to be more proactive in Space and as a result it has developed its own small satellite missions and applications as a competitor to SSTL. The next UK Strategic Defence Review should examine the pros and cons of MOD's Space dependent relationship with the US; having specific regard to its impact on UK industry, and the competence of the EU post Lisbon. These small satellite systems are applicable both to gathering economic data and to inform security decisions. It should therefore be possible with an MOD lead to gain pan-government funding and support for such development.

There is also a clear implication that a system of small configurable satellites coupled with a collection and analytical capability offers a capability to many smaller countries who wish to enter the Space business. As such the UK experience with PFI, upstream construction and downstream exploitation potentially offers a complete package which has already proven to be very marketable especially to emerging nations with little legacy infrastructure who aspire to high tech solutions.

Today the UK has a powerful military satellite communication capability delivered via a successful and innovative service arrangement, whose export market achievements continue to grow. While this success is recognised, there are, as ever, opportunities to do more to develop and ensure further achievements.

National and export requirements for capacity and connectivity continue to expand, driven by demands for near real-time information processing and dissemination, the increasing use of Unmanned Airborne Systems (UAS) and their associated dependence on milsatcoms and mobile operations calling for secure, IP and large data rate communications.

There are problems which need to be addressed with the MOD stance on development of the communications service. MOD wants to retain competition but doesn't want to spend on next-generation R&D. There is a clause requiring Paradigm to spend a limited R& D budget on service development. This is quite insufficient either to support R&D on development of technology for future phased arrays for example. Neither is it sufficient to support in-orbit demonstration on a small satellite or incremental capacity in new frequency bands. It is unrealistic of MOD to expect a multinational company to prioritise unfunded and uncommitted MOD wishes over profits for shareholders. That is the trade that a business must make.

It is recommended that the UK MOD moves to an incremental development of key technology and parallel replacement of satellites so that the rewards of spiral development and level financial investment may be gained. Such a programme would be ideally linked to a National Space Technology Programme, and the cross- fertilisation achieved between commercial and defence satellites.

Opportunities exist to increase government, both civil and defence, and commercial cooperation to achieve focused involvement through PPP in the manner that achieved the successive benefits of the Skynet 4 and Skynet 5 programmes. For example, the UK has started to apply its military communications satellite capabilities in the security arena. The size of the global security market is potentially very large but the UK is not uniquely placed to offer secure civil satellite communications, to the market. France, Germany and Italy covet this market too. By building out from its defence PPP there is an opportunity for the UK to win exports ahead of these and other competitors.

The European Defence Agency (EDA) is a developing player in this field and many international organisations may accept a security focused, rather than military, solution. The UK needs to embrace this infant European organisation now and help its development into an effective European player in the security field for collective benefits.

The demand for persistent, high resolution, pattern of life data drives the user to the airborne arena. Indeed the plethora of UAS Unmanned Aerial Systems) already employed in this role testifies to this trend. Space cannot match the very long endurance and resolution capabilities of a MALE (Medium Altitude Long Endurance) or HALE (High Altitude Long Endurance) UAS. However, such vehicles require significant bandwidth to pass back their data in real time. Thus unless a commander can operate these vehicles in line of sight to a high bandwidth data link, satcom offers the only viable over the horizon transfer of data in real time.

Thus, satcom becomes synergistic with UAS. This idea can then be carried further; each UAS could become a communications node as well as a sensor platform. A theatre could be given instantly multiple UHF channels which can then be transferred into more Space efficient waveforms for long haul to the command centre. Combine this idea with the potential to integrate collection of radar, EO and SIGINT data simultaneously in multiple, potentially stealthy, platforms produces the possibly of linked system of systems which is compatible with US notions of a Global Information Grid or NEC (Network Enabled Capability) for UK forces. Developments in technology to maximise the collection potential of a UAS and the ongoing improvements in high bandwidth satellite communications offers huge growth potential.

This idea of a ready-made system of systems for data collection and analysis using space/UAS has very great attraction. The ability to have at high readiness a system of UAS interlinked with satcom channels (spare X band capacity on Skynet 5) offers a potential disaster relief system or on a smaller scale a total surveillance package for a major event. Almost all the technology to offer this package already exists in the UK and needs only the will and the funding to create a marketable product with early demonstration and showcase under the guidance of DCMS at the London 2012 Olympics. The Aerospace IGT has developed a UAS roadmap. The Space IGT outputs should be integrated with this to develop joint services model.

## What collective action is needed

This IGT wishes to emphasise that this global industry is undergoing growth and that someone in this global market will take action to capture it. Therefore, larger investments by the UK will increase the size of the prize. If the UK is to share in this global prize, there is a clear and immediate need to act, which leads us to recommend mutually beneficial and visionary action by government and industry.

The need for structural change has now been recognised – the BNSC partnership approach was not working, as evidenced by the failure to implement the changes identified in the 2007 Select Committee Report and 2008 Space Strategy, and the need to now repeat and reinforce them in the IGT.

Even though the evidence suggests that significant funding should not be allocated now, there are a number of important areas in which we need to have a small involvement, or at least watch closely. Before 2030 the Space sector will have to revisit the decision on additional funding for Human Space flight, whether the investment in disrupter launch technology should lead to an involvement in future European launch capabilities and whether the Space tourism industry has matured and expanded to involve flights from the UK for customers and satellites.

## Removing Policy Barriers to Cross-Government Efforts to Stimulate Growth

The IGT found that there is an overall lack of coherency among the disparate stakeholders in Space and policy areas. We attribute this to the lack of horizontal responsibilities between Government Departments, and to the current implementation (centred on a partnership of interests) being insufficiently inclusive.

The UK has adopted a user-led model - such as the Meteorological Office - for its approach to the provision of services for policy delivery. Although this directly meets user needs, it can promote a narrow focus on value for money that ignores the wider economic and societal benefits of manufacturing and services. It can also lead to each entity defining its requirements for policy creation and delivery in isolation, and particularly in times of economic stress, it leads to each entity focusing exclusively on the short-term potential within its own domain. This acts as a disincentive for any one group to lead on behalf of others.

All candidate European infrastructure programmes - SESAR, security, Galileo, GMES - present the current UK Space community with a problem. This is typified by the position DfT is put in on SESAR where NATS needs access to sufficient income to play a full role in the development and deployment phases. The DfT approaches this, quite logically, at Departmental level and does nothing that might jeopardise future UK use of European Air Traffic Management infrastructure. However, in doing so the DfT avoids any possibility that it may be called on to pay for development work which may take ten years before the system becomes operational. This has detrimental effects for all concerned.

It ought to be possible for Space-related stakeholders to come together and recognise that combining their interests in an optimal way could lead to something greater than the sum of its parts, and a benefit for the nation as a whole. For example, the UK investing in Meteosat Third Generation through ESA as well as through EUMETSAT would have unlocked industrial return and therefore continuing economic activity in the UK in regular production of flight spacecraft. Instead the potential for work in future data services has been lost following the award of the contract for Meteosat Third Generation satellites to Thales Alenia Space of France and Italy and OHB of Germany. Instead of the project work being carried out in the UK, a team led by France, Germany and Italy will now build Europe's next-generation meteorological satellites in what is likely to be the biggest single space-hardware contract to be signed this year in Europe. The contract value is expected to be around 1.4 billion euros. The total Meteosat Third Generation (MTG) program is budgeted at about 3.3 billion euros, including the construction and launch of the satellites, a ground infrastructure and two decades of system operations.

Some 75 percent of the total budget is from Europe's Eumetsat meteorological satellite organization of Darmstadt, Germany (to which the UK contributes around 17% in proportion to its GDP), with ESA acting as satellite contracting authority.

It seems that Departments are not inclined to support the interests of other silos in Government alongside their own when it involves compromise on their own budgets – why notsupport a common national infrastructure to deliver smart metering (lead: DECC) on the same platform as HDTV (lead: DCMS), rather than simply deliver a policy goal that only delivers HDTV content to the maximum number of consumers?

The mechanism for achieving consensus and compromise for Space-related stakeholders in the UK is the British National Space Centre, a partnership of six Departments (around one third of the total), two Research Councils, the Technology Strategy Board and the Met Office. Some of the 10 member organisations fund at a very low level, while other Departments, that are using or have the potential to benefit from Space-derived data and services in their policy delivery - DFID, DCMS, Health and the Home Office - are not represented. The influence each partner exercises is in proportion to its own civil Space funding, which in recent years has reflected a strong shift toward Science and away from technology innovation and new operational services. The underlying difficulty for BNSC is that it cannot force each partner to take a wider policy view to achieve a greater synergy, and nor is it empowered to draw down budget from a central source or appropriate it from Departments. There is a tendency for Departments to resort to brinkmanship in the run-up to, and during, ESA Ministerial meetings for instance, with the result that UK Space subscriptions are:

- seen as infrastructure-driven;
- assembled in an ad-hoc fashion;
- follow European objectives rather than defining and leading them;
- lead to reduced economic and societal returns.

The IGT finds that this leads to reduced economical and societal returns across a number of areas including investment where budgets are split across multiple sources and/or are sub-critical in scale after the brinkmanship is played out. Procurement is conducted against the narrowest set of requirements rather than an overarching aggregation, and fragmented in responsibility and/or timescales, thus leading to suboptimal solutions of services to/for citizens. International influence is reduced as the UK punches below its weight in funding to ESA and EC. Lack of cross-government co-ordination and strategy development means that the UK lacks bargaining power when it comes to international negotiations on both infrastructure programmes and the uses to which Space-derived data can be put. This, in turn, compromises the interest in participation and leadership at the highest level, creating a vicious circle. Industrial strategy is incoherent; industry is not directed or assisted to move ahead in areas that would benefit the UK Government downstream and the UK Government does not position itself to take the benefit of industrial innovation in operational services. The result is a failure to deliver maximum economic return to the UK, resulting in a loss of competitiveness internationally.

While there are examples of joint policy creation and delivery, they tend to be at a low level of influence and overall scale. Overall the IGT has determined that Government needs to assess and determine whether space-derived data and services, and where appropriate the infrastructure behind them, are a nationally important asset for creation and delivery of policy. If they are, then a new approach to such a cross-cutting sector is needed to realise optimal opportunities and benefits over the next 20 years.

The IGT concludes that the lack of an adequately resourced and informed central body is a risk to delivery of Government and industry objectives and that the solution is clear. Adopting a new approach to the creation and ownership of an overarching National Space Policy should result in a flow-through of opportunities. A strategic view is needed in order to optimise investment choices. With the right structures, this leads to incentives for identifying cross-Department requirements and thence to a willingness to hold and deploy such budgets, which would consequently enable procurement of shared infrastructure programmes and/or multi-use data procurement and/or greater use of dual-use systems.

But in order to achieve this, it requires a focus of expertise within Government, which can translate Space into policy and create a wider knowledge of Space. It follows then that policy makers would be more open to Space-based solutions because the technology is integral to the delivery not a perceived special interest. There is an opportunity for review of some regulations and improved process efficiency of others while remaining sensitive to competition factors such as state aid. There should be greater links with the private sector to leverage shared use/funding of resources and to provide aggregation of government and commercial requirements, capacity and solutions.

Although the Civil Space Strategy is a good foundation, it needs to be developed more explicitly as a Government Policy, be widened across the Public Sector, and have single focus for implementation through Government Departments and other agencies. The crucial element of the Policy, and hence its authoring body, is that it must be linked explicitly with delivery of the mainstream policy objectives of Government, rather than being seen as a 'functional' add-on. The Cabinet Office is well placed to co-ordinate such a Policy having access to central expertise and information, proposing effective performance metrics against policy objectives and providing incentive structure to facilitate delivery by other Departments or a delivery agency.

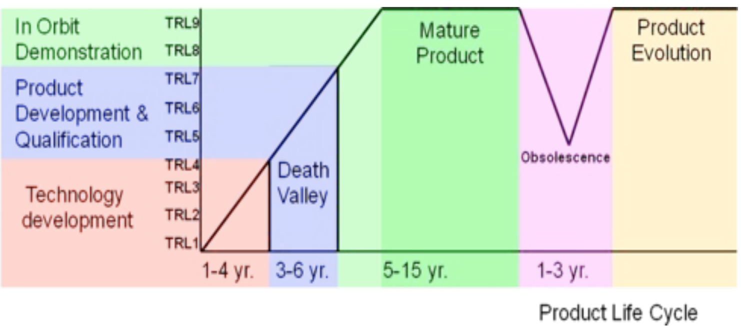
## Removing Technological Barriers to Growth

There are many new technologies which are currently being developed which have great potential for industrial application and when combined with new approaches and concepts provide solutions for the societal challenges of today and tomorrow.

Technology concepts originating in R&D often emerge in the form of technical papers and patents but are unable to grow in maturity through development and qualification phase due to an effect commonly known as Death Valley. The problem is simply that emerging Science side technologies receive little push from their originators who have no responsibility for exploitation or industry. The UK is poor at providing sensible levels of R&D support for priority topics of public or commercial importance, by comparison with most other OECD members. This effect is clearly seen within the Space industry perhaps even more severely than terrestrial based products which are discussed in the following sections. An Executive Agency might make more progress if it is funded to bridge the gap.

The overall product life cycle is shown in the figure below. Technology maturity is reflected by Technology Readiness Level (TRL), originally developed by NASA.

**Death Valley**




Funding for Space research and development is derived from multiple sources including UK Research Councils European Space Agency and Regional Development Agencies (RDAs). The current diverse funding streams inevitably leave gaps that preclude continuous and efficient progress through the stages of innovation, development and industrial implementation. This is simplistically shown in the figure above. A coherent overarching technology and funding strategies would enable the exploitation of UK Space technology and enhance its economic impact. Funding gaps which separate parts of the Space research community require identification and bridging efforts. Similarly, any unaligned activities need co-ordination to facilitate transfer of concepts between different stages of development. It is notable that the journey from innovation to implementation involves passage and communication of technology between different cultures ranging from the academic to the industrial and financial, all who would benefit from a clear and mutually accepted single vision.

Overall, Science is a fundamental part of the economy providing the technologies, capabilities and facilities that will be used in both present and future markets including the commercial and security elements of space.

This comes about because Science attempts to achieve unprecedented goals with accompanying new technologies, capabilities and facilities. During these efforts, the envelope of current capabilities and technologies is inevitably expanded and new exploitable commercial, scientific and economic areas are uncovered. It is scientific activities and low TRL basic technology research that lead to breakthroughs that represent the 'disrupters' or 'game changers' of the near future.

The scale of investment required, enabling the conversion of these low TRL and scientific achievements to marketable technologies should be regarded as medium term (5 to 10 years+) but fundamental to a continuously growing economy. Short-term returns, however, are possible and, as might be expected when dealing with innovation and ground-breaking advances, the link to the market may be novel and surprising. Moreover, Science often leads to a new appreciation of existing situations that cause currently unrecognized opportunities to be exploited that may only appear obvious in retrospect. In this context, Science and industrial research act as catalysts for the instigation of more rewarding activities.

Noted in the section above this is where Death Valley is a critical factor in the success or failure for concepts progressing through to into a product at the market place. Within all business sectors, from this stage onwards, development and qualification requires high interaction with the environments of operation. For Space application in orbit, demonstration is, therefore, mandatory to achieve TRL 8 & 9. For most commercial customers there is a requirement that new technologies have full flight heritage before they can be considered. This can create a considerable barrier for future developments.

Other Space nations, including the US, France, Germany, the BRIC (Brazil, Russia, India, China) countries and Korea, are using national missions to great effect within their Space programmes.

National Space missions would bring many benefits to the UK for industry, commerce, the scientific community and political standing. It retains highly skilled capabilities and inspires the next generation of engineers and technologist in schools and academia. A National programme facilitates a supply chain of companies to be established and downstream services to be developed that utilise the available data types.

It also has a 'shop window' effect where heritage and UK Governmental support to programmes should not be underestimated in the eyes of foreign buyers and agencies. This leads to enhancing the UK's political influence with Space-based data and our capability to interact with our international partners.

National missions should also complement gaps for the development and maintenance of critical technologies and capabilities to strategically position the UK for major European programmes. This helps to ensure the exploitation of Space assets for the benefit of the UK economy as a whole. Such national missions need to be derived from the overarching Space policy and the Technology Strategy and associated technology roadmaps which sit below. The technology strategy and roadmaps together will provide a focus for UK investment in infrastructure technologies and achieving the significant economic and public good benefits within this complex framework.

The position of the UK within the ESA community needs to be strengthened as this is currently a limitation for the UK achieving what are currently considered mission and key technology objectives. It is fundamentally important that a top-down strategy approach is used to focus the key strengths of the UK Space community with the necessary financial resources. There needs to be a correct balance between ESA and national budgets to ensure that capability achieved through national programs can be used to showcase and position UK companies for national, European and wider international opportunities.

A number of approaches for technology demonstration missions have been identified in Volume 3 of the IGT report. These range from Cubesat programmes through to small technology demonstration missions and fully operational development payloads. Technology roadmaps are likely to consider a combination of these demonstrators whilst bearing in mind the strengths of each. The TechDemoSat proposal led by SSTL and VEGA is a good example of this approach.

## Improving Connectivity in the UK Space Community is Essential

To ensure the future success of the UK Space industry it is vital that there are good links between academia and industry. SMEs need special measures to enable them to thrive in a difficult operating environment as well as to help them be more active in innovating into the Space market. They would benefit from an effective networking support structure across the industry and with academic involvement. SMEs feel they are often playing on an uneven field when it comes to competing with large organisations and Government research and development facilities which sometimes compete with them. The UK has much to gain in providing opportunities for its Space SMEs. A

UK Space Agency and funded UK Space missions would facilitate this.

The Harwell Campus and associated ESA centre offer opportunities for UK Space. However, physical clustering at Harwell is not a necessity except perhaps for new companies that wish to locate there. There are many centres of excellence throughout the UK which can be used in a ‘Hub and Spoke’ arrangement with Harwell. It is not necessary to centralise everything at Harwell. Not only is it costly it also affects those other regions, which have their centres of excellence and associated staff removed.

Virtual centres of excellence should be used wherever possible. The Centre for Earth Observation Instrumentation (CEOI) is an excellent and very successful example which merges the capabilities of industry and academia to develop the next generation of Earth Observation Instrumentation. Details of CEOI are given in a white paper prepared for this group in volume 4. CEOI is complemented by the Centre for Earth Observation another virtual grouping led by the University of Reading.

Harwell should be, therefore, viewed as a possible location for new national facilities that may be required, including some linked to disruptive technologies. An example here is facilities required for test of nuclear-based systems and production of structural materials associated with them. In terms of co-ordination it should provide an information hub to link the various components of UK Space activities and act as focal point for national workshops and meetings associated with, for example, the development of the Space roadmaps.

## Creating a Supportive Regulatory Environment (Spectrum, Outer Space Act)

We must ensure that we have the right regulatory environment in the UK that does not inadvertently constrain growth or the adoption of new technologies or services.

There are immediate concerns over the availability of extra spectrum for the Universal Service Commitment and Final Third (NGA) projects set out in Digital Britain. This additional spectrum is needed to ensure that, as government services move to electronic delivery, these services are available to everyone and not to just to the urban population. In the longer term, the UK will need to have multiple providers of satellite capacity for direct to home HDTV and broadband if it wishes to preserve competition.

It is important that Ofcom includes Space-enabled services for the commercial and security sectors in its reviews of spectrum allocation, and that in certain spectrum bands, UHF, S, Ka and Ku, specific allocation is made for new growth in bandwidth for Space services. We endorse the overarching policy of competitive bidding for bandwidth as it becomes available, but this must be done within a framework that includes provision for Space services.

Consideration should be given to removing the satellite spectrum responsibility from Ofcom and handing it over to a Regulatory team within the Executive Agency in a similar manner to the way military spectrum is handled within the Ministry of Defence. This template has been proposed for certain spectrum used by Department for Transport.

High transponder usage prices in Europe should be investigated as they discourage new satellite service applications and providers. If space-enabled services grow quickly this may create a shortage of transponder capacity putting further pressure on prices.

Technical demonstration of a fully digital and regenerative payload would enable various options for innovative features, such as virtual channels, IP switching and adaptive bandwidth per channel, to be evaluated against a background of the most cost-effective options for operators and new entrants. As part of its Climate Change agenda, the Government should make a clear international signal that it backs the retention of the C-band frequencies in current use for satellite services as a key component of its support to the poorer nations who rely on these frequencies for high availability services, especially after disasters.

We recommend that Government should modify the regulatory regime on spectrum allocation to remove barriers that disadvantage the development and adoption of Space-derived data, services and infrastructure with their consequent carbon and ubiquity benefits. The Executive Agency should take a lead within Europe to establish an effective process to eliminate paper filings from the ITU register and to secure fully co-ordinated orbital frequency resources for existing and aspirational UK operators.

The Outer Space Act needs to be reformed. The new Agency needs to end the insurance-based regime, which deters all UK launch service initiatives. One result of this is a possibility that we will deter Space tourism operators from developing UK launch locations because the outer Space Act requires operators to provide the UK Government with an unlimited indemnity against damages resulting from an accident and provide £100 million insurance cover. This is a potentially important consideration as the technology used for Space tourism could provide the basis for launching small satellites into low Earth Orbit, a potentially lucrative niche market where launch capacity could become scarce. We recommend that the Government sets a clear timetable of no later than the end of 2010 to resolve the issues around launching from suitable UK locations based on the current discussions between BNSC and the CAA (Civil Aviation Authority).

## The Need for MOUs in the Space Sector

The United Kingdom has many Memoranda of Understanding (MOUs) with other governments concerning agreements about aid, scientific research, and a wide range of civil and military technologies. Such MOUs are treated formally by HMG as “TREATIES”, and are generally signed by an FCO Minister.

HMG does not enter such agreements lightly, and expects their terms to be adhered to by both sides. There is likewise an expectation that MOUs will be mutually beneficial, though the expected overall balance of advantages can be quite different for both parties as regards policy objectives, regional influence, and access to technology, financial support, credit guarantees, and access to markets and scientific collaboration.

When competing in international markets – especially in response to opportunities in the National programmes of other Space nations – MOUs play a very important part in ensuring that UK firms are competing on even terms. In these cases, there are generally benefits to both countries, though their characteristics – while balanced – can be quite dissimilar.

Taking a recent example, the impact for the UK of a proposed new MOU is very likely to provide:

- a direct response to objectives identified at a Ministerial Trade meeting in November 2009, and are thereby fully consistent with UK/BIS trade objectives in this priority target market;
- continued access, at preferential rates, for UK firms and UK government to Space launch services;
- access at more competitive prices for ESA/European launch services due to the effects of competition;
- access for UK firms on a competitive basis to export opportunities (value approx £50m pa and growing at 10% pa) in the National Space programme of that country. These would otherwise be denied to UK firms due

to the considerable tax and duty advantages in that Nation that are available on imports from other countries that already have a comparable MOU;
- continued ability to collaborate on Space and Earth Science projects and missions;
- expectation that this Nation will take a more responsible position as a major supplier of launch services in negotiations about international agreements and legislation to mitigate the effects of Space debris;
- a direct contribution to FCO short/medium term objectives to rebuild good relationship with that nation;
- helps DECC regarding collaboration and influence building necessitated by limited success of the December 2009 Climate Change conference in Copenhagen.

The perceived benefits to that Nation are:

- immediate confirmation that UK and that Nation are already working together to follow-up on promising trade discussions held in November 2009;
- recognition by UK of the peer government Department status of its Federal Space Agency;
- completion of a policy by its Space Agency to negotiate new MOUs with all of its major partners; thereby acknowledging its new status and responsibilities;
- confirmation that UK firms will be able to bid for procurement opportunities in its National programmes; subject to known rates of its duties and taxation on its imports that are already preferentially enjoyed by other Nations which have negotiated a MOU;
- confirmation that UK will continue to allow its small satellite industry and their customers to purchase its launch services on a competitive basis, despite the UK's membership of ESA;
- continued access – though not on a preferred basis – for its scientists to participate in collaborative opportunities alongside other Space and earth scientists;
- evidence that mutually beneficial collaborative research and business opportunities will develop progressively over coming years;
- expectation that greater awareness of that Agency's Space plans will result in greater willingness on the part of the UK to facilitate collaborative opportunities at ESA, and other means to combat side effects of US ITAR (International Traffic in Arms Regulations).

It has been disappointing that UK officials have taken a rather narrow view of the benefits flowing from MOUs, in particular when assuming somewhat arrogantly that the benefits accrue to the collaborator, rather than mutually or to the greater benefit of the UK.

In this regard, it has been particularly disappointing that HMT/HMRC (Her Majesty's Treasury/Her Majesty's Revenue and Customs) have been reluctant to engage in discussion about standard clauses for MOU's; regarding imports of Space goods by nations with whom the UK does not currently have a fully functioning Space MOU.

It is important, therefore, that UK officials and Departments give prompt and knowledgeable support to negotiation of MOUs by providing the following:
- focused support on MOUs in market sectors prioritised by a joint government/industry advisory committee TPIC, starting with Russia;
- prompt coordinated responses from OGDs (Other Government Departments), so that BNSC – or a subsequent Executive Space Agency - can thereafter enter into negotiation with International Space Agencies;
- Cabinet Office involvement, if required, to resolve any inter-Departmental concerns;
- sufficient resource to BNSC to support overseas inward and outward missions in target market prioritised by TPIC or agreed

with Ministers, and to negotiate MOUs with other countries and their Space Agencies.

## Increasing Skills and Awareness

The case for raising awareness is a strong one – it touches many aspects affecting the future growth of the industry, ranging from the supply of skills, public sector awareness of the benefits of Space (and therefore their buy-in to those programmes), awareness and support from the tax-paying public, right through to relations with the downstream users.

There are many interdependencies within awareness, for example, high public awareness and support of Space will raise public sector awareness through their status as taxpayers. It can also improve skills supply, as career choices are influence by parents and teachers who are themselves representatives of the public.

Thus, while these interdependencies may currently be pulling in opposing directions, it suggests it is also possible to create a virtuous cycle of awareness by addressing a few key issues.

The IGT has investigated awareness issues affecting Space and has found there is an awareness gap which, unattended, will act as a barrier to the future growth of the sector. This largely stems from the widespread fragmentation of the market, combined with the fact that there are no clear lead organisations that are specifically tasked (and resourced) to provide outreach and education on the sector.

This is manifesting itself in several ways among key audiences:

**a) The General Public**
The IGT conducted an Ipsos Mori study of public awareness, which concluded that although public interest in Space was high, awareness of UK Space and the benefits Space can deliver was low1.

- Only 5% of respondents to the question, "Who do you think is responsible for Space in the UK?" gave 'BNSC' as their answer.

- 81% of the British public know that weather forecasting is enabled by space-based technology, only 47% think that Sky News is, 22% think that settling financial transactions between banks is and just 7% thinks it helps disseminate National Lottery results.

- The areas that the people most associate with Space typically revolve around rocket launches and human Space exploration, which are the areas that the UK Space industry does not participate in. Thus, we see that over 50% of people expressed a degree of uncertainty as to whether the UK had a Space industry (including the 21% that said they believed it didn't)

Somewhat contrary to this was the fact that there was a large number of organisations trying to promote and raise awareness of Space, including the British National Space Centre, four separate trade associations, at least two research councils, at least four learned societies, plus museums, and the private sector operating in the Space industry.

The issue was that as a result of these multiple outreach activities, there was no obvious "go-to" point for interested parties (whether media, teachers, students civil servants or the general public) to get information about Space. The fragmentation was also compounding the issue as messages were getting diluted and there was no overall strategy to target key audiences for the sustained future growth of the sector.

**b) Public Sector**
In many ways the awareness of the Public Sector in general is no different from that of the wider populace unless the individual has particular responsibilities for a Space programme within their job. However, even many of those directly involved with Space programmes are often still not aware of the wider aspects of the sector or that the UK has a Space industry that

supports these Space programmes and is a thriving successful commercial base.

A lack of awareness of the sector by civil servants and politicians may result in restricting or damaging the UK's global position or constraining the sector's growth. Therefore, a greater awareness of Space is essential if a full appreciation of the role and economic benefit the Space sector plays in the UK everyday is to be realised; and to ensure the Space sector is considered when drafting government policy.

Within government Space is seen primarily as an asset for Science and the preserve of chief scientific advisors - not as an enabler to wider HMG policy or as a contributor to the UK economy.

To put Space in the broader political context, it is not considered a mainstream electoral issue or even a significant party political delineator. It has not featured in the manifestos of the main parties in recent General Elections.

Interaction between the Space industry and government is less established than in other equivalent high-value industrial sectors. Furthermore, it does not have the same representation in government as other manufacturing sectors.

A common single voice from the UK Space industry that is trusted by Government and can represent the sector in government would go a long way to raising awareness and facilitating relations in those circles, as well as providing a one-stop shop for government for information on the sector.

**c) Business**

As mentioned in other sections within this IGT report the future growth of the UK Space industry relies to a great extent on growth in the downstream activity, which means that relationships with downstream business users of the data, services and applications that satellites enable become more important.

The IGT research interviewed a number of downstream users providing a crucial glimpse into space's relationship with its customers, and indeed many of those interviewed expressed delight that the UK Space industry wanted to interact with them and seek their contributions. It identified several common themes including a call to recognise the role of resellers and

systems integrators in adding value through their ability to understand sector-specific challenges and protect the end user from some of the issues of dealing more directly with the upstream.

There were criticisms of the Space industry as being in danger of "pushing technology" rather than coming up with solutions to the end user's strategic business challenges.

Another common theme was the UK Space industry performs few outreach activities that reach its end-users. Most of its advertising activities are targeted at others within the Space industry; most of its trade shows are attended by representatives from the Space industry; it is not represented at the trade shows of its customers. The IGT research among downstream businesses did discover that there are initiatives in place to address these, but these are largely in their infancy, and other nations are seen as much more progressive in this regard. Users welcomed efforts by the Space industry to engage with them and thus extensions of such initiatives are recommended.

**d) Future employees**

The Space industry has possibly the most highly skilled workforce of any UK manufacturing industry, and is among the highest for productivity. The industry directly supports some 70,000 jobs, and is expected to create 100,000 high-value, highly skilled new jobs in the next 20 years if the recommendations within our strategy are implemented.

But the UK Space industry is displaying skills gaps within the existing workforce as well as difficulties in recruiting sufficient new employees. If left unaddressed, these shortages will affect its ability to fulfil its growth potential.

A 2008 BNSC survey indicated that two thirds of vacancies for experienced staff and half of vacancies for graduates with applied degrees were not filled at the first attempt. New employees often lack the skills needed to help them make a more positive contribution to the business and existing employees are missing skills that would make the business more efficient and competitive.

Issues around STEM (Science, Technology, Engineering and Maths) skills shortages are not unique to the Space sector; they are affecting engineering industries in general. This is widely documented and understood with several initiatives already underway to address them.

In this respect, Space represents just a small part of the problem; however, through its unique ability to inspire young people to take up STEM subjects, the IGT believes Space could be a big part of the solution.

Government has recently agreed an extra 10,000 university places in STEM subjects and has increased funding for apprenticeships by almost a quarter between 2007/8 and 2009/10, to over £1bn . The Science & Innovation Investment Framework 2004-2014 set down extensive challenges regarding the education system and STEM issues, and the 2009 Skills White Paper Skills for Growth included proposals for the creation of 35,000 new advanced and higher apprenticeships by 2011, and supporting Diplomas.

The industry's sector skills council, SEMTA, similarly identified a number of priority areas including supporting advanced and Higher Engineering apprenticeships, development and acceptance of Foundation Degrees, increasing the relevance of degree courses, including sandwich courses, and efforts to recruit women and ethnic minorities.

The IGT acknowledges the substantial efforts already being made by Government and the Skills Councils to address the shared STEM skills issues, and recommends that the best way to ensure that the Space industry benefits from them is to demonstrate its full commitment to the priority areas identified.

Through its power to inspire young people and influence their education choices, Space championship of initiatives such as apprenticeships, sandwich courses and diplomas could make a significant difference to their uptake, thus benefiting not only the Space industry itself, but the wider UK engineering industries.

**Communications from Industry**

To understand the landscape in greater detail, we also looked at how the Space industry was communicating, and how its messages were being received by different audiences. In the first instance, we saw the industry to be very highly internalised with prevalent use of jargon. This was discriminating against those outside the industry and, more importantly, those who were looking to join it.

A particular example is use of the terms: upstream, midstream and downstream. Even though upstream is generally understood within the industry to mean satellite manufacturing, there are differences of opinion as to the definition of mid-stream and where this becomes downstream. Potential recruits to the industry find language around upstream and


downstream at best confusing, and at worst off-putting.

The IGT also studied the outreach and marketing habits of the industry. Though taken through a small sample size, the results were revealing. For example, we saw that around 40% of marketing spend is directed within the Space industry itself, but only a combined 16% at schools, academia and the general public. Similarly, we found that industry advertising spend was less than a quarter that of the wider B2B market, and about 1/8th that of B2C markets. Overall marketing spend was just 0.4% of revenue compared to an average of 4% for other sectors.

**Easing Skills and Awareness barriers**
In order to remove these barriers to growth, the IGT recommended that some key actions are needed to defragment the market. These involved tasking both UK Space and the new space agency with specific objectives for education and outreach, and equipping them to fulfil these. These two organisations will become clear go-to points and trusted ambassadors for those interacting with the sector, although it is recognised that organisations with commercial interests will maintain their own outreach programmes. It is also hoped that, concurrently, the developing European Space Education Resource Office (ESERO) will be able to increase coherence and accessibility in the use of space related activity across education.

In addition, the Space industry needs to match the government commitment to improving STEM issues, and use space's power to inspire young people, by acting as an exemplary sector champion for existing initiatives. This should be done through greater engagement with the sector skills council and with education providers, including championing the professionalisation of apprenticeships and employer involvement in degree design to produce higher quality graduates.

Due to the inter-relatedness of awareness issues of the public, public sector, business, and skills, the adoption of these recommendations will begin to fuel a virtuous cycle which in turn will contribute to the sector's future growth.

## Government Providing the Environment for Success

The work of this IGT has built on previous work. Much of the IGT work is therefore, not wholly new and many conclusions have been seen before. Some of these can be found in the conclusions of the 2007 Select Committee and the 2008 Civil Space Policy, or in industry's 2006 Case4Space.

Despite the clear and reasonable recommendations of previous work, there has been a consistent failure of implementation. This IGT was required to re-crystallise prior conclusions in the light of new information like, for example, new perspectives from the Space Exploration Working Group. It was also informed by the new policy environment with its focus on Climate Change and Zero Carbon Electricity Generation and the need for sustainable and pervasive economic growth - as highlighted in the World Bank's Growth Report of 2008. Further prompting came from the need to reduce the cost of provision of public services (primarily through universal electronic delivery)

- as highlighted in the Smarter Government White Paper of December 2009.

The industry has quite long development cycles for infrastructure and services which range from five to 15 years. This requires that government creates a consistent policy environment sufficient to convince industry to invest beyond its normal financial horizons and government CSRs. Likewise, if the UK Government accepts this IGT view, industry calls on it to have sufficient confidence in this valuable, recession-resilient industry to include it in immediate efforts to stimulate the UK economy.

We envisage a Cabinet Office led process to formulate and agree a policy across Departments at Ministerial level. This policy for Space should build on the strategy contained within this Innovation and Growth Strategy. An objective of the policy must be to meet national needs from Space but also the National Policy should maximise export opportunities for UK-based Space companies.

# 5.0 UK Benefits

## Impact for the UK of Achieving the Vision

Achieving this vision will produce significant growth and will drive up the UK's current share of the global Space market from 6.5% to 10%. This is seen as a stretch goal but one that is achievable if industry and government adopt an ambitious approach to promoting Space use. In absolute terms this would grow UK Space from today's £5.8 billion sector to one of £80 billion by 2030.

The Space industry will become a leader in a return to strong growth for high technology and advanced manufacturing sectors. It will also be an enabling factor in improving the future lives of the citizen by means of smart, digitally enabled housing, coherent energy and carbon reduction policies, advanced travel policies and a safer more secure Britain.

A future Britain will recognise Space capability as strategic - a critical infrastructure and capability central to the future prosperity of the nation. Industry will see the benefits of this change in attitude and will continue to attract private funding and inward investment to develop new companies, technologies and projects.

## How Space will impact society in 20 years time

The following sections show selected examples of 'a day in the life' scenario to illustrate how our invisible Space assets will further impact our lives. They also highlight opportunities where the UK can address societal challenges. If the UK were to choose a non-participatory course of action, then commercial applications will still prevail. Revenues may well then go to other countries.

## A Day Begins In 2030…

**…..For Everyman in 2030**

Waking up to the radio is a thing of the past: The mobile phone has developed into a General Purpose Personalised Electronic Device. It has picked up all the news over the home UHF broadband network overnight from the Set Top Box (STB). It wakes you with an alarm at 7:05 and starts your favourite audio news and music programme from the beginning. It warns you that the heavy overnight rain has reduced your normal road to work to one lane due to flooding and that a departure slot has been booked 5 minutes earlier than usual with an alternative route.

**Watching breakfast news**: The STB is the hub of the home area network, using the frequencies released by the termination of the terrestrial TV and radio transmissions in 2018. The internet and TV have been integrated into an on-demand service and the STB receives its multimedia content by satellite. Whilst town dwellers have a fibre connected uplink you live in the leafy suburbs of Birmingham and use satellite for the uplink too, along with 8 million other households. The news announces that the overnight heavy rain has affected the entire Severn watershed but is predicted to be the first of this magnitude to be completely without damage to property.

Natural disasters are now mitigated by the availability of satellite imagery supplemented by a rainfall sensor network connected by low data rate satellite communications. The predictive model of water flow enables emergency organisations to concentrate on mitigation measures involving diverting water to huge emergency floodplains and reservoirs on agricultural land. Some road restrictions and closures are forecast but even here it is now possible to marshal relief efforts and resources more effectively. The satellite overlay ensures that during such emergencies, essential users are always connected by their usual handset even when the terrestrial infrastructure is down.

**Checking the weather forecast:** The meteorological satellite constellation provides continuous real-time weather data. These are fused with data collected by satellite from millions of terrestrial weather sensors. Together, they provide weather models of uncanny accuracy. Real-time personalised weather forecasts are sent to both the home and handset, allowing efficient management of the home through predictive heating and air conditioning, as well as accurate weather warnings direct to your handset using GNSS data.

**Travelling to work:** Your car has been charged overnight and has your new route logged through the home area network. By opting for the longer journey you have received 200 free car miles from your Traffic Service Provider. The last five minutes of your breakfast show has been downloaded so you do not miss the end of the video programme if you engage the autopilot. GNSS allows data to be gathered to generate real-time congestion statistics for road and rail. Satellite continues as the predominant means of digital radio transmission on the move and digital satellite radio sets are installed in all European cars. Road signs are being replaced by head up displays and verbal directions are provided if you choose to take over control of the vehicle. The Traffic Information System (TIS) enables accurate route finding and increased battery range.

Trains are also controlled to reduce fuel consumption and increase safety despite decreased separations and increased speeds.

**Always connected:** The Satellite overlay provides a signal everywhere to every handset. There is no wilderness in Digital Britain and deaths on country roads have been reduced as responders are alerted of accidents and emergencies the moment they occur. Combined satellite services are socially connecting people through communications, location and timing. In the office, satellites provide high capacity, immersive environment communications allowing realistic virtual meetings and energy savings.

**Using the internet:** Satellite provides an affordable and energy efficient high speed Next Generation Access service to businesses and households even in the most remote parts of the country. The rural economy has blossomed under its influence and more and more businesses are choosing to relocate to rural areas to retain staff by providing a better work/life balance. Mobile broadband is now a reality to hand held terminals that seamlessly switch between terrestrial and satellite networks for uninterrupted service.

**Returning to a smart home:** Smart domestic energy networks use satellite links to manage energy use and billing throughout the country. The national grid is managed to reduce peaks and troughs, improving efficiency, whilst GNSS timing is used to synchronise local power generation from solar and wind to the national grid. Whilst you were out your home environment was monitored and you are told on your return that no alerts were necessary.

**Evening meal**: Earth observation satellites provide the weather forecasting and environmental monitoring essential in agriculture. Even the most remote rural communities can be connected by satellite, allowing safe and efficient farming and food production.

Precision agriculture enables satellite control of farm machinery and GPS-enabled harvesting for yield measurement. In getting the food to consumers, satellite GPS tracks the logistics chain to keep the supermarket shelves stocked.

**Evening TV Entertainment**: Satellites now broadcast Super High Vision TV to 100 inch screens. Pictures are stunning even for moving images as the programmes are played at 400 frames per second. Smart satellite STBs store all your favourite programs and anticipate the programmes you want to watch, offering them on demand through your own personalised interactive TV guide. Advances in satellite technology offer greater programme-carrying capacity for unprecedented picture quality and viewer choice.

### …For our public servants in 2030

Following the launch of four surveillance satellites by the UK's imagery service provision organisation in 2013 the constellation has grown with contributions from partner nations to provide near real-time imagery via the commercially run data relay network based in London. Data from all of the satellites is collected and supplied to the UK Executive Space Agency, the 'anchor tenant' for the constellation, and a variety of commercial customers as well as to partners.

The satellites operate in near-polar orbits, providing real-time access to any location on the globe at least once per day. This extremely timely imagery capability gives the UK-led constellation a significant commercial edge and the UK's anchor tenancy has enabled three UK-based former SMEs to become global names in image-based services.

The satellites are equipped with multiple sensors that enable different resolution images to be captured, allowing a wide range of government departments' agendas to be addressed.

**1.00am** - Following a major earthquake In New Zealand, the agile satellites are used to collect high-resolution imagery of lines of communication and determine which routes are open for the provision of aid. Data is supplied to FCO and DFID.

**2.30am** - Areas of the Indonesian rainforest are imaged and data collected to provide confirmation that areas of vegetation that have been set aside under an international climate change treaty are indeed unaffected by illegal logging. Data is supplied to DECC.

**4.00am** - Areas of China are collected at high resolution to support a national mapping programme. Data is supplied to a commercial imagery customer in Beijing.

**5.30am** - Areas of Bangladesh are mapped as part of a DFID-sponsored programme to plan for, and hence mitigate, the damage and displacement caused by flooding and a global rise in sea levels.

**7.00am** - During passes over the latest war zone the satellites receive commands, and wide-area images are collected over current operational areas. These are compared with imagery collected over previous days and weeks to indicate areas of recent change, and used to cue persistent unmanned aerial system (UAS) coverage, saving many hours flying time. The satellite data is supplied via a direct in-theatre downlink to the allied theatre commander. The entire operation is completed within 20 minutes. One of the satellites is also used to survey a building thought to be involved in the manufacture of Improvised Explosive Devices.

**8.30am** - Over the east coast of Africa, the satellites gather imagery which is down-linked directly to the international naval task force addressing piracy in the region.

Data is supplied to MOD, the FCO, and the UK's Allies in the region. During the pass, water levels behind dams on important water courses are monitored using high-resolution data to assess the likelihood of tension over access to this key resource. Data is supplied to FCO and MOD for conflict prevention.

**11.30am** - A similar imaging pass is conducted off the Western coast of Iberia on behalf of our European allies. Maritime data is exchanged under an MOU agreement which provides the UK with access to Space surveillance data from European satellite systems such as Helios, SAR-Lupe, and COSMO-SkyMed. The surveillance data is used to monitor the potential positions of boats off North-West Africa being used by illegal immigrants attempting to enter the EU, (thus benefiting the Home Office).

**10.00am** - In southern Africa, DFID targets are monitored to evaluate the adoption of improved agricultural methods promoted under a UK-sponsored education programme. Parts of central Africa are monitored to assess the likely grain harvest, the failure of which would lead to a humanitarian crisis. Again, data is supplied to DFID.

**1.00pm** - The satellites are used in wide-area mode over the area south of Greenland to collect data for maritime safety on sea surface conditions, weather patterns, and icebergs. Data is supplied to a variety of maritime agencies on a commercial basis.

**2.30pm** - Maritime data is again collected, this time over the Caribbean, and is supplied via direct downlink to the RN vessel conducting drug interdiction duties in the region. Data is supplied to MOD and combined with Automatic Identification System information to highlight illegal vessels.

**4.00pm** - The constellation is cued to map the path of destruction caused by a major tornado over the central states of the US on the previous day. The data is sold to a commercial news organisation, which includes it in their evening news bulletin.

**5.30pm** - The forest fire season is close to its peak, and areas of Los Angeles are at risk. Imagery is acquired of the smoke plumes to aid the efforts of the fire-fighters and supplied to the UK's principal ally on humanitarian grounds. This process is coordinated via the International Charter, which is invoked on the UK's behalf by the Cabinet Office.

**7.00pm** - Arctic images are collected for the oil and gas industry, which is monitoring movements of the ice sheets to maximise exploratory drilling opportunities in the seas off Northern Alaska. Data is supplied on a commercial basis.

**8.30pm** - Imagery of the North Pacific is collected to help marine pollution clear-up operations in the region. The motion of the ocean currents, which constrain the debris, is mapped, and these are used to direct the clean-up operations. Imagery is supplied to an international consortium.

**10.00pm** - Satellites are used to collect wide-area imagery of Antarctica to provide an update on the maximum winter extent of the Southern Hemisphere ice sheets to evaluate the potential effects of global warming. Data is supplied to DECC.

**11.30pm** - UK coverage is used for multiple purposes, including support of 3D digital mapping to generate hi-res maps for the Home Office and DEFRA to monitor changes in land use. Images are also used to assist fisheries protection patrols by providing ship-detection data to DEFRA to help target suspected illegal fishing activities off the East coast of Scotland.

### ….For our inquisitive educators and for inspiration in 2030

The UK has established a significant European lead in mobile robotic system integration and associated technologies such as avionics, control systems and instrumentation. The credibility and experience gained from acting as European lead and deploying an operational mission through ExoMars Rover has proven far more valuable than isolated research and development projects.

Launched in 2018, the ExoMars Rover mission progresses understanding of the make-up, geology and history of our solar system and hints of past Life on Mars. Through this increased understanding, insights were gained into the history and future evolution of our own planet and its climate via the subject of comparative planetology. Following the recent chance discovery of bacterial fossils deep under the surface of Mars, shocked astrobiologists are planning a systematic search for more discoveries to test hotly debated scientific theories for the rise and demise of Life on Mars.

New robotic missions are on their way to other suitable targets such as Europa (Moon of Jupiter) and Enceladus and Titan (Moons of Saturn), whilst robotic exploration of Mars is returning high-quality data to infer the evolutionary history of water and climate on the planet.

The UK capability has developed beyond the Exomars mission and is now a regular co-prime with NASA's Jet Propulsion Laboratory. This has strengthened our position within Europe and made us a partner of choice for other nations. India and Japan have approached the UK to join a mission to build a robotic solar cell fabrication facility on the Moon.

The UK is now recognised as a leader in planetary rover design and manufacture with particular expertise in planetary robot control software design and implementation.

Other skills developed in the UK cover planetary manipulator design and build, development of planetary instrumentation and Space & planetary robot sample acquisition technologies.

Technologies and techniques developed for exploration have found their way into other areas and the UK has been quick to develop medical applications. Hyperspectral cameras are now used to easily identify skin cancer and detect early-stage liver disease in medical diagnostics. This has brought about considerable benefits in reducing the numbers of deaths and has helped to optimise the use of NHS resources. Patients are now able to be diagnosed and set on a treatment path within one consultation.

Life Detection instruments have formed the basis of bed-side medical diagnostic instruments. They provide instant diagnosis of many diseases and also allow instant detection of hospital infections.

Autonomous rover technology has enabled us to provide platforms to transport individuals around large buildings. At airports customers with reduced mobility are transported from airport drop-off points through the check-in process and are delivered to their boarding gate. Hospital patients are now able to be moved around the ward and to other departments without needing to be escorted by staff.

Robotic people carriers help the elderly and robotic nurses care for the elderly, allowing people to stay active within the community.

New power-generation and materials technologies provide safe nuclear power systems helping to minimise carbon emissions.

Long-lived and highly robust power systems are able operate in remote and harsh environments. This allows long-term monitoring of the Earth and its climate even in the most inhospitable locations.

The development of novel power sources for Space has had direct application in terrestrial situations where power supplies are limited or disrupted, which proves particularly useful in emergencies such as earthquakes.

Solvent systems, developed to extract organic molecules on Mars, are used in the green economy for chemical processing and extracting petroleum for use in manufactured goods from low-yield oil shales, providing clean technologies.

Small, smart, tough autonomous platforms with higher-fidelity sensors and instrumentation monitor UK borders, and are used in disaster relief operations and monitoring the effects of climate change.

Smart autonomous rovers are able to detect and disable IEDs (improvised Explosive devises) without human intervention.

## Final Remarks

The Space industry will become one of the key industrial sectors which will help to forge a return to strong growth in advanced technology and manufacturing. It will also be an enabling factor in improving the future lives of citizen by means of smart digitally enabled housing, coherent energy provision, carbon reduction policies, advanced travel solutions and a safer more secure Britain. The Space industry is more than just a creator of wealth. It is also a vital part of the UK's critical infrastructure and a major contributor to the welfare and security of its citizens. Space is pervasive - its timing signals underpin the country's financial institutions, communication networks and other pivotal infrastructures. It provides the imagery to protect borders, deal with natural disasters, enhance agricultural productivity and much more beyond. The new applications it enables through navigation, data and telecommunications are already spawning exciting and vibrant new companies. Space is inherently carbon neutral and the measurements of the climate it allows provide the data that will enable the solutions to global warming to be found.

In the future, Britain will recognise Space as a critical infrastructure and vital to the future prosperity of the nation. Industry will see the benefits of this change in attitude and will strive to attract private funding and inward investment to develop new companies, technologies and projects.

However, our vision for future growth will not happen as a result of empty rhetoric or half-hearted deeds! It is only attainable if we take the steps we have recommended in this report, as we are confident that they will create the solid foundations upon which future growth can be built.

Acknoweledgements

All images, unless otherwise stated, are courtesy of Jupiter Images and the European Space Agency.