STRENGTHENING THE EVIDENCE BASE FOR BUSINESS SUPPORT RELATED CIVIL SPACE ACTIVITY

Technical Report

Annex 4: Downstream Market Applications

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TABLE OF CONTENTS

1 Introduction

1.1 This Annex discusses the downstream market applications of civil space activity more broadly defined. In previous annexes of this Technical Report for the project, 'Strengthening the Evidence Base for Business Support Related Civil Space Activity', we have explored:

- the development of the global civil space industry,
- the views of the principal UK space companies, as well as
- the impacts of and spillovers from specific DTI business support civil space programmes.

1.2 As such, we have focused specifically on the development of the civil space stack (as defined in Annex 2) at a global level and in the particular case of UK space industry. Of course, this has captured the value and impact from the direct use of civil space assets themselves, which is most evident in the case of scientific space programmes and technology development, as well as the benefits of technology transfer of products, technologies and capabilities generated in the production of space assets and applied to other markets. However, most of the economic and social value of civil space activity more broadly defined emerges from its impact on *downstream* market applications, in other words the activities which rely on the use of data and signals generated by space assets (notably satellite network infrastructures).

1.3 Our objective in this annex is to outline the three most significant areas of downstream market applications at present: communications, remote sensing / Earth observation and navigation. We have distinguished between the effects derived from the application to other environments of capabilities generated in the course of building space assets (termed in this project as *spillovers*), and the downstream economic and social impacts derived from their use. The spillovers generated have been discussed in Annexes 2 and 3. Here we focus on the downstream impacts in an economic and social sense, the position of UK industry within these downstream markets, and key trends and opportunities arising from these.

2 An Analysis of Downstream Market Impacts

2.1 Firms operating in the civil space downstream markets develop and provide the applications that use space assets which have been produced for scientific, military and civil purposes worldwide. Programmes supporting space activities may result in the development of new services and applications accessible to the whole society. This is the area where potential impacts may prove most substantial, as they may affect in a direct way the whole of society and economic life. Proponents of space programmes place great emphasis on these effects as the main channel through which the returns to space investment take place.

Approach to Impacts

2.2 Downstream economic impacts are defined here as the direct economic gains generated from the growth of markets for products and services generated by space-based assets. The outputs generated by space-based assets and their spin-offs include the data, images and signals provided by the established satellite infrastructure and the supporting ground stations network. Downstream economic impacts of civil space activity would include the economic activity (insofar as it is dependent upon the generation of these signals, data and images from space assets) of satellite TV, satellite communications, GPS services, remote sensing and the like.

2.3 Of course, there is considerable difficulty in determining the degree to which a market is dependent upon space assets. One approach is to consider how much more inferior (and in what way) would be the second best option for meeting the demand needs of these markets, if space assets were not used. This approach is analogous to opportunity cost valuation of assets, except that instead of valuing an asset based on its next best alternative use, we consider the value and potential of the next best asset (or technology) for that particular use. Nevertheless, such estimations frustrate the development of a reliable judgement on the value of downstream economic impacts, further complicated by the persistent uncertainty clouding the analysis of future worth. It is necessary also to address the effects on social welfare generated by some space-based activities. Not all benefits can be attributed a market value; some are non-discriminatory goods for which normal markets cannot function. It is here that substantial spillovers in the traditional sense are likely to occur. It is in this area of potentially large social benefit that quantification becomes also most difficult.

2.4 It is not the objective of this report to assess quantitatively the economic activity attributable to the specific space programmes, its multiplier effects, and its effects on the global competitiveness within the industry of the space firms involved in the programmes. Examining the impact of downstream impacts raises key measurement issues. Suppose the chosen downstream use is 'weather forecasting' – how are we to gauge the economic benefits of better weather forecasting, and thus the contribution of space programmes thereto? In the development literature this tricky assessment is finessed by examining the cost of the next best way of producing equivalent weather forecasts. So one would estimate what a combination of aeroplane observation, barometric assessment, balloons and other devices as substitutes for space observation would cost to produce the same results. This cost would be expected to be higher than using space observation, and the amount by which it is higher represents the economic benefit of having the space-based alternative available. In economic equilibrium, the cost gain and the productivity gain are dual to each other, so the one measures the other.

2.5 It would obviously be a mammoth task to investigate the best alternative to every single use of the space programmes. It is generally considered good enough as a first approximation to get an average cost of the alternative, which may be expected to apply over a wide range of uses. It may indeed be sufficient to adopt a simple ranking approach, according to which the cost gain per dollar/pound spent on the programme is expected to result in an enormous/average/minuscule figure, depending on the use to which the programme's outcomes are applied. Approaching the issue in this way clarifies why it is that in some circumstances space-based systems will represent a large gain whereas the same technology may provide only a small gain in another context. For example, it is expected that certain kinds of satellite-based communications will have a big impact per dollar in a country like China or Brazil, but a smaller one in a country like the USA. This is because the cost gain depends on the cost of the next best alternative. If there is no suitable alternative in place – that is, terrestrial communication infrastructure is very limited in China – the unit cost gain will be proportionately much larger than when very good substitutes already exist.

2.6 It should also be noted that the above 'counterfactual' or 'opportunity cost' approach – somewhat similar to 'additionality' assessments of government spending – are only a first approximation. Indeed it can be shown that any such figure is almost certain to be an upper bound to the spillovers arising out of the programme. This is because the approach requires exactly the same final activities to take place under the 'counterfactual' assumption of not having the best technology to produce them. In formal economic terms, this is supposing that we are imposing perfectly inelastic demand and perfectly inelastic supply. More accurately, one might expect that, if the space 'solution' were not available to be used, individuals and

societies would not necessarily choose to do/use the same things where they had now (hypothetically) become very expensive. They would reallocate their resources to consuming other, now relatively cheaper, items – the demand curve would be less than perfectly inelastic. Indeed if the demand curve were highly elastic, the amount spent on consuming the item would fall in the hypothetical world. Equally, a perfectly inelastic supply curve is assumed in the calculation, because the same amount is supplied at the (existing) higher cost of the alternative technology. Again, one might expect that in a world in which only poor alternatives were available, effort would go into developing some hitherto undiscovered alternatives. In this case the supply curve, too, takes on its ordinary upward-sloping shape, reflecting the expansion of better alternatives (albeit still inferior to the space-based system), which again will reduce the net benefit of the space-based system.

2.7 All of these rough calculations are retrospective, working from the outcomes actually witnessed at the end of the period of observation; but returns to a space programme or similar can be thought of as very long-term, and far from exhausted at present. Nevertheless a similar 'counterfactual' logic applies. It is not a question of whether the programmes open up rich new technological trajectories. The issue is whether the technology track opened up by these programmes would develop faster or slower than conceivable alternatives. For example, the reusable launch vehicle (RLV) programme has often been seen as one which cost a very large amount for the gains it has delivered, and is ever likely to deliver; if these views are correct then other means of meeting the objectives may have brought cheaper benefits.

2.8 Aside from the above considerations, this brings to the fore the issue of 'ownership' and location. To what extent has it been necessary to have a British space programme to attain the preceding spillovers? Or, how far could the UK have drawn on space programmes in other countries without sacrificing such spillovers? If the upstream components and downstream outputs could have been obtained at 'fair' market values then it might appear simpler to 'buy' rather than 'make' the technologies. Conversely, if there are barriers to the mobility of the ideas, knowledge (people) or equipment arising, then there is evidently an advantage to carry out the space activity within the country. Intellectual property rights may restrict the outflow/inflow of ideas, reluctance to emigrate/immigrate may restrict the flows of highly skilled people trained in the programme. The emphasis on 'tacit' rather than 'codified' knowledge augments the case for doing the research oneself. It nevertheless remains to underline that the question of whether the latter is necessary needs to be tackled directly.

Key concepts addressed

2.9 Without embarking upon an extensive fieldwork programme, we have restricted our efforts to identifying some key issues in the nature and scale of downstream impacts as they have occurred. We have discussed these issues in detail with representatives from downstream markets, supporting organisations and civil space experts and consulted the trade and academic literature. Following the points raised in our approach to impacts, the key issues addressed through the literature review and the interview programme are presented below in Figure 1, *Analytical Frame of the Study*. We discuss each of the three main downstream market areas – communications, remote sensing/Earth observation and navigation – with respect to these issues.

Figure 1 Analytical Frame of Study

1) **Development of downstream market application**
   a) Value of the market
   b) Nature of competition

2) **Impacts of Civil Space Activity**
   a) In scale
   b) In timing
   c) Next-best technology solution

3) **Reliance on Civil Space Assets**

4) **Social Externalities**

5) **UK position within this market**

6) **Future trends and opportunities**

2.10 We focus here on the key emerging markets described in the trade literature and recognised by our interviewees selected for the Contextual Interview programme (described in Annex 1). The first and fastest developing area of downstream applications has been in the field of communications, which includes mobile telecommunications and broadcasting (TV and Radio). The second market area to show some significant growth in recent years has been space-assisted navigation services, most evidently Global Positioning System (GPS) services but also all of the services from navigation satellites. The third market area we will discuss is that of remote sensing, which includes both earth observation imaging and multi-spectral sensing systems. The remote sensing market has grown the least in a commercial sense, but it has important social externalities. We are *not* considering here:

- space tourism (as there is not really an observable market as yet),

- technology development (as this are generally part of scientific satellite activities discussed in Annexes 2 and 3), or

- materials and/or product development (which is expected to involve experiments in microgravity in space, but is still not a visible market as yet).

3 Communications

Value of the market

3.1 The communications markets related to satellite services are the most mature of the downstream market applications. These currently include mobile telephony, very small aperture terminal (VSAT) services, satellite TV and satellite radio. Future markets include satellite broadband internet access, particularly for consumers in remote areas. In 2002, Futron (on behalf of the US Office for Space Commercialization) estimates that $36.6 billion was spent that year on commercial satellite services worldwide (Futron, 2003). This same study described the growth of these services in the US and the world over the period 1996 to 2002, and growth was comparably strong in the US (which comprises roughly one third of the market broadly defined) and the rest of the world (an annual average of 25% for the US and 23% in the rest of world).

3.2 Mobile telephony was a major source of growth in satellite services and growth in revenues for satellite industry in the 1990s. Mobile telephony itself grew from the switch from analogue to digital networks in telecommunications, and the ubiquitous nature of mobile telephones has now reached (near) global saturation. According to the business press, the number of mobile telephone users is expected to surpass 1 billion by the end of 2003. (Hoovers, 2003) As we approach saturation, unsurprisingly, growth in new mobile telephone subscriptions (which was double-digit throughout the second-half of the 1990s) has nearly halted except in developing countries. A new competitiveness amongst mobile telephony operators has come into play.

3.3 Satellite telephones are somewhat different to terrestrially linked mobile telephones (which involve satellite relays). Industry pundits often claimed that satellite telephones would play an important role in countries lacking mobile phone infrastructure. However, by the time satellite telephone systems were in place, terrestrial systems for mobile telephony (with satellite supports) were often in place, bringing the commercial failure of projects like Iridium. (AACST) Moreover, satellite telephones do not meet the same existing demand structures: these telephones have been overly complicated to use and have required the user to identify the appropriate ground station for uplinks. Whilst these satellite telephones have been redesigned to be more fit-for-purpose, there has yet to be a strong take-up of satellite

telephony beyond the telephones provided on aircraft and the satellite telephones used in remote areas (and on sea) and for military security.

3.4 Direct TV has been the main engine for growth in services from the mid-90s onward, accounting for one-third ($9 billion) of the total value of retail and subscription satellite services.(Futron, 2003) This has been further expanded through satellite Direct Radio. Consumer access to Direct TV and Radio is being facilitated by satellite broadcasting services companies (like Sky TV) with simple to use and economic access equipment. Direct Radio is cheaply installed in cars in the US, with the option of purchasing the Direct TV built-in receivers in some new vehicles and monthly service payments combined with overall car repayments. These companies are focusing on how to make this as easy as possible for the consumer to buy. (AACST) Beyond the consumer, satellite broadcasting also provides important inputs into other services. For example, news networks are heavily reliant on the satellite broadcasting system.

3.5 Satellite provision of broadband internet services has been much discussed, but has been slow to emerge as a commercially viable market. The target market for these services is consumers in remote locations. One such offering comes from a company called Wheat Wireless Services, based in the US, which has launched a high-speed service to provide internet services to vessels at sea. This "Blue Satellite Service" provides downloads of 512 Kbps, which is comparable to many cable modem services, and the company expects to develop the technology further to provide services of between 1 Mbps to 40 Mbps in the future. The service is offered on a flat-fee basis (of $999.95 per month) for unlimited use. This is one example of several new company ventures to establish the market for satellite-based internet services.

Nature of competition

3.6 Mobile telephony is extremely competitive, and the main providers have consolidated substantially in recent years. Currently UK-based Vodafone is the largest wireless communications service operator, with 122.7 million subscribers. Vodafone has investments worldwide in wireless communications operators, amongst other industries. Its principal competitors are BT, France Telecom and Deutsche Telecom in Europe, and AT&T Wireless, Cingular Wireless, Sprint PCS and Nextel in North America.

3.7 In the case of satellite broadcasting, the competition is fierce between satellite broadcasters and the cable companies. In a recent article, it was reported that the US satellite broadcasters expected their subscriptions to rise from 20 to 30 million by the end of the decade. (Cooper,

2003) This growth was anticipated to derive from the push for the development of advanced onscreen programming guides, personal video recorder (PVR) capability and interactivity, and this growth was expected to come entirely at the expense of the cable broadcasting industry. (Ibid) In this same review, it was noted that 2002 was the first year that the US cable broadcasting industry lost subscribers, falling by 700,000. The cable broadcasting industry is fighting back by offering value-added services such as video-on-demand and high-definition TV which are currently not available through satellite broadcast. British Sky Broadcasting Group (BSkyB) is the leading UK pay-TV provider, competing fiercely with both NTL and Telewest, cable service providers in the UK. There is still growth in the UK, with a further 11 million homes without pay-TV services, and the 3 million cable TV homes to win over.

3.8 Despite the launch of satellite radio services in 1992 when the US Federal Communications Commission (FCC) allocated a spectrum in the "S" band (2.3 GHx) for nationwide broadcasting of satellite-based digital audio radio service (DARS), satellite radio broadcasting is only now emerging as a consumer service; and thus this market is less developed. Almost all of the current broadcasters are in the US, including XM Radio and SIRIUS satellite radio, having paid $80 million each for a license to broadcast. However, WorldSpace is broadcasting to Africa and Asia and will begin broadcasts to South America soon. Recently, the BBC has also launched its digital radio offering, which is available through digital satellite television, digital cable television and the internet; however, the digital radio service is not yet available through satellite radio.

Impacts of Civil Space Activity

In scale

3.9 The advantages of satellite access are that it is location-indifferent; it allows the user to travel freely and to leapfrog weaknesses in local telephone infrastructure. The commercial advantages in satellite broadcasting are more about choice and quality of broadcast. However, satellite linkages in general broadcasting are so pervasive now that they have become part of the broadcasting 'fabric'.

In timing

3.10 Ultimately, the goal is to provide communications and broadcasting on demand. Satellite services make it possible for location to become irrelevant. This also has a timing benefit, insofar as the consumer does not have to travel before they can communicate or benefit from broadcasting services.

3.11 This benefit is essential in the myriad of ways that communications and broadcasting are featured at many levels of social and economic activity. For example, the company Voxiva has 'changed the way information is shared and business is transacted in Peru. The company partners with Telefónica, the dominant local carrier, to offer automated business applications over the phone.' (Prahalad and Hammond, 2002: 9)

Next-best technology solution

3.12 Satellite support for mobile telephony has become part of the wireless infrastructure nationwide. As such, it is not possible to claim that terrestrial mobile telephones and satellite telephones are alternatives. They are part of the same location-free solution for communications, albeit at different ends of the cost and need spectrum. For military security purposes, secure landlines are still a common alternative to satellite telephones. In remote areas, there really is no other option other than to extend terrestrial communication infrastructures to these areas at a relatively high cost per use.

3.13 Likewise, the contest between satellite TV and cable is also somewhat overstated, given that cable TV services are now also linked with satellite networks. Nevertheless, the struggle for subscribers is very real between these two industries, which are locked in a process of improving technologies to bring better quality and service on demand for their customers. The alternative to both satellite and cable TV is the conventional TV service via aerial; however, the quality of signal is significantly poorer and the limited programming cannot compete with the hundreds of channels available on satellite (and in fewer number on cable).

3.14 Satellite radio has an advantage in that it is not location specific and it is a digital (high quality) offering. The competition to satellite radio is wide and varied: the conventional radio stations, pre-recorded music and digital radio (like the BBC) distributed via aerial.

Reliance on Civil Space Assets

3.15 BSkyB uses services provided by the satellite operator, SES, as well as EutelSAT. These services are purchased through several types of leasing structures. Whilst BSkyB currently owns no satellites (BSB owned two prior to the merger between BSB and Sky in 1990), they have invested in some of the ground station structures and transmission uplinks. BSkyB noted that, whilst there has been some stated concern by UK public authorities over the maintenance of public services (the BBC) on 'foreign' satellites, they have absolutely no concern about the security and continuance of services on their contracted satellites.

3.16 Essentially, the companies in this field are communications companies or broadcasting companies. If satellites were not available to them, they would use a different platform to deliver their services. The advantages of satellite-provided services are noted above, however.

Social Externalities

3.17 Communications and broadcasting are important elements in social well-being. Some small communications companies, like the US start-up Voxiva, have focused on filling important institutional gaps in developing countries. Without question, the social externalities from satellite-supported communications and broadcasting are very significant, but not altogether dissimilar from the arguments for communications and broadcasting in general. The added value of satellite based services of this sort is that they are location indifferent, and this brings added value to people in remote or underdeveloped locations and to people on the move.

3.18 Such satellite-supported services then provide a reliable platform for additional services. For example, the Voxiva network in Peru provides a platform for reliable banking services with microfinance institutions and for health provision (via a dissemination of information, pharmaceutical ordering and active links with health care workers). (Prahalad and Hammond, 2002: 9) Likewise, the satellite radio service WorldScope can provide a platform for important information systems (for warnings, advisories and co-ordination).

UK position within this market

3.19 The UK is host to the largest mobile telephony company (Vodafone) and one of the largest satellite TV companies (BSkyB). Although there is little yet with respect to satellite radio and satellite internet, there is certainly scope and potential for the UK industry to take strong positions in both of these markets as they develop.

Future trends and opportunities

3.20 Beyond satellite radio, the next communications/broadcasting market expected to grow is that for satellite internet services. Satellite internet connections have been highly anticipated as a service, but the roll-out has been much slower than anticipated. Demand is not expansive, as broadband telephony services are still in the process of rolling out and are more cost-effective. Nevertheless, recent investments by satellite operators and other communications companies signal a growing expectation that the demand will develop into a full-fledged market towards the end of the decade. Certainly, examples like Wheat's Blue Sea Services

are already emerging with cost-effective and technologically appropriate services already posted.

4 Navigation

Value of the market

4.1 Like mobile telephony, direct TV and Radio, GPS receivers and services are likely to be actively developed as consumer goods and services. The demand for GPS is slotting into an existing pattern of demand for knowledge of location, previously managed in a more roundabout way through consulting maps, sextants, landmarks and passers-by.

4.2 According to Futron (2003), the GPS industry is "sharply segmented", comprising consumer and professional, civil and military markets. The Frost & Sullivan GPS Report from May 2000 described "[i]n terms of revenue, over the course of 1999, the aviation markets for GPS products grew around 10 percent, the land market grew just over 24 percent, the marine market grew 11 percent, the military and timing markets both grew just under 25 percent." (as quoted in Futron, 2003) Of these markets, the land market accounted for nearly two thirds of revenues in 1999. More specifically GPS units sold to the car navigation and consumer markets comprised 57% of the total sold in the US in 2000. (ibid)

4.3 Although commercial GPS receivers were available in the mid-1980s (retailing at $150,000 and requiring two people to carry), the GPS market was largely established in the 1990s (Ouellette, 1995: 8). Expectations by the mid-1990s were that sales would reach $5 billion by 2000. This was not too far off, as sales worldwide were calculated to be worth $6.22 billion in 1999. The sales of the leading GPS producers (Trimble Navigation, Thales Navigation (which owns Magellan), SiRF Technology and Garmin Ltd) have grown steadily, reaching a combined turnover of these four companies of roughly $1.1 billion in 2002.[1] Nevertheless, those interviewed remained very optimistic for accelerating future growth of the industry, buoyed by three supporting changes in the service delivery structure. The first of these was the integration of GPS receivers in cars; to begin with, GPS was only included in high-end cars, but the trend is to extend this down the value range to ultimately the most basic of cars. As in the case of satellite radio, facilitating customer use in a well-understood and accepted format is an important step to ensure diffusion of a new technology.

[1] Calculated from published financials and interview data (Thales Navigation).

4.4 The second service delivery change is beginning now, that is the inclusion of GPS receivers in mobile telephone handsets. Industry pundits claim,

> An irresistible force is moving across our quiet landscape, a force that is expected to increase demand for GPS by over one hundredfold, from a few million to hundreds of millions of units per year. This force is the demand for location capability in cell phones, driven in the United States by the Federal Communications Commission (FCC) requirement that cell phones be able to identify their location automatically with GPS-like accuracy. (van Diggelen and Abraham, 2001)

4.5 In this article, the authors also point out that in 2000, the four GPS leaders sold approximately two million units. However, in 2000, there were 426.5 million mobile telephones in use worldwide. The orders of magnitude of difference and the regulatory requirements in the US and Canada signal a likely fast growth in this market, and this perspective was confirmed through our interviews. Another push to market expansion was the rescinding of the scrambling of signals in the US Global Positioning System (GPS), which allowed GPS receivers to increase their horizontal accuracy from 'no worse than' 100 metres to 15-25 metres.

4.6 A third service delivery change is anticipated in the arena of e-commerce with respect to the use of GPS for timing. According to the 2000 Frost & Sullivan report (quoted in Futron, 2003), GPS timing products will be applied to internet applications such as e-commerce. GPS companies currently specialised in the timing market include Absolute Time, Datum, TrueTime and Zyfer; these are all US based companies. Nevertheless, many other GPS providers (like Trimble and Thales Navigation) have timing applications. Timing applications are useful for company systems (e.g. intranet, asset tracking) as well as for synchronisation. Communications company AT&T uses a GPS system for this purpose:

> AT&T's GPS-based PRC uses a GPS receiver to provide long-term timing accuracy for its telecommunications networks. . . . All the nodes are interconnected, with timing signals transmitted from the PRCs via dedicated links. For the first time, a national telecommunications network

> is being monitored and verified to perform at a precision well in excess of existing standards. (Edward Butterline, AT&T)[2]

4.7 The GPS market roughly divides into two broad markets: a consumer GPS market and a professional GPS market. The professional GPS market comprises surveyors, military, commercial transportation companies and the like. The growth described in handsets and cars is largely based in the consumer GPS market. Thales Navigation describes this growth as explosive, accounting for roughly 30% increases in sales since 2001.

4.8 GPS services are used for navigation, such as guidance to a destination (as in the case of cars); for accurate timing; and for accurate positioning. The 'pinpointing' value of services has been used extensively by oil and gas companies, transportation companies, bridges and train systems. In the future, such services are also anticipated to be of value to environmental security.

Nature of competition

4.9 Most GPS companies are in the US and Canada. Proximity to the US defence establishment and familiarity with the GPS system are seen as the reasons for this dominance. The market leader in professional and consumer GPS products is Trimble Navigation (based in the US), specialising in the navigation, surveying and military market segments. The second largest GPS producer for the consumer market is Thales Navigation[3], which is also headquartered in the US but has European sales headquarters in France. The other leading companies, Garmin Ltd, specialised in hand held GPS, and SiRF Technology, specialised in GPS chips and receiver components, are also based in North America.

4.10 It is widely thought that North American firms are dominant in these markets mainly because the US Department of Defence fully funded the GPS infrastructure. The European Union recently approved the development of the European Global Navigation Satellite System (GNSS), named 'Galileo', for services to begin in 2008. Galileo may alter the balance across the globe, although, by design and negotiation, Galileo and GPS are seeking to become complementary in coverage and services. Research is being undertaken to enable the eventual implementation of the Galileo system that may provide opportunities for UK companies to develop new hardware and services in the developing field of navigation. However, it must

[2] Edgar W. Butterline AT&T, Bedminister NJ, Manager of networks synchronization in AT&T`s Network Services Division. "Reach Out and Time Someone" Reviewed September 2003. http://www.absolutetime.com/Industry%20Info/at&tar~1.htm

[3] Thales Navigation now owns Magellan which has businesses in hand-held, navigation, aviation, marine, military, survey and timing.

be recognised that the existing navigation services firms have substantial first mover advantages in technological development and the distribution aspects of GPS services, particularly in the consumer market. Moreover, these firms are already actively designing and developing receivers for Galileo signal services[4], and they are investing heavily to position themselves for new opportunities provided by Galileo and the GPS-3 upgrade (in 2002 Trimble alone spent $61.2 million – 13.5% of its turnover -on R&D). Industry pundits expect that users may ultimately use receivers that are capable of accessing both GPS and Galileo systems, and therefore they may benefit from using a wider mix of satellites for a better quality and more robust location signal. (Brewin, 2003)

4.11 Alliances have been an important feature of development of the GPS market, both with the application services (such as in cars and mobile telephones) and more generally. Trimble established an alliance with Siemens to develop GPS products. Garmin has alliances with boat manufacturer, Ranger, and airplane manufacturer, New Piper, to incorporate Garmin GPS products into the final vehicle. More recently, Trimble has also established a joint venture with Caterpillar, Caterpillar Trimble Control Technologies, to develop advanced electronic guidance and control technologies for earth-moving construction and mining machines. It is clear that the service of identifying and tracking location precisely may eventually become an important 'general purpose technology' across the economy, and this is certain the strategic aim of some GPS producers.

Impacts of Civil Space Activity

In scale

4.12 We use several methods and artefacts to help us to ascertain location. GPS has provided a faster and more precise method of doing so. The key advantages of satellites in helping individuals to find locations and to track movement are the increase in accuracy and robust results.

In timing

4.13 The accuracy by which GPS can locate an object, person or phenomenon is not possible through terrestrial alternatives within realistic costs. According to the companies themselves,

[4] For example, in September 2003, Trimble issued a recent press released disclosed that the company's latest RTK technologies will be Galileo-ready.

GPS provides world accurate time to nanoseconds and accurate position to meters without high-cost precision equipment (comments from Trimble Navigation engineers via website).

Next-best technology solution

4.14 According to our interviewees, satellites provide global coverage and three dimensionality. With conventional systems, the trade off is between coverage and accuracy. In conventional systems, the information is more accurate, but with beacons, for example, you can only have two-dimensional information. From airplanes, you can achieve some three-dimensional data, but these are limited.

4.15 In some cases, terrestrial alternatives would be cheaper. For example, road grids need only laser beams to provide the signal. However, it would be an expensive technology to roll out across the globe. Moreover, conventional systems are not suitable for consumer GPS products, and so there is some lock-in with current consumer investment that would need to be overcome. Thales Navigation actually comprises four companies (two French companies and two US) which were merged in 2001; their two French companies used these conventional systems in the past. Trimble also acquired conventional systems through its purchase of Thermo Electron; these systems are used for machine guidance and fleet management applications.

4.16 Interviewees argue that satellites have 'killed conventional systems'. There are now very few terrestrial products available and they are only used as a back-up to the satellite services. For example, in building a tunnel, GPS is used everywhere except inside the tunnel, where optical/laser beams are used because of the physical conditions. In their view, satellites provide superior and cheaper signals.

Reliance on Civil Space Assets

4.17 A Global Navigation Satellite System (GNSS) is a network of satellites that transmits high-frequency radio signals containing time and distance data that can be picked up by a receiver, allowing the user to pinpoint their precise location anywhere around the globe (Thales Navigation). Currently, there are two GNSS in operation: the US Global Positioning System (GPS), first developed for military purposes, and the Russian Global Navigation Satellite System (GLONASS). The third GNSS will be Galileo, which aims to provide a higher standard of integrity and reliability than the other two and to make obsolete the need to use augmentation systems (called Satellite-Based Augmentation Systems or SBAS). Both GPS and GLONASS require SBAS to provide improved accuracy, providing differential signal

corrections for transmissions with the use of ground stations and geostationary satellites in specific regions (e.g. GNSS-1 for high-precision satellite navigation).

4.18 In addition to regional SBAS, or specifically the US Wide Area Augmentation System (WAAS) and the European Geostationary Overlay System (EGNOS), companies often use private GPS services to add value by sending signals to improve accuracy. Thales Navigation uses Thales Geostation Solutions and Fugro (NL) for these services. Thales Geostation Solutions owns a worldwide network of reference (observation) stations and a communication hub in Aberdeen. The use of these services is on a pay-per-use or annual subscription.

4.19 In addition to Galileo, GNSS-2 is underway and involves the launching of new satellites into orbit and a complete upgrade of the existing satellite systems. GALILEO, scheduled to begin service in 2008, is being developed to meet the standards of GNSS-2 for rapid and reliable certified precision positioning. This is not to imply, however, that GPS and Galileo will necessarily serve as competitors; these systems will provide the potential for a combined enhanced provision of signal integrity and detail, as discussed earlier.

4.20 Without satellites, GPS services would be limited to bespoke uses, such as positioning for oil rigs using terrestrial beacons. In the view of our interviewees, there would be really not much of a GPS market to speak of, without satellites.

Social Externalities

4.21 GPS systems are often used in remote locations to locate people and objects for safety and security purposes. For example, Canada now requires that all new mobile phones manufactured from 2004 will have a GPS device installed mainly for search and rescue purposes, although there are commercial benefits from this infrastructural development as well.

4.22 The consumer advantage of personal mobility was remarked upon in our interviews. As people wish to be more mobile, they require better geographical and navigational information, as well as location-based services. With respect to the latter, examples given included identifying the location of young children and pets, finding services nearby in an unfamiliar area and the like. Of course, to be 'chipped' may also be interpreted as an incursion into privacy, and these are difficult issues that still remain to be explored in depth.

UK position within this market

4.23 None of the leading GSP service providers or manufacturers is headquartered in the UK, but many have sales offices here. BAE Systems Canada is the only GPS firm with a link to a UK company. As part of the wider Galileo programme, the UK industry may have opportunities in the future (particularly in niche markets), but these companies will be entering a competitive market where the incumbents are well positioned to capture the value of new opportunities like Galileo.

Future trends and opportunities

4.24 Clearly, Galileo figures large in the future development of GPS services globally, and we have indicated the keen competition which is currently assessing the developments in the Galileo programme. Beyond Galileo, there is some exploration of new platforms to continue the broad consumer use of GPS services. The technological goal has been set forth as 'no chip' technology, reflecting the effort to reduce the physical parameters of GPS receiver technology to accommodate its integration into a broad range of platforms, including portable devices. Likewise, efforts to enhance the use of GPS signals are also being made in the professional market. Trimble is currently developing Internet-based positioning services, which it expects to be an important new product for the professional GPS market.

5 Remote Sensing and Earth Observation

Value of the market

5.1 The space-based services market for remote sensing and Earth observation (EO) has been slower to develop, despite the fact that earth observation and remote sensing satellites have been in space since the early 1970s. There are very few existing specific industry studies in this field at present; in fact, a search brings up the two key aspects for which remote sensing are used: (1) public sector weather and climate control and (2) oil and gas development. The remote sensing and Earth observation services market is expected to grow, but at a much lesser scale, as is now indicated for satellite internet provision.

> "Of course, there is a growing demand for Earth imagery, and thus there will be some commercial remote-sensing satellites launched in the next few years, including ones for the Eros, Ikonos, OrbView, Quickbird and SPOT systems. But you're certainly not talking about hundreds or even dozens of these types of satellites, so their market impact will be minimal." (Caceres 2003, pp 152, 154)

5.2 The oil and gas industry has used satellite-based remote sensing since the 1970s to assess oil seepages, geological structures as well as environmental risks to field sites. However, satellite imagery and analysis is frequently combined with airborne imagery to complete the detail. This was a lead commercial sector for the development of remote sensing, and it still remains the most significant commercial 'customer' for satellite-based remote sensing data. There was also a significant use of satellite-based imagery for the telecommunications industry for the placement of mobile telephony masts at the turn of the century, but this market has now completely collapsed. There is also use of remote sensing products by local authorities and government for planning purposes, but this aspect of demand is the least developed thus far. Insurance companies also use remote sensing data in the US for risk planning, but, as yet, the UK insurance companies have not approached the UK-based remote sensing companies interviewed with the exception of the Met Office.[5] The Met Office is developing services to estimate the impacts of weather on property (for the insurance

[5] We understand that the British National Space Centre has sponsored a study on the uptake of EO services by the insurance industry and that a representative from General Accident has been a member of the Earth

companies) and on health (for the health service). At present, the Met Office is approaching the Department for Health to fund the hospitals to use such a service.

5.3 Of course, the military is also an important source of demand for remote sensing for intelligence purposes. Arguably, military interests have been an important driver for the development of remote sensing technologies and markets. Whilst the market for commercial remote sensing has grown to provide 1-metre resolution products and services (as provided in the US only by Presidential Decision in 1994), military concerns continue to shape and structure the industry. "As more 1-meter resolution remote-sensing satellites are launched, defense officials worldwide are becoming concerned about the potential use of high-resolution by adversaries to gain tactical and strategic advantage in the future. Shutter control regulations are designed to address such concerns but tend to be vague and subject to broad interpretation." (Futron, 2003) Besides satellites producing commercially available imagery, there is activity in military space with respect to remote sensing; however, we are restricting our view to civil space activities in this study.

5.4 According to the Futron report (2003) and our interviews, the key trends in satellite-based remote sensing include an increasing demand for high-resolution panchromatic, radar and multispectral imagery, the choice of which is determined by the application needs. The market for remote sensing services is mixed, involving both commercial and public sector service providers such as the US Geological Survey Earth Resources Observation System (EROS) Data Centre (EDC). The presence of both commercial and public sector service providers in direct competition has generated some controversy, given their comparative cost bases and the pricing of services. The sales of basic imagery are growing worldwide, reaching rates of 14% per annum according to Futron (2003). This same study also reveals that over a third of all such sales over the period 1996 to 2002 were accounted for by France's SPOT organisation. In 1999, worldwide sales were confirmed to be worth $154 million.

5.5 For one of our interviewed companies, space-based remote sensing generated a turnover of roughly £7 million in 2002, whilst airborne remote sensing generated a further £8 million. Another firm was almost a niche player, deriving 70% of turnover from oil and gas contracts. The third firm had yet to formally begin to sell into remote sensing markets, but had a long company history in services to navigation and maritime trade. We also interviewed the Met Office, which is a Trading Fund and is owned by the MoD.

Observation However, none of the EO companies we interviewed (which including two of the leading EO companies in Europe) have sold to insurance companies nor are they currently marketing to this sector.

Nature of competition

5.6 Because this market is at such an early stage and demand is so limited, there are very few large(ish) players in this sector. Only three companies provide satellite-based remote sensing data to the oil and gas industry: Infoterra, Nigel Press Associates (NPA) and Earth Satellite Corporation (US). Overall the EO community is hugely fragmented. According to our interviewees, there are many very small companies and a few 'bigger' fish. Most of these small companies in Europe are clustered in Toulouse, supported in a variety of ways by the Centre National d'Etudes Spatiales (CNES). This view was confirmed by VEGA that is currently conducting an EO Market Development Survey for ESA. The average size of firms they have interviewed is twenty employees or less; these firms have very limited commercial turnover and are surviving largely on grants. Interviewees felt that this industrial (lack of) structure was similar in the US and Canada. The two largest remote sensing companies in Europe are Spot Image (France) and Infoterra (UK).

5.7 The Met Office also provides data and images internationally, and they have revenues of £160 million per year from providing data and imaging to private UK weather companies and to EUMETSAT. They are currently developing a new market in radio occultation, whereby users can predict and control for solar activity, which blacks out commercial satellites and power transmission networks. The UK National Grid currently buys radio occultation service from a US company, and the Met Office is aware that several European power companies are also interested in such a service. Other potential customers include the MoD (for its defence satellites) and the airlines. However, the growth in the market is currently limited because the Sun is going through a 'quiet period' which is expected to last a further 8 years. Moreover, there is also a potential market for weather forecasting services on other planets, such as Mars. The first Russian Mars landing in the 1970s resulted in the destruction of the space capsule due to a Martian storm. However, it is probably safe to argue that this is not likely to be a major market within the next decade or two.

5.8 Leading remote sensing service providers, like Infoterra and Nigel Press Associates (NPA) in the UK, negotiate distribution contracts with all major satellite operators with EO/remote sensing data and images. Such operators include NOAA, ESA, Digital Globe (a private US operator) and Spot Image (a private French operator). Their objective is to get UK exclusive rights to the data and the images if possible. Larger companies (or companies part of much larger groups) are said to have an advantage in negotiating discounts; however, any company can negotiate access contracts with the operators. The value added that companies like Infoterra and NPA provide is the processing and selection of the data and the images and their provision in a user-friendly format.

5.9 Foreign competitors to the UK remote sensing companies often have an advantage insofar as they own their own satellites, e.g. Ikonos and Early Bird (US) and Spot Image (France). There is an advantage in having owner-access to a satellite network. However, this would require governmental support in the establishment of such satellites; and whilst privileged access to satellite data and images would help these companies directly, it was not always clear whether the benefits of this would outweigh the costs of investment for the UK as a whole.

5.10 In essence, much of remote sensing and Earth Observation is a 'lighthouse' market. No one single company is going to be able to establish the market and no one single customer (or selective group of private customers) is going to be able to afford the development of the network of satellites required to achieve the full potential of Earth Observation and remote sensing services. Moreover, much of demand is going to have to be marshalled from the public sector, for planning and development, emergency services and military issues. As in the case of light houses, a failure of co-ordination by a market structure leaves the stage open for a public sector actor.

Impacts of Civil Space Activity

In scale

5.11 The key advantages of satellite provision are in the speed of imaging and the relative costs (compared to airborne), but this is dependent upon the nature of the imaging task. A very wide area is better served by satellite; however, more detail is possible with aerial imaging. In weather forecasting, space-based sensing is required for prediction. Interviewees at the Met Office maintained that without space, their capability in and the quality of prediction would be significantly affected.

5.12 The remote sensing companies interviewed all maintain airborne sensing services; and in fact, for Infoterra, most of their private-sector turnover is still derived from aircraft services. Aircraft remote sensing can be most cost-effective when there is a broad scale of detailed coverage that is often not time-sensitive. Customers for such services often include local authorities, for example. There is a clear synergy between remote sensing technological developments on airborne and space-based platforms. For example, the new Ikonos satellite aims to have resolution of 1 metre observation quality, which is much closer to airborne photography than to the 25 metre resolution of LandSat. And so, there is clearly a gradually differentiating continuum of remote sensing options, based on resolution, timing and cost requirements.

In timing

5.13 Remote sensing by satellites for the oil and gas companies is often used to deliver relevant imaging and data when time is of the essence.

5.14 It was clear to one of our interviewees that without space investigation, the scientific level of weather forecasting today would be hypothetically around the level that was actually attained (with some help from space assets) in the early 1970s. According to the Met Office, the current 10-day forecasts are as accurate as the 3-day forecasts used to be, and this is largely (even entirely) as a consequence of civil space activity.

5.15 An improvement in mapping due to remote sensing from space also has impacts for weather forecasting, particularly in the less populated areas such as the southern hemisphere.

Next-best technology solution

5.16 Aerial and satellite imaging are not complete substitutes; these imaging approaches are considered more like 'options in a toolbox' than successive technological versions of imaging. At first, satellite images simply assisted terrestrial sensing systems by providing broad views of the phenomenon in question. Over time, satellite data began to be collected and used quantitatively for simulation and prediction, supported by concurrent development in computer processing power and modelling techniques.

5.17 The Met Office has looked for terrestrial alternatives, but it has been concerned with their cost and practicality. For example, it would be expensive and impractical to survey polar regions and oceans. Ocean buoys can collect more accurate data than satellite data, but they are very costly. The Met Office collects terrestrial data and the cost of this reaches £15 to 20 million per year. The UK pays about £10 million per year to be part of EUMETSAT. This is only a fraction of the cost of the satellite, and the payment is based on Gross National Income.

Reliance on Civil Space Assets

5.18 Remote sensing service companies and the Met Office use geostationary satellites, polar orbiting satellites and communication satellites to complete their data and image requirements. These are owned by both public and private operators. The Met Office is part of the World Weather Watch of the Global Observatory System run by Geneva-based World Meteorological Office. The Global Observatory System satellites are owned by the US (Naval Oceanography and Atmospheric Agency (NOAA)), China, India and Europe (EUMETSAT).

5.19 Interviewees from academia felt very strongly that without civil space assets, remote sensing research and the resulting applications would be inconceivable. Programmes addressing climate change (in particular, the Kyoto protocol) require sophisticated, broad-scale monitoring that is only possible with space assets.

5.20 At some scales of resolution (e.g. 25 metres) and some periodicity, satellite remote sensing is not replaceable by any terrestrial option. Moreover, future developments in space-based remote sensing will add further unique benefits. For example, there are plans to combine radar satellites to enhance the value of GPS, which on its own cannot capture elevation. This would bring a much enhanced version of GPS services more amenable to aircraft navigation and the like.

Social Externalities

5.21 Decades of research in remote sensing in the UK have established a world lead in 'assimilation', that is an aspect of modelling that links observation to theory. For example, the Japanese team in charge of the world's largest supercomputer introduced into forecasting come to the UK to tap into the knowledge base established in this arena. The UK lead was attributed to this country's past investment in civil space activity related to remote sensing. The Met Office also pointed out that it takes about 5 years to extract value from the data for services in weather forecasting and that the Met Office is working at the state of the art in data handling.

5.22 Perhaps more clearly even than for communication and navigation, space-based remote sensing and Earth observation have important social externalities, the scale of which may be justification in themselves for such activity. The changes to our physical world affect us all, and this is an important benefit to social cohesion if such data and images can be marshalled to prevent suffering and to improve the effectiveness with which we use our resources.

UK position within this market

5.23 The UK does not have the majority of remote sensing companies active in Europe, but it does have two leading companies based in the UK: Nigel Press Associates and Infoterra. It is not a foregone conclusion that Infoterra, now owned by Astrium, will remain in the UK, however.

5.24 Some interviewees put forward the argument that a principle of reciprocity in international agreements and networks (particularly in the case of EU collaborations through ESA) requires

partners to be perceived as technologically comparable in strength, although complementarities are also advantageous. However, without a perceived UK strength in space technologies – through its academic and industrial base – there is a concern that a greater (and growing) share of subsequent UK bids to these international programmes will fail. To rely on NASA investment as a strategy was also considered suboptimal, as the NASA programme left too many gaps in the coverage of science and technological development needed to progress remote sensing.

Future trends and opportunities

5.25 A fundamental technological difficulty in earth observation and remote sensing is the robustness of EO satellite systems, the placement of these satellites and the frequency of imaging. The resolution is also critical, as greater value is generated by smaller resolution widths. The current set of satellites is not delivering the right kind of data, as resolution is greater than 10 meters. Moreover, there is a growing demand for 'real time' remote sensing, which is currently not possible given the feed characteristics of satellite networks in place. In this sense, the space asset itself has a direct impact on the nature of downstream services derivable from it.

5.26 The key issue for the value added services companies is access and 'control' of the satellite data and images. If all companies are given free access to all EO data (as currently being considered by ESA), the leading incumbents will face an erosion of their commercial position and a loss on their past considerable investments into the development of these space assets and their systems.

6 Summary of Impacts and Opportunities

6.1 Discussing downstream market applications of civil space activity usually results in a laundry list of potential areas of application. There is clearly no lack of creativity with respect to how civil space assets can be used to generate value in economic and social terms. However, every one of these ideas has to pass the same critical test: is it better (in terms of timing or scale) than our current alternatives? And if this test is met, there is still another: there may be a need for this service, but is there a market?

Downstream Economic and Social Impacts

6.2 From our study of these three downstream market applications, it is clear that satellites do not need to be owned or produced in the UK for downstream service companies to successfully develop their businesses. However, in the case of remote sensing, ownership of the relevant satellites can provide an advantage in terms of access to the data and the images.

6.3 Different subsectors of communications, navigation and (especially) remote sensing are affected by latent demand which is not defined by the technology but by the underlying needs and preferences of the consumer. The markets for satellite television, satellite-supported mobile telephony and GPS services have fitted directly into a pattern of consumption that made adaptation easy; this stands in contrast to the limited take-up of satellite telephony thus far. Competitive alternatives have proved important blocks to satellite telephony (in developing economies) and may prove so in the case of satellite radio and satellite internet.[6] The value proposition must be clear to the consumer. However, in some cases, the value to the individual consumer is vastly outweighed by the cost, although the social value is much greater. In these cases, frequently referred to as 'lighthouse' markets, the public sector generally needs to step in. From our interviews and research, this is clearly the case of remote sensing and Earth observation.

6.4 In some cases, demand is latent because the value needs to be demonstrated. If indeed the value can be demonstrated, then this requires not only education but also good demonstration projects. Not all space-based solutions are the most appropriate for a given need in a given context. In other cases, the market is often held back because of contingent goods development. For example, the GPS boom really picked up speed when GPS receivers

[6] These constitute some of the 'network spillovers' (positive and negative) discussed in Annex 1.

became truly portable, easy to use and reliable. Satellite radio take-up is being facilitated because the receivers are being installed in cars direct from the manufacturer. Access by consumers to inexpensive, easy-to-use receivers is essential for further roll-out, and indeed, this has been one of the barriers to the take-up of satellite telephones.

6.5 Demand development is easiest where services are being laid over existing patterns of consumption that are similar in nature and frequency. Oftentimes, this requires the services company to re-engineer their offerings with a better understanding of what was desirable (and undesirable) in the service (or product) being replaced and how was it used.

6.6 Satellite services have become so much part of the socio-economic fabric that it is not evident where all of the dependencies on satellite services exist. The following list indicates indirect satellite benefits: cash machines, payment terminals, weather forecasting, news gathering, traffic reporting, urban planning, internet (via the ISPs), pagers, international telephony, radio and TV broadcasting (via the broadcasters). (AACST, pp: 14-15) As such, it is difficult to identify comprehensively where and how we are dependent upon civil space activity. In some cases, the value of satellites is in their indirect use, for example where satellite services are a producer service (e.g. VSATs in retail).

6.7 As one interviewee explained, space-based services have provided the means to collapse planning and search cycles, making time ("when") and space ("where") more manageable for individuals, companies and governments. This generates efficiency gains for all. For example, the value of using satellite imagery and GPS in urban planning and transportation development allows us to *use terrestrial space better*. Remote sensing, GPS and better communications allow us to improve our ability to plan against risks, such as weather, traffic and collision; space allow us *to move through terrestrial space better*. Through improved and more immediate communications and accuracy through GPS, we are able *to use time better.*

Issues and opportunities for the UK

6.8 In order to encourage a greater take-up of downstream market applications, there is a role for government to act as a lead user in some selective instances, as in the case of remote sensing. One interviewee (ASTOS Chairman) argued that the government could act as an "anchor tenant" by using satellite data for multiple services, including global warming data, flood management data, drought data and traffic flow data (for development of effective road tolls, road development and train safety). The key action, according to some, is education, by which the cost and quality benefits of using satellite data would be demonstrated to government departments and their comprising units. Other interviewees emphasised,

however, that demonstrating by explaining is a poor substitute for actually enabling departments to try these data for themselves through specific funding lines to encourage the take-up of satellite data resources to support departmental missions. For example, a government act was established to provide $10 million annually for the greater use of EO/remote sensing amongst the public sector in the US. Likewise, the US President's office issued a Directive to all public sector agencies to use commercially provided remote sensing images wherever possible.(Wall and Asker, 2003) A similar programme has been set up by the Global Monitoring for Environment and Security (GMES), which is supported by the EU and ESA. GMES has a fund of 85 million Euros available to the GSE (GMES Services element) to support end-user take-up of remote sensing services.

6.9 In undertaking public-private partnerships or co-investment in civil space activity, there is a tension in the balance between making things freely available to the wider public and private returns for the investing companies. Currently, this is a debate concerning the EO data and images discussed in ESA's Oxygen Project. In the ESA document, *'A New Perspective for Earth Observation, The Oxygen Project (O_2 Project)'*, the argument is made that '[i]n this new paradigm, easy and inexpensive access to Earth Observation data is seen as the critical element and should be granted too any partner willing and capable of developing new applications and services.' (2003: 2) Such a view discounts the importance of sunk investment costs made by existing remote sensing services companies as well as the real demand characteristics for EO services. In other words, this is policy by pushing on the 'supply' string. Tensions between public and private ownership is also evident on matters of disclosure of design and technologies related to civil space activity.

6.10 Whilst downstream markets may be less contingent on UK owned/produced/operated space assets, there may be a wider concern for security of information and space infrastructure of national importance. From our research and the interview programme, we could not get a clear sense of whether there was an agreed social value for the UK government and space community of the fail-safing the country's access to communications, remote sensing and navigation services. The commercial viewpoint is that such access has always been available, and they estimated the risk of losing access to critical space assets as very small. On the other hand, another expert pointed out that reliance on US assets could be a mistake, particularly on the measurement of climate change where the two countries appear to have different agendas. Similar issues of national security relate to key space services suppliers to the MoD; what is the outcome for security when key private-sector suppliers are acquired by companies headquartered in different countries?

6.11 Another outstanding issue to discuss involves the establishment of new markets. In markets where demand patterns have yet to be successfully established, when (if at all) should the government act to develop these markets further? For example, how should the UK government act to encourage UK company participation in satellite radio or satellite supported internet services?

6.12 Given that some leading space asset producers are no longer headquartered in the UK, important issues for policy makers now include: (1) how to maintain previous levels of participation at the international programmes for civil space activity and (2) how to reap the greatest rewards from downstream market applications. With respect to the former, there is a concern that the UK will lose its position 'at the table' of civil space science and technological development. As such, the UK could be surrendering its role to help shape the future of civil space activity and thus the areas of potential spillovers and downstream activities, of which the country could ultimately benefit. Beyond these 'architectural' objectives, if the UK were excluded to a greater extent from international civil space activity, we may lose the opportunity to further develop technological capabilities amongst participating UK firms and scientists, thereby impacting the nation's human capital base.

6.13 The UK has had success in reaping rewards from downstream market applications, notably in satellite broadcasting. SKY has demonstrated that their ability to spot a market opportunity, and this ability has derived directly from the company's deep knowledge and capabilities in satellite transmission and service contracting. SKY leases satellite services from the satellite operators around the world, but the value added is in the successful manner by which the company has put together a business model for broadcasting, which is made possible and economical by using satellite services. The focus for the development of downstream market applications must be first on the needs that these services and/or products will aim to fulfil, and then on how civil space assets can better meet these needs.

Appendix: Selected references

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