Routes to Market Report

35 - Satellite Technologies for Weather Services

Innovate UK

LE London Economics

CATAPULT Satellite Applications

Contents

1. Introduction and Scope

This market briefing assesses the market opportunity for new weather services that can be derived from the current and future meteorological missions, the provision of new observations addressing the gaps in the observing system and the exploitation of satellite data into innovative combined products.

Both Earth Observation (EO) and Global Navigation Satellite System (GNSS) technologies are used to obtain meteorological data, which is processed through specialist analysis and combined with other (satellite-based or terrestrial) data to produce increasingly specialised and targeted weather, seasonal and climate products and services.

The market briefing covers both the upstream (space manufacturing) and downstream (space operations and space applications) elements of the space economy value-chain. The focus lies on the market opportunity for UK companies and estimates of industry revenue and the wider benefits associated with the provision of (new) weather services.

The market briefing covers 2016-2020 (near term) and extends to 2030 (longer term).

2. Market Overview and Opportunities

Satellites provide a major contribution to the 'Global Observing System' (GOS), the coordinated system of facilities for making meteorological observations on a global scale.[1] There are two primary types of satellite orbits used in operational meteorology – geostationary orbits (GEO) and polar low-Earth orbits (LEO).

- GEO satellite imagery provides a unique view of large regions of the Earth from a fixed location, providing rapidly updated low-resolution imagery that enables forecasters to track the movement of the atmosphere and monitor weather features that can change rapidly, such as localised severe weather events. GEO data is used primarily for now-casting, to assess the accuracy of model forecasts, to fine tune them as they evolve and to monitor the state of the atmosphere between model runs.
- LEO is used for detailed measurements of the structure of the atmosphere, primarily for input into numerical weather prediction (NWP) models. A satellite in LEO will provide global coverage every 12-hours, including polar-regions not visible from a geostationary orbit. The observations of atmospheric temperature and humidity from instruments on these satellites have a greater impact on NWP performance than any other observation type.

The value chain for weather services therefore starts with space manufacturing, where meteorological satellites and ground infrastructure are built and launched. In the space operations segment, satellites and ground segment are operated. Services and applications derived from meteorological satellites represent a key segment having an impact in a wide variety of customer areas (civil aviation, climate monitoring and prediction, natural hazard and resilience management).

2.1. Space manufacturing and operations

Opportunities from public procurement (large weather satellite systems)

Due to the cost and complexity of satellite missions, European countries are satisfying their shared requirements for space derived data to support operational meteorology through the European

[1] http://www.wmo.int/pages/prog/www/OSY/GOS.html

Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). EUMETSAT operates core programmes for geostationary (Meteosat) and polar orbiting (EPS) satellites.

The second generation of EPS satellites (EPS-SG) will provide continuity of the European contribution to the global LEO service, following on from the current EPS satellites as they reach the end of their operational lifetime. The proposed EPS-SG Programme has an overall budget envelope of €3.3bn (2012 prices), with expenditure falling over the period 2015 – 2044. The remit of the programme includes the launch of the initial satellites, procurement of recurrent units, ground segment development and 21 years of operations.

EUMETSAT is responsible for overall user requirements, procurement of the launchers and LEOP services, development of the ground segment and performs the operations. EUMETSAT coordinates with the European Space Agency (ESA), which is responsible for the funding and development of the prototype satellites (platforms and instruments) through the Metop-SG programme. Nations across Europe will be asked to provide various instrumentation in proportion to their contribution to the ESA part of the EPS-SG programme. EUMETSAT will procure instruments from European manufacturers based on open competition.

The key objectives of EPS-SG are the sustaining of essential observational capabilities to ensure continued service and the bringing of additional capabilities to improve NWP accuracy and to enable the development of new products and services to address emerging markets and user requirements.

Small satellites opportunities

Technology improvements are opening up new business model opportunities based on Smallsat constellations. The Satellite Applications Catapult estimates that between 2,000 and 2,750 Nano/Micro-satellites will be built and require a launch from 2014 through 2020.[2]

Small satellites are becoming a significant new tool for remote sensing. Smallsat systems can collect data through the GNSS radio occultation techniques, where satellites receive signals from GNSS (e.g. GPS) satellites that pass through the Earth's atmosphere. Those signals can serve as probes of the atmosphere, providing data about conditions that can be incorporated into weather models to improve the accuracy of forecasts. These systems are intended to augment, and not replace, the existing and planned much larger weather satellites which take more than a decade to develop.[3] These small satellites thus allow for new meteorological data to be collected within or outside the scope of the intergovernmental contracts described above.

Example: In summer 2016 the UK Met Office was able to take advantage of a nanosatellite being used as a technology demonstrator by ESA to gather weather observations over a large part of the globe.[4] GomX-3, the nanosatellite built by the Danish CubeSat developer GomSpace, had originally been designed to collect Automatic Data Surveillance – Broadcast (ADS-B) messages to track aircraft from space for Air Traffic Control purposes. Collaboratively GomSpace, ESA and the Met Office reprogrammed GomX-3 whilst it was in orbit to collect Mode-S Enhanced Surveillance (EHS) parameters, which are required to calculate wind and temperature observations.[5]

[2] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/82047/introduction_eo_for_ofcom_june_2015_no_video.pdf

3 Smallsats provide opportunities and challenges for weather data http://spacenews.com/smallsats-provide-opportunities-and-challenges-for-weather-data/#sthash.q7NQg0F0.dpuf

[4] Met Office Press Office (2016). Can space tech help measure the weather? Available at: https://blog.metoffice.gov.uk/2016/11/30/can-space-tech-help-measure-the-weather/

[5] Met Office Press Office (2016). Can space tech help measure the weather? Available at: https://blog.metoffice.gov.uk/2016/11/30/can-space-tech-help-measure-the-weather/

Example: On 12 December 2016, NASA launched the Cyclone Global Navigation Satellite System (CYGNSS), which will provide previously unavailable data on surface wind speeds inside hurricanes and tropical cyclones at high time-resolution. The CYGNSS mission consists of eight micro-satellites, which use radio signals from four GPS satellites to measure the wind speed near the ground in the tropics where most hurricanes form. As the CYGNSS and GPS constellations move around the earth, the interaction of the two systems will result in a new image of wind speed over the entire tropics every few hours, compared to every few days for a single satellite.

2.2. Space applications and services

As mentioned above, several intergovernmental organisations are involved in coordinating Earth Observing programmes to satisfy common international requirements. The World Meteorological Organization (WMO) coordinates the global constellation of meteorological observing satellites, and the satellites are owned and operated by WMO Member States. By fulfilling their respective satellite contributions to the GOS, countries automatically secure free unrestricted access to meteorological data and information.

National Meteorological Services, intergovernmental organisations[6] and private-sector meteorological firms process observations through specialist analysis and input them into meteorological models, which are run on supercomputers. Model outputs are converted by meteorological and hydrological specialists into weather, seasonal and climate services; which are then packaged and distributed through different channels such as weather apps, websites, or TV weather programmes. Further downstream, software developers combine weather forecasts as provided by meteorological companies with other datasets to create added-value.

Opportunities for meteorological companies

It is estimated that there are **more than 100,000,000 observations available globally each day that are currently not being collected or used by the meteorology community**.[7]

National Meteorological Services (NMS)

The UK Met Office is a unique global institution, delivering integrated weather and climate services to government institutions, commercial and private users. The Met Office serves sectors such as defence, aviation, construction and energy, offering a range of services that meet specific industry demands.

In 2016, the Met Office signed new, five-year contracts with both EasyJet and Gatwick Airport, underlining the value of embedded, on-site meteorologists for the aviation industry.

Newer markets include retail and insurance. DemandMet™, for example, is a tailored forecasting tool for UK retailers that helps retailers predict end-consumer demand created and affected by weather conditions.

A very large market opportunity for the Met Office also lies in the realm of international development and consultancy services. Indeed, the Met Office is one of only a small number of NMS's who sell services to government institutions in other nations. In 2016, the Met office partnered with the Kenya Meteorology Department (KMD) and the Tanzania Meteorology Agency (TMA) to identify opportunities for commercial weather and climate services serving the East African energy sector.

[6] These include the European Centre for Medium-Range Weather Forecasts (ECMWF) or the World Meteorological Organisation (WMO).

[7] Met Office Press Office (2016). Can space tech help measure the weather? Available at: https://blog.metoffice.gov.uk/2016/11/30/can-space-tech-help-measure-the-weather/

Substantial investment is committed to increasing forecast accuracy over the next five years with the Met Office successful bid for a capital grant from BIS for its next HPC investment from 2015 to 2020. The business case set out how capital investment of £97m in a new HPC for the UK would enable socio-economic benefits (SEBs) of some £2bn over five years[8]. Exploiting these technological enhancements into improved forecast accuracy will require strong science research base and the "unlocking" of new areas where forecast accuracy is not currently good enough. This could include better fog forecasting at Heathrow, better convective precipitation forecasts to enable surface water flood warnings, or reliable seasonal forecasts to enable strategic winter resilience planning.

Private meteorological companies

Private weather companies can do a lot of value-added work for specific clients, as this is the case in the US. The biggest European private sector meteorological company is MeteoGroup, which is based in London but owned by US General Atlantic LLC. From spring 2017 onwards, MeteoGroup replaces the Met Office as BBC's main weather forecaster. MeteoGroup provides tailored products to professional, media and consumer markets. MeteoGroup's weather app, WeatherPro, is the most sold paid for weather app in Europe. Other top selling weather apps of MeteoGroup are MeteoEarth and Magical Weather. In the UK, the private sector weather services market is relatively nascent.

In addition to an improvement in accuracy and more targeted weather forecasts, a potentially important growth area for both national weather services and private meteorological companies are real-time weather forecasts. An example hereof is AccuWeather's (US) Minute by Minute™ rain forecasts.

2.3. Integrated applications

Significant market opportunities lie in the fusion of satellite-derived weather data with other data sources and the exploitation of weather forecast data into combined products and integrated solutions.

A fast-growing area is the provision of **decision-support systems** based on **highly-localised weather forecasts**, which are specific to the microclimate prevailing at a certain locality. Such forecasts consider both regional weather forecasts and the local features that may affect the climate of a site, including altitude, distance from the sea, and topography (nearby significant ranges of hills or mountains).

Localised weather forecasts and micro-climate consulting based on the combination of weather and topographical or geographical data have a wide array of applications. An important example is precision agriculture, where site-specific forecasts allow farmers to optimize growing conditions on a plot-by-plot basis, boosting yields, improving quality and cutting costs in the process. Such site-specific forecasts require a combination of weather and topographical data, for example because the lowest area of a glen may sometimes frost sooner or harder than a nearby spot uphill or because sunlight might inactivate herbicides by ultra violet (UV) light in particularly sun-exposed areas on the South side of hills in the Northern hemisphere. Successful UK applications in this area include *FarmingTruth* developed by Cranfield University and Agrovista UK's *Forecast Xtra*.

Another important area for localised weather applications is traffic management, both in the air and at sea. For example, Lufthansa Airlines is using real-time aircraft, airport, and weather sensor data to improve on-time performance and optimize operations. *SEMAFORS*, the BMT ARGOSS Ltd-led 'ship efficiency monitoring, weather forecasting and optimised routing service' supported by ESA, provides

[8] Public Weather Service Value for Money Review, Mike Gray, Public Weather Service Customer Group Secretariat March 2015

the shipping industry with weather forecasts along the planned route to help the vessel crew avoid adverse weather conditions, realise efficiency gains and maintain safety for crew, vessel and cargo.

The next logical step for weather applications is the **fusion of weather forecast data with other satellite or terrestrial data** sources:

- *Earth Observation* imagery can provide a key role in providing information on climate variables such as soil moisture content, sea levels and sea surface temperature, clouds, land cover, ozone and aerosol content. In this context, ESA has launched a programme called *Climate Change Initiative* (CCI), which builds long-term data records based on Earth Observation for several essential climate variables. The fusion of EO climate data with weather forecasts has important applications for hazard prediction and mitigation. For example, EO data on the stock and moisture content of forests can help optimise fire hazard prediction, and imagery of snow cover, surface temperature and wetness is important in the context of avalanche warnings.

- *GNSS* can be used for geo-referencing the area of interest for localised weather forecasts and of in-situ weather and climate measurements. *Satellite communication* technologies are important in downstream weather applications to provide automated data transmission from weather stations and data loggers, in particular when terrestrial networks are not available (e.g. avalanche warnings in mountains).

Numerous applications further arise from the combination of terrestrial sensor data with (localised) weather forecasts. For example, data from water sensors monitoring reservoir and borehole depth or water levels in pipes can be combined with rainfall predictions for the reservoir catchment area for more effective demand management and flood prevention. Similar opportunities lie in the use of data derived from pollution or wind sensors.

3. Customer and End-user

Weather services are used by private consumers, businesses and government agencies.

Individuals and households use public weather forecasts and warnings to make better informed decisions in their day-to-day life.

Weather services are moreover essential for informing decision made by industry. A large range of sectors including **agriculture, offshore oil and gas, construction, coal mining, financial and insurance services, transport, emergency services, retail, electricity, water management, tourism** and **health care** are directly or indirectly impacted by weather and/or climate conditions. Lazo *et al.* (2011) provide estimates of the climate sensitivity of different economic sectors for the United States, finding that up to 15% of the gross value added created by those sectors is sensitive to weather and climate. Gray (2015)[9] estimates that 17% of the total UK economy is weather dependent. Industry is the most important client for the rapidly growing downstream market described in the previous section. Among the most important customer segments are the agriculture, transport (air and marine), energy and insurance sectors.

9 Public Weather Service Value for Money Review, Mike Gray, Public Weather Service Customer Group Secretariat March 2015

Finally, **government agencies** and **emergency response services** use weather services to effectively predict and prepare for, mitigate and respond to severe weather events such as storms, floods, bushfires, cyclones, hurricanes, or cold spells/heatwaves. Weather services prevent (part of) the damage associated with severe weather events and save lives.

4. Value Proposition to Customer and End-User

4.1. Space manufacturing and operations

The EPS-SG Programme is expected to be one of the most important (global) sources of satellite observations for all forecasts based on NWP in the 2020–2040 timeframe. With the current EPS series approaching the end of its operational life, EPS-SG is required to maintain essential observational capability and **ensure continued service**. However, the next generation will also **deliver enhanced capability**. New instruments include a microwave imaging mission to provide enhanced coverage and robustness for monitoring of precipitation, an ice cloud imaging mission to monitor ice clouds, and a multi-viewing multi-channel multi-polarisation imaging mission to monitor and quantify the effects of atmospheric aerosols on the heat balance of the Earth. The new generation of continuity instruments will also have a higher capability in terms of number of spectral channels and spatial resolution.

Small satellites allow for **previously unavailable data to be collected** and an increase in the area on Earth that can be measured. In addition, these satellites allow for **significant cost reductions** in the collection of data for atmospheric measurement. The use of additional data in conjunction with/instead of the freely available raw data provided by the WMO hence provides potential customers such as governments, National Weather Services, and private meteorology firms with a competitive advantage. The CYGNSS mission, for example, will improve meteorologists' ability to understand the formation and intensity of tropical cyclones and hurricanes and hence help improve hurricane intensity, track and storm surge forecasts.

4.2. Space applications and services

Meteorological companies

Novel methods of gathering weather data and new space missions will deliver more data, which can be used by NWS and private-sector meteorological firms to provide **higher-quality weather forecasts and alerts**. The **increasing number of meteorological observations** is particularly important to drive the mathematical models used in weather forecasting. The increased amount of data is used to nudge the model of the atmosphere closer to what is being measured, ultimately leading to improvements in the forecast. Hence, an increase in the amount of meteorological data available will lead to a **more robust observing system** and assure **reliability and data quality**.

Integrated applications

The use of satellite data in a novel way further enhances the end-user's experience through increased ease of access of the weather information and more targeted products. Fusing weather forecasts with other satellite or terrestrial data sources allows for the creation of more **targeted, localised and timely products**, to support decision-making and help increase profits and avoid damages in the private industry and support effective hazard mitigation and emergency response in the public domain.

5. Market Competitiveness

Global meteorological observations amounting to over 40GB per day are gathered from many different sources including satellites, buoys, ships, aircraft, radiosonde, land stations and more. Over recent years, operational meteorology and climate research have continued to grow increasingly dependent on high quality NWP models that in turn rely on steadily improving, sustained sources of data.

Satellites have increasingly become the primary source of these data. The observations of atmospheric temperature and humidity from instruments on these satellites have a greater impact on NWP performance than any other observation type. The Met Office internal business case for EPS-SG[10] concluded that out of all observations assimilated, satellite missions are responsible for 64% of the accuracy of global forecasts. Current EPS satellites alone were estimated to make up 24% of the total benefit.

Another Met Office study in 2005 compared the accuracy of a forecast 500hPa height field for a 5-day period in July 2001, with and without satellite data included. The study found that forecast accuracy can be improved by up to 10 hours by the addition of satellite data (i.e. the quality of the X + 10-hour forecast is as good with satellite data as the X hour forecast without) in the Northern Hemisphere and up to 48 hours in the Southern Hemisphere.

Satellite data are particularly important in areas where the terrestrial observation network is sparse, such as Africa and oceanic regions and over the Arctic and Antarctic regions. Studies have also demonstrated that satellite data reduce the number of poor quality forecasts, often referred to as forecast 'busts'. By reducing poor quality forecasts, NWS' can minimize the number of predictions that fail to warn communities of high impact events.

6. Role of UK Companies

6.1. Space manufacturing and operations

Public procurement

The UK space industry benefits from UK's membership in EUMETSAT funded through the PWS. There are two methods by which return can come to the UK. Firstly, EUMETSAT ground segments and operations contracts are let on a competitive basis to companies domiciled in EUMETSAT member states. UK industry has had success in winning these tenders, with total contracts worth in the order of €15m over 5 years[11]. Satellite development and build is funded jointly by ESA and EUMETSAT, with ESA funding roughly 30% of the costs and EUMETSAT 70%. EPS-SG satellites are built under the industrial leadership of Airbus Defence and Space, mainly on sites in France and Germany. With ESA expenditure on programmes allocated on a geo-return basis, the UK investment at ESA (£85 million subscribed) secured significant contracts in the satellite build.

The biggest UK contribution to Metop-SG is a follow-on to the Microwave Humidity Sounder (MHS), which feeds data into multi-day forecasts. The new instrument, which will be made **by Airbus Defence and Space Ltd**, will be known as the MicroWave Sounder (MWS) and will have significantly improved performance.

10 Developed by Turner, S., Truscott, B., Mundy, P. and Barber, A. (2014)
11 Public Weather Service Value for Money Review, Mike Gray, Public Weather Service Customer Group Secretariat March 2015

In addition, UK manufacturers might secure repeat order from the EUMETSAT recurrent satellites, 'noble' contracts.

Private sector: Small satellites and instruments

Surrey Satellite Technology Ltd (SSTL) delivers small satellite missions and instrument for collecting weather data. The Space GNSS Receiver-Remote Sensing Instrument carried on the NASA CYGNSS mission was developed by SSTL. SSTL, in collaboration with ESA and the National Oceanography Centre (NOC), further researches new techniques and applications to derive weather data based on the data received from TechDemoSat-1, a small technology demonstration satellite launched by SSTL in 2014.

ClydeSpace, a UK SME with a key focus on the design and manufacture of hardware for CubeSats, small satellites, nanosatellites**,** is in a strong position to benefit from the increased use of CubeSats (as demonstrated by the reprogramming of CubeSat GomX-3) for the collection of meteorological data. 40% of ClydeSpace's business comes from the US, so that the company is well positioned to serve the growing demand worldwide.

Dartcom is one of the leading manufacturers and integrators of weather satellite and remote sensing ground stations worldwide. Dartcom products cover X-band EOS data from Terra, Aqua, Suomi-NPP and FengYun-3 polar-orbiting satellites, HRPT data from the NOAA series of polar-orbiting satellites, AHRPT data from the Metop series of polar-orbiting satellites, DMSP data from the DMSP-5D series of polar-orbiting satellites, LRIT/HRIT data from EUMETCast, MSG direct broadcast, GOES, MTSAT, COMS-1 and Electro geostationary satellites, and GVAR data from the GOES series of geostationary satellites.

6.2. Space applications and services

National Weather Services

The **UK Met Office** provides internationally recognized world-class weather and climate research using its unified weather and climate model. It is one of only a very small number of NWS's who sell services to government institutions in other nations, including supplying services to Australia, South Korea and the US Air Force. Furthermore, the UK Met Office is one of only two World Area Forecast Centres, hence delivering forecasts globally and playing a key role in enabling civil and military aviation. Due to its unified model and existing international relationships, the UK Met Office is uniquely positioned to seize market opportunities globally.

Private-sector meteorological companies and integrated applications

UK companies are in a strong position to seize the downstream market opportunities in the weather services industry due to the status of the UK Met Office as a world-leading National Weather Service.

The biggest European private sector meteorological company is **MeteoGroup**, which is based in London but owned by US General Atlantic LLC. **AccuWeather UK & Ireland**, the subsidiary of US Açu Weather, dominates the UK's Online Weather.

Plantsystems of **Agrovista UK** provide consultancy services, forecasts & equipment to the agriculture industry. **BMT ARGOSS Ltd.** specialises in metocean consultancy and weather forecasting. They seek to elevate their clients' operational efficiency, minimize unnecessary weather related downtime on marine operations and assess metocean engineering design requirements. **Fugro EMU Limited**'s MetOcean team provide physical meteorological and oceanographic survey and consultancy services. **Fugro GEOS** is a supplier of met and oceanographic services for offshore/coastal engineering

applications. **Mar-Met** provide a range of services for the offshore and constructions industries worldwide. **Met Marine** based in London provide world-wide marine weather forecasts for skippers. **MetWorks**, a marine weather services company based in Bracknell. Finally, **StormGeo**, a global weather services provider focussing on offshore, renewables, media and shipping, has 3 UK offices.

Other UK-based players in the downstream weather market include **EuroTempest** (provider of innovative weather risk products to benefit the warning and management of weather risk across Europe); **AvBrief** (provider of flight briefings for pilots); **Metcheck** based in Manchester specialise in tailored forecasts for business; **Metdesk** based in Wendover deliver bespoke solutions to weather sensitive industries; **MetraWeather**, the international subsidiary of New Zealand Met Service; **Netweather TV** (supplier of weather data, forecasts and information to a wide range of businesses); **Norman Lynagh Weather Consultancy** (specialists in services to marine and film industries); **North Sea Weather** (providing services to oil/gas, offshore construction and fishing industries); **Speedwell Weather** (specialists in analysing, structuring and placing weather risk); **WeatherEvents.net** (specialists in mobile, real-time weather data acquisition and imagery); **WeatherLab** (quality-controlled historical weather data and reports from the UK); **Weathernet** (weather information for insurers); **Weatherology** (specialising in demand forecasting); **WeatherQuest** (forecasting company); **Weather Research** (specialising in weather impacts on sales); and **Weather2** (provider of multi-media, multi-channel weather info services).

7. Revenue Projections

	2016	**2017**	**2020**	**2030**
Met Office revenues	£227m[12]	£240m	£275m	£450m
Downstream application revenues in proportion to Met Office revenues	10%	15%	30%	50%
Downstream application revenues	£20m	£35m	£80m	£225m
TOTAL REVENUES	**£247m**	**£275m**	**£355m**	**£675m**
Wider benefits (end-user)	£600m	£600m	£700m	£850m

7.1. Calculation of Results

Space manufacturing and operations

Airbus Defence and Space Ltd's contract to make a follow-on to the Microwave Humidity Sounder (MHS) for Metop-SG is worth up to €155.5/£135m (up to 3 units will be purchased).

Space applications and services

National Weather Services revenues (Met Office)

The Met Office has two reportable business segments: Government business and Commercial business. In the 2015/16 fiscal year, the Met office generated **£195,710,000** public sector bodies and **£31,419,000** from commercial contracts.[13] The UK Met Office's total revenue equated to **£227,480,000** in the 2015/16 financial year (including corporate investment and other central income of £351,000).

Markets and Markets estimates that the global weather forecasting services market (public and private) will grow at a CAGR of 7.15% between 2016 and 2021, from $1.10 billion in 2016 to $1.56 billion by 2021[14]. Applying a slightly more conservative growth rate of 5% to current Met Office revenues, we estimate that Met Office revenues will stand at £275m in 2020 and £450m in 2030.

This estimate is broadly in line with market projections provided by Markets and Markets, who estimate that the European share[15] of the global weather forecasting services market will amount to £230m in 2020 and £460m in 2030.

The Markets and Markets research report does not yet consider potential future applications in the realm of localised weather forecasts. If this market segment grows from a current revenue level of 10% of the met Office's revenues to 50% by 2030, it is estimated that private weather companies and providers of integrated applications realise £80m in revenues by 2020 and £225 by 2030. Total revenues are hence estimated at £355m by 2020 and £675m by 2030.

Wider benefits

In addition to the revenue streams discussed above, the application of space technologies in weather forecasting also generates substantial wider benefits to the UK economy. As highlighted in the 2015 Case for Space (London Economics, 2015), the total annual average **benefits from satellite-based meteorological observations** is estimated to be in the range **£600 million to £850 million in the UK[16]**.

13 Met Office Annual Report 2015/16. Available here: http://www.metoffice.gov.uk/media/pdf/n/9/annual_report_web.pdf

14 Markets and Markets (2016). 'Weather Forecasting Services Market by Industry (Renewable Energy, Oil & Gas, Shipping, Media, Agriculture, Insurance, Retail, Aviation), Purpose (Safety, Operational Efficiency), Forecasting Type (Short, Medium, Long) and Region - Global Forecast to 2021. Available here: http://www.marketsandmarkets.com/Market-Reports/weather-forecasting-services-market-218398014.html

15 They estimate that 20% of the global market will be served by European participants.

16 http://www.ukspace.org/wp-content/uploads/2015/07/LE-Case-for-Space-2015-Full-Report.pdf

8. SWOT Analysis

8.1. Space manufacturing and operations

Strengths	Transparent ESA procurement principles Established relationship between ESA and UK space manufacturers Established UK strength in production of micro- and nanosatellites
Weaknesses	Few major gaps in the GOS of great value No current commercial model for meteorological data provision
Opportunities	Cost reductions enable commercialisation of weather satellites
Threats	High market share of National Weather Services and institutionalised data sharing between NWS might limit demand for additional paid-for data

8.2. Space applications and services

Strengths	Established UK strength in weather services Access to data/products by private meteorology firms in line with current Open Data and CEMS strategy
Weaknesses	Possibilities for exploiting data in niche rather than major markets
Opportunities	Development of integrated applications based on fusion of weather and other satellite/terrestrial data Diversification of weather services among several providers thanks to smallsats
Threats	Data charges/restrictions restrict take-up of available data Long lead-times in securing international weather consultancy work

9. Market Enablers

9.1. Space manufacturing and operations

Manufacturing contracts related to the EPS-SG programme and Europe's future satellite missions are guaranteed by the ESA procurement principle of geographical return. Continued funding of relevant ESA programmes by the UK Space Agency is key.

The use of smallsats to obtain new meteorological data relies on an appropriate identification of opportunities by potential customers (National Weather Services, private sector firms). Smallsat manufacturers need to ascertain whether there is a user community able to fund the mission.

9.2. Space applications and services

A key difference between the US and European weather services markets is that in the US data produced by the National Weather Service is available for free, whereas the UK Met Office as well as other large NWS across Europe charge for some of the data they provide or restrict the data. An abolition of data charges and the removal of protection from markets that are currently protected such as civil aviation by the Met Office are key enablers of the UK private weather industry.

10.Market Dynamics

10.1. Space manufacturing and operations

The upstream market is characterised by regional supply chains and a large involvement of government and intergovernmental institutions.

The development and operation of meteorological satellites is coordinated by the WMO. Platforms and instruments are generally sourced in regional markets. In Europe, weather satellites are procured by EUMETSAT and ESA. ESA awards contracts proportional to the funding provided by the national governments and EUMETSAT's (competitive) procurement policy favours European manufacturers.

The market for weather instruments is more fragmented.

The market for smallsats is emergent, but is believed to have strong growth potential.

10.2. Space applications and services

In Europe, the downstream weather services market has historically been dominated by the National Weather Services, so that the private weather market is still relatively nascent. This is in stark contrast to the US market, where it is estimated that about 50% of the weather industry is serviced by private sector companies[1]. The public-sector market for weather services is by default very concentrated, with there being only one National Weather Service in each country. In the private sector in Europe, there have also been some consolidations in recent times, with Nowcasting International (IE) and MeteoMedia (CH) both having been acquired by MeteoGroup (US). Some of the smaller private sector firms moreover did not survive the recent recession and have dropped out.[17]

11.Market Trends

Climate change is likely to result in a higher frequency and severity of extreme weather events. Over the last decade, global economic losses caused by extreme weather events have risen to nearly $200 billion a year, a trend which is expected to continue. **Population growth** and the related increase in number of homes, businesses, infrastructure and other assets, as well as **urbanisation** and the associated move of people to disaster-prone areas (coastal cities) will further increase the costs associated with severe weather. These factors thus result in an increased demand of government agencies, emergency response services as well as private firms and individuals for timely and accurate weather alerts.

11.1. Space manufacturing and operations

The steady **proliferation of micro satellites** is expected to drive market growth and eventually lead to a commercialisation of weather satellites. The U.S. National Oceanic and Atmospheric Administration (NOAA) established the 'Commercial Weather Data Pilot' in 2016 to assess the potential viability 'of commercial weather data in [NOAA's] weather modelling and forecasting'. This is the first time NOAA has contracted to purchase satellite weather data from commercial providers. Contracts have been awarded to Geoponics' ($695,000) and Spire Global ($370,000), both of which will provide GNSS radio occultation data to NOAA by April 30, 2017 to demonstrate data quality and potential value to NOAA's weather forecasts and warnings. Planetoid will launch the first commercial constellation exclusively focused on weather, climate and space weather, with 12 microsatellites on orbit by early 2018.

[17] http://onlinelibrary.wiley.com/doi/10.1002/met.1470/pdf

11.2. Space applications and services

International private weather companies are marketing **tailored weather information products** intensively and have generated considerable demand, which is expected to lead to a growth of the private weather forecasting market and mobile applications. Demand for tailored weather services is further growing because of widespread **negative impacts of climate change on a wide range of economic sectors**, including agriculture, mining, forestry, construction and energy. Factors such as rapid industrialization, growth in transportation (aviation and shipping), and the desire to reduce greenhouse gas emissions and increase the production of renewable energy are further accelerating the growth of the weather forecasting services market.[18]

[18] http://www.prnewswire.com/news-releases/156-billion-weather-forecasting-services-market---industry-forecasting-type--region---global-forecast-to-2021---research-and-markets-300378905.html