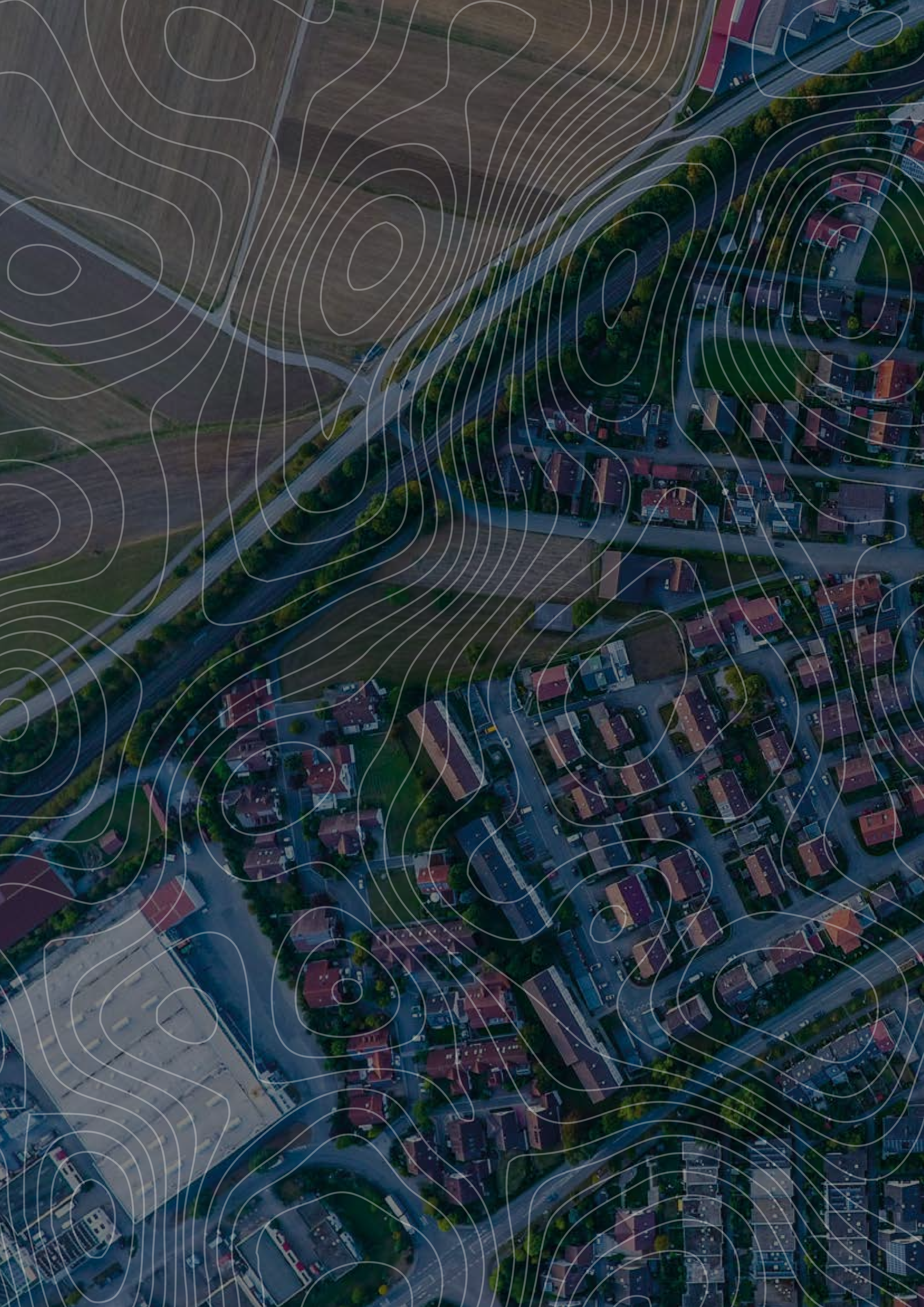
PUBLIC

Geospatial Commission

FUTURE TECHNOLOGIES REVIEW

HOW NEW TECHNOLOGIES WILL SHAPE THE FUTURE OF THE UK'S GEOSPATIAL SECTOR



MANY OF THE EMERGING TECHNOLOGIES THAT HAVE SHAPED ALMOST EVERY OTHER INDUSTRY LOOK SET TO TRANSFORM THE UK'S GEOSPATIAL SECTOR

PUBLIC

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THE UK'S GEOSPATIAL TECHNOLOGY SECTOR IS RECOGNISED AS THE SECOND MOST DEVELOPED IN THE WORLD, ONLY BEHIND THE US

EXECUTIVE SUMMARY

We are living through a period of enormous technological change, and it is evident that there are emerging geospatial technologies which are offering exciting opportunities to help deliver economic growth and increased productivity for the UK. In a world where data, of which geospatial data is a vital element, is central to much of this technological change, these emerging geospatial technologies are becoming increasingly important. Indeed, many have the potential to transform multiple existing sectors of the wider economy.

Recognising this potential, this report was commissioned to seek to identify and provide an account of eight key emerging technologies in the geospatial sector. In addition to analysing the geospatial opportunity, the report also considers the maturity of each technology in the UK and provides numerous case studies and success stories.

This report does not set out to provide an exhaustive account of geospatial technologies, but rather to draw out key technologies being utilised by innovators and startups, and to map their potential future impact across the economy. Moreover, the report seeks to showcase these success stories to outside of the geospatial community - including to readers who have never knowingly engaged with geospatial technologies. As we show, new innovations in this sector have the potential to transform many areas of our lives, and many of our most important industries.

The last few years have seen a significant increase in investment in geospatial technologies, which is set to increase further. Due to their cross-cutting nature, segmenting geospatial technologies and clearly defining their scope is a significant challenge. As such, this report aims to provide a clearer picture by providing a broad segmentation into technology areas.

The UK has a strong history of embracing new geospatial technologies. From the early adoption of laser scanning surveying methodologies in the 1990s to the subsequent implementation of mobile mapping, the UK is at the forefront of the application of 3D scanning and imaging systems for mapping and modelling.

According to the most recent global 'Geospatial Readiness Index', the UK's geospatial technology sector is recognised as the second most developed in the world, only behind the US.[1] The last few years have seen the emergence of a new geospatial startup community in the UK, with

1 GeoBuiz. 2019. Geospatial Industry Outlook and Readiness Index.

A CENTRAL AIM OF THIS REPORT IS TO SHOWCASE THE NEW PRODUCTS AND SERVICES BEING DEVELOPED BY STARTUPS AND ENTREPRENEURS

a number of highly skilled and specialised companies offering technological solutions and services.

Data Analytics and AI startups represent the area of greatest recent growth within the sector. With a significant increase in the number of geospatial data sources available from remote sensors, bottom-up sensors and smart devices, investors are beginning to appreciate the potential value of companies that can translate this data into meaningful use cases.

Our research also identified a growing community of value-add resellers for **3D Scanning** solutions. For example, Nottingham-based GeoSLAM received £5.4m of growth investment to develop its 3D mobile mapping and monitoring technology, before merging with 3DLM in 2018.

There are a number of startup accelerators and incubators which offer geospatial startups the opportunity to develop and seed their solution or technology. Most notably, the Geovation Hub, coordinated by Ordnance Survey, has supported 86 companies from an early stage in their development.

Additionally, SpaceCamp was set up in 2017 by Seraphim Capital, the world's leading dedicated space technology investment fund. The aim of this growth programme is to support early-stage space startups, with a number of geospatial data startups in its early investment portfolio.

A central aim of this report is to showcase the new products and services being developed by startups and entrepreneurs. This is not to downplay the innovations, or the significant investments, taking place in established geospatial centres of excellence in the UK, including in many public authorities and universities. Rather, it seeks to highlight that the UK has developed a highly productive and dynamic geospatial startup market in its own right, and that protecting and promoting it will be central to maximising the value of geospatial data in the future.

The Investment Landscape

The majority of the startups that we assessed had raised Seed funding, with a reasonable cohort of Series A companies, and very few at Series B or beyond. Indeed, across the board, there was a general lack of landmark or late-stage funding. This may reflect the fact that the geospatial startup ecosystem is still relatively emerging, with most companies being founded after 2015. As such, many companies may not yet be at a stage in their development cycle as to require substantial external growth investment.

These trends reflect a broader lack of investment appetite or opportunities for geospatial companies looking to scale. This particular view resonated with the feedback from many of the startups that we engaged with: they stated that they had found early stage investment and business incubation support relatively available, but that scaleup funding had been more difficult to identify.

There are now a number of startup accelerators and incubators which offer geospatial startups the opportunity to develop and seed their solution or technology. Geovation's PropTech incubator, also supports startups in the property industry, many of which are using geospatial data, including LandInsight, Realyse, and Urban Intelligence. These three startups are also funded by Europe's first dedicated PropTech VC – PiLabs – recently established in London and Madrid.

GEOSPATIAL TECHNOLOGY

MATURITY ASSESSMENT

CAMERAS, IMAGING AND SENSING

CURRENT

- Satellite EO Platforms
- Aerial Fixed Wing, Rotary & Drones
- Vehicle Imaging & Laserscanning
- Backpack Imaging
- Multispectral Sensors
- Synthetic Aperture Radar
- Mission Tasking
- 360° Panoramic View
- Semi-automated Data Processing

EMERGING

- SmallSats & CubeSats
- High Altitude Pseudo Satellites & Sensors
- HD Video Streaming
- Environmental Operating Parameters Enhancements
- Power Source Efficiency
- Robotic Processing Automation (RPA)
- Automated Image Blurring
- Simultaneous Localization & Mapping (SLAM)
- Analysis-Ready Data (ARD)

FUTURE

- Intelligent Point Clouds
- Real-time EO
- Persistent EO
- Sensor Miniaturisation

UNMANNED VEHICLE SYSTEMS AND DRONES

CURRENT

- Drones for Mapping & ISR
- Tethered Drones
- Beyond Visual Line of Sight Drones

EMERGING

- RPA
- Counter-Drone & Drone Monitoring Systems

FUTURE

- Swarm Capabilities
- Autonomous Mission Configurations & Management
- Urban Traffic Management
- Delivery Drones
- Passenger Drones

SURVEY, MEASUREMENT AND SCANNING

CURRENT

- Surveying & Laserscanning Equipment

EMERGING

- Backpack & Handheld Laserscanning & Imagery
- Hybrid Precision Measurements & Positioning Systems
- SLAM
- Cooperative Positioning
- Indoor Mapping Application
- Warehouse Logistics Automation Enablement
- Crowdsourcing
- Mobile Phone Data Application

FUTURE

- Ubiquitous Positioning
- Automation & Ambient Intelligence
- Intelligent Point Clouds
- Quantum LiDAR / Quantum Radar

ARTIFICIAL INTELLIGENCE

CURRENT

- Location Intelligence (LI)
- Dashboard Visualisation
- Predictive Analytics

EMERGING

- Data Mining
- Artificial Intelligence
- Machine Learning
- RPA
- Geosocial Networking

FUTURE

- Natural Language Processing
- Deep Learning
- Computer Vision

SMART SENSORS AND INTERNET OF THINGS

CURRENT
- Telemetry Systems
- QR Codes
- Barcode ID
- RFID
- Dashcam
- Event Data Recorders
- Smart Phones

EMERGING
- Smart Meters
- IoT / IoMT
- Intelligent Sensor Networks
- IoT / IoMT analytics

FUTURE
- Smart Dust

IMMERSIVE TECHNOLOGIES

CURRENT
- 3D / 4D Geovisualisation
- 3D Projection Mapping

EMERGING
- Virtual Reality
- Head-mounted Display
- Head-up Display
- Immersive Location-Based Entertainment

FUTURE
- Augmented Reality
- Mixed Reality
- Spatial Augmented Reality (SAR)

SIMULATION

CURRENT
- Computer Assisted Design (CAD)
- 3D Modelling
- BIM Level 0-1
- Environmental Modelling
- Line of Sight Modelling / Zone of Visual Influence

EMERGING
- BIM Level 2
- Thematic Digital Twin
- Environmental Modelling, Simulation & Advanced Warning
- Facility Operating Systems

FUTURE
- BIM Level 3
- Smart City Digital Twin
- Real-time Monitoring
- Urban Operating Systems

CONNECTIVITY

CURRENT
- UK Fibre / Copper WAN & Connections
- 3G Mobile
- 4G Mobile
- UK PSN
- UK Emergency Services Network (ESN) Airwave
- WiFi

EMERGING
- UK Full Fibre WAN & Connections
- UK Public Service Network (PSN) with Cloud Native
- UK Emergency Services Network (ESN) with 4G
- 4G Mobile Expansion
- 5G Mobile
- Global Sat Comms Broadband Coverage
- LiFi / LoRa

FUTURE
- Ubiquitous Connectivity
- 6G Mobile
- Quantum Internet

CAMERAS, IMAGING AND SENSING

DEFINITION

In the context of Earth Observation (EO), Cameras, Imaging and Sensing refers to: the platforms used to collect EO data and the equipment and instruments used to collect, store and process EO data.

MATURITY

We are entering a time of near-persistent observation. The geospatial community has never had so many diverse imaging and data sources at its disposal: with space, airborne, drone, vehicle, and ground-based imaging and sensing, as well as new sophisticated camera networks. These technologies and capabilities are positively impacting our cities and rural communities, our transport and infrastructural projects, along with our safety, security and environment.

GEOSPATIAL OPPORTUNITY

Recent advances in technology in this area have been tremendous. First, we have seen the development and widespread adoption of new platforms for collecting EO data, including **High Altitude Pseudo Satellites** (HAPS), **Small Satellites** and **Drones.** This has resulted in greater coverage across satellite constellations, more accurate targeting, increased capture options (time and place) for customers of EO data and the ability to undertake persistent observation and monitoring. Second, there have been significant improvements in the resolution and accuracy of cameras and sensors, which has unlocked a number of new geospatial use cases.

There are a number of sectors that will benefit from these improved EO capabilities, with improved persistence coverage particularly important to sectors such as security and defence. Improved EO capabilities also allow for greater accuracy, which is crucial for sectors such as infrastructure, asset management and agriculture. Indeed, the UK is particularly well-placed to be a global leader in the applied use of **HD Video** from Space, primarily through the work of startup Earth-I, as well as through HAPS for intelligence surveillance, reconnaissance (ISR) and mapping, manufactured by companies such as Airbus and Astigan.

CASE STUDY
EARTH-I - STREAMING HD VIDEO FROM SPACE

Earth-i is a Surrey-based startup that is building a large constellation of high-resolution satellites, delivering near real-time video and still images from space. This aims to open new opportunities for the development of tools and applications that can leverage value from high-frequency, high-resolution image and video data. In 2020, Earth-i will deploy its own constellation of small, agile EO satellites. This constellation will aim to provide images and high-definition colour video with resolutions that are better than one metre, as well as the ability to accurately film in color video moving targets such as vehicles, vessels and aircraft.[2]

2 Earth-i. 2019. Analytics and Insights.

? EXPLAINER

HIGH ALTITUDE PSEUDO SATELLITE (HAPS)

HAPS are unmanned platforms on an object that rest at an altitude of 20 to 50 km at a specified, nominal, fixed point relative to the Earth. HAPS is the miniaturisation of sensor and communication technologies to these more lightweight platforms with inherent power limitations. As such, HAPS offer significant new opportunities to provide improved EO products and services. Entrants in the global market for HAPS include Airbus, Facebook and Lockheed Martin.

Across every aerial platform, there has been a recent increase in the range of sensing capabilities available, including **Multi-spectral** and **Oblique Imaging**, **Thermal IR** and **LiDAR**. In industries that require highly granular ground level data, such as agriculture and farming, the more accurate and precise imaging which these technologies provide is invaluable.

Additionally, there will be opportunities to provide new sectors services, with the combination of aerial imagery with other map data and land use data. Combining integrated sources with aerial imagery can allow for a deeper and more nuanced understanding of urban environments, enabling highly accurate 3D models. Companies such as Getmapping and Bluesky International have developed products and services that combine multiple datasets with aerial imagery to gain a deeper and more nuanced understanding of a given location. Bluesky recently invested in the Leica City Mapper, the world's first hybrid airborne sensor combining vertical and oblique imagery together with 3D laser scanning, in order to capture major cities throughout the UK

Moving down to ground-level, **Vehicle Sensors** are becoming increasingly common, with a number of different public and private sector organisations undertaking vehicle drive-by imaging and mapping surveys. These projects are being completed for a wide range of applications, including asset management, 3D city modelling, street canyon imaging and utility surveys. In addition, drive-by surveys are used as data sources for global on-line mapping, imaging and navigation platforms. For example, Google StreetView, Apple, HERE and TomTom are all using vehicle sensors for their navigation platforms.

Finally, there are emerging technologies being used for ground-based photography through **Static and Backpack Imaging**. The emergence of backpack-mounted imaging systems and static camera options has been brought about by the requirement to image and texture 3D city models, provide imagery context for indoor spaces and support for floor plan mapping. GoogleTrekker is an example backpack system used by surveyors for the capture of immersive imagery for Streetview.

UNMANNED VEHICLE SYSTEMS AND DRONES

DEFINITION

Unmanned Vehicle Systems (UVS) are vehicles that are either controlled remotely or operate autonomously, by sensing their environment and navigating including without human intervention.

MATURITY

Unmanned Vehicle Systems and Drones are a vibrant and continually evolving part of the geospatial community. They are firmly positioned as important components in the acquisition, processing and production of geospatial data. The growth of new sensor capabilities in these systems will increase their value to the geospatial sector even further.

GEOSPATIAL OPPORTUNITY

Currently, there are three areas of major geospatial interest relating to Drones. First, Drones are being used as an aerial platform for EO and mapping projects, as outlined in the previous section. Second, Drones are being used as delivery systems for the delivery of lightweight packages, postal services and medicines. Finally, and most recently, Drones are being developed to carry and transport passengers within urban areas.

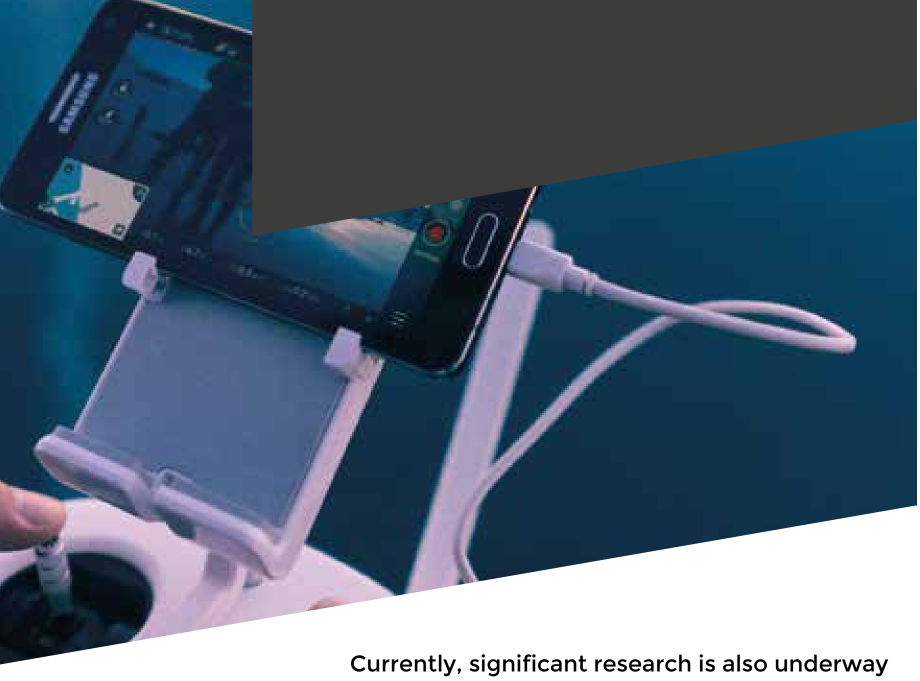
Within the geospatial sector, the application of Drones as a tool for data acquisition is the most mature, with a number of well-established use cases across government and industry. For instance, most police forces in the UK are currently using Drones for sustained monitoring and surveillance, as well as for tracking and identifying actors in first-response situations. With over 40 CAA-approved police Drone operators and five top-of-the-range aircraft funded by the Home Office, Sussex and Surrey Police currently have the largest combined Drone units in the UK.

Drones are also increasingly being used to support the monitoring and inspection of the condition of energy distribution assets and networks across the UK. Indeed, many of these inspections are beginning to leverage **Computer Vision** to recognise images of infrastructural assets, using deep networks and convolutional neural networks to identify different types of faults and anomalies. Since 2018, EY has been running a number of pilots in Paris relating to the use of autonomous Drones to inspect faults in solar panels.

With the increasing use of Drones in urban environments, it is likely for Drones to be used more frequently as part of wider **Urban Traffic Management** (UTM) initiatives. In the USA, the UAS Center for Excellence and Innovation in Texas is currently piloting NASA's UTM system to test whether it can safely and effectively manage drone traffic in an urban area. In the future, the UK may adopt a large-scale pilot of a similar system within a testbed urban environment.

CASE STUDY
GEOCURVE AND REMOTE MONITORED SYSTEMS - UVS IN SURVEYING AND MAPPING

In 2015, Remote Monitored Systems acquired UK startup Geocurve to bolster its surveying capabilities in the engineering and construction sectors. Geocurve is a specialist surveying company that combines traditional survey techniques with innovative technologies including 3D Modelling, LiDAR Scanning and Hydrographic Modelling. This evidences the fact that the use of Drones and related technology is becoming commonplace among the surveying and mapping professions, especially for projects in high-risk or hard-to-reach environments.



EXPLAINER

EMERGING CAPABILITIES IN PASSENGER AND DELIVERY DRONES

The first passenger Drone was introduced at the Consumer Electronics Show in 2016 by Chinese startup Ehang. The company has now raised over £39.3m in growth funding.3 Since then, Dubai has launched a drone-based taxi service and has ambitions to have self-driving vehicles account for a quarter of journeys made by 2030. Delivery Drone capabilities are slightly more mature: Amazon successfully trialled the first drone parcel delivery in the UK in 2016 and further work is underway by National Air Traffic Services (NATS) and others to support the roll out of delivery Drones at scale in the future.

3 Consumer Technology Association. 2016. Consumer Technology Association Awards.

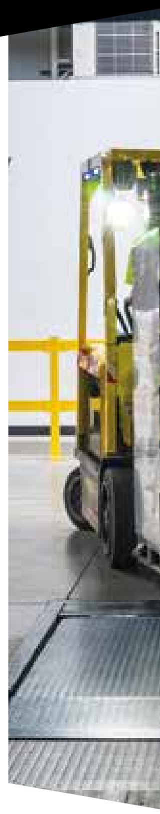
Currently, significant research is also underway to develop future Swarm Capabilities in command and control systems. Drone 'Swarms' are groups of Drones that capable of being programmed to perform a set mission or action: the operator can set a task for the entire swarm, while the individual Drones act autonomously and exchange information between each other. In the future, Drone Swarms will allow operators to programme a specific mission, using a swarm of autonomous Drones to collect multiple data inputs or undertake a blanket search of a geographic area. In addition to use cases in policing and security, Drone Swarms will become increasingly applied to the monitoring of urban infrastructure: to rapidly monitor and assess the progress of construction and development projects.

Over the next ten years, we should expect to see the use of Drones to extend from EO, mapping and monitoring into the domains of parcel and passenger delivery. For the geospatial community, the primary goal will be to provide first and last mile geospatial reference and navigation data to support these systems. In addition to geospatial data, both delivery and passenger systems will require variable levels of geospatial-based control in support of their operations. This includes, as a minimum, systems such as geo-awareness, geofencing and GNSS-based locational requirements. These systems and control requirements will be addressed by the drone manufacturer's themselves as well as by the authorities responsible for monitoring drone activity.

SURVEY, MEASUREMENT AND 3D SCANNING

DEFINITION

Survey, Measurement and 3D Scanning systems provide the foundation upon which the geospatial ecosystem is built. Here, we focus on downstream GNSS chipsets, GIS data capture, 3D scanning hardware, software and value-add services.



MATURITY

The UK has a good geographic spread of survey hardware, software and support companies, including a number of global technology companies (OEMs). These technologies and actors underpin above-ground, underground and indoor positioning systems and are at the heart of a number of the UK's most prominent industries. Further, they are crucial for enabling numerous emerging technologies, such as Internet of Things, Autonomous Vehicles, Building Information Modelling, VR, AR and MR.

GEOSPATIAL OPPORTUNITY

Recent improvements in positioning and scanning technologies will continue to enable a number of new geospatial opportunities. The geospatial community will continue to see the introduction of efficiencies to the existing surveying and measurement processes, which will have a positive impact on cost, time and on-site health and safety. More accurate and precise positioning systems are central for the operation of complex sensors systems at scale, such as IoT systems, where connected devices collect and communicate location intelligence by transmitting signals in real-time.

Geospatial technologies are harnessing multiple **Global Navigation Satellite Systems** (GNSS) sources to support navigation and tracking. In addition to the current feasibility work started by the UK Space Agency in 2018, multiple institutions (such as the Nottingham Geospatial Institute, University College London, and the University of Oxford) are undertaking cutting-edge research into future technologies that might affect position, navigation and time systems. This includes areas such as the acquisition and tracking of GNSS signals, and the applied use of GNSS for intelligent transport systems.

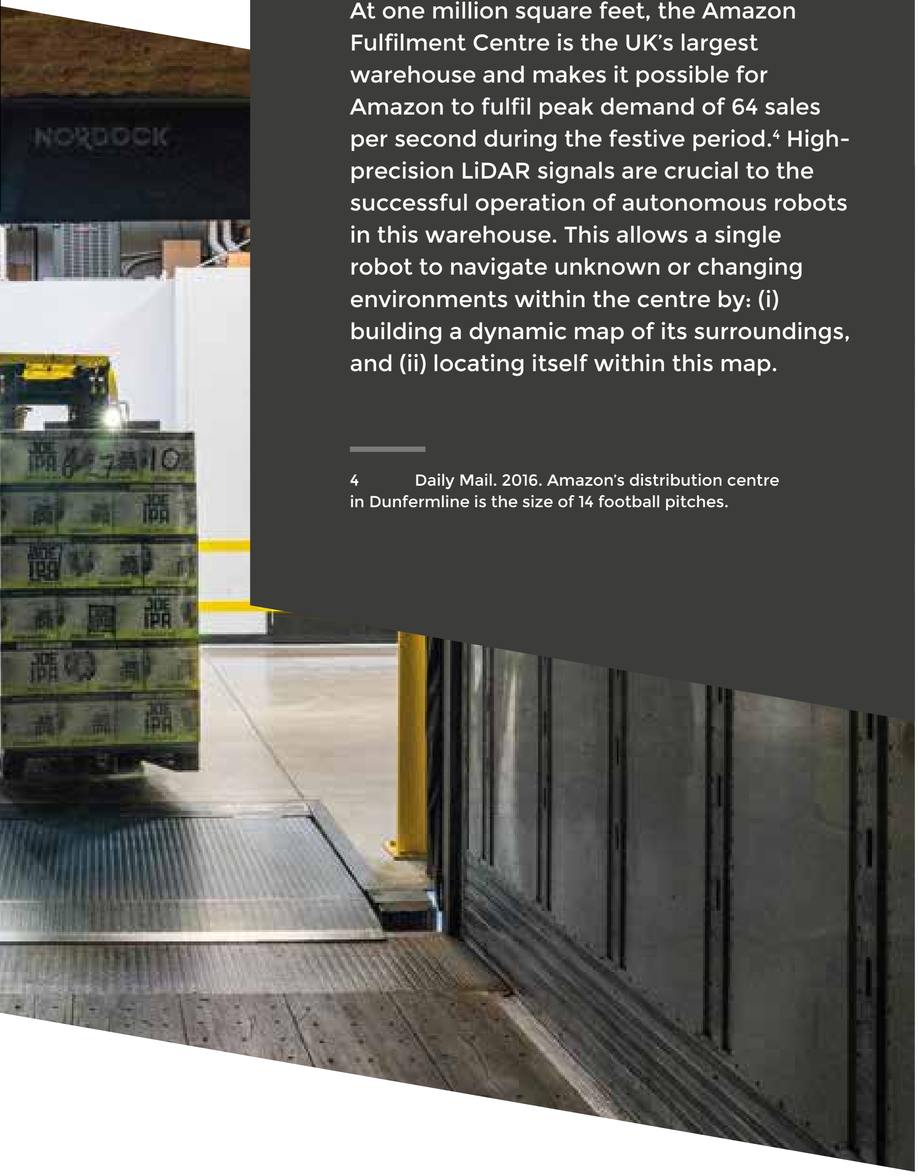
At the ground-level, there are a number of sensors that are becoming more widespread in surveying and measurement. **Telemetry** is the traditional process by which ground-based remote sensors transmit data to stationary data acquisition systems. Advances in ground sensors can enable **Ubiquitous Positioning**, where positioning can extend to indoor and more remote locations. This allows surveying and measurement to be conducted using multiple remote sensors, and is an important enabler of IoT systems and an 'always on' concept of operation, which allows different sensors to communicate continuously.

A number of new geospatial technical capabilities support and enhance a user's location and navigation experience. **Cooperative Positioning** allows for the sharing of key information across clusters of GNSS users,

CASE STUDY
AMAZON FULFILMENT CENTRE – USING SLAM TO NAVIGATE FULFILMENT ROBOTS

At one million square feet, the Amazon Fulfilment Centre is the UK's largest warehouse and makes it possible for Amazon to fulfil peak demand of 64 sales per second during the festive period.[4] High-precision LiDAR signals are crucial to the successful operation of autonomous robots in this warehouse. This allows a single robot to navigate unknown or changing environments within the centre by: (i) building a dynamic map of its surroundings, and (ii) locating itself within this map.

4 Daily Mail. 2016. Amazon's distribution centre in Dunfermline is the size of 14 football pitches.



providing faster computation of positions with higher levels of reliability. **Simultaneous Location and Mapping** (SLAM), enables a user (or autonomous device) to create a dynamic map and to navigate complex environments while using the map that it generates in real-time. SLAM enables the remote creation of GIS data in situations where the environment is too dangerous, or small, for humans to map themselves. In many factories and fulfilment centres, autonomous devices are using this technology to recognise features such as shelving units and the travel paths of other robots.

LiDAR is a well-established geospatial technology that involves using pulses of light to capture and model a feature or an area environment in three dimensions. LiDAR can be applied across multiple sectors and requirements, including mapping an industrial site in granular detail, providing ground model data for flood modelling, and providing the spatial context for developing immersive environments.

Indoor positioning is a particularly significant opportunity for the geospatial community. Due to a litany of issues such as limited accuracy, complex maintenance of indoor sensing platforms, and a lack of data quality assessment tools, this area has struggled to match the levels of innovation and widespread uptake seen in outdoor positioning. However, applications utilising a mixture of bluetooth, WiFi and magnetic positioning can connect to smartphone without requiring any additional infrastructure. Navenio, a spin-out from the University of Oxford, has built a scalable and frictionless indoor positioning solution for a number of customers healthcare, infrastructure and retail.

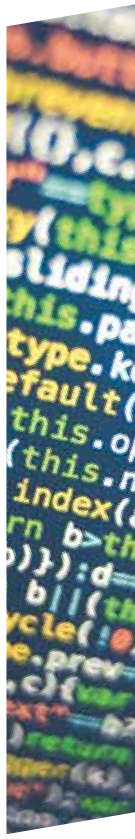
Crowdsourcing or **Volunteered Geographic Information** (VGI) is a further key emerging geospatial technology area. In 2019, Geospatial Commission awarded ten projects to UK companies to investigate how crowdsourcing can best support both the geospatial community need for data capture and updating, while demonstrating the benefits of the same across a number of different sector applications.

Other new techniques such as **Analysis Ready Data** (ARD), where EO data is processed into a useable form in real-time, and **Robotic Process Automation** (RPA) are being leveraged to support automated **Feature Extraction** for thematic and national mapping requirements. For example, an insurer may use this technique to validate the presence of a new extension on the side of property, or a farmer may use it to validate seasonal captured satellite imagery for an agricultural payment claim.

ARTIFICIAL INTELLIGENCE

DEFINITION

Artificial Intelligence refers to systems or programmes that can complete tasks that would normally require human intelligence, such as data analysis, visual perception, speech recognition or decision-making.



MATURITY

Artificial Intelligence (AI) is anticipated to be one of the primary areas of growth in the UK geospatial sector over the coming years. AI will fundamentally change how analysis supports the day-to-day business operations, providing enhanced intelligence opportunities for entities a multitude of sectors.

GEOSPATIAL OPPORTUNITY

To date, AI techniques have largely been used by the geospatial community to analyse **'Structured'** geospatial datasets. These datasets tend to be quantitative, easily grouped and stored in spreadsheets or other kinds of traditional databases. **'Unstructured'** data, on the other hand, can be more qualitative and potentially difficult to store and analyse. Examples include various types of video footage, such as satellite video imagery and CCTV footage, as well as speech and natural language data.

Machine Learning (ML) involves building statistical models based on sample data to make predictions or decisions without being explicitly programmed to perform the task. This has been effectively leveraged by geospatial companies to allow systems to derive insights and make decisions from Structured and Unstructured datasets with minimal human intervention.

Earth Observation (EO) technologies routinely apply image processing and classification techniques to interpret and map landscapes and features of interest. More recently, the industry has been able to apply change detection algorithms to automatically identify areas of change, including the identification of new areas of deforestation, urban development, or to support damage assessment mapping following a disaster event. For instance, Ryelore Ai, is developing **Deep Learning** algorithms capable of detecting patterns in satellite imagery, to support financial institutions to make better investment decisions. There are a number of startups using similar techniques for environmental protection purposes, including Global Surface Intelligence, a startup that has developed an AI system to provide actionable natural resources management information.

Geospatial companies are also utilising these technologies for land management. Urban Intelligence has a built an AI system which aims to provide a 'credit score' for plots of land, based on their suitability for development. A number of service providers in the geospatial community have also moved towards supporting insurance intelligence requirements. In particular, ML is becoming more effective at assigning risk-profiles to certain customer behaviours. Within the car insurance market, for example, patterns of driver behaviour are now being processed and analysed by ML systems with onboard devices, and linked to location to provide tailored analysis.

CASE STUDY
GYANA - DEVELOPING 'GEOSOCIAL NETWORKING'

Innovative solutions companies, such as Gyana in the UK, have harnessed so called **'Geosocial Networking'**. This uses location-based (structured) and social media data (unstructured) and has benefited from the improvement of analytical tools to assist companies or organisations in their predictive capabilities. Gyana works in a number of sectors, including retail, to predict competitive market share, reveal customer behaviour preferences, determine physical catchment areas and analyse marketing ROI. In the future, ML systems will be able to find patterns in human behaviour far faster and more accurately if they continue to develop at their expected rate.

? EXPLAINER
INDOOR POSITIONING SYSTEMS AND LOCATION INTELLIGENCE

Indoor Positioning Systems (IPS) will be an extremely important part of the geospatial sector over the coming years, allowing for the potential ubiquitous positioning of individuals or machines. Pointr has leveraged indoor positioning and AI, using bluetooth sensors which gather information on customer movement in retail spaces and other indoor environments. With this data, Pointr can model footfall and customer movement to help clients to develop targeted marketing and business strategies.

In the field of **Location Intelligence** (LI), GNSS and positioning technologies are being positively affected by AI, affecting industries such as logistics and navigation systems. For instance, through processing millions of GPS points in real-time, systems will be able to forecast changing road and traffic conditions for truckers and hauliers. Geollect is a startup that provides geospatial imagery analysis and overlays this information with other location data feeds to create real-time safety, security and risk assessments for the maritime trade sector.

LiDAR and **Radar** will also require enhanced automated analytical capabilities if future applications such as Connected and Autonomous Vehicles (CAV) are to become a reality. The E-CAVE (Enabling Connected and Autonomous Vehicle Environments) project, led by OS, aims to explore how CAVs can share positioning and safety information in real-time. Further, through this project, OS is also engaged in supporting and collaborating with CAV testing across four CAV test bed projects, announced in 2018. Overall, by combining up-to-date geospatial data with smart car technology, OS is helping to accelerate CAV testing programmes using geospatial technologies and standards, thereby supporting the government's vision for Britain to lead the way in CAV markets globally.

Combining AI with other emerging technologies such as **IoT** will also bring about a number of new opportunities for the sector. The increasing number of sensors within **Smartphones** and other tracking devices require advanced analytics to draw meaning from the information that they transmit. For example, embedded health trackers and wearables increasingly assist health professionals in recognising the signs of illness, aided by advanced diagnostic algorithms. Going forward, analytical systems will potentially be able to map population health metrics across entire communities, the adoption of advanced analytics will only improve such capabilities.

SMART SENSORS AND THE INTERNET OF THINGS

DEFINITION

Smart Sensors and the Internet of Things are the networks of physical objects that contain embedded technology to sense changes in their internal states or in the external environment, and communicate this information with other connected devices.

MATURITY

The Internet of Things (IoT) is being rolled out at scale across multiple sectors, with significant investment being directed towards UK companies delivering IoT services. To realise the true value of IoT, it will be necessary for there to be greater integration between multiple sensors and smart devices, especially in the context of 'Smart Cities' or other large connected ecosystems.

GEOSPATIAL OPPORTUNITY

Perhaps the most highly anticipated use of geospatial technologies and sensors is in the 'Smart City' domain. Smart City applications rely on an integrated IoT network of devices across a set of different services and businesses. CityPulse has been running trial projects in Aarhus, Denmark to deliver a route planning system that is capable of providing drivers with real-time analytics of road conditions. These advances are attempting to tackle issues of congestion, pollution and energy consumption by using location-enabled technologies.

Urban Hawk collates and consolidates data collected from multiple geolocated and timestamped sensors and public sector datasets to monitor the security and resilience of assets in urban areas. Similarly, data-gathering motion sensors offer opportunities for continuous and real-time footfall analysis. These early use cases reflect a general trend of IoT being used to support a more flexible and demand-responsive high street economy.

Further interesting use cases include transport and mobility. It is now becoming increasingly common to see mobile phone sensor data being used to analyse transport activity. In addition to the highly successful startup Citymapper (which has raised c.£40m in growth funding), there are a number of emerging companies using **Crowdsourced** mobile data to provide transport insights to cities and local councils. TravelAI is one such companies, which analyses crowdsourced data to provide cities with data and insights about how its residents use transportation infrastructure. It has worked with cities such as Leeds, Newcastle and Oxford.

In agriculture and farming, IoT solutions using geospatial technologies are seeing significant results. The main aim of IoT in farming is to monitor important environmental factors such as water quality, soil condition, ambient temperature, moisture, irrigation, and fertiliser for improving crop production.[5] Hummingbird Technologies has developed an artificial intelligence that combines imagery and data analytics from Satellites,

5 Bhanumathi and Klaivanan. 2018. Unmanned Aerial Vehicle based Reliable and Energy Efficient Data Collection from Red Alerted Area using Wireless Sensor Networks with IoT.

CASE STUDY
TAMOCO AND GEOSPOCK - BUILDING FUTURE GEOSPATIAL PARTNERSHIPS

Tamoco is a startup that has developed and implemented the world's largest sensor network, aggregating information from a reported one billion sensors in over 180 countries. In 2018, Tamoco partnered with GeoSpock to deliver sensor-enabled geospatial analysis at scale. Tamoco's sensor and beacon datasets feed into Geospock's indexing engine to extract rapid and actionable geospatial insights about cities, communities and other complex environments.

THERE IS AN OPPORTUNITY FOR GEOSPATIAL ANALYSIS USED IN SENSORS FOR MONITORING AND SUPPORTING THE MANAGEMENT OF FUTURE SMART ENERGY GRIDS

Drones and planes with ground sensors to provide farmers with actionable insights on crop health. Sensors have also been used to monitor livestock. Another UK startup, Well Cow, a commercial spin-out from the Roslin Institute's agricultural research wing, uses IoT and **Telemetry Systems** to monitor livestock location and behaviour to improve productivity.

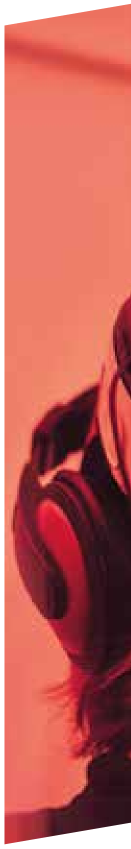
Finally, there is an opportunity for geospatial analysis used in sensors for monitoring and supporting the management of future smart energy grids. These grids are composed of connected devices and sensors (including smart meters and smart appliances) and are capable of detecting changes in local energy usage in real-time. The roll-out of the smart grid relies on highly accurate geospatial information to ensure that demand analysis is accurate and reliable. One geospatial startup, Energeo, is working to support the roll-out of smart grids, utilising geospatial technologies to assist the management of geolocated charging stations for electric cars.

New sensors will continually come to maturity in this field, enabling new capabilities. **Smart Dust** is a new sensor type that offers the potential for blanket monitoring and surveillance of an area. These sensors can be as small as a grain of sand and can remain suspended in an environment like a particle of dust. they can be equipped with GPS in order to provide a locational aspect to their measurements. These sensors are also capable of storing and processing data on the device, and communicating it to cloud or edge computing centres.

IMMERSIVE TECHNOLOGIES

DEFINITION

Immersive technologies emulate physical environments through the creation of a digital space allowing visualisation and interaction with an environment.



MATURITY

The UK is a hotbed for Immersive Technologies, largely spurred on by its global reputation for providing cutting-edge gaming technologies. Within the geospatial community, these technologies are typically used to produce advanced geovisualisation environments and to allow presentation of geospatial data.

GEOSPATIAL OPPORTUNITY

Any level of geospatial detail can be presented within an immersive reality, from a skeleton geometry in **3D**, through to an **Intelligent Point Cloud** which updates as a real-time digital representation of a building. Geospatial acquisition technologies, such as **LiDAR**, provide a greater level of detail and context in the immersive model. Further, they enable true location orientation inside the immersive environment including in three dimensions (x, y, and z). Some **GIS** technologies are also becoming integrated with immersive systems, and we are starting to see the early adoption of these solutions in certain niche sectors.

A significant amount of **Virtual Reality** (VR) and **Augmented Reality** (AR) innovation is taking place in the military domain. In particular, these technologies are being used to improve the training conditions for soldiers in their preparations for conflict. Using wearable mobile devices, AR can transport users into new geographic locations to bring about context-awareness remotely. This is now broadening out to a whole new set of services within the armed forces, with pilots underway (led by NATO, amongst others) to assess whether maintenance engineers can give their expertise from anywhere in the world. However, these are early trials and this technology will take a number of years to reach full maturity.

Trimble is an example of a well-established geospatial technology company that has recently broken into the field of Immersive Technologies. Trimble's solution presents a **Mixed Reality** for site workers, providing precise alignment of visual data from the planning process and the actual physical environment that construction teams are working in. This enables workers to review their models while overlaying them in the context of the real world, leading to significant time and cost savings as well as on site health and safety benefits.

Immersive technologies are also providing new ways to present and communicate important geospatial data. Slanted Theory is a startup from Sheffield offering the opportunity for companies to visualise their operational data. They provide the user with sensory experiences, to tell stories with the data, for example displaying the last 100 years of rainfall in the UK.[6]

While in its relative early stages today, we expect to see more R&D and innovation work in the geospatial enablement of immersive technologies over the next five years. Depending on how mainstream computing presentation technologies evolve, we may see this become a highly important domain area for geospatial exploitation going forward.

6 Tech Nation. 2017. Slanted Theory is building the future of data visualisation tools.

SIMULATION

DEFINITION

Simulation technologies allow a user to model various scenarios within a digital environment. This involves building digital representations, or 'Twins', of a specified geographical area, and manipulating relevant variables to model likely effects.

MATURITY

Maps are traditionally analogue representations of the real-world, sometimes combining multiple representations into one place. Today, maps are increasingly becoming digital representations of a specific time and place, with users able to interact with and manipulate the underlying data. Geospatial simulations are already being widely applied in specific thematic areas such as flooding simulation and road traffic movement. The most significant future opportunities relate to the integration of thematic models at a city-wide, or even national, level.

GEOSPATIAL OPPORTUNITY

3D Modelling is now a commonplace service offered by geospatial companies. We expect that these 3D requirements will continue to grow as the emerging technologies in this area mature, and as user communities begin to increasingly apply 3D systems to support their business operations and decision-making. With advances in **AI** and **ML**, multi-dimensional modelling and simulation will improve maintenance and decision-making processes for organisations. The UK has ongoing programmes involving these techniques for flood-risk modelling and simulation, air pollution modelling and environmental noise mapping. These cases all use detailed ground models from the geospatial community to assign operational data to network geometries such as road traffic and vehicle movements.[7]

GIS technologies also offer a number of benefits for modelling facility management scenarios, including space management, visualisation and planning. **Facility Operating Systems**, which manage large operations such as airports, industrial and power plants will be the main beneficiaries of such developments. Increasingly, Smart Cities will coordinate these systems with smart sensor capabilities which will model and simulate urban planning. Fields such as construction and development are also increasingly adopting continual sensor monitoring and reporting on assets.

The greatest opportunity - and challenge for the sector - lies in scaling these thematic modelling efforts to undertake city-wide scenario simulations. In general, however, for these simulations to be effective, there is a need for greater access to public and private datasets across a city. This kind of service is currently offered by Immense Solutions, a startup that uses a combination of passenger and vehicle data to simulate and visualise different local transport scenarios. In the future, the effectiveness of highly complex and interconnected simulations will depend on the quality of the underlying data, and the ability for local entities to open up and share important datasets.

Digital Twin and Simulation technologies are growing rapidly in the geospatial sector. These technologies have the potential to support multiple future Government innovation initiatives, such as MHCLG's Future High Street Fund, the roll-out of Smart City projects, and initiatives such as TFL's 'Smart Port 2030'.

7 USC. 2018. 4 uses of Geospatial Data.

CONNECTIVITY

DEFINITION

Connectivity technologies refer to the communications infrastructure across which geospatial data is transferred and exchanged.This includes satellite communications, as well as fixed and mobile telecommunications networks.

MATURITY

The UK geospatial landscape is benefitting from greater network optionality and resilience than ever before. There are a number of emerging connectivity networks now available for the transmission of geospatial data, including dedicated public sector and emergency neworks, as well as increased satellite communication constellations and new mobile broadband networks. In particular, higher speeds and lower latency offered by 5G, and in the future 6G, will allow data to be transferred more efficiently, cost-effectively and securely. Further, whilst significantly benefitting as a communications customer and user, the geospatial community and geospatial data also has a key role supporting the planning, roll out and operation of our communications infrastructure.

GEOSPATIAL OPPORTUNITY

In addition to the ongoing investments to achieve full fibre wide and local area networks, going forward, the single largest game-changer in geospatial connectivity is likely to be **5G**. 5G technologies use existing and high-frequency spectrum, enabling rapid data transfer speeds, making it easier to download and upload on mobile devices. Where 5G networks are deployed, they will build on and add to the foundation created by previous mobile generations (as part of a wider ecosystem of mobile connectivity). In the longer term (anticipated by 2030), some form of **6G** technology will emerge and be commercialised. Notable research currently underway in 6G is taking place at the University of Oulu (Finland) in cooperation with Nokia, as well as a number of universities in the UK.

In addition to these improvements in mobile broadband networks, there have been dramatic advances in the network capacity of satellites over the past decade. Going forward, small and miniaturised satellite constellations - such as those operated by OneWeb - will present new global network and communications opportunities. Two further important connectivity assets in the UK are the cross-governmental **Public Service Network** (PSN) and **Emergency Services Network** (ESN), which will support communications between front-line officers and bluelight services.

? EXPLAINER

LATENCY AND SPEED

Latency: the time a signal takes to travel between an internet connection and the nearest (or designated) internet server - the time delay before the transfer of data begins.

Speed: how fast digital information travels through an internet connection.

CASE STUDY
ONEWEB - NEW SATELLITE CONSTELLATION OPPORTUNITIES

In March 2019, British company OneWeb announced investment of £1.1b to allow the company to accelerate the development of the first global communications network by 2021. In 2019, OneWeb will begin monthly launches of more than 30 satellites at a time, creating an initial constellation of 650 satellite to enable full global coverage, followed by additional satellites to meet growing demand.

? EXPLAINER
EDGE COMPUTING

Improved local connectivity will also allow geospatial actors to develop new **Edge Computing** strategies. Edge Computing relies on local networks of micro data centers close to the sensor or scanner, and is particularly important for delivering lower-cost data processing and storage for IoT systems.

These emerging high-capacity, fast, and low latency communications channels will enable geospatial data to be transferred at volume, at speed and securely. Considering all UK network investments collectively, we should anticipate that our motorways and main rail routes will have enhanced connectivity by 2025 along with our major towns and cities, in accordance with the published 5G network plans of primary network operators.

Improved network capacity and data speeds will allow the expansion of the use real-time image and video streaming, including **HD** and **Ultra-HD Video**. Currently, it is very difficult to stream HD Video and images from aerial cameras, due to the sheer volume of data required in video streaming. One clear use case for improving network capacity in public spaces is for persistent monitoring and surveillance using video and image streaming for specialised policing and security services. Better connectivity will also allow more geospatial actors to leverage the scalability and computing power offered by cloud computing. Improved connectivity to the cloud will allow data to be stored and processed in cloud centres in real-time, allowing constant connection between field, office and cloud.

The reduced latency of 5G technology will be crucial to the future adoption of Autonomous Vehicles and Drones. This is because Autonomous Vehicles require extremely fast networks with no delay or lag to operate without fault. This reduced latency will also better support the effective streaming of real-time imaging data on the move, as well as continuous sensor availability to support spatial analysis at scale in real-time. Constant and secure connectivity will also be crucial for Drones and other unmanned vehicles when performing missions covering large land areas, including surveying, mapping and the monitoring of energy grids.

The greater level of network optionality for geospatial data also provides increased resilience. There are a number of emerging connectivity networks now available for the transmission of geospatial data. In particular, improvements in **Satellite Communications** are enabling high-volume geospatial data to be transmitted across these networks, which could previously only handle low volume audio data such as voice. This optionality guarantees greater network resilience because companies transmitting geospatial data can switch across multiple networks in the event of a network fault. As such, a geospatial company transmitting data over Mobile Broadband networks can switch to Satellite Communications in case of a temporary fault in the local or national mobile networks.

To support the significant investments and operation of our communication infrastructure, telecommunications and utility companies require a wide range mapping, survey and geospatial analysis services. These not only represent significant future opportunities for the geospatial community, but they also demonstrate how the geospatial community can both benefit from and enable the development of key emerging technologies in the UK.

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