Routes to Market Report

13 - Satellite Technologies for Future Cities

Innovate UK

CATAPULT Future Cities

CATAPULT Satellite Applications

Contents

1. Introduction and Scope

While there is no one definition of 'Future Cities', it is a term broadly used to conceptualize what cities will be like, how will they operate, what systems will orchestrate them and how will they relate to and involve their stakeholders, including citizens, businesses and governments.

The concept of Future Cities aims to enable cities to achieve their prosperity and social cohesion potential, create higher standards of environmental efficiency, citizen health and well-being, and strengthen international relations.[i] The term is widely applied and is often used in the same context as 'Smart Cities' – generally taken to mean the use of technology to improve a city's efficiency, optimisation, predictability, convenience and security.

The recent momentum that the concept of Future Cities has gained globally stems largely from the need to shape and manage the rapid urbanization being faced by cities globally. Increasingly, leaders across the world are becoming aware of the social and environmental threats that un-managed urbanization can lead to. The future form, functionality, appearance and ambience of cities will have a direct impact on people's lives, whether they are city dwellers or not. The future city will not only impact societies, but will also influence wider global environments and economies.[ii]

Cities are beginning to, and will continue to, integrate technological dynamism into municipal operations, from transportation to infrastructure repair and more.

1.1. Future Cities – Challenges and Opportunities

Owing to their critical scale of population size and density, cities can make transforming impacts on the environment and social well-being. Cities, accounting for as much as 80% of human generated carbon emissions[iii], harbour the scale for low-emission transport, effective land-use planning, mass retro-fitting, building efficiency, viable water and electricity systems, and product recycling (UNEP, 2014). Cities can also access global markets and resources, and create and sustain international flows of varied goods and services.[iv]

By 2055, an estimated 75% of the world's population is projected to live in cities, putting infrastructure, transport, natural resources and other supply systems under extreme pressure. Future cities will need to adapt to, or in some cases work to mitigate against complex and rapidly evolving phenomena, including:

- Climate change
- Population growth
- Globalization
- Technological developments
- Geo-political changes
- Human mobility
- Ageing populations
- Inequality and social tensions
- Insecurity (e.g. energy, food, water)
- Changing institutional and governance frameworks

Cities in emerging countries, on their way to see most of the urban growth over the next 30 years, will face the more severe form of these challenges, often, with the lowest levels of resources and institutional capabilities. With globalisation placing cities into direct competition with one another, cities are required to deliver prosperous economies, improved living standards, political stability, business friendliness and lower environmental impact.

The dual trends of urbanisation and globalisation also present enormous opportunities for cities, in emerging and developed countries, to adopt and capitalize on the technological innovations that offer 'smart' urban solutions fit for the challenges and needs of future cities. The market for 'smart' urban solutions that bridge across traditional domains could be vast, with up to $40 trillion of global investment forecast in city infrastructure over the next 20 years.[v] The global smart cities market is now worth an estimated £280bn and is and forecast to be worth more than $1.56 trillion by 2020.[vi]

As established by a range of studies in the recent past, these smart urban solutions necessitate the uptake of technologies that offer cross-sectoral solutions to address urban challenges. With ever growing advances in space-based technologies and their lowering costs, it is expected that their various capabilities, including data, positioning and communication, will play an instrumental role in applications that support the development and operation of Future Cities.

2. Market Overview and Opportunities

With a rising demand of cities for effective and innovative solutions, the potential applications of space-enabled technologies in the development of Future Cities have gained increased prominence over the recent years. While satellites continue to be the most effective means for reaching areas beyond terrestrial coverage, technological advancements have augmented the relevance of satellite applications in the urban landscape, particularly across the three key areas of Communication, Positioning and Earth Observation (EO). Offering a range of applications, from communications and environment monitoring through to navigation and security, the role of space-enabled technologies in future cities is predicted to grow rapidly over the next decade. [vii]

Higher share of urban population globally will place high demands on areas such as communications and broadcasting, control systems, transport logistics and coordination of emergency services. This requires high service resilience, continuity and interoperability and provides opportunities for the combination and integration of satellite communications, long-duration high altitude platforms (HAP)[1] and terrestrial communications networks.[viii]

Space technologies can be instrumental in addressing a range of these challenges and offer innovative products and services for cities of the future. For instance, in case of poor or no coverage of cellular networks, a satellite network, presents a highly reliable communication channel and is already under extensive use for communication backhaul in urban areas. Additionally, satellite systems are expected to act as fundamental components to reliably deliver reliably 5G services across the world, at all time and at affordable costs.

Based on a preliminary analysis that included review of existing literature and desktop research, some of the key applications of space-enabled technologies within the realm of Future Cities are elaborated below:

[1] High-altitude platforms (HAPs) are aircraft, usually unmanned airships or airplanes positioned above 20 km, in the stratosphere, to compose a telecommunications network or perform remote sensing.

2.1. URBAN MOBILITY

"Harnessing the potential of new technologies to improve mobility and accessibility in cities, especially through integration with other city infrastructure and priorities"

Optimising road transport through satellite navigation and telecommunications:

Satellite navigation is now a commonplace technology in road vehicles. But the main advantages of satellites – their ability to provide a uniform, reliable and quickly updated service across large geographical areas – provide opportunities for a range of other services. [ix]

a) **Connected Vehicles:** In the next five years, more than 220 million connected cars are expected to be built and sold globally.[x] Research firm IDC defines connected vehicles as those that contain software, sensors and IP-enabled connectivity either independently or through a mobile device, for service delivery, data collection or asset management. Broadband connectivity on cars, trains, cargo vehicles and maritime vessels is a growing trend across the global transportation landscape, and satellite communications is key to enabling the next generation of connectivity services across the world.[xi]

   Delivering bandwidth to vehicles on-the-move offers a major market opportunity for satellite companies. The global nature of satellite systems and the ability to broadcast to multiple points will enable auto manufacturers to reach all their vehicles on a single network, irrespective of their geographic location, to provide services such as software updates and remote-vehicle diagnostics. This is in stark contrast to having to contract with a large number of terrestrial network providers to achieve global coverage.[xii]

   The ability to send software and firmware updates to computers on board automobiles will be a boon for car manufacturers. Multicasting like this can both eliminate the need for an owner to bring a car into a dealership for a routine maintenance check and speed the response to manufacturer recalls. While privacy issues need to be resolved, through 'connected cars', insurance providers, car rental companies and others will be able to monitor driver behaviour and manoeuvre their offerings accordingly.

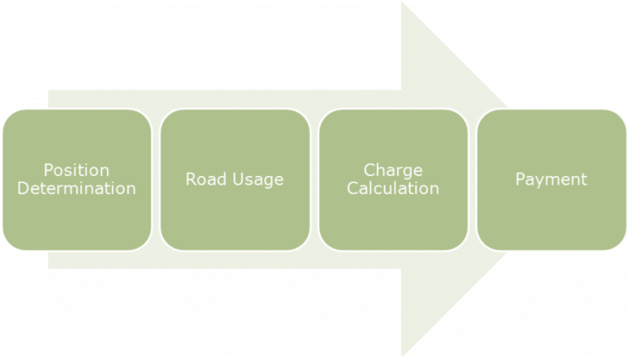
   Furthermore, big data deriving generated from connected vehicles will allow auto manufacturers to improve their fleet, offering information that can feed into safety equipment, Recently, Toyota announced that it will use Kymeta antennas to power their connected cars. To demonstrate, UK-based firm Kymeta leveraged Intelsat's satellite technology and completed an 8,000-mile journey across the United States using a Kymeta and Intelsat satellite-enabled test car.[xiii]

b) **Traffic Management – Free-flow tolling, Congestion Charge and Vehicle Taxation:** With cities across the globe introducing a range of measures for road traffic management and reducing congestion, space technologies can play a crucial role in enabling access to accurate positional and time data. It is foreseen that traditional ways of road tolling will be substituted by solutions based on positioning by means of GNSS.[xiv] For instance, a GNSS such as Galileo combined with 3G/4G mobile phone technology can ubiquitously create positional and timing services leading to a vehicle taxation policy based on usage and better management of congestion.

   The use of GNSS for Electronic Tolling Collection (ETC) has many advantages compared to other technologies as it allows for a flexible and scalable system with minimum specific roadside infrastructure. This translates directly into a simple and cost-efficient system. In fact, the interoperability directive 2004/52/EC adopted by EU in 2004 prescribed the development and deployment of a European Electronic Tolling Service (EETS), recommending the adoption of GNSS.[xv]

Road and urban tolling based on GNSS implies that the position and trajectory of a vehicle is determined using GNSS to decide if the vehicle must be charged or not and to compute the charging value. ETC applications are being implemented using On Board Units (OBUs) developed for that specific purpose that use GNSS data to compute the charging values. Some OBUs also integrate information from additional sensors – such as gyroscopes, accelerometers or OBD (On-Board Diagnostics) input data – to increase accuracy and minimize incorrect charges. Firms such as Siemens, EFKON, Satellic are already providing OBU (on-board unit) for vehicles capable of managing space-enabled toll systems.[xvi]

Figure 1: Illustrative Tolling Process Using GNSS



The technology can be designed to meet local and national highway authorities' needs for traffic management, such as setting traffic lights in a way that response times for emergency responders are improved, for example when fire and police vehicles need to pass quickly from one place to another.

Further, a recent European project, iTRAQ[xvii], affirmed that satellite applications can address traffic management and air quality control requirements such as:

- Delivery of real-time information on traffic flow, delay, and congestion throughout the urban network
- Delivery of real-time information on pollution levels throughout the urban network
- Delivery of forecast information on traffic conditions and pollution levels
- Delivery of optimised real-time traffic light settings on strategic routes, such that the travel time is improved while congestion target limits are maintained and air quality targets are met

c) **Vehicular Internet & Infotainment through Mobile Broadcast:** With passenger entertainment or 'infotainment' applications on the rise, multimedia content delivery to vehicles presents another substantial opportunity for space technologies. In 2014, SafeTRIP[xviii], an EU project organised by the French Ministry of Innovation and Research, demonstrated the possibilities for commercial services based around the S-band communication channel available via the Eutelsat 10A satellite. This channel is optimised for broadcast multimedia content delivery and two-way data communication via small mobile units that are ideal for vehicle applications.

The project's business model – to develop an open standardised architecture for low-cost terminals – is the same as that used for other successful mobile devices, such as satellite navigation. The model allows third-party software developers to produce applications for download, initiating a new and valuable market for mobile/tablet applications.[xix]

The DVB-SH standard[2] available via the S-band on Eutelsat is optimised for mobile conditions – even at high vehicle speed – and would allow passengers to access programmes via smartphones or tablets. The output of the SafeTRIP box could be integrated into the vehicle's audio-visual entertainment system. Such a system was demonstrated in both private cars and a Eurolines coach during the project.

Future services could also include live TV and digital radio or video on demand.

d) **Road Safety Applications:** The use of GNSS for emergency services and incident management can make the response to emergency situations much faster and efficient saving lives. The precise location of vehicle can be sent to rescue authorities and can use the emergency and rescue vehicle fleet management system to assign the most adequate vehicle to respond to the incident. These include applications via an automatic emergency alert system that connects with roadside assistance services or a local garage in the event of an accident or breakdown. The technology can be made interoperable with other emergency alert systems.[xx]

e) **Air Traffic Management**: Development of space technologies aimed at modernizing air traffic management is already underway in Europe and other parts of the world. In 2016, building on existing developments in Europe, ESA and UK satellite operator Inmarsat partnered to steer ahead the development of air-ground communications via satellite as part of Europe's plan to maintain safety in the sky as air traffic increases.[xxi]

This Iris Service Evolution will identify the technical, commercial and operational requirements of the satcoms part of the Single European Sky ATM Research programme, which promises to boost efficiency, capacity and performance of air traffic management worldwide.

By 2028, the Iris long-term service will enable full 4D management over airspaces across the globe and the data link will be the primary means of communications between controllers and cockpit crew. [xxii]

f) **Autonomous vehicles:** The development of the driverless car and other automated vehicles is already a reality. Driverless cars are projected to create a £900bn industry by 2025 and directly benefit car users, scientific research, developers and the automotive manufacturing sector.

Autonomous cars will likely utilize several systems for their self-drive capability, including radar and LiDAR, accurate and continuously available satellite navigation and satellite broadband connectivity are likely to be important enablers.

Observations from satellites could also assist urban planners in altering urban designs to account for changes in parking, traffic and public transport provision as automated vehicles become more prevalent.[xxiii]

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[2] DVB-SH is a transmission system standard designed to deliver video, audio and data services to vehicles and handheld devices. The DVB-SH is a hybrid satellite/terrestrial system that allows the use of a satellite to achieve coverage of large regions or even a whole country.

2.2. INTEGRATED URBAN PLANNING

"Harnessing the potential of new technologies to plan and run cities better."

Integrated Urban Planning as a concept encapsulates how new technologies can help to manage the growth and complexity of cities better and improve citizen outcomes, promotes efficiencies and reduce costs, through better, more integrated planning, the integration of city services and fostering better planning and resilience of critical infrastructure.

a) **Satellite Communication:** Currently, all major TV content generators rely on satellite communications to be able to broadcast live. Satellite communications also take place also in case of cellular network saturation, which often occurs during crisis / emergency situations or in case of poor or no coverage of cellular networks. Satellite communication is already under extensive use for communication backhaul in urban areas. With the ongoing advancements in the technology, such as reduction in latency, satellite communication offers the potential to provide the complementary ICT infrastructure to both the fixed fibre optic and wireless networks, in the near future. Depending on the architecture adopted for the Next Generation Broadband infrastructure, satellite communication can deliver as much as 40 million tonnes of CO_2 savings per annum for the UK compared to terrestrial infrastructure.[xxiv]

b) **Urban Land Use and Development**: Satellite imagery offers the potential to be used to gather strategic planning information pertaining to an entire city for urban land development. Earth Observation can provide substantial support to planning activities through the production of maps showing the current stage of development of an area.

   For instance, a recent research study by MDPI[xxv] on mapping urban land use in Beijing by using LandSat images and open social data found that the generated land use map revealed significantly more details of the spatial pattern of land uses than the land use map released by the government.

   Some of the key strategic urban land use and development applications that satellite imagery offer include:

   – **Aid the planning process through identification of land cover and development areas** and prioritising them by identifying features such as existing use, access to public transport, access to social and physical infrastructure. High resolution satellite imagery and LiDAR incorporated into a GIS[3] and CAD has already gained traction among planners and developers for large scale mapping
   – **Monitor site construction and development progress using regular satellite imagery**: Satellite imagery combined with GIS mapping is being used for evaluating construction costs as well as environmental impact of alternative routes for utility and transport corridors
   – **Identification of population groups at risk** where human intervention is most needed to limit and prevent hazards during development stage[xxvi]
   – **Monitor physical developments** in the city such as illegal land occupation
   – Periodic monitoring of the state and amount of green cover in a city

c) **Subsidence Monitoring:** While satellite applications for monitoring ground subsidence due to mining activities on a large geographic scale are widely known, their applications for monitoring ground subsidence in cities has only recently gained attention. Recent research

[3] Geographic Information Systems

studies, such as by the International Association of Hydrological Sciences[xxvii], have found satellite interferometric synthetic aperture radar (InSAR) data to be effective and valuable in the analysis of urban subsidence phenomena based on multi-temporal radar images.
Depending on the processing technique and the resolution of the SAR sensor, InSAR can be used for monitoring individual structures, but also to provide information at regional and at larger scales. In another study, the Canada Centre for Mapping and Earth Observation and University of Colorado, USA measured ground subsidence in the coastal cities of Vancouver, Canada and Seattle, USA using advanced image processing methodology[4] applied to earth observation data obtained from various SAR satellites[xxviii]. The advanced image processing methodology allowed them near real-time monitoring of ground subsidence with high spatial resolution and high precision, therefore increasing level of preparedness and mitigating risk. Results from satellite InSAR make it a unique instrument for ground displacement analysis and can be used in other applications such as:

- Monitoring areas prone to sinkholes and subsidence, terrain compaction
- Monitoring phenomena induced by tunnelling works
- Monitoring the stability of individual buildings

InSAR data can be updated regularly, as more SAR images are acquired by satellite sensors, and can provide new ways to design early warning systems covering cities to entire nations, where satellite information can highlight areas where in situ sensors and continuous monitoring tools should be installed. The research also points out that most of the challenges related to an operational use of InSAR data including monitoring urban subsidence have now been overcome and the technology can now become a standard tool for studying subsidence and other geological processes.[xxix]

d) **Precision and Urban Agriculture**: Satellite navigation is already being used extensively in agricultural applications for crop and soil monitoring as well as surveying the fertility of agricultural fields to control the distribution of chemicals and fertilizers.[xxx] With the resolution of information provided by Earth Observation systems improving gradually, there is a growing potential for satellite data applications in urban agriculture. The integration of GNSS positioning with information from various sensors has already revolutionised precision farming.[5]

The global market size for precision farming has been estimated to grow over $6.34 billion by 2022 at an estimated CAGR of 13.09% from 2015 to 2022. The emergence of more affordable, dual-frequency and multi-constellation receivers, as well as evolutions of PPP solutions, will further support precision farming – contributing, for example, to the improvement of GNSS-based machine auto guidance.

By integrating GNSS with other technologies, the agriculture industry can benefit from:

- Improved monitoring of the distribution and dilution of chemicals
- Improved parcel yield from customized treatment or
- More efficient property management

[4] Multidimensional Small Baseline Subset Differential Interferometric SAR (MSBAS-DInSAR)
[5] Precision agriculture (PA) or satellite farming or site-specific crop management (SSCM) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources.

GNSS-based agricultural applications often integrate Geographical Information Systems (GIS) data with position data making these systems more effective. Some of the applications offered by these systems include:

- **GPS mapping service:** Provides detailed information about fields, aids to create new maps, verify existing maps or add information to existing maps. The precision maps are usually acquired from specialized companies such as Trimble, Hexagon and Topcon. The maps tend to have several features such as soil conductivity to identify differences within field soils
- **Yield mapping:** Refers to the process of collecting georeferenced data on crop yield and characteristics, such as moisture content, while the crop is being harvested. Various techniques currently in use a combination of GPS technology and physical sensors, such as speedometers, to track crop yields, grain elevator speed, and combine speed.
- **Soil sampling and nutrient mapping applications:** These applications can help to map where the fertilizers are needed, as well as the exact quantities to be applied in each area. The knowledge of the soil characteristics will be improved, the fertilizer costs can be reduced and the cultures can be tailored to use the most adequate fields
- **Altitude mapping:** These capabilities aid drainage and crop plans. Farmers need to be able to map the high and low-yield areas of fields so that a varying application of chemicals can improve the yield with minimum environmental impact and cost.
- **Time crop applications:** These applications will permit an efficient crop stage management
- **Crop surface measurements:** These applications will allow farmers to declare their actual cropped area, for situations such as insurance claims, without relying on historical documents that show property lines, not the actual agricultural parcels that change every season
- **Online agricultural management projects** such as Agrista, provide services where farmers can store farm information and exchange data with their business partners and service providers, using GNSS products to obtain information.

e) Internet-of-Things and Machine-to-Machine (M2M) communication: According to Harbor Research, the global IoT market could hit €1 trillion in 2020 with applications in almost every sector of the economy, from automotive to consumer electronics, healthcare, manufacturing and logistics. As many IoT applications require positioning information of each ‘thing’, IoT could provide a significant knock-on demand boost for satellite positioning capabilities in several market segments.[xxxi] Market research and consulting firm NSR estimates that by 2023, there will be 5.8 million M2M and IoT connections via satellite around the globe. Currently, satellite-enabled IoT is dominated by narrowband providers, such as L-band.

With further uptake of high-throughput Ku- and Ka-band connections, the volume of opportunity in the IoT and M2M sectors is expected to grow even higher. Low-earth-orbit satellites (LEOs) and other NewSpace innovations are also expected to play a key role in the IoT and M2M growth, as Google and others seek to capitalize on their heavy extra-terrestrial investments.

Sigfox, a French start up that specializes in low-cost wireless networks, along with partners Airbus Defense and Space, CEA-Leti and Sysmeca, is working on a hybrid system of earth- and sky-based technologies to enable IoT connectivity across the globe.

Some of the IoT and M2M applications where satellite operators can deliver strategic advantages over terrestrial deployments include:

- **Connecting remote assets**: Business operations that extend to geographically remote environments depend on satellites to provide the critical communication means to conduct remote facility monitoring and real-time asset management at unmanned sites and offshore platforms
- **Deployment of Smart Grids:** While the deployment of smart grids holds the promise of a better way to power communities, it requires utilities to address several emerging communications requirements for the smart grid. Satellite communication plays an important role in Smart Grid deployments, because of its high reliability, ease of use, better cost effectiveness compared to a few years ago, no weather influence and the highest level of security.[xxxii] Satellite solutions are being used across range of grid-related applications, including: substation connectivity, distribution automation, advanced metering infrastructure (AMI), mobile workforce and disaster recovery. For instance, the Inmarsat Broadband Global Area Network service (BGAN) solution is being used as secondary communication path to critical Smart Grid infrastructure such as reclosers, fault indicators and capacitor banks[xxxiii]
- **Smart waste management:** Satellite technologies are not currently widely used in the Waste Management sector, however, local authorities and other entities across the world are exploring the potential of satellite technologies in supporting new or improving existing services for this sector. In Italy, the Wastemon project provides key support for waste management practices using space-borne remote sensing images for the Puglia region. Under the project, a waste mapping and monitoring service to improve waste management practices and to detect illegal landfills using satellite Earth Observation data is used by the environmental protection agency of the Puglia region and by Conversano, a small town in the same region.[xxxiv]
- **Facilitating mobile banking and retail services**: Satellites can serve as the main communications backbone that keeps wireless ATMs and mobile point-of-sales applications running smoothly across a broad geographical span

f) **Energy Loss Detection:** Heat loss detection is an important aspect of infrastructure maintenance. Rising fuel prices and growing ecological concerns have led decision makers and engineers to explore efficient and effective ways to improve energy efficiency. Satellite-based thermal remote sensing offers opportunities in detecting and monitoring heat loss from both residential and commercial areas and buildings in urban areas by identifying specific buildings, or parts of buildings, where heat is escaping due to lack of insulation or other defects. The identified areas can be targeted for repair and re-insulation to reduce costs and conserve energy.[xxxv]

Although ground level surveys are more flexible and can easily be performed on demand. They are, however, prohibitively time-consuming when dealing with a large study region. Further, the results of the ground survey cannot be easily integrated into modern GIS systems. Satellite-based surveys, on the other hand, offer vast coverage, collect imagery at regular intervals and at lower costs. Data obtained from satellite-based surveys can be easily georeferenced, imported into any GIS system and prepared for automated analysis.[xxxvi]

In 2015, Latvia-based Foundation Ventspils High Technology Park (VHTP) launched a study of the possibility to identify the heat loss from buildings and plan to prevent this by using satellite technologies. The project used a tool created by SIA Astrosat, which processes information from thermal infrared (IR) satellites (e.g., Aster and Landsat), as well as data obtained from Copernicus optical and radar satellites.

The tool also allowed for urban classification algorithms that identify and mark the local government-owned buildings. Urban planners could use the thermal map to identify priorities for heat insulation measures. These new technologies would theoretically enable reducing the time spent on energy auditing to as low as one month[xxxvii].

g) Identifying and Forecasting City Heat Islands: Satellites are helping to forecast the location of urban areas most affected during heat waves, helping planners to design cooler, more comfortable cities. The temperature in densely urbanised areas can be several degrees higher than in nearby rural areas or less densely populated areas – a phenomenon known as the 'urban heat island' effect. The negative effects of this increase in urban temperatures are multiple: health problems, higher energy demand, air pollution and water shortages.
Monitoring thermal radiation can help city planners to design more 'liveable' cities, assist civil protection authorities in taking adequate measures during heat waves and create maps of energy efficiency.

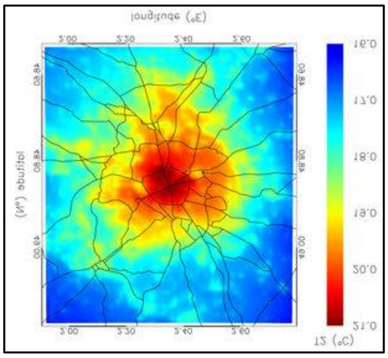


Figure 2: Night temperature in Paris

In a recent project by the European Space Agency (ESA), satellite sensors were shown to play a significant role in collecting data and providing thermal-infrared measurements that scientists then used to improve urban climate and weather prediction models that can forecast heat waves. Two airborne campaigns and multiple ground sensors also contributed.[xxxviii]

h) Use of meteorological data to help predict energy and water demands: Rising fuel prices and sensitivity to national fossil fuel emissions continue to ensure increasing importance of the efficiency of the power generation industry. Satellite remote-sensing data is widely used in the energy sector for applications ranging from climatology to identification of solar and wind energy sources, yet there is significant potential to expand energy applications in the energy sector.

Operational meteorological satellites play an important role in the generation of the short-term and seasonal weather forecast products that are employed in the power industry. Daily forecasts of temperature, humidity, precipitation and wind speed, and warnings of severe weather events play a key role in the prediction of electricity consumption in a typical day. Accuracy of electricity consumption forecasts are pivotal for the power generation industry. Energy sector meteorologists have suggested that, in the USA, inaccurate forecasts can have an impact on the electricity generation industry by as much as US$1 million per degree Fahrenheit per day.[xxxix]

Weather forecasting improvements resulting from the introduction of new, advanced satellites are, therefore, of significant value to that industry. It has been estimated that the economic benefit to the U.S. supply industry resulting from improvements included in the GOES-R mission[6] alone would amount to US$451 million in 2015. This benefit would be

[6] The Geostationary Operational Environmental Satellite-R Series (GOES-R) is the next generation of geostationary weather satellites.

realised in the form of savings, primarily from improved load forecasts and better real-time weather information.[xl]

In the medium term, improvement of energy resource management activities using satellite Earth observations will largely stem from the improvement of short- to medium-term (up to 8–10 days) weather predictions, as well as progress in seasonal to inter-annual climate forecasts. Application of current Earth observations to alternative energy resource assessment will continue to be exploited as deployment of these technologies increases.

i) **Water Management:** “Satellite-based Earth observation, complemented with other applications, is a cost-effective method for effective management of water resources and it provides essential data to decision-makers. Upon conversion into practical information, the data could be used to support the development of policies and programmes at the various scales, from global to local.” – Mazlan Othman, Deputy Director General, United Nations Office.

In the wake of growing urbanisation and efforts towards water conservation, water resources managers continue to face challenges with the characterization, understanding, and prediction of water demand, supply, and quality. Water resources management can benefit from the application of remote sensing and hydrologic models. Satellite and airborne remote sensing observations can provide valuable information and can be used to support the operational water resources community for management practices and decisions. For instance, The Water Authority of Sardinia uses a remote-control system of the infrastructure for distributing raw water between various users, saving time and money.

In West Slovakia, The Western Slovakia Water Company is using satellite positioning for precise geo-localisation of water pipes and infrastructure, to ensure efficient and secure maintenance of the water supply to 507 municipalities. The improved maps enable maintenance workers to avoid damaging existing infrastructure when intervening on buried infrastructure. Finally, the company provides a more competitive and reliable service to its customers. [xli]

j) **Emergency rescue and disaster relief operations:** Satellite-based services including both communications and positioning, are already vital to the success of emergency rescue and disaster relief operations around the world. Satellites provide highly responsive, flexible, cost effective and dependable communications when local infrastructure is compromised, destroyed or non-existent. Mobile and fixed satellite services played a key role following the 9/11 attacks and the 2004 Indian Ocean tsunami, as they do today in support of the relief efforts following the Haiti earthquake.[xlii]

In the field of disaster management and response, meteorology data is often used to warn and monitor potential hazards, while Earth Observation images are frequently used during natural disasters such as tsunami in Asia and earthquake in Haiti to rapidly map the area and assess damage. Earth Observation images can be scrutinised to identify pockets of potential survivors for rescue operations.

2.3. HEALTHY CITIES

Refers to harnessing the potential of new technologies to improve the design and operation of cities to enhance health and well-being.

a) **Air Quality Monitoring:** Maintaining an acceptable air quality is high on the agenda for communities. Studies suggest that air pollution results in about half a year of reduced life expectancy and costs the UK up to £20 billion per year.

Satellite data of atmospheric pollutants are becoming more widely used in the decision-making and environmental management activities of public, private sector and non-profit organizations. They are employed for estimating emissions, tracking pollutant plumes, supporting air quality forecasting activities, providing evidence for 'exceptional event' declarations, monitoring regional long-term trends, and evaluating air quality model output.

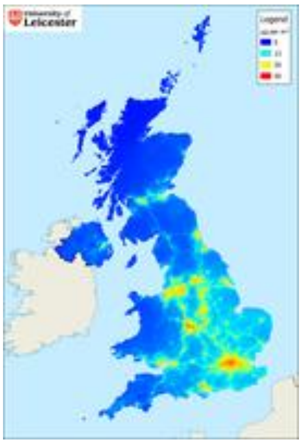


Figure 3: UK air quality map

The U.S. Environmental Protection Agency (EPA) and many state Air Quality agencies recognize the utility of satellite data and some of them are actively considering how they can be further used for monitoring and regulatory purposes. A research study[xliii] identified four main categories of current applications i.e., tracking pollutant plumes, support for air quality forecasting, evidence in exceptional event demonstrations, and input to air quality models and data for model evaluation.

The study also identified two main categories of potential applications i.e., estimating ozone precursor and aerosols emissions, and monitoring regional long-term trends in ozone precursors and aerosols, all of which take advantage of the much larger spatial coverage that satellites offer over the conventional ground-based monitoring networks.

CityScan, developed by the University of Leicester in partnership with Surrey Satellite Technology Limited, constructs virtually real-time, 3D maps of pollution over entire urban areas of up to $25km^2$. CityScan undertakes monitoring of nitrogen dioxide and aerosols, effectively acting like a pollution radar.

b) **Telemedicine:** Satellite communications for telemedicine applications in rural and remote areas are well-known. Developing countries such as India have a well-established telemedicine network connecting remote or rural hospitals and Mobile Units through the satellites to major specialty hospitals in cities and towns.[xliv]
Telemedicine, in its current form, is increasingly using a variety of electronic communications media, ranging from teleconferencing to image-sharing to remote patient monitoring, to provide clinical services to patients in underserved areas, Telemedicine is also considered a way to significantly reduce the cost of treating health conditions, including hypertension, diabetes, which benefit from continued monitoring of a patient's condition.
Satellites can also play a key role in 'ehealth' areas such as enabling remote medical education, clinical research or remote administration and governance. Further, satellites are the most promising technological instruments to enable mandatory ad-hoc broadband communication in case of medical trauma, emergencies, and disaster situations.[xlv]

- **Healthcare at home:** Satellite positioning services or GPSS forms an indispensable component of healthcare at home; in emergency cases, GPSS can seamlessly extend healthcare facilities and professionals to the mobility radius of the patient, diminishing geographical or physical barriers and overcoming the lack of facilities through connectivity with existing resources. Coined as a first deal in telemedicine, in 2013, Hughes Network Systems partnered with New England Telehealth Consortium to provide broadband satellite services through high-performance routers to healthcare units. These routers are integrated with AvL Technologies' auto-deploy antenna to enable applications such as videoconferencing, transfer of electronic health records, viewing of X-rays and other digital images and voice calls.

- **Healthcare on the move:** Satellites communication and positioning applications can substantially improve eHealth and Telemedicine for citizens on the move by air, sea, or ground
- **Healthcare financing** can be enhanced through improvement of information systems to support more effective resource allocation and purchasing (electronic pooling and purchasing where physical infrastructure does not exist will support transparency and efficiency)
- **eLearning:** Satellite technologies have the potential to provide an important impact on health care resource generation through remote healthcare education and training

c) **eSurveillance and eGovernance**: Satellite technologies offer the potential to impact health system stewardship by improving information systems for decision making and enabling early response in emergency situations

3. Customer and End-User

3.1. Urban Mobility Solutions

a) Connected Vehicles

- Automotive manufacturing industry players across different supply chain tiers
- Rental Cars and automotive fleet managers and manufacturers: The technology allows for software updates and remote-vehicle diagnostics to be implemented
- Insurance Providers
- Local and National Highway Authorities

b) Free-flow tolling, Congestion Charge and Vehicle Taxation

- Local and national highway / traffic management authorities
- Ease of payment for motorists and road users

c) Vehicular Internet & Infotainment through Mobile Broadcast

- Mobile application developers
- Media and broadcasting companies
- End users (motorists)

d) Road Safety applications

- Roadside assistance services
- End users (motorists)
- Motorists
- Traffic management / highway authorities

e) Air Traffic Management

- Air traffic controllers (ATC)

f) Autonomous vehicles

- Automotive manufacturing companies
- Car buyers
- Motor insurance companies

3.2. Integrated Urban Planning Solutions

a) Satellite Communication Services

- Telecom companies
- Public sector
- Media Companies
- End-users

b) Urban Land Use and Development

- Planning authorities
- Utilities (Water, Electricity, Gas and Telecom)
- Developers
- Mapping agencies
- Citizens

c) Subsidence Monitoring

- Planners
- Developers
- Geologists
- Home Buyers

d) Precision and Urban Agriculture

- Urban farmers and agriculture companies
- Agriculture products and service providers

e) Internet-of-Things and Machine-to-Machine (M2M) communication

- Businesses such as logistics companies
- Utilities
- Waste management/recycling companies
- Local authorities

f) Energy Loss Detection

- Home-owners
- Planners
- Utilities

g) Identifying and Forecasting City Heat Islands

- Planners
- Local Authorities
- Citizens
- Research Institutions
- Environment Agencies

h) Use of meteorological data to help predict energy and water demands

- Utilities
- Demand Forecasting Agencies

i) Water Management

- Utilities

j) Emergency rescue and disaster relief operations

- Centre for the Protection of National Infrastructure
- Local, Regional and National Disaster Response and Rescue Operation Agencies

3.3. Healthy Cities

a) Air Quality monitoring

- App Developers
- Local Authorities
- Environment Agencies
- Citizens
- Research Institutions

b) Telemedicine

- Healthcare providers (physicians and hospitals)
- National healthcare agencies such as NHS
- Application developers
- Patients

4. Value Proposition to the Customer and End-User

Satellite-based applications in future cities, as outlined in the previous sections, offer the following key advantages to its customers:

- **Broad Coverage and Global Deployment:** With global coverage and high speed everywhere (vs. 2G and 3G in most places and 4G in few areas), satellite has a distinct advantage over cellular in terms of network consistency. With a global network, satellite application customers, such as car manufacturers, benefit from a single network. With a cellular network, they would work with hundreds of terrestrial carriers and need to access multiple distinct technologies around the world for any kind of data broadcasting[xlvi]

- **Lower Risk of Cyber-attacks:** Satellites' ability to provide a global, private network offers a consolidated content distribution opportunity that reduces cyber-attack vectors by eight or nine orders of magnitude when compared to cellular in terms of entry and exit points, demonstrating the security benefits that satellites deliver

- **Superior Performance:** For two-way IP networks, the speed, uniformity and end-to-end control of today's advanced satellite solutions are resulting in greater use of satellite by corporations, governments and consumers

- **Cost Effective:** Cost of satellite capacity does not increase with the number of users/receiver sites, or with the distance between communication points. Whether crossing continents or staying local, satellite connection cost is distance insensitive. Thus, satellite applications, when used over a large scale, can provide economies of scale and thus, prove cost efficient. For instance, in the case of transmission of content to connected cars, the cost of content is largely independent of the number of receivers, thus, the distributor's expense to provide content from a satellite broadcast or multicast is the same irrespective of the number of receivers[xlvii]

- **High Quality Signals Irrespective of Location:** Compared to optical fiber communication, the quality of transmitted signals and location of sending and receiving signals are independent of distance, thus, requiring less infrastructure investment and offering high quality communication

- **Superior Reliability**: Satellite communications can operate independently from terrestrial infrastructure. When terrestrial outages occur from man-made and natural events, satellite connections remain operational[xlviii]

- **Immediacy and Scalability:** Satellite has proven its value as a provider of "instant infrastructure" for commercial, government and emergency relief communications. Additional receive sites, or nodes on a network, can readily be added, sometimes within hours.

- **Versatility and Broad Range of Applications**: Satellites effectively support on a global basis all forms of communications ranging from simple point-of-sale validation to bandwidth intensive multimedia applications. Satellite solutions are highly flexible and can operate independently or as part of a larger network[xlix]

5. Market Competitiveness

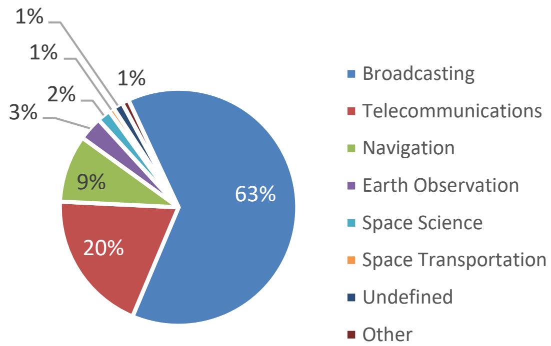


Figure 4: UK Space Economy Turnover by Capability, 2012/2013

Aerial Surveys offer some of the advantages that satellite-based surveys offer; however, often a combination of both solutions is used to achieve the desired outcomes

Use of drones for Earth Observation is gaining popularity for small coverage areas; however, unlike satellites, drones are faced with a range of technological and regulatory constraints[l]. Some of these limitations include:

- Limitations of the payload and endurance
- Instability of the platforms (wind, electromagnetic influences, etc.)
- Regulations and insurance
- Use of low-cost sensors denies high-end performance and accuracy

Use of optical sensors or other technologies for positioning applications instead of GPSS may take off – however, GNSS's established market and continued advances, such as hybrid technologies that allows users to access location data in any environment, render it a more a competitive technology in the current market

Use of 5G and other advanced generations for communication: Ongoing reduction in latency of satellite communication and advances in the antennas used for satellite communication, such as by

Kymeta[li] and Phasor[lii], and making it suitable for several advanced forms of communication (including on-the-move communication). Further, the successful development of 5G network is expected to integrate telecom technologies including mobile, fixed, optical and satellite[liii]

6. Role of UK Companies

The recently published Case for Space 2015 report shows that the UK space industry, growing at a rate of 8.6% a year, has doubled its turnover over the past decade to £11.8bn a year and aims to achieve a turnover of £40bn by 2030.[liv]

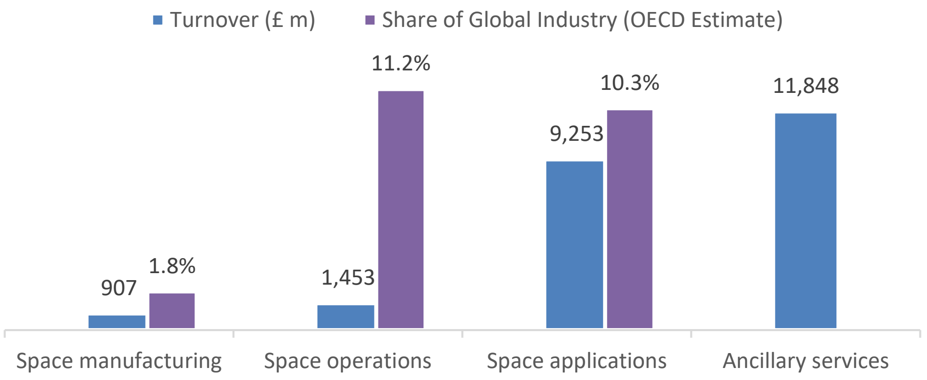


Figure 5: Global Comparison of UK Space Economy

At 1.8% of the global market, the UK has only a small part of the global space industry's upstream business – the manufacture of space vehicles. However, the country is well represented in the downstream sector. Britain's space companies have 11.2% of the operations market for space vehicles, and 10.3% of the applications market for the services and data provided by satellites. Overall, this implies the UK has 7.7%[lv] of the global space industry's annual turnover, estimated at about £160Bn a year.[lvi]

Compared to manufacturing, the UK currently is a much stronger global player in the space operations (11.2%) and space applications (10.3%) segments – indeed, for these latter segments, the UK already has achieved the 2030 target, set by The Space Innovation and Growth Strategy 2010, of achieving 10% of the global space economy. [lvii]

The UK is home to some of the leading global providers of **fixed and mobile satellite data communication** services, supported by a strong value chain. The UK also has some world-renowned organisations that rely on satellite connectivity for core operations as well as enhancements of customer offerings.

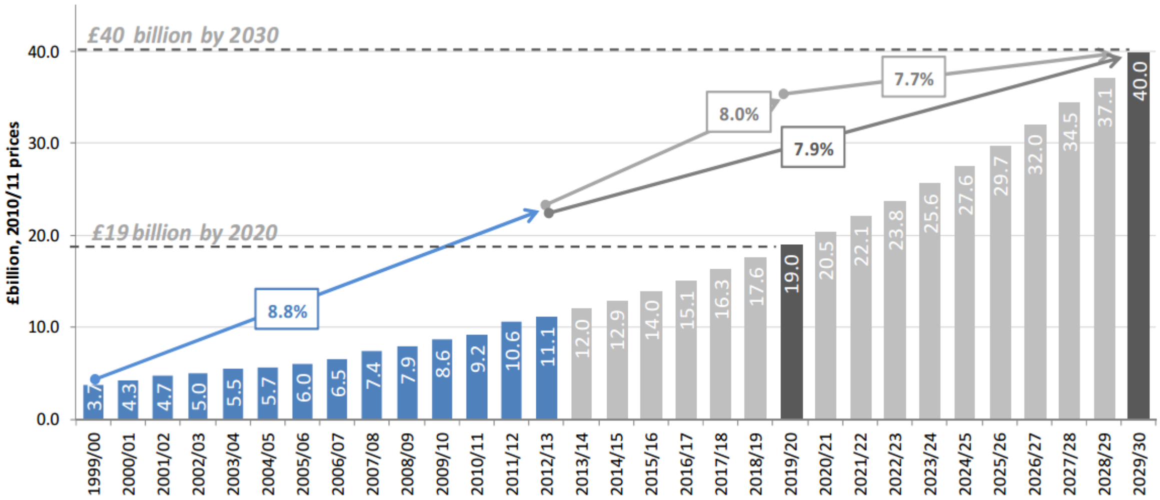
UK companies and research organisations are now at the global forefront of space sector-led innovation, offering products and services fit for cities of the future and spanning over a wide range of disciplines:

- **Space Manufacturing:** Organisations involved in the manufacture of Launch vehicles and Systems; Satellites, payloads, spacecraft, Ground segment systems and equipment; and providers of Scientific and engineering research and consultancy. Some of the key British players include Airbus Defence and Space UK, Surrey Satellite Technology Limited (SSTL), QinetiQ Group
- **Space Operations**: Organisations involved Launch provision and brokerage services, Proprietary satellite operation (incl. sale/lease of capacity), Third-party ground segment

operation. Key players in the UK include Inmarsat plc, Airbus Defence and Space UK, Arqiva, Commercial Space Technologies (CST) and SIS Live

Space Applications: Organisations that receive data from Earth Observation, Navigation or communication satellites and develop applications such as DTH provision, Very Small Aperture Terminal (VSAT) network provision, Value-Added Resale (VAR)/ Value-Added Services (VAS) for end-users, science, government and Industry. Examples include Cambridge Silicon Radio (CSR), Avanti and BskyB

7. Revenue Projections



Note: Arrows indicate compound annual growth rates of UK space industry. Figure presents values required to achieve the target of £19 billion by 2019/20 (based on a compound annual growth rate of 8.0% between 2012/13 and 2019/20). All values are presented in 2010/11 prices, in line with the base year used in the Space Growth Action Plan.
Source: London Economics analysis and Space Innovation and Growth Strategy Steering Board (2013).

Figure 6: UK Space Growth Action Plan Targets

With a Compound Annual Growth Rate (CAGR) of 8.8% since the year 2000, the UK space economy has outperformed the global space economy, increasing its share of the global market. Growth in the global space economy stimulates growth in the UK through the large share of UK space economy turnover that is generated in foreign markets through exports.

Currently, broadcasting accounts for the largest share of 63% of UK space sector's total turnover, followed by telecommunication (20%), navigation (9%) and earth observation (3%), however, this mix is expected to change over the next few years with increased uptake of satellite communications, navigation and earth observation capabilities for future cities applications.

The global core GNSS downstream market is forecasted to increase to c. £110bn by 2023, growing at 8.3% annually between 2013 and 2019 before slowing down to 4.6% towards 2023. This means the GNSS downstream market is expected to grow, on average, faster (7%) than the forecasted global GDP during this period (6.6%).

Market research and consulting firm NSR predicts satellite's share of the IoT and the related machine-to-machine (M2M) sector revenue alone will exceed $2.4 billion in 2024, up from $1.4 billion in 2014 In its recently. NSR found that by 2023, there are estimated to be 5.8 million satellite M2M and IoT connections globally.

With driverless cars forecasted to create a £900 billion industry by 2025, it will have a large spill over effect on the space sector.

8. SWOT Analysis

8.1. Urban Mobility (e.g. Connected Vehicles, Free-flow tolling, Congestion Charge and Vehicle Taxation)

Strengths	– With global coverage and high bandwidth irrespective of location (vs. 2G and 3G in most places and 4G in few areas), satellites offer a distinct advantage over cellular in terms of network consistency. With a global network, satellite application customers, such as car manufacturers, benefit from a single network.
Weaknesses	– Satellite communications suffers from latency or the time delay in the receipt of signals transmitted; however, technological advances have reduced the latency significantly. This is currently improved by using assistance data provided over mobile networks, giving the receiver orbital information about the satellites and allowing for a faster location fix.
Opportunities	– Delivering uninterrupted bandwidth to on-the-move vehicles for communication and media broadcast
Threats	– Advances in terrestrial means of communication

8.2. Integrated Urban Planning

Strengths	– Satellite-based remote sensing holds certain advantages in monitoring the dynamics of urban land use because of the large spatial coverage, high time resolution, and wide availability. – Satellite remote sensing data and products provide unique, objective information that has the additional advantage of yielding global, homogeneous, and repetitive coverage.
Weaknesses	– The quality of the satellite signals received can be adversely affected by several factors, including the weather (especially heavy rain), obstructions (such as trees and leaves), or whether the satellite dish (receiver) is correctly angled to receive the signal – High-resolution urban land use maps covering large spatial extents are often expensive due to lack of skill and supply companies (oligopolistic industries).
Opportunities	– Satellite imagery offers the potential to be used to gather strategic planning information pertaining to an entire city for urban land development, agriculture and IoT.
Threats	– Aerial remote sensing or use of drones for remote sensing; however, these can only be used for coverage of small areas and face restrictions on fly-zones.

8.3. Healthy Cities

Strengths	– Satellite remote sensing data provide unique, objective information that has the additional advantage of yielding global, homogeneous, and repetitive coverage.
Weaknesses	– A degree of technical skill is required on the part of the data end-user, which is often problematic for air quality agencies with limited resources. – Currently, satellite data is only available daily (instead of hourly for ground monitoring), and that it does not work with cloudy sky.
Opportunities	– Satellite data of atmospheric pollutants are becoming more widely used in the decision-making and environmental management activities, especially for developing countries where sensors are not available.
Threats	– Differences between what satellites measure and parameters of interest to decision-makers, limited collaboration between the environmental measurement and Earth observing satellite communities to develop robust satellite-based indicators, and a lack of cross-cutting technical and funding resource.

9. Opportunity Barriers and Enablers

Apart from some of the inherent shortcomings of the current services offered by satellites, such as disruption due to weather conditions, there are several external barriers, constraining the take-up of the applications that space-enabled technologies offer including policy barriers, market constraints, governance difficulties, lack of standardisation, insufficient technical knowledge and less clarity on the benefits of the technology being to the users.

Delays in satellite launches[lviii], weak data distribution system, combined with a complex governance framework, are the most critical factors holding back a faster uptake of satellite applications in future cities concepts.

- **Policy/ strategy issues:** Insufficient and delayed support actions for the downstream sector
- **Market constraints and lack of awareness on potential and current satellite applications in future cities:** With future cities continuing to be a growing market that is gradually navigating its demand for technological solutions, the satellite industry could benefit from raising awareness among city authorities through networking, dissemination seminars and workshops. The industry could also benefit from including the perspective of users/business in developing future services
- **Fragmented market:** Lack of standardisation of the equipment, software and data across vendors and systems
- **Technical development**: Need to reinforce IT solutions to distribute archived and new Earth Observation data, including pre-processed EO products; Potential to harmonise the access to national space data among various stakeholders
- **Business Model**: Given high initial costs for satellite manufacturing and launch, there is a need for lower cost satellite applications, given competition from low-cost terrestrial applications in some cases

– **Regulatory Changes**: The government should take account of the wider value of space-enabled services to determine radio frequency spectrum allocation, the operation of the Outer Space Act, allocating orbital slots for new satellites and treaty negotiation with other countries[lix]. The UK should make specific allowance for new growth in bandwidth for Space infrastructure and services as this is likely to require reserved rights to that part of the radio frequency spectrum that is most useful to future satellite-based services
– **Funding sources**: The satellite and associated industries need to explore alternative funding sources, such as seed fund from the Government, an industry funding pool for R&D activities from industry players and venture capital firms

Skills: Shortage of appropriate skills, for instance, to process EO data for innovative applications for future cities; The industry could benefit from undertaking knowledge-exchange and training for existing personnel in the satellite industry and establishing academies/institutions focusing on innovative applications of space-enabled solutions, guided by the demands of future cities

10.Market Dynamics

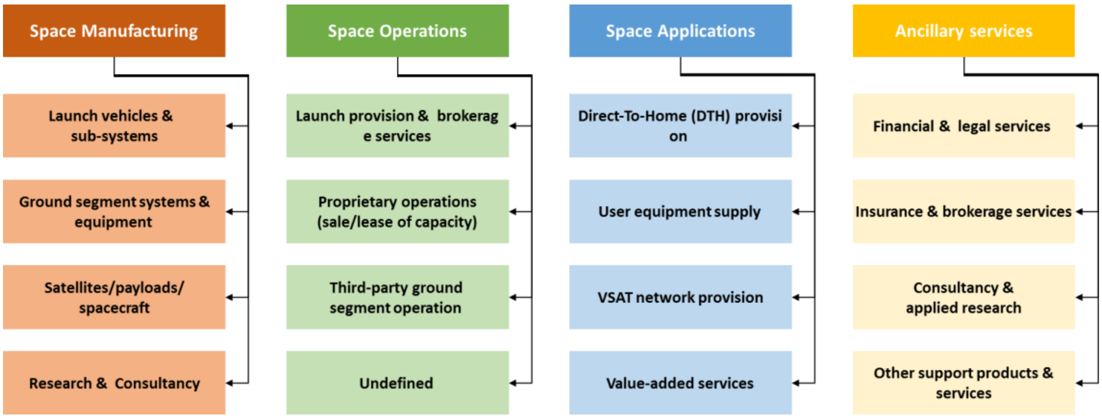


Figure 7: Global Space Industry Value Chain

The UK space economy covers the full spectrum of company size, from start-ups with little turnover to multinational conglomerates turning over billions. Organisations also vary in the intensity of space specialisation or 'space share' – from a limited range of targeted products or services to whole operations in the space sector.

As a general trend, small firms tend to be specialised into space while large companies are more diversified and have a progressively smaller share of the business active in space. [lx]

With only nine companies accounting for 64% of the UK space turnover, the UK space sector is highly consolidated, particularly in the space manufacturing and operations segments, owing to a series of merger and takeovers in the last few years. However, the space applications segment can be classified as an increasingly fragmented industry, given the growing emergence of smaller players in the segment.

Table 1: Size Composition of the UK Space Economy, by Turnover

Total turnover	Number of companies	Space turnover (£m)	Weighted average space share
<£100k	17	1	65%
£100k-£1M	30	9	72%
£1M-£10M	34	101	64%
£10M-£100M	54	713	41%
£100M-£1BN	27	3,327	29%
>1BN	9	7,216	16%
Total	**171**	**11,366**	**19%**

From application point of view, the global GNSS downstream industry is broadly classified into three groups of companies:

- **Components manufacturers**, producing receivers for stand-alone use or integration into systems, including chipsets, antennas and safety beacons
- **Systems integrators**, integrating GNSS capability into larger products, such as vehicles and consumer electronics, as well as dedicated GNSS devices such as PNDs
- **Value-added service providers**, whose services improve access and use of GNSS, including map providers, augmentation service providers and GNSS calibration or testing activities

The global GNSS market is **highly consolidated,** especially at the level of component manufacturers, representing the core GNSS industry. The system integrators are mostly car manufacturers and smartphone vendors, for which the GNSS represents only a small part of their product offering (similar in the case of value-added providers). There is a high potential for application developers, including SMEs and start-ups, on top of the major market players. Users download more data and applications, and the global app economy (which GNSS apps are part of) is growing at an annual rate of 27% globally.

The industry is characterised by a few very large companies and a plethora of SMEs. The big players in the GNSS industry have embarked on multiple take-overs in recent years, implying consolidation at the top. In 2012, the top companies by turnover related to GNSS accounted for 34% of total GNSS market and the largest company had 12% of the global market share.[lxi]

10.1. Key Players in the UK by Application Areas

Earth Observation

Segment	Activity	Main UK players*
Space manufacturing	Satellite manufacture (incl. subsystems)	SSTL; Airbus; Qioptiq; MDA Space and Robotics; ComDev
	Launch (incl. brokerage)	CST; SSTL
	Ground segment manufacture	SSTL; CGI
Space operations	Ground segment operator	Airbus (Infoterra); CGI (for Eumetsat)
	Satellite operator (including lease of capacity)	Airbus (Infoterra); DMCii
Space applications	Retail added value services	Airbus (Infoterra); Pixalytics; Stevenson Astrosat; Ambiental; Climate & Carbon modelling; MET Office (DemandMet); Exelis Visual Information Services; Crop Performance; Rezatec; Starlab Ltd.; Ursula Agriculture; Landmark Information Group; Telespazio VEGA UK Ltd; Magellium; Terra Recovery; Geospatial Insight; Transport Research Laboratory
Users	Commercial users	Oil & Gas, Mines & Energy; Ordnance survey; Schlumberger; Online map providers (e.g. Google); Farmers; Retailers; Energy supply management (e.g. EDF, British Gas, SSE, E.ON, npower, Scottish Power); Weather forecasts (all media outlets); Adas; EOCI; Assimila Ltd.; WeatherSafe
	Governmental users	DECC; DEFRA; Environment Agency; Future Cities Catapult; Natural England; MET Office; British Geological Survey; British Antarctic Survey; Centre for Ecology and Hydrology; Forestry Commission Scotland; Forestry Commission; Macaulay Land Use Research Institute; Scottish Agricultural College; Scottish Crop Research Institute; Scottish Environment Protection Agency; Defence Geospatial Intelligence Fusion Centre; Highways Agency; Traffic Scotland; Traffic Wales; Traffic Watch Northern Ireland
	NGO users	Disaster response; Aid relief (e.g. British Red Cross); Deforestation charities (WWF, Greenpeace); Agriculture and Horticulture Development Board

Note: *: Companies with UK headquarters or offices.
Source: London Economics

Navigation

Segment	Activity	Main UK players*
Space manufacturing	Satellite manufacture (incl. subsystems)	SSTL; ComDev
	Satellite payload manufacture	SSTL; Airbus; Qioptiq; Qinetiq
	Launch (incl. brokerage)	
	Ground segment manufacture	Airbus, CGI (EGNOS & Galileo)
Space operations	Ground segment operator	Airbus, CGI (Galileo)
	Satellite operator (including lease of capacity)	Inmarsat; Veripos; exactEarth
Space applications	User equipment manufacturer	Cambridge Silicon Radio (CSR); Laird; Garmin UK; Veripos; Raymarine; Qinetiq; Broadcom UK; Qualcomm UK; McMurdo (Orolia); MetaSystem; Quartix; Trimble UK; B & G; NASA Marine; Polar; Rockwell Collins; Nottingham Scientific Limited; Alstom; Icom; Deimos UK; AGCO; Sci-Tech;
	Retail added value services	Hailo; Google; Honeywell Global Tracking; CGI; Bombardier; G2Way; Progressive Agriculture Solutions; Crop Performance; Teletrac; Wunelli; MyDrive; Masternaut; Trimble UK; Ursula Agriculture; AGCO; GeoCento; e-Canal; i-Geolise; Bounts; ManagePlaces; Mapskey; exactEarth; Applied Satellite Technology Limited
Users	Commercial users	Fleet management; Admiral; Aviva; Insure-the-box; Oil & Gas, Mines & Energy; Network synchronisation using GNSS timing (telecommunications and utility companies); GNSS time-stamping (finance); Ordnance survey; Network Rail track management; Eddie Stobart; Automobile manufacturers' retail; Farmers; Tracking of lone workers; Esk Valley Railway; Port operators; Hays Ships ltd; Schlumberger; Gardline Group; farmers; Construction surveyors; Instantview; Travel AI; Interasight; TeamSurv; Mobile telecoms companies (e.g. EE, Vodafone, 3, O_2)
	Public sector users	Emergency response (eCall; Search & Rescue); Police force (PMR); Bridge monitoring (Nottingham Wilford Suspension Bridge; London Millennium Bridge; Humber Bridge); Alderney Airport EGNOS procedures; NATS; Tracking of dementia patients; HM Coastguard
	Private users	Individual smartphone users; Individual motorists; Tracking of children, pets, luggage; Fitness tracking

Note: *: Companies with UK headquarters or offices.
Source: London Economics

Fixed and Mobile Communication

Segment	Activity	Main UK players*
Space manufacturing	Satellite manufacture (incl. subsystems)	Airbus; Qioptiq; Printech Circuit Laboratories; ComDev
	Launch (incl. brokerage)	CST
	Ground segment (teleports) manufacture	iSat
	Ground segment components manufacturer	iDirect; CGI; Hughes Network Systems; iSat
Space operations	Ground segment (teleports) operator	Inmarsat; Arqiva; Avanti; Goonhilly Earth Station; Harris Caprock UK
	Satellite operator (including lease of capacity)	Inmarsat; Avanti; Intelsat; O3b Networks
Space applications	Retail service providers	Inmarsat; Avonline Broadband; BT; Rural Broadband; Broadband Wherever; Satellite Internet; Apogee Internet; Telespazio VEGA UK Ltd; Honeywell Global Tracking; iDirect; 7E Communications; Ashbury SatCom; GeoBorders; Global Telesat Communications (GTC); H2OSatellite; Imtech Marine; Marlink; Mobell; Mobile Communication Network Int'l; Navarino; NSSL Global; Satcom Direct; Satcom Global; Spectra Group; Stream Technologies
	User equipment manufacture	Inmarsat; Thales UK; Invacom; Cobham; Triax UK; Icecrypt; Raymarine; Phasor Solutions; iSat; SIS Live; Telespazio VEGA UK Ltd; Applied Satellite Technology Limited
Users	Commercial users	British Airways; Farmers (large); Businesses in broadband not-spots; Maritime users (e.g. P&O); Telemedicine (e.g. Medical Support Offshore, MSOS); Foreign correspondents (BBC, SkyNews, ITV, etc.); Discovery Channel; Deep sea shipping; Oil & Gas platforms; Explorers; Aid workers
	Private users	Consumers in not-spots; Business aircraft; Leisure maritime; Explorers

Note: *: Companies with UK headquarters or offices.
Source: London Economics

11.Market Trends

Some of the global space industry trends that strengthen the case for the opportunities set out in the earlier sections, as identified by a recent report by London Economics, include:

- **New Space Age:** Owing to decades of investment in R&D, exploration and infrastructure development, the space industry is entering a 'New Space Age' or the age of applications. The relationship of the average citizen or company with space has changed in the last decade than in the previous four.

- With a strong applications sector (accounting for 78% of the UK space economy) and focus on applications in the business incubator programmes and public funding opportunities, the UK is well placed to grow its application business and capture a larger share of a growing world market

- **Rising commercial dominance:** The rising applications sector also makes its mark on the split between and commercial sector activities. The Space Report, for example reports that government accounted for 33% of global space activity, which dropped to 24% in 2013

- **Internationalisation of space value chains:** Like other economic sectors, the UK space industry is adapting to globalisation to ensure its success in the face of competition from the rest of the world. UK companies have successfully won contracts from ESA and NASA, and delivered in other countries (e.g. Nigeria and Kazakhstan).

- While internationalisation is an opportunity for UK companies to cater to a growing global future cities market, it is also a challenge as it opens the UK's domestic market to foreign suppliers. However, as with other industries, this is an opportunity to make UK offerings more competitive and innovative. In recent years, the UK space economy has enjoyed strong growth rates in exports, suggesting companies are starting to better exploit this opportunity

- **Internet of Things (IoT) and everywhere:** In the future, IoT will likely become the Internet-of-Everything. Various providers have forecasted the market, but as the scope is unclear at present, the forecasts vary. According to Cisco, IoT will create value of $19 trillion over the next decade. To create value, the 'things' need constant and secure connectivity – a key capability of satellite-based solution.

- **Trend towards smaller satellites**: SSTL and Clyde Space are prime examples of UK market leaders in small satellites and CubeSats, respectively, and the companies will likely benefit from the recent trend of small satellite launches in recent times. For instance, in 2013, 85 nanosatellites were launched, a substantial increase on the 10-20 satellites launched annually over 2008-11.

- Smaller satellites are becoming especially relevant with the clusters/constellations meant for Low Earth Orbit (or lower) that can provide remote sensing, satellite broadband and many innovative new services in the future

- **Radical and new business models**: The term 'NewSpace' refers to a nascent, but fast growing global community of entrepreneurs, private companies and organisations active in the space economy, possessing many the following features:
  - **Reliance on private finance** (sometimes supported by government contracts)
  - **Low cost approach** for competitive pricing
  - **Clean sheet design and innovation driven technological development** approaches differ substantially from mainstream space industry
  - **Incremental development** funded by commercialising limited capability models satellite
  - Target commercial markets - high net worth individuals or mass market consumers

- **Miniaturisation of technology**, including GNSS chipsets attached to high value or sensitive goods, allowing for the tracking of their location throughout the transport chain. The advent of flexible electronics will allow GNSS receivers to be included in personal items that could assist in locating lost and stolen items[lxii]

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