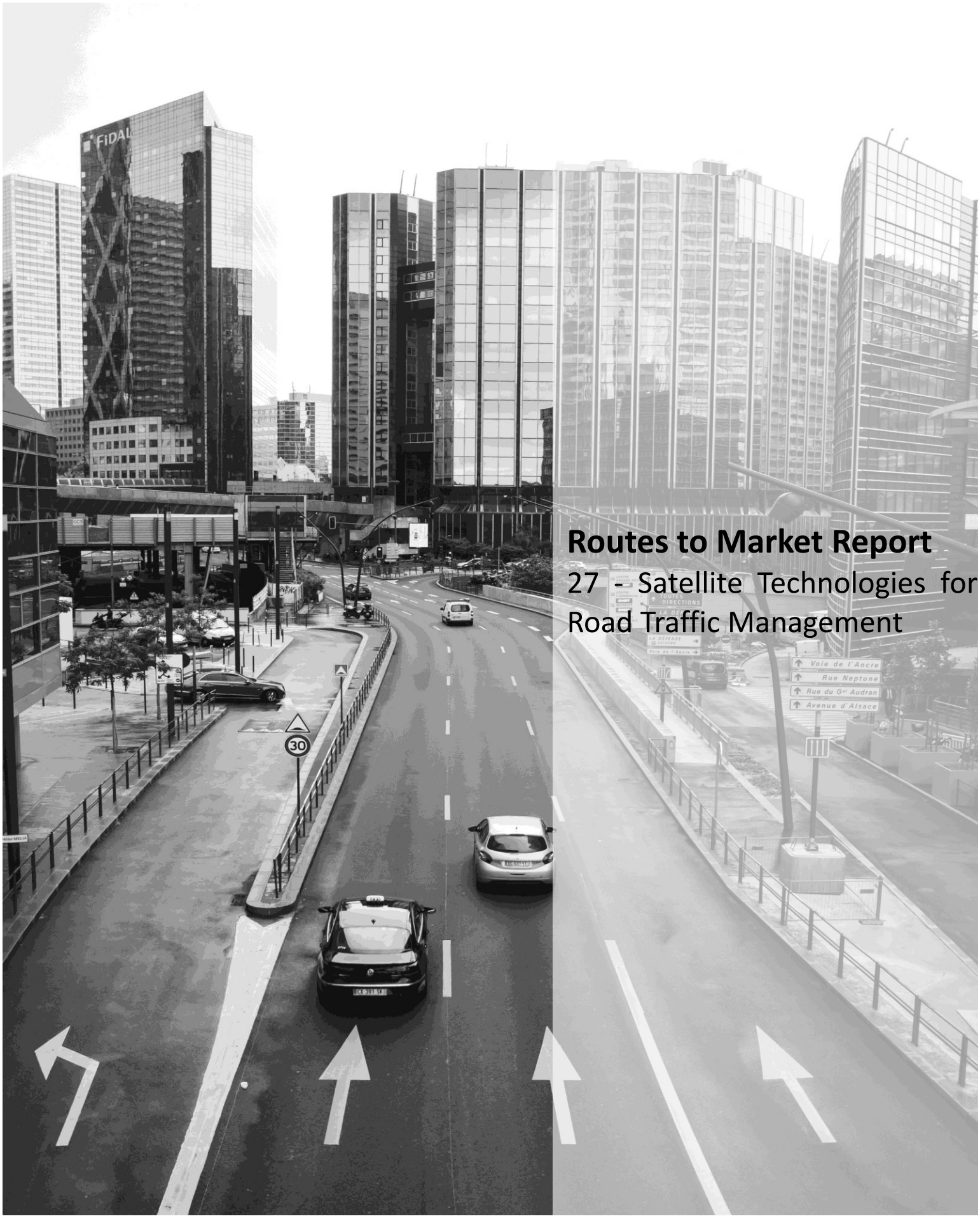

Routes to Market Report

27 - Satellite Technologies for Road Traffic Management

Innovate UK

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Contents

Executive Summary

This report examines the challenges faced by road operators and maintainers, policy makers and emergency services across the globe, focussing on the roads rather than vehicles that use them. It filtered these challenges to those where satellite applications have potential to offer partial or full solutions in terms of remote sensing, communications or navigation.

It shows two potentially large and expanding global markets where remote sensing could be applied, for additional emissions monitoring for cities and detecting changes in assets such as road structures, road surfaces and junction layouts. The scope of the addressable market by satellite applications is not yet clear, but the global market sizes are such that even a small niche would be valuable to UK industry. Both solutions would need to be delivered to clients "as a service" – i.e. as feeds of events and information rather than raw data.

An application is wide scale monitoring of networks to identify areas of change that other technologies can then investigate fully, e.g. to support highly automated vehicles. Both these are global problems but where the UK is at the spearhead of needs for solutions, due to our ageing infrastructure, reduced public funds and congested networks. The key here will be to show the conservative roads industry of the capability and cost saving of the solutions and be able to integrate with existing asset management and emissions monitoring systems.

In navigation, apart from the need for vehicle centric solutions discussed elsewhere, there soon will be increasing demand for road charging solutions worldwide using GNSS, especially for trucks. This is an established technology in Europe so the opportunity lies in integrating GNSS charging with other in vehicle devices and services, making better and cheaper devices and adding back office intelligence for example to detect fraud. It is likely that the current market model for a dedicated on-board unit (OBU) just for road charging and tolling will reduce, with more value from integrated solutions with fleet management and tachograph, and wide use of smartphones. This market is proven, and ripe for rapid innovation by UK companies for short term export markets.

In communications, there is limited scope market in UK and Europe for satcoms to roadside equipment, as much of the communications infrastructure is in place or provided cheaply. Only in remote areas without communications might there be a market, which tend to have smaller demand for traffic devices. The market here lies in countries like India and Russia with little existing infrastructure. To access this, industry needs to partner with roadside system providers to give turnkey solutions.

For the emergency services, there is a potential market for both speech and data communications but the services are highly risk averse and demand end to end solutions- currently there is interest but a lack of solid solutions. Opening this market will require strong engagement with the customer base.
There are many other areas of challenge we considered but where for reasons such as maturity of current infrastructure, cost, or capability there is no clear market potential for satellite solutions.

In summary, the key actions for industry will be to demonstrate capability in asset management and emissions over and above current systems, or more cheaply, and engage with the risk averse roads industry clients, and to integrate and innovate GNSS road charging solutions with other services.
The products, actions, customers and values are shown below.

Product	Customers	Actions to develop market	Comment
Emissions monitoring	Government, Global cities and towns	Understand extent to which Sat apps can measure emissions is key	There is a large enough market here that even a small inroad could be worth £100m by 2020
Asset management	Roads operators, towns, cities,	Engage with asset management industry to understand data capability and integration opportunities	Again, a small slice in a large market could be worth £300m by 2020
GNSS for charging	Roads concessionaires, fleet operators, OEMS, users	Integrate GNSS charging with other services, offer light vehicle solutions, engage with UK government re HGV charging, offer back office added value	This is the current market growing fastest as new schemes rollout and as older schemes refresh. US market likely to develop fast. Could be worth £850m by 2020 and still grow
Communications for roadside systems	Road operators	Link to ITS system developers to offer turnkey solutions	Small but niche market worth £100-£150m globally by 2020.
Emergency services communications	Emergency services	Resilient and secure link to entire command and control chain. Show business case	Small market worth £10- £20m

1. Introduction and Scope

General space technologies covered

1. Earth Observation.
2. Global Navigation Satellite System (e.g. GPS) and
3. Satellite Communications

The report takes a global view, as whilst the UK and Europe have some mature markets, other parts of the world are now adopting new technologies, and as traffic management is already a UK export.

Scope of Traffic Management

This report focuses on products and services that are associated with the operation and management of road networks and activities associated with their control, planning and charging, as well as policing and security.

We have not looked in depth at the market for automotive applications for individual road users (e.g. satnav for vehicles, GNSS in highly automated driving, ...) except where this is driven by a traffic management policy (charging, dangerous goods monitoring etc.) or where this might be integrated with traffic management (e.g. road charging and pay as you go insurance are the same technology, with different financial flows

The briefing covers 2017 to 2020 (near term) and then to 2030 (longer term)

We include as an appendix a brief review of other areas considered where there is little market opportunity to avoid any further wasted exploration.

2. Market Overview and Opportunities

Traffic management" is not a single market. It has a variety of different problems owned and solved by different customers. So, in this brief we have focussed on three key customer areas:

- Towns' and cities' road authorities
- Inter urban Road operators (Concessionaires, Agencies and central Government)
- Emergency and enforcement services associated with roads

Looking at their challenges, we have focussed on the following key problems where we see potential.

2.1. Emissions – the big issue

In the UK and Europe, the most pressing challenge for traffic managers today is to meet air quality limits in cities and urban areas set by EU law. This also applies globally, with different political drivers e.g. in China. There are many emissions studies but all suggest more people per year in cities like London will suffer early deaths through vehicle related pollution than from vehicle accidents.
The UK failed to address breaches for nitrogen dioxide (NO2) in 16 areas that include London, Birmingham, Leeds, Southampton and Glasgow. Germany, France and Italy are being served warnings alongside ongoing infringement cases for other countries. Even post Brexit, this is a public policy problem for the UK, the fines offer an immediacy of need for action. And it's getting worse – removing diesels will take time and electric vehicles are not catching on as predicted.

The issue is to manage exposure to pollutants at a localised, urban level not a wider area as we currently do. Typically, air quality issues are localised around schools, hospitals, industrial areas. Measures are already being taken such as introducing Low Emission Zones (LEZ). But a key issue is the accuracy required to measure pollution locally (at child head height) and determine the impact of our mitigation actions. So currently, we use roadside pollution monitoring devices that monitor CO, NO, NO2 along with noise, temperature, and humidity. There are known problems with these that lead to inaccurate measurements and they need regular costly maintenance, such as sensor and battery replacement.

Hence any new form of surveillance that can add to knowledge of current problems, and measure changes in emissions due to actions like vehicle bans, would find a large immediate market especially for fusion with other sources. The problem is so large that even a small improvement is valuable to consider.

Local authorities increasingly do not want to buy infrastructure, so providing emissions data "as a service" would be welcome. A key area might be a "go look here" alert to identify from a large city or regional spatial area of emissions change where more detailed roadside measurements are needed.

This approach applies to many themes for customers in transport – "tell me where to look in detail as I can't look everywhere at once with the resources I have".

Local authorities worldwide have little money for new services and have issues with maintenance of existing equipment. They also lack skills and resources to process data. So, any "as a service" offering that saves time and money will be of interest, although local authorities in the UK struggle with revenue funding.

Any solution that helps understand, control and monitor emissions would attract interest currently. This is a political drive with a financial cost to cities, and will not get better quickly.

2.2. Asset surveillance and monitoring

Road operators have large and remote assets to maintain day to day. Knowing of a small problem that is growing that can be fixed will prevent a larger one. Examples include potholes, slippage of cuttings, settlement of structures, bridge scour in floods and blocked gullies. Animal tracks across roads for example cause hazards, or need to be included in new road design.

This need increasingly applies with the impact of global warming meaning wetter winters, so more land slips / mud slides and flood damage. Monitoring remotely in real time loss of infrastructure would be useful, but even more would be alerts that for example a remote road cutting has slipped. This might be in an area with no communications links. Detecting land movement would be a key here to a) saving lives and b) responding to mitigate damage.

Again, the theme of "somethings changed since our last look at this– go look here" applies and providing this as a service of alerts to a road operator would be attractive. There are quality systems for asset management such as the ISO-55000 family and products and services to help manage delivery, such as software called "agile assets" and many other approaches. However, these are often based on time based "protocols" – i.e. "examine this asset every 3 months", not condition based "this asset is deteriorating". **The lack of data for this second approach is the gap to fill here**.

There will also be a market for self-driving vehicles for such areas as car park space counting (to gain historic data on use patterns and layout for navigation). Even today, car park surveys are an expensive cost for a local authority and are an immediate market.

A key aspect of this is autonomous vehicles and keeping their maps updated. Autonomous and connected vehicles even with a low level of autonomy will require millimetre accuracy maps, to navigate vehicles through junctions and avoid obstacles. Such mapping also allows providing new services, such as GLOSA, where signal settings are sent to a vehicle.

Whilst vehicle makers and map providers such as the company Here can already survey junctions using vehicle based LIDAR sensors, and vehicles themselves can in the future provide updates, the real issue is during early penetration of the vehicles. Early adopters will expect good quality mapping but for local authorities and map makers keeping up with the daily evolution – planned and unplanned – of roads will be a challenge. Damage to kerbs, missing signs and changes in roadside structures could fool autonomous vehicles and give poor service at the exact time where high performance is needed to encourage adoption.

Building on the above, a service to locate changes in the road layout and road hinterland and alert to the need for a more detailed survey would be interesting. Roads authorities have little resource to keep up with such changes let alone survey them. Detecting artefacts like unlicensed roadworks and skips would also be needed for high quality parking.

There may also be communications opportunities in remote areas for broadcasting updated maps (e.g. US Freeways mirroring satellite radio) and software updates for vehicles. This is beyond the scope of this report.

The vehicle industry has an expectation that the cities or cellular providers will give them the connectivity they need – there may be satellite alternatives that have the robust and secure nature needed. However, where connectivity is most useful is in towns and cities where other forms of communication are likely to be available.

2.3. Roadside communications – more for less, and new places

Communications to traffic management devices is well developed and is largely based on internet or mobile communication systems and, in developed countries, has a highly competitive marketplace of service providers. Some small niches of remote communications e.g. Highlands of Scotland remain a challenge. But in developing countries this level of infrastructure doesn't exist, except in major cities, so remote areas are a potential market. The industry is slowly moving from analogue to digital communications so this also potentially offers an opportunity.

A good example is India. Intelligent Transport Systems on a National Highway between two large towns were planned to improve safety on a new road. Site visits quickly highlighted the lack of communications infrastructure with just 3G mobile communications available which is not ideal. This is just one small example where ambition outstrips the practical realities of delivering traffic management and ITS based solutions in remote areas of developing countries.

These developing countries are using ITS to expand road capacity and safety where they cannot afford physical roads. And often these roads are tolled – needing communications and enforcement. Hence there is a potential market for relatively low bandwidth but highly robust communications from remote roadsides, for cameras, tolling equipment and future roadside beacons.

2.4. Navigation/positioning for road charging

Truck charging based on GNSS is now almost ubiquitous across Europe and increasing globally. Only the UK and Ireland are yet to try to adopt this (France's system is installed but failed for political reasons) and the UK is about to come out to consultation for its HGV levy replacement. GNSS tolling no longer requires a dedicated-on board unit as was the case for the Tollcollect service in Germany in 2005 but can use commercial fleet management systems and even smartphones as in Hungary). Germany is hoping to roll charging to all vehicles soon, not just trucks. Hence the market for low cost accurate devices is growing. Germany may adopt all vehicle charging by GNSS soon, as may many US states.

This means a market also for skills and services that can support the electronics in better map matching, TTFF reduction, urban canyon fixes (although these are less of an issue that expected) and denial of service. Detection of fraud from GNSS signals is an evolving market too – detecting patterns of vehicle use that suggest inoperative GNSS/ antennae covering. So, back office software for analysis is the main area here though, to lever off capabilities of devices already in place (see OBD2 below).

GNSS is also used for fleet management, tachograph and hazardous goods tacking. Hence the markets for fleet and mobile asset management devices is now saturated for above 3.5 tonne vehicles, but there are opportunities for in vehicle devices for smaller commercial vehicles and cars. These tend to use an OBD2 "dongle" that includes GPS and communications as well as a connection to the vehicle canbus.

These devices are already used for:

- Insurance and driver monitoring
- Smart parking (to pay only for the time spent parking)
- Remote driver monitoring (a duty of care corporate responsibility)
- Asset management (e.g. plumber's vans – to find one near the customer)
- Road charging (in Oregon an OBD2 dongle replaces the typical on board unit)

The market here is in better, cheaper dongles (with potential to add DSRC communications to allow retro fitment of connected vehicles technology to older cars) and in big data to analyse the GNSS and other data (e.g. for road asset management such as potholes). Having a GNSS unit (and other radio devices) in the foot well of a vehicle is a challenge of course.

Politicians have often spoke of the key to road charging as being able to "piggyback" of other technologies. Hence the market for navigation devices might be increased by road charging requirements for light vehicles, and by single on board devices that offer for example an electronic tachograph and truck charging.

Integration and innovation for this proven and expanding market is the key opportunity here.

2.5. Roads emergency management and surveillance

The use of satellite services and products for Emergency Services globally has some potential. As above, this is where there is a requirement for service provision, locations are remote/ there is little existing infrastructure, or mobile service not relying on conventional infrastructure. There are clear areas of technical advantage for moving towards satellite solutions.

These include:

- Communications to vehicles and personnel. These may be single workers widely spaced

- Secure and reliable data feeds for example for remote enforcement units for tolling and speed cameras, able to send imagery in real time to a central location
- Navigation and fleet management as above

Currently the development and provision of satellite services for the emergency services is following a path often dictated by industry itself rather than the user. Services that will use technology broadly fall into three categories.

- Technology rich organisations, but poor in terms of the number of personnel available to deploy.
- Technology poor, but rich in the levels of manpower that are available for deployment.
- Formerly technology rich countries, now losing ground technologically, (Older systems), poor in terms of the number of personnel available (Reduced head count due to cost cutting).

Whichever a service falls into, solutions to all emergency services globally, with several caveats.

- High resilience of service provision, which should include redundancy.
- Security of the service, resistant to Jamming and Spoofing.
- Low cost provision, and continuance of service.
- Ability to integrate with legacy systems especially command and control system.
- Ability to link with existing and developing sensors.

The emergency services are conservative in their approach to technology, so there must be a clear demonstrable benefit in the use of satellite provision. So far, this report has seen evidence of market activity generated by the industry, but no meaningful engagement by the emergency services, which reinforces the conservative nature of the emergency services.

If there are to be a significant uplift in the use of GNSS capabilities by the emergency services globally, then the business case must be made by the industry.

2.6. Summary of Opportunities

From the above there is a wide range of problems in traffic management to solve, but essentially far fewer products where satellite applications could potentially help.

1. New Emissions monitoring offers for developed cities
2. A service to monitor wide areas of road network for changes in assets that other services and products may then investigate in more detail, or to look for trends
3. Low cost communications for roadside devices especially in rural and underdeveloped areas
4. Cheaper and more reliable GNSS devices for tolling/ charging and fleet management, and services to process the data received from them
5. Secure and reliable communications for emergency services

3. Customer and value proposition to the customer and end user

There are different customers for the traffic management products, as summarized below:

Customer	Might buy which products?	Global market	Appetite for innovation	Comments

National government (e.g. US DoT), Bulgaria, Kazakhstan	All products and services above, although typically procured via agencies	<50	Low to Medium	Wants risk free solutions at minimum cost. Often devolves procurement to agencies
Mega city e.g. Paris, Sao Paulo	Emissions, asset monitoring, cheaper GNSS, secure communications for emergency services and compliance	<50	Can be high	Much variation in appetite depends on political lead
City road authority e.g. Birmingham	Emissions, asset monitoring, cheaper GNSS, secure communications for emergency services	>1000	Medium	Often places where first adopters can gain advantages
Inter urban road authority E.g. Traffic England	Asset monitoring, low cost communications, secure communications for compliance	<100	Low to medium	Traditionally cautious due to roads not IT based skills.
Rural/ County road authority e.g. Kent County Council,	Asset monitoring, low cost communications	>10000	Low	Likely to be cash and resource poor
Emergency and enforcement services E.g. Police, GoSafe in Ireland	Secure emergency communications	>100	Low	Needs secure and reliable communications above all. Often conservative
Road concessionaire/ tolling operator e.g. Autostrade	Asset management, low cost communications, GNSS for tolling	<100	High	Wants to minimise costs whole life
Fleet Operators	Cheaper GNSS devices	>100000	Medium to high	Wants to save money and show compliance with law
Vehicle makers esp. HGV	Cheaper GNSS devices	<20	medium	May combine GNSS tolling with other applications

Product	Benefit

• New Emissions monitoring offers for developed cities and towns	Reduced costs of monitoring emissions vs fixed infrastructure across wider areas. Ability to measure impacts of mitigation measures more quickly, leading to reduced healthcare costs. Ability to combine with other forms of point data
• A service to monitor wide areas of road network for changes in assets to then investigate in more detail, or to look for trends for condition based monitoring	Ability to detect change and measure impacts, leading to earlier interventions that may save time and money. Automated feeds into asset management systems Reduced manpower and infrastructure costs of asset surveys and monitoring. Ability to cover whole networks rather than piecemeal data. Reduced survey costs for regular surveys Support for mapping for highly automated vehicles
• Low cost communications for roadside devices especially in rural and underdeveloped areas	Enabling benefits from further technologies for road safety and congestion, road charging / tolling and traffic control without the expense of dedicated communications networks or reliability issues of cellular data. This enabling step is important – communications technology on its own has no benefit unless part of another system supplied by others Ability to lever off "internet of things" approaches and support future connected vehicle systems Ability to secure revenue – e.g. from tolling or enforcement devices.
• Cheaper and more reliable GNSS devices for tolling/ charging from fleet management, and services to process the data received from them	Less cost of installation of on board units and more accurate data means schemes have less resistance to deployment (e.g. as freight vehicles do not have to be taken off the road to install units. Cost of road charging schemes reduces giving better net revenue (e.g. to counter fuel tax reductions) More data use allows better fleet planning, smart parking payment, pay as you go insurance and driver training/ monitoring. However, these tend to be private customers not traffic managers and are best seen as an automotive led market. Save costs but help protect corporate legal responsibilities e.g. tachograph with integrated devices.
• Secure and reliable communications for emergency services	Wider and more secure coverage. Ability to receive roadside data in real time for "joined up" activities, e.g. enforcement. Reliable communications when loads on networks are highest. Ability to undertake remote surveillance Communications in rural areas where time is critical in emergencies response.

4. Market Competition

Product	Alternatives
1. New Emissions monitoring offers for developed cities	Fixed roadside and people borne emissions sensors. Data from vehicles tailpipes and in vehicle sensors. Data from traffic models and weather models. New IOT approaches for sensors. **Customer would buy satellite if** gave cost or coverage advantage as an additional data source. Also, if it could bring greater insight into meteorological and other aspects of emissions
2. A service to monitor wide areas of road network for changes in assets that other services and products may then investigate in more detail, or to look for trends. This also maps to emergency services customers for people and asset security monitoring	Vehicle borne sensors from connected vehicles or specialist devices e.g. LIDAR. Cameras, OBD2 dongles. All the above require reasonable levels of penetration and hence regular asset surveys • Regular video surveys (e.g. cameras on dustcarts) • Fibre in road sensing (Optasense) • Limited drone use • Smart IOT sensors **Customer would buy satellite if** it gave cost or coverage advantage as a new data source (they will not replace sunk investment in sensors) and could be integrated into existing asset management systems and processes
3. Low cost communications for roadside devices especially in rural and underdeveloped areas	Cellular / microwave communications / wireless mesh/ fibre. All of them require additional infrastructure and power and maintenance. Often cities have more than adequate bandwidth for traffic systems e.g. signals. **Customer would buy satellite if** it is lower whole life cost or can be deployed more quickly for the same bandwidth, or if additional bandwidth required cannot be provided cost effectively, and if integration is easy
4. Cheaper and more reliable GNSS devices for tolling/ charging and fleet management, and services to process the data received from them	**No real competition,** so market is for replacement or expansion of equipped fleets, and for analysis of data from existing units to gain further value. Almost all vehicles in Europe and US>10T already fitted. Key market opportunity for lower weight vehicles for new charging schemes Customers will choose GNSS over beacon or ANPR technology if wide area charging needed and different time/ distance/place charging policies are needed (typically this is the case for trucks as it makes more revenue) Customer will buy more or replace existing kit if: • Costs are reduced for the same service • New services are added.g.V2V or V2I communications

	• New tolling/ charging schemes require additional equipment in vehicles • New legislation requires fitment
5. Secure and reliable communications for emergency services.	Microwave and digital trunk radio Emergency Service Network **Customer will buy satellite only** if it is lower whole life cost or can be deployed more quickly for the same bandwidth, or if additional bandwidth required. And if can be integrated into existing systems end to end

5. Role of UK Companies

UK companies could play the following roles:

5.1. Remote Sensing:

- Provide remote sensing "services" for emissions and asset monitoring, focussing on both wide area "something has changed, go look here" and point based "this asset is moving" detection. Emphasis is on end to end service provision – to sell the same service to many different customers in different areas. Companies should not simply not provide data feeds or imagery – the value add is in interpretation, building intelligence and alerting road operators as well as fusion with other sources. The end users would be asset managers and their software systems so understanding integration with these systems, or working with suppliers, maybe a route to market (e.g. work with asset management system providers to integrate satellite based monitoring data with other feeds, to offer competitive advantage and new services)
- Work with infrastructure designers to build in remote sensing to the design stage for critical infrastructure especially in remote areas
- Work with asset management service suppliers to integrate (see below)
- Work with roads authorities and CAV map makers to offer a "this network has changed here" alert function for road networks for use in the early stages of automated vehicles
- Show pilots and demonstrations to the conservative traffic industry new capabilities.

5.2. GNSS

- Offer even better performing, more fraud and denial resilient and lower cost GNSS devices, especially integrating DSRC v2V and V2I communication and ability to access OBD2 data to accelerate the uptake of connected vehicles and road charging. Combine several applications in one on-board unit with GNSS e.g. tachograph, or in an OBD2 device
- Offer IP and analysis to make the most of existing data from GNSS devices in services – e.g. fraud detection, avoiding denial of service, fleet management added value, Big data approaches
- Potential ability to combine GNSS location with sat communications for areas with little cell coverage, although for most systems buffering will cover this
- Piggyback charging with other retrofittable devices (e.g. pay as you go insurance)

5.3. Communications

- Work with Europe wide traffic systems providers to offer new ways to deploy ITS systems in remote rural areas. Traffic customers tend to let turnkey systems contracts and large system vendors are a key route to market. Emphasis needs to be on low whole life costs. Ability to use minimal power would assist adoption as there is little point in having isolated communications equipment needing significant power supply infrastructure

Work with emergency services' command and control providers (which are often global), fleet managers. The UK is still regarded as one of leading lights in the advancement of emergency response and management across all four emergency services, in a commercial context. However, emergency services are slow to embrace technologies until resilience is proven. Our investigations show that most land-based emergency services were issued with Satcom for voice traffic at the turn of the millennium for resilience. In the main, these devices have remained in their boxes. However, technology has moved on and now offers real advantages within difficult to reach areas, though this should be balanced against the new UK emergency service network launched from 2018.

6. Revenue projections

For emissions, asset management and rural communications, the proportion for satellite depends on the capability of the technology to support customer needs. Charging and emergency services communications are in contrast direct estimates for satcoms/ navigation only as the capability here is clear

Opportunity	2016	2017	2020	2030	Proportion for satellite services	2020 global value
Emissions/ Air Quality	UK = £3.7m EU = £10m Int = £1Bn	10% 7% 10%	7% 7% 15%	7% 7% 15%	Unknown, but likely to be <10%	£100m?
Asset services	UK = £20m EU = £350m Int = £1.4Bn	5% 5% 5%	5% 5% 5%	5% 5% 5%	Unknown, but could be 20%	£300m?
Charging and tolling GNSS devices	UK = 0 EU = £70m Int = £100m	0% 10% 20%	to £15m 50% Growth to £850m	- - 20%	All	£850m for units only
Rural Communications	UK = £0.5m EU = €10m Int = £100m	5% 10% 10%	5% 7% 15%	- 7% 15%	All	£120m
Emergency services communications	UK = £1m EU = £5m Int = £10m	5% 10% 10%	10% 15% 15%	10% 15% 15%	All	£10-20m

For **emissions, this** was based on the level of public sector investment currently attributed to resolving air quality issues in cities and regions relating to road transport. This also considers the medium to long term funding required for consecutive years and is based on data currently published by the public sector. We cannot assess the proportion of spend that would be for remote sensing but given the need for roadside data we have assessed a maximum of 10%

For **rural communications,** this was based on identifying the likely demand, or need, to communicate with ITS devices located on strategic roads that current communications systems (e.g. dedicated radio, GSM/GPRS, WIFI etc.) struggle to reach with coverage. For the UK market, due to the geographic size and current communications deployment, this is a low-level requirement but may be of value in some of the remote areas in Scotland or Wales.

For the European market, this is a much wider opportunity where the geographic size is much bigger and spans several countries where cross boundary services could be seamlessly delivered from the Nordic countries through to mainland Europe.

The International market builds further, and significantly, on this approach where many countries (e.g. Africa, India, China etc.) have strategic roads crossing the country where ITS deployment would be highly desirable (e.g. safety reasons) but cannot be delivered due to lack of reliable services.

The scaling was based on lengths of strategic roads and likelihood of need for satcoms (e.g. rural nature of roads)

For Asset management, this was based on looking at the total costs of UK road assets, the spend on maintenance and typical asset management systems, and the potential for improvement in costs using additional data to give a suitable cost: benefit ratio. The value was checked against various industry sources. This was then extrapolated by road length for Europe and a global market of developed countries such as the US and Russia with older infrastructure. Newer economies e.g. UAE, Brazil and China have newer assets and so less need for asset management.

Again, we cannot readily assess the proportion of the market that remote sensing might achieve but it is likely to be higher than for emissions, so have conservatively used 20%.

For **charging and navigation,** the value was based on units installed in the vehicle numbers in known and likely HGV and all vehicle tolling and charging schemes, and various datasets from the GSM Association for turnover of equipment, as well as discussions with global tolling providers. The profile of future schemes was developed using IBTTA and other tolling industry data as well as our industry knowledge – for example we include the UK as DfT is about to come out to consultation on HGV charging technology to replace the HGV "paper" levy. The Catapult should be well placed to help move to a GNSS solution as for other countries and enable the UK market. Germany is also looking to charge all vehicles, not just trucks, on a miles-travelled basis. All these are likely to happen around 2020-2025 in the EU, after which all vehicles will be equipped. Costs were based on current OBU costs for tolling. We also made an allowance for US HGV truck charging and other US vehicle charging schemes which may occur in the longer term.

For the **emergency services**, this was based on the number of emergency services numerically in the UK[1], coupled with investigations from British-APCO as the communications body for the UK emergency services. Interviews with both Commerce, IT and Communications leaders for emergency services, Senior Officers in the respective services. In the interviews, again it was stressed the conservative nature of adopting new technologies, and the need to work with the relevant services to develop systems and services that truly serve the emergency service needs, not the commercial requirements of industry.

Sanity check:
To sense check the above estimates of value we have looked at the projected growth for the satellite industry as a whole.

The 2015 Satellite industry revenue was $208.3 billion showing an overall industry growth of 3% worldwide. Satellite services is the largest market segment where revenues grew by 4%. Source: Satellite Industry Association

In 2012, the European Earth Observation (EO) downstream market was estimated at €0.7 Bn. According to a study published by Euroconsult the EO downstream market was forecast to reach €1Bn in Europe and over €2Bn globally; growing at a Compound Annual Growth Rate of 7%

Source: Copernicus GIO/Space-tec Partners

The above shows potential markets of £400m for remote sensing worldwide, £850m for GNSS and £100-£120m for satcoms. Hence the remote sensing opportunity might offer significant but not disruptive growth, while GNSS would be an effective doubling of the current market. Communications is a small but niche area that may be easy to exploit with off the shelf equipment.

Hence overall the above estimates match overall growth expectations, except for GNSS for truck charging where there is rapid political change.

This analysis work is detailed in an Annexes 1-5.

7. SWOT Analysis

7.1. Earth Observation (Optical, Radar and other remote sensing if relevant)

Strengths	Numbers of constellations and functionality increasing, increased availability and coverage areas. Can cover very large areas with one sensor. No need for data collection from sensors on ground (and associated manpower or communications) Could be provided "as a service"
Weaknesses	Weaknesses of the solution are really a lack of understanding by the road transport sector of the capabilities. For example, it is perceived by transport market are that some services seen as expensive. Subject to weather e.g. will it work in clouds? Is resolution good enough? How often is a single site resurveyed? Are the communications too expensive? A ground based infrastructure solution is well understood and perceived to be "risk free" in comparison to a satellite solution,
Opportunities	The need to be able to survey large areas to see if something is detected where in the past personnel were used. Satellite now becomes a cost-effective option. **Transport**: The monitoring of emissions is a governmental priority for both local and central administrations. Observation of the road network to detect degradation of embankments, verges. Deformation of the road pavement itself detected by changes in the path taken by vehicles **Public authorities:** are moving away from investing in infrastructure, their needs could be provided by satellite technology as services. **Emergency Services**: The ability to be able to monitor extensive areas, or a highly defined geographic area for either activity in or moving into or out of an area. The significant and continued reductions in emergency service personnel make the adoption of earth observation attractive where this option now becomes an attractive possibility. As an example, traffickers bringing cargo to a country, possible points of entry are known, they are could be multiple, and often remote for effective traditional surveillance, unless a many people are deployed. Earth observation could provide this facility linked with other sensors to provide an encompassing response.
Threats	That the provision of Earth observational services is seen to be the remit of either military or highly secure and/or high value assets, this perception needs to be changed. That satellite services are perceived as too high a technology risk. That IOT devices, drones, etc. may offer lower cost ground based solutions That remote sensing data cannot be integrated with existing approaches and data sets

7.2. Position Navigation Timing (e.g. GPS, Galileo etc.)

Strengths	Numbers of constellations increasing, increased availability. Satellite is still the go to solution for outdoor positioning, increased constellations and new systems will increase availability and drive cost down. New chipsets improving the service reducing cost and improving time to first fix and urban canyons. Ability to not rely on a single system, and Galileo offers new capabilities e.g. enhanced accuracy.
Weaknesses	GPS still seen as the primary navigation medium, system maintenance and upgrade paid for by the US Military and, this is a perceived weakness to be addressed in that the "political situation could have a direct bearing on GPS". Some systems are susceptible to interference or denial, which limit or degrade the applicability. Map fit accuracy e.g. in urban canyons still sometimes a problem, although TTFF is less so now, but GNSS unlikely on its own to be accurate enough for self-driving vehicle navigation. Need to install antennae and power for multiple GNSS devices – can be addressed
Opportunities	Technology development will have a direct impact on how these systems and services develop. New technologies are improving the user experience. **Emergency Services:** The Internet of Things and Internet of Public Safety Thing will pervade society, and impact on how the emergency service will gain alerting data to an emergency. Key to this is the provision of accurate location information. This will be linked to additional data from other sensors. Link this to the ability to use Satcom for transmission of data, and this provides a potential package for GNSS linked sensors to communicate in areas where traditionally this had been impossible. **Road Traffic:** The combination of GPS and other technologies and communication mediums offers new possibilities for integrating road user charging, emergency caller location, smart tachograph, personal emergency call. Smart phone technologies are transforming how GNSS is regarded. Autonomous vehicles are a whole new opportunity for the provision of highly accurate and current mapping. High dependency requirements (eCall, Tachograph, fleet management) have higher requirements. Charging for kilometres travelled is now widespread for trucks**. The key is integration for new and older vehicles** **Public Authorities:** Linking satellite communication with GNSS offers can monitor assets that previously needed physical survey at set time intervals
Threats	The need to understand the criminal mentality, for example if there is a financial advantage from either carrying out or not carrying out an action (e.g. GNSS denial). Will there be a criminal driver to disrupt/alter Satellite activity? Spoofing Jamming and Meaconing. Systems are still power hungry. Weak performance in the urban environment, and physical limits imposed on unit size, due to antenna size. Other navigation devised for automated vehicles may provide solutions to the above.

7.3. Satellite Communications (e.g. narrow band – IoT or Broadband - 5G etc.)

Strengths	Highly flexible system can be established to provide a service to users quickly. It can provide communication where no other system can operate. Requires little or no infrastructure. Niche applications Satcom can provide a communication capability where no other system can, when linked to IoT devices (eCall). Can provide the "Infill" Technology with other communication services
Weaknesses	Satcom is not a ubiquitous communication solution, it must be linked to another downstream "client". So, for Satcom to fully integrate into the emergency services command and control infrastructure, there will be a need to explore system integration needs to link Satcom with existing Command and Control Systems, or there will be little market demand for a stand-alone system Perceived significant capital costs to establish the service and maintain it (Space and Satellite element).
Opportunities	The continued development of Internet of Things (IoT) and Internet of Public Safety things (IoPST) will offer significant commercial opportunities generally, especially in areas where the unique capabilities of Satcom have been demonstrated. **Emergency Services**: Require reliable communication or transmission of data where there is limited existing communications. This is coupled with the need to be able to integrate across services in joint operations. The possibilities offered by Satcom are a real opportunity, coupled with the forthcoming change to the UK Emergency Service Network (ESN). As this is based on conventional mobile communication, this offers possibilities to switch between ESN and Satcom. The provision and transmission of data as a service. Emergency service have an ongoing requirement for secure and remote communications across a variety of services, with a high degree of resilience and flexibility. **Traffic management:** The introduction of the connected car assumes that connectivity for data and voice will be provided by cellular providers. Satcom could provide a robust and secure alternative, where there are significant gaps in cellular provision. Roadside communication is currently built around cellular communication however there are significant areas where there is no cellular signal, due to either local topographic conditions or remoteness precludes installation of communication infrastructure.
Threats	Satellite is still regarded as a high cost option, with highly specialised uses. Until this perception is removed any future expansion of the market will be limited. Conservative user communities that need to see clear financial benefit for the early adoption of satellite based services.

8. Opportunities/Blockers/Enablers

These markets (and customers for potential products, except for road charging) are:

- Largely unaware of the opportunities from satellite
- Conservative and risk averse
- Have specific requirements for performance, and for interfacing with existing systems.

This means a need to engage and educate as follows:

Engagement with user communities in the public sector.

- Local Government Association, Association of District Councils, Association of Metropolitan Authorities (UK)
- European cities and regions cooperating for innovative transport (POLIS)
- European Road Transport Telematics Implementation Co-ordination (ERTICO)
- Public Safety Communications Europe (PSCE)
- Council of European Municipalities and Regions (CCRE)
- World Road Association (PIARC)

Representative bodies from industry

- Society of Motor Manufacturers and Traders (SMMT)
- Institution of Engineering and Technology (IET)
- European Automobile Manufacturers Association (ACEA) and motorcycle Industry (ACEM)
- International Road Transport Union (IRU)
- European Committee for Standardization (CEN) and Telecommunications Standards (ETSI)
- European Association of Operators of Toll Road Infrastructures (ASECAP)
- Transport technology forum and ITS-UK
- International Bridge, Turnpike and Toll Road Association (IBTTA)

Representative bodies from the emergency services in UK and elsewhere

- National Police Improvement Agency (NPIA), replaced by the College of Policing (2013)
- National Police Chiefs Council (NPCC)
- Chief Fire Officers Association (CFOA)
- Association of Ambulance Chief Executives (AACE)
- Traffic Information Systems Police (TISPOL)
- Interpol and EUROPOL
- European Emergency Number Association (EENA)
- Federation of European Fire Officers

Key actions with these stakeholders are:

- Dispel the myths re satellite applications being “rocket science” to people without knowledge of the industry
- Showcase use of satellite applications in their problem areas, with case studies of cost savings and functions already made
- Understand the “pain points” e.g. procurement of innovation
- Understand how their procurement works (e.g. in the UK transport technology is purchased via several Government Frameworks, which do not yet allow for example for satellite communications.

Building from the above, some specific examples of actions to help accelerate growth are:

- Technical development – outdoor positioning demonstrations for connected vehicles, asset management as a service
- Business Model evidence – lower cost sat communications compared to infrastructure for roads – a case study
- Funding sources – CCAV and Innovate UK, ESA, some venture capital especially that associated with connected vehicle
- Skills – inform academia of shortages, also to find traffic people interested in working in sat apps to bridge the divide

- Manufacturing and R&D – ensure ITS supply chain considers sat Apps as a solution

Realisation of market growth/potential and realisation needs work by:

a) the public sector, and
b) the private sector

The public-sector work is developing National, European and International functional requirements in resolving their problems and issues such as:

- Communications: need to determine where satellite communications can replace existing communications systems by thinking at functional and performance terms and not specifying the technology
- Data collection and management: thinking of new data sources from Sat applications and how these can be used with others
- Remote sensing: helping roads asset managers move from time based surveying to asset condition based management. This is starting but it both a mindset change and a need for change in protocols and guidance
- Asset tracking/management: As above, moving from a mindset of "daily/ weekly/annual check" to a more event and condition based approach
- Road charging capability: For too long, road charging by GNSS has been seen by the public as too technologically demanding/complex or costly. Recent Eastern European trends in charging schemes show this is no longer the case. The time is ripe to influence decision makers that GNSS offers more policy choices at less cost than other solutions, as for example has been achieved in Belgium, Hungary, Bulgaria, Germany and increasingly the US.
- Finance: why they should migrate existing capital and revenue funding into new technology. What happens to old technology "sunk" cost? Again, case studies that show the potential value for money are a key area here (see the IET's Guide to Emerging Technologies for Local Authorities as an example)

Any public-sector organization is risk averse, so key to realisation of the market is to help them to see the business case for change from the status quo. This is what makes this offer better/cheaper/more reliable than what is already in place? So, is this just driven by cost alone and what other factors are in play? There is a clear role here for the Catapult.

Also, there is a need here to consider data protection and privacy issues for the public sector and the level of "intelligent client" needed to develop to procure and manage new technology and services. Again, the Catapult can help advise here.

An additional problem for the public sector is that they cannot keep pace with technology change a key issue is to determine just when do they invest at a reasonable risk level? The Catapult, working with other bodies like the Transport Technology Forum is well placed to advise on this.
Some Government funding will be needed to pump prime use of satellite technology in the UK by the public sector and help local and regional Government to de-risk their involvement.

Away from the UK, we can expect similar public sector funding to explore the use of satellite technology and typically this is an area where EU funding will be applied through programmes such as H2020.

The private sector face similar problems but on a different scale in terms of understanding:

- How to win their risk averse customers over to satellite solutions even if they offer better value for money than their existing products
- How to integrate and interface satellite solutions into existing systems and services.
- The impact on R&D and product development programmes of newly emerging services
- The demand for satcoms in the UK and internationally vs tried and tested communications - is there sufficient volume to justify investment
- Applications that this technology will impact on in terms of:
    - ITS and traffic management
    - Asset management
    - Data management
    - Communications for emergency services

There is a role for the Catapult to play here in bringing satellite applications and traffic industry suppliers together, to compare products and undertake gap analysis, and to inform UK government on policy choices.

9. Market Trends

Connected and autonomous vehicles could provide a new dimension to traffic management along with dealing with existing problems i.e. emissions, asset surveillance, communications etc. But the public sector is risk averse and needs to utilise as much of its existing legacy systems as possible and provides the key marketplace.

They have pressures increasing in terms of transport investment and the need to meet performance measures, accessibility, productivity and environmental requirements. The public-sector market dynamic is output driven against whole life cost, so there is attraction in lower cost services for communications for example and for asset management.

Hence the market overall is likely to grow for transport management applications per se. The question is the extent to which satellite applications can capture the share:

Product	Growth and sustainability
• New Emissions monitoring offers for developed cities	The global air quality monitoring market has seen steady growth in recent years owing to the increasing level of air pollution across the globe. Therefore, the outdoor air quality monitoring market should be growing at a fast rate due to rapid urbanisation and industrialisation in emerging economies, such as India. China and India should be the prominent markets in the Asia Pacific region due to increasing air pollution issues in these countries and in response we should expect market leaders delivering satellite sensing services to launch innovative solutions to increase their global outreach. This is likely to grow quickly in the next few years as more and more pressure is put on emissions policies and interventions. The drivers for growth will be the ability to more cheaply and accurately monitor and predict emissions. If a satellite application can do this “as a service” the market would be highly sustainable

• A service to monitor wide areas of road network for changes in assets to then investigate in more detail, or to look for trends for condition based monitoring	As infrastructure ages, globally, asset management will become an even larger business – to squeeze the last value from decaying infrastructure and reduce costs of replacement. The key drivers will be reduced public spend, reduced fuel tax revenue or maintenance and infrastructure threats caused by global warming (e.g. slope stability, floods). If a satellite application can do this "as a service" the market would be highly sustainable However, in the longer term the asset management market will peak as older infrastructure is replaced or becomes stable, and as roads infrastructure becomes smarter
• Low cost communications for roadside especially in rural / underdeveloped areas	There is no sustainable UK market for this but instead likely to be a short window of large opportunity to provide satcoms for new ITS deployments before widespread 5G type communications expand into rural areas. As bandwidth rolls out the market will reduce, although there will still be some need. Hence this is a small market that will peak in the next 5 years for equipment and services in the UK but grow elsewhere as new roads in other countries need communications.
• Cheaper and more reliable GNSS devices for tolling/ charging from fleet management, and services to process the data received from them	The next 5 years will be key as new schemes come on line (German all vehicle, some US states on the West Coast), Possibly UK, France and others all requiring on board devices. The drivers for this are need for revenue from roads and to charge for the damage caused, and the falling likely fuel tax revenue (see above). After that the demand will be for new fit to new vehicles, and for replacement of older on board units from old schemes (e.g. Toll Collect has 1 million OBUs nearly 10 years old in Germany) The opportunity is to piggyback other services e.g. fleet management as dedicated OBUs are not a sustainable business for tolling/ charging only long term, and as light vehicle charging may focus on smartphones
• Secure and reliable communications for emergency services	This is likely to be a small but steady/ growing market as countries in the BRIC area and other developing countries require communications, as enforcement rolls out globally and due to the need for more security surveillance. Drivers will be the state of global crime and terrorism, rollout of cellular communications and other devices, and added value from satcoms. The market for services is likely to be sustainable

Looking in more detail:

9.1. Emissions

There is a need for caution. The DEFRA Report "Investigating the Feasibility of Innovative Technologies to Improve Air Quality Monitoring over the Medium to Long Term" October 2015 summarised that satellite sensors appear unlikely to replace the UK's AQM monitoring network over the next 10-15 years. The conclusion was their temporal and special resolution are not expected to match current monitoring networks and that they cannot yet meet the data quality of EU Air Quality Directives. The report also anticipated technical hurdles and that these sensors are expensive in comparison to current technology.

However, satellite based sensors did offer potential advantages such as:

- estimating pollutant concentrations across large areas against fixed point monitors
- identifying regional sources of air pollution affecting local air quality and,
- providing simultaneous and continuous measurement of multiple pollutants

These advantages can be exploited and suggest that satellite borne sensors can be used, over the next 10-15 years, to supplement not replace air quality monitoring networks on a regional or national basis. Outside of air quality monitoring, the report also concluded that satellite borne sensors could provide an important contribution to validation of national emissions inventories.

9.2. Satellite Communications

For the UK market, due to the geographic size and current communications deployment, this is a low-level requirement but may be of use in remote areas, such as Scotland or Wales. F or the European market, there is a much wider opportunity where the required geographic coverage is much wider and spans many countries. Satellite communications could be a potential enabler for services that could be delivered from the Nordic countries through to mainland Europe.

The International Market builds significantly on this approach where many countries (e.g. Africa, India, China etc.) have strategic roads crossing the country where ITS deployment would be desirable (e.g. for safety reasons alone) but cannot be delivered due to lack of reliable services. The market place can be summarised as follows:

- North America: Highly developed road network and communications infrastructure based on fibre communications and high degree of toll roads. Introducing satellite based communications will be challenging but Interstate highways may be a suitable target zone.

- Australia: Cities will have existing infrastructure but, as with USA, rural road network could be a target zone for communications and asset management services

- China: Highly developed road and communications infrastructure. Potentially very difficult to break into the market place and fierce competition from Chinese companies

- India: One of the largest road networks in the world that carries high volumes of freight and passenger traffic. High Government spend annually to improve network that has significant safety and environmental problems.

- South Africa: Limited infrastructure largely deployed within cities such as Johannesburg so potentially this is a suitable target market for satellite communications and EO services

Drivers in the supply chain are important in traffic management. Traditionally traffic management has been, and still is, highly regulated market. For the public sector this provides stability, lower risk and value for money. This approach has resulted in a more open albeit quite a specialised market that prevents supplier lock in scenarios and bespoke systems.

The public-sector preference remains with a highly-regulated market but is shifting from buying, and operating, systems to procuring managed services. Added to this is a growing demand for data to be used more effectively on open data platforms for wider use. The demands to migrate to “smart cities” are driving the wider use of data internally.

The key market trends are associated with:

- Emissions monitoring as above

- Asset monitoring and Infrastructure management
- Communications – alternatives to broadband
- Mobility pricing as discussed above
- Connected ITS (C-ITS)
- Connected Autonomous Vehicles (CAV)
- GNSS for charging, tachograph and hazardous goods

The market here is already proven – the expansion will be in replacing older units or adding new on board units to support new charging schemes. However, the need for a dedicated on-board unit is now passed, with emphasis on:

- Use of data from smartphones and other existing low cost devices
- Lower cost integrated devices, especially using the OBD2 port
- Added value services such as pay as you go insurance

So, a key growth area will be integration and "piggybacking" of services.

There is a virtuous circle here, in that the more services that one "unit" can provide, the easier it is for politicians to decide to charge trucks especially (and in the future all vehicles) as the better the "sell" to the users will be. In Hungary and Bulgaria, truck charging has been possible as it uses existing services like fleet management to avoid mandating installation as was required in Germany. Adding pay as you go insurance and road charging for all vehicle schemes would be an obvious way to "sweeten the bitter pill" politically.

9.3. Emergency Services

The emergency service industry is trying to demonstrate that there is an appetite for new markets, systems and services. But for true engagement with the services themselves, these must be shown to be resilient, secure and capable of integration with existing systems and services. This is in line with global public service requirements to demonstrate value for money. In respect of Satellite services this has not been the case so far, and so significant work with the services will be required. The current climate of reduction in the level of emergency services, increased demand for services, and the drive to do more with less could therefore then offer opportunity to the industry.

An example of this is the deployment of eCall in Europe. Whilst this is a conventional communication medium (2G and 3G, migrating to 4G), there is a significant opportunity to develop an eCall which will use sat comm. This is a UK derived enhancement, which has not been replicated in potential markets like Russia so far even allowing for the (GLONASS system). There are major areas of the world who would have a demand for this type of IoT device that has no reliance on fixed communication infrastructure.

In line with the other automotive devices, we have not considered the market for this as it may well be combined with other services.

10.Conclusion

The above report shows for traffic management a variety of potential markets for remote sensing and communications, subject to capability and price, as well as an expansion of GNSS use in road charging as this is more widely adopted.

The summary of these overall business is as shown below:

Product	Customers	Actions to develop market	Comment
Emissions monitoring	Government, Global cities and towns	Understand extent to which Sat apps can measure emissions is key	There is a large enough market here that even a small inroad could be worth £100m by 2020
Asset management	Roads operators, towns, cities,	Engage with asset management industry to understand data capability and integration opportunities	Again, a small slice in a large market could be worth £300m by 2020
GNSS for charging	Roads concessionaires, fleet operators, OEMS, users	Integrate GNSS charging with other services, offer light vehicle solutions, engage with UK government re HGV charging, offer back office added value	This is the current market growing fastest as new schemes rollout and as older schemes refresh. US market likely to develop fast. Could be worth £850m by 2020 and still grow
Communications for roadside systems	Road operators	Link to ITS system developers to offer turnkey solutions	Small but niche market worth £100-£150m globally by 2020.
Emergency services communications	Emergency services	Link to entire command and control chain. Show business case	Small market worth £10- £20m

The key to exploiting the first two markets is for the satellite industry to match its remote sensing capabilities to emerging policy needs in emissions and asset management. The market for communications relies on links to suppliers for both the ITS and emergency services industry, while the GNSS market is ripe for exploiting as road charging continues to rollout, at all levels from in vehicle devices and their components to adding value to GNSS data.

11.Appendices

11.1. Appendix 1: Calculating the Market for emissions

UK – 153 LHAs of which 100+ LHAs utilise UTMC systems and services.
Air Quality Grant Programme 2016-2017 £3.7m (18 LHAs or LHA consortiums funded)
Previous years Grant allocations 2013/14 £1m; 2015/16 £0.5m
Can assume similar grant programme for 2017/18 onwards as AQM issues intensify

Europe
LIFE Environment programme
Projects have been funded since 1992

298 projects funded totalling €628m to which EU has contributed €217m

EU Copernicus Programme: existing service with a dedicated set of satellites (the Sentinel families) and contributing missions supporting six thematic service streams that includes Climate (C3S). Current tenders and Grants planned for 2017 include Climate Change Monitoring Service (C3S) for essential climate variable products derived from observations. Estimated costs €8.24m to €10.3m. Copernicus programme budget is €583,567,000 maximum and financed from chapter 02 06 of the General Budget of the EU for 2016.

Copernicus market study assessment of the potential market value for Earth observation and Copernicus downstream services and the potential resultant impact on employment was undertaken in 2012 and sought to project the future markets for downstream services over a long-term horizon of 2015 to 2030.

11.2. Appendix 2: Market for asset management

The 18.5% growth of traffic on UK road networks over the last 20 years has made a substantial demand on ageing and deteriorating infrastructure. With a value of £344bn, our road network is the backbone of UK's economy but the gap between road asset management costs and available resources is growing, estimated at ca. £2.4bn p.a., in addition to a backlog of £12bn.

Highways England (2015) reported that "approximately 40% of highway structures were built before 1980, and there is a risk that the number of structures in need of intervention may increase more quickly that we can make interventions".

Across Europe, the road network consists of more than 3.11M miles with 41,450 miles motorways valued at over £7,000bn (EU Road Federation, 2014). The cost of maintenance has risen from ca. £20k per mile 2001, to £40k in 2014 (EU Road Federation, 2014).

In the UK, the total expenditure on road asset maintenance is ca. £5-6bn (DfT, 2017; HE, 2015), i.e. £20k per mile, versus the minimum of £7.4bn, demonstrating a substantial resource gap, in addition to the £12bn pothole backlog (LocalGov.uk, 2016).

In July 2016, Highways England reported a drop in its network condition Key Performance Indicator to 92.3%, below the RIS target of 95% (ORR, 2017).

The gain from smart infrastructure management has been estimated at between 5 and 15% (CIPFA, 2012; Lloyd, 2009; UK Road Liaison Group, 2013).

If we take the total £6BN UK spend on asset maintenance works and take a typical 1% of that for management, this means a UK asset management cost of £60m. From the above if we spend an additional £60m this could reduce costs by £300 to £1500m.

Of this we assume 1/3rd of the spend would be on new data, making a UK value of £20m. Factoring for road length for mature infrastructure developed EU Countries (France, Germany, Italy etc.) gives a £350m EU market, and adding India, China, US and Canada makes £1.4bn

We can assume modest early growth globally but then a plateau as early cost savings are no longer achieved and as the infrastructure backlog is addressed

11.3. Appendix 3: Market for HGV tolling

The UK market is currently zero, but if GNSS HGV tolling was deployed 300,000 trucks would need devices. As many will have fleet management devices we assume only £50 per truck for additional functionality based on UK DfT TDP study data and costs in recent schemes. This still give a £15m UK business.

Adding Belgium and replacing Germany with dedicated OBUs in 2016 gives £70m this year, along with £30m calculated on a similar basis for emerging US and Australian truck schemes.

By 2020 Germany will have all vehicle charging in place, UK may have adopted GNSS and France restarted its programme. Bulgaria and many other eastern states will adopt GNSS charging. Adding these vehicles at £25 per vehicle suggests substantial growth

If half of the US states adopt GNSS truck charging on the same basis across 31 million trucks this gives a £775m business

The above revenues will flatten in EU but increase in the US.

US all vehicle schemes and Indonesia, Malaysia and Hong Kong have not been counted in the above due to the political risk. It is important to remember that there are as many abandoned road charging schemes as deployed ones (UK HGV, France ecotaxe, Denmark, Netherlands, Manchester,) so focussing on committed schemes and those with politically easy deployment (trucks) is key.

Dangerous goods and VAT/Customs tracking are assumed to be integrated into the above units.

11.4. Appendix 4: Market for rural communications

Starting point estimates are based on

- UK Highways England and UK LHA budgets for communications; HE spend on network technology in England is £160m p.a.
- Transport Scotland: £144m budget for next generation broadband infrastructure (2011-2030)
- Transport Wales: £500m capital programme for Trunk Road Network. (2017 -2021 budget)

Based on the above capital spending programmes it is reasonable to forecast that 5% of capital spending could be gained by the satellite industry based on the need for rural communications (Scotland has already invested in satellite communications as part of its broadband delivery strategy). So, the baseline figure of £0.5m can be considered as a conservative estimate at this point and is based on the potential market in Scotland and Wales as HE has an extensive fibre communications network in place. The predicted growth rate is also a conservative estimate based on the year on year capital spending programme and tracking the predicted growth rate (CAGR) for EU emissions and air quality satellite based services.

The EU market place is clearly larger and has a higher potential for the deployment of satellite communications for rural areas but more difficult to determine current investment levels across. Therefore, it is reasonable to take the current UK based figures and apply a factor of 20 to give a current start point and take the same, conservative, view on scale of growth percentages.

The same methodology has been applied to the International market place where a factor of 40 has been applied and similarly conservative views taken on the scale of growth which can be expected to be higher than the EU rate as this market has a far higher potential for satellite based communications

based on a greater total of strategic roads/motorways and a lower level of existing communications infrastructure in rural areas. It should also be noted that some countries, such as Germany and Australia, comprise of "states within states" so there is a need to market to several administrative bodies. Examples of the volume of motorway style roads (and toll roads) per country that are potentially applicable to this market analysis are provided below:

Country	Strategic Roads (km)	Toll Roads (km)	Comment
UK	3,519	<100	90% fibre communications provision
France	11,100	7,845	All major routes are toll roads
Germany	12,800	0	No toll roads
Italy	6,700	~2,000	
India	66,000	~1,780	Rapid expansion in growth
China	85,000	85,000	Rapid expansion in growth
USA	75,938	~4,500	
Canada	17,000	150	

The above table provides snapshot examples of the UK, European and International road structure and clearly the potential market place is clearly considerably higher but will require a structured marketing approach. For example, whilst China has the largest road network above it is also one of the most difficult markets for western technology companies to penetrate and has associates risks to IPR.

In contrast the Indian network offers a more realistic target as it has multiple challenges to address, such as incident detection, is relatively undeveloped in terms of ITS deployment and has an annual expenditure of $3.7bn to improve the road network.

11.5. Appendix 5: Market for emergency services

The greatest challenge for encouraging the use of satellites for the emergency services is the engagement of the services themselves. If not the user community will not be represented. GNSS is still seen as expensive and extremely niche. However, changes in all of the emergency services with reductions in staff headcount means that GNSS presents and attractive option.

Remote asset surveillance

The prices quoted are rated at medium resolution images, the higher or more specialised the image required the higher the cost. This would apply to the emergency services who may require highly detailed images, with a high refresh rate, or advanced filters were applied e.g.

Generic ongoing commercial rates negotiated on a 1-5-year term depending on the images required:

New Image[2]

Per image

- £19
- £23

Ongoing contract

Per image

2 The costings here are derived at the cost of a single image (frame). The image is of medium detailing. The financial value was achieved by averaging three suppliers, who were willing to publish commercial rates, and then converting the average sum which was expressed in USD to GBP.

- £8
- £14

Whilst it is recognised by this report that costs would fall, when emergency service providers are making strategic decisions concerning ICT, the decisions will be based initially with what is on the market now. To make this imagery attractive for the emergency services, considerable work will be required to provide rates that are not linked to existing charges as these would be regarded as unacceptable in the current financial climate

Communications

The provision of Satellite communication to the emergency services has already been recognised, especially where there is a requirement for high availability independent of existing communication infrastructure (Millennium Operations[3], New Venture Programme[4]), where a high degree of resilience for communication was required where there was a possibility of no communication infrastructure.

Handsets

Cost Range £403 > £1200

These prices do not reflect security requirements or bulk purchase, and in the case of the lower priced handsets regional restrictions.

Airtime

Voice

Cost Range £10 > £27 per calendar month

Data

Cost Range £10 > £14 per calendar month

Costs for airtime are estimated according to USD conversion across a range of commercial providers dependent on predicted use

Navigation

Emergency Service Asset Tracking

Device

Cost Range £87 > £1070 dependent on the sophistication of the device required, relating to coverage security, resistance to tamper.

Air time

Cost Range £2 > £10 This is totally dependent on the refresh rate of the communication and the level of data transmitted.

11.6. Appendix 6: Market for Emergency Services

The below list is a categorisation of the emergency services as a potential market in the UK. This has drawn the distinction that for the UK there are 4 defined services that respond to the public. If this were scaled up as a potential market, most other European Markets would be larger, geographically and in head count, this can also be extrapolated globally in the region of a factor of 5 for Europe and a10 market globally[5].

[3] All emergency services issued with Satcom as it was unknown how the date change would affect communications

[4] UK response to Chemical, Biological, Radiological or Nuclear (Explosives) (CBRN)

5 The difficulty in expressing values for potential markets, especially in the United States, is the structure of the emergency services, who in head count are very small outside of the

Though the rule outlined in the report would apply in the distinction of member states.

- Technology rich organisations, but poor in terms of the number of personnel available to deploy.
- Technology poor, but rich in the levels of manpower that are available for deployment.
- Formerly technology rich countries, now losing ground technologically, (Older systems), poor in terms of the number of personnel available (Reduced head count due to cost cutting).

Mountain Rescue
England and Wales: 58 Units
Scotland: 28 Units
Ireland: 12 Units

Border Force
5 Operating Centres in the UK

Marine and Coast Guard Agency
Search and Rescue: 352 Units
Shipping Control: 6 centres
RNLI: 350 Stations
Ambulance: 18 Trusts in the UK
Police: 43 Forces in the UK
Fire: 52 Brigades in the UK

major conurbations. Most agencies have extremely low numbers as they are categorised on town or parish boundaries with 5-10 personnel per service.

11.7. Appendix 7: Areas not considered as key to market and reasons

Opportunity	Scope for use in traffic management	Comment on market and satellite applicability
Connected and self-driving vehicles data	High as data feed of location	Will be provided by smartphone/ black box or OEM line fit for other purposes e.g. infotainment – traffic management is not the customer
Self-driving vehicles navigation	Medium	Will be an OEM product likely derived from extra sensors e.g. LIDAR. Little interface with traffic management clients
Emergency call	high	As above re GNSS element Very little real use of sat communications for emergency location on roads to date. Likely to be a niche for rural roads and corporate use
Urban Traffic management systems e.g. signals	high	Need power which often means communications is readily available. Wi-Fi and fibre already widely used
Motorway systems e.g. VMS and gantries	high	Power and communications often available, or routes for fibres sold as revenue stream
Traditional road surveys and asset monitoring periodically	medium	Now done by in vehicle cameras or google maps is often good enough
Mandatory Satnav replacing road signs	low	Unlikely to occur in medium term until almost 100%penetraion except for POIs
Mandatory speed control (ISA)	medium	Complexity of link to engine ECU means an automotive product (e.g. Ford S Max)
Smart engine management (e.g. gear selection by GPS)	low	As above, an automotive product
Road monitoring e.g. queues at signals	high	Unless 24/7 AND high resolution imagery available conventional “always on” plus vehicle data are key solutions
Vehicle and people movements	high	Cellphone and GPS data already widely used and market saturated
Accident detection	high	ecall and other systems offer easier and data rich solutions
Major Road crisis e.g. flood, typhoon, earthquake	high	May already be used by other agencies therefore double counting. Minor road problems e.g. blocked gully is asset management.
Mobility as a service	low	Likely GNSS elements will be OEM line fit and have little connection to traffic management clients
Communications to HGVs in rural unconnected roads	Low	Fleet management communications may be done by sat communications in some rural markets but OEM or after-market fit – niche volumes for high value loads.