RECOMMENDATIONS FOR

AREAS OF FOCUS AND INNOVATION FUNDING FOR EGNSS R&D

WHITE PAPER

GALILEO EGNOS
NAVIGATION SOLUTIONS
POWERED BY EUROPE

European
Global Navigation
Satellite Systems
Agency

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01 INTRODUCTION

This White Paper was developed from input gathered from European GNSS (EGNSS) users during the 1st Galileo User Assembly that took place in Madrid on 28-29 of November 2017. It confirms the importance of investing in the development of EGNSS downstream applications in order to capture economic and technological returns from Galileo and the European Geostationary Navigation Overlay Service (EGNOS) by:

- Identifying the priority areas for investing in EGNSS downstream applications by market segment;
- Analysing the different funding tools that could support EGNSS market uptake;
- Describing the desirable characteristics that define best practices for EGNSS R&D application programmes.

1.1 EGNSS PROGRAMMES

Global Navigation Satellite System (GNSS) refers to a constellation of satellites that provides signals from space that transmit a navigation message to GNSS receivers. The receivers then use this data to determine a user's position, velocity and time.

Galileo is the EGNSS providing standalone navigation, positioning and timing information to users worldwide. Unlike other systems, it is under civilian control and was designed in response to the diverse needs of different user communities. Specifically, Galileo offers a range of high-performance services worldwide, including: Open Service (OS); Galileo High Accuracy Service and Signal Authentication services; Search and Rescue (SAR); and Public Regulated Service (PRS).

EGNOS is a Satellite-Based Augmentation System (SBAS) that increases the accuracy of GNSS positioning and provides information on its reliability in Europe. EGNOS provides three services: Open Service, Safety of Life and EGNOS Data Access Service (EDAS). EGNOS is suitable for such safety critical applications as aircraft flights and navigating ships through narrow channels.

1.2 WHY FUNDING FOR EGNSS APPLICATIONS R&D IS NEEDED

The metrics for measuring EGNSS' success include a realistic Return on Investment (ROI) and the extent of its market penetration. Both of these are closely linked to the development of innovative applications. R&D, which plays a key role in the innovation process, is an investment in technology and future capabilities that can be transformed into new products, processes and services.

Over the last few years, the European GNSS Agency (GSA) has applied a market-oriented approach to innovation in downstream applications. This has proven to be a major factor in the market uptake of EGNOS and Galileo. The successful implementation of FP7 and H2020 have led to the creation of a portfolio of products and advanced prototypes:

- 86 FP7 projects: 115 demonstrations, 125 products/prototypes, 40 % funding to SMEs;
- 40 H2020 projects: already 22 products, 7 patents, 73 prototypes.

It is important that this market-driven approach to the management and development of innovative GNSS applications – which exploits technological synergies in such user markets as aviation, rail and road – is continued. In fact, this is key to supporting the competitiveness of the EU's EGNSS industry. Although we expect that a significant market uptake of EGNSS will be achieved by 2020, there will still be much to do to position Galileo as the market leader. Market development activities will also be needed to secure Galileo's Open Service as the constellation of choice. In particular, these activities will not only drive the recognition of the important role that multi-constellation plays, but also the significance of fusing multi-constellation GNSS with other positioning technologies, like Wi-Fi and eLoran.

After 2020, when the Galileo system is fully operational, all of its differentiators will be available for use in the development of innovative applications. The primary goal will be to establish Galileo as the leader in those markets and sectors that best exploit these unique differentiators. For example, one objective will be to complete the 'approval' of Galileo in regulated market sectors, such as aviation, autonomous vehicles and rail.

The competitiveness of EU industry in general and of SMEs in particular must continue to grow. Consequently, R&D activities that focus on EGNSS applications must be increased. This will not only enable EU companies to export innovative products, it will also support the continuing growth of EU industry and enhance the competitiveness of SMEs. However, the creation of enabling technologies for new businesses and new business models that link industry and academia will be key challenges.

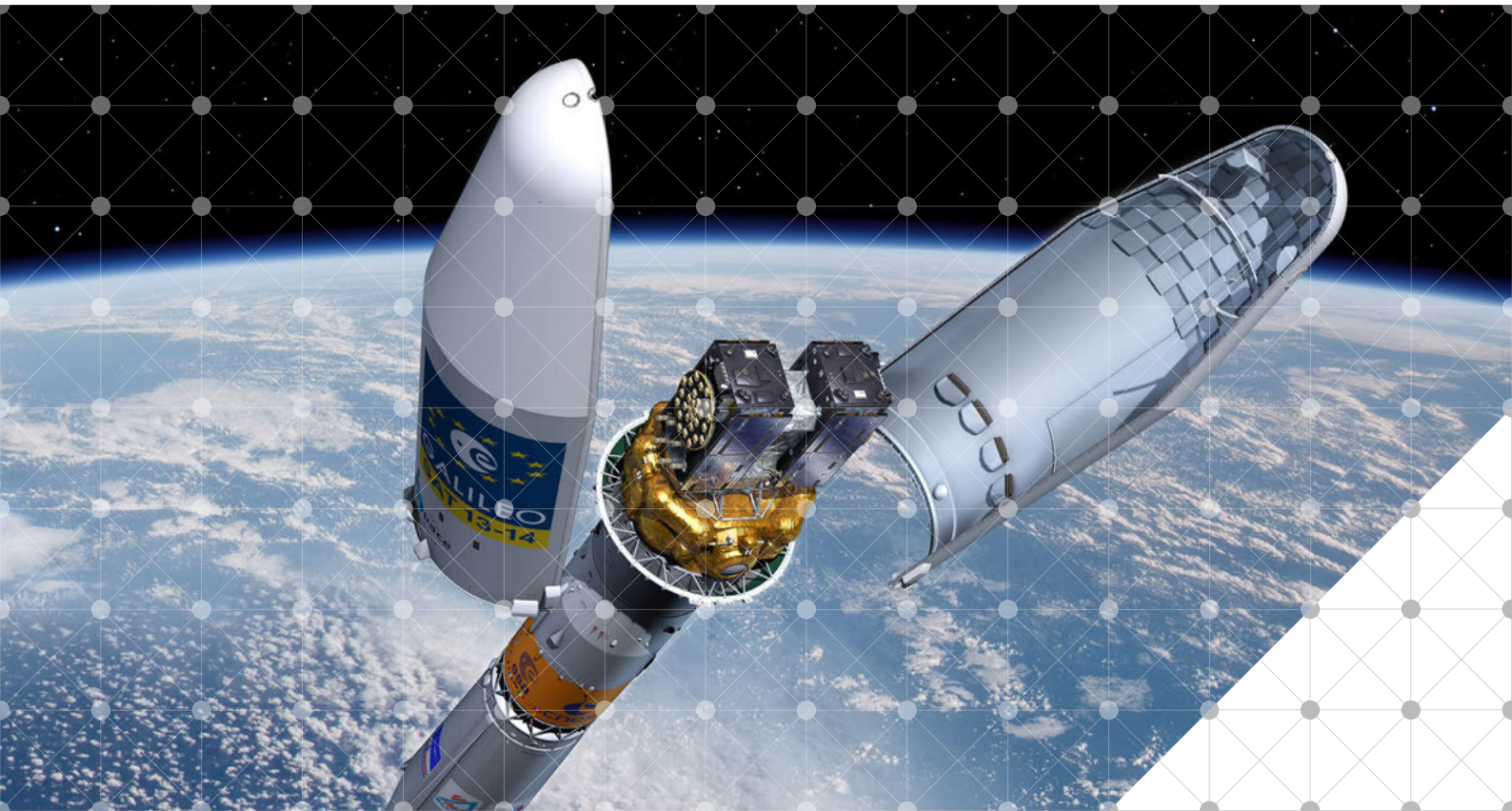
1.3 HOW EGNSS R&D FUNDING RESPONDS TO EU POLICY OBJECTIVES

Overall, the European Commission's strategy proposes actions that support EGNSS market uptake, including actions to:

- Promote the uptake of EGNSS solutions in EU policies, where justified and beneficial;
- Stimulate the development of space applications with a greater involvement of new actors from different domains;
- Step up efforts to support space R&D activities;
- Strengthen the use of innovative procurement schemes to stimulate the demand-side of innovation and explore new ways to leverage private sector investments and industry partnerships;
- Use EU funding programmes to increase support for space entrepreneurs and facilitate further financing of investments in the space sector.

EGNSS-enabled solutions respond to several policy objectives, including:

- Sustainable development (health, food, energy, transport, resource efficiency, etc.);
- Integrating digitisation in all industrial technologies and societal challenges;
- Strengthening international Research and Innovations (R&I) cooperation;
- Societal resilience;
- Market-creating innovation.



02 EGNSS R&D: AREAS OF FOCUS BY MARKET SECTOR

2.1 INTRODUCTION TO EGNSS MARKET SECTORS

The global GNSS market enjoys steady growth, with the number of GNSS devices currently in use forecast to increase from 5.8 billion (2017) to nearly 8 billion in 2020.

The value of this global market is estimated to grow from EUR 92 billion (2015) to EUR 259 billion by 2025. Three Regions, Asia Pacific (38 %), North America (25 %) and the EU (24 %) account for 87 % of the market.

The Location Based Services (LBS) and Road sectors dominate the market, accounting for nearly 94 % of all in use-use devices, with smart phones being the leading device (~80 %)

While the number of GNSS devices currently in use in the professional sector is significantly lower than in the commercial sector, due to the important services this sector provides, this market is also experiencing substantial growth.

The downstream market is defined as activities where GNSS Position, Navigation and Timing (PNT) is a significant enabler of functionality. The global GNSS downstream market, which comprises both devices and augmentation services, is forecast to grow by 6.4 % annually between 2015 and 2020.

However, towards 2025, this growth is expected to slow to 3.8 %, primarily due to the growing maturity of the market, more competition and increased pressure on price.

> THE GLOBAL GNSS DOWNSTREAM MARKET, WHICH COMPRISES BOTH DEVICES AND AUGMENTATION SERVICES, IS FORECAST TO GROW BY 6.4 % ANNUALLY BETWEEN 2015 AND 2020.

2.1.1 MARKET SECTOR OVERVIEWS

The GNSS market can be divided into several sectors, each having specific characteristics and serving different user needs:

- Agriculture;
- Aviation;
- Location Based Services (LBS);
- Mapping & Surveying;
- Maritime;
- Rail;
- Road;
- Timing & Synchronisation.

2.1.2 CROSS SECTOR TECHNOLOGY REQUIREMENTS

The following EGNSS requirements are relevant to most market sectors:

- High accuracy and integrity, for both position and time, is increasingly required for applications and services in most sectors;
- Multipath is a serious challenge for applications used in urban environments;
- Reducing power consumption is a challenge, particularly for the LBS and IoT sectors;
- Reduced acquisition times and Time To First Fix;
- Improved antennae level performance, especially for small, low-cost devices;
- Increased demand for hybridisation and sensor fusion.

AGRICULTURE

GNNS penetration of the global agriculture market, which is defined as the proportion of all high- powered tractors equipped with GNSS, is approximately 15 %. It is expected to reach almost 30 % by 2020. [1]

Although the EU holds just 6 % of the global agriculture market for GNSS components, it commands a 42 % share of the global system integrator market.

Precision Agriculture (PA) can trace its roots to the 1990s, when the first GNSS-equipped tractors entered the market. It is an IT-based management system that uses site-specific data gathered on, inter alia, soil state, crops, nutrients and pests, to optimise profitability and sustainability and to protect the environment. In addition, it helps farmers comply with standards and regulations.

GNSS applications are used across all phases of the agricultural life cycle and are thus fundamental to the concept of Precision Agriculture . For example, the use of Remotely Piloted Aircraft Systems (RPAS) as a key enabler of data gathering in support of PA is growing rapidly.

CROSS SECTOR TECHNOLOGY REQUIREMENTS

Many of the challenges that farmers face are agronomic, environmental and technology-related. However, for all farmers, and particularly those with smaller farms, the most important factor is economic. For example, Variable Rate Technology (VRT), which is expected to continue to drive the market with a range of methods that enable site-specific crop management (one being GNSS), have received mixed reports as to ROI. Consequently, R&D into fundamental technological aspects that improve the value proposition of EGNSS is required. In addition, R&D into agri-specific Costs-Benefit Analysis (CBA) tools will complement the technological work.

Another concept in which EGNSS plays a key role is Farm 4.0, where everything on the farm is connected and a farmer can manage it from his/her smartphone. Furthermore, big data applications, robots and autonomous vehicles are applications that leverage EGNSS' differentiators.

The "in-field" testing, demonstration and piloting of project outcomes to farmers will establish the robustness and added value of EGNSS. It is particularly important to demonstrate a clear economic benefit from the investment to the small farmer.

AVIATION

North America and the EU dominate the aircraft manufacturing sector, with North America producing 65 % of all GNSS devices used in aviation and the EU 25 %.

GNSS penetration in the global aviation market, which is defined as the proportion of all aircraft that are fully GNSS-equipped, is approximately 70 % (2017). It is expected to reach 75 % by 2020.[1]

The distribution of global GNSS sales is expected to shift to the Asia Pacific and Middle East regions, where there is strong growth in both commercial and general aviation.

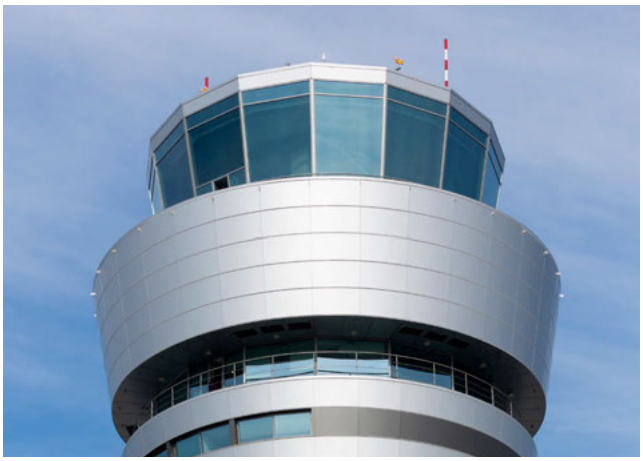
Currently, GPS is the sector's constellation of choice, which reflects the dominance of North American avionics systems. However, the introduction of Galileo, together with EGNOS, is expected to provide a catalyst for growth for EU GNSS device manufacturers.

The global aviation segment is a key driver of the global economy, with a third of all global trade by value sent via air.

The sector is increasingly reliant on GNSS systems. For example, GNSS underpins the expansion of Performance Based Navigation (PBN), particularly in Europe where dual frequency Multi constellation (DFMC) applications are becoming increasingly important. In addition, rotorcraft operations are rapidly expanding their use of SBAS.

All types of platforms – fixed wing, rotary wing and now RPAS – are subject to regulations established and managed by international and national bodies, such as the European Air Safety Agency (EASA) and national Civil Aviation Authorities (CAA).

The RPAS segment is broad, with fixed and rotary wing platforms extending from the nano-size up to platforms with wingspans in excess of an Airbus A320. In many ways, RPAS operations mirror those of 'conventional' aircraft. However, as RPAS have been described as a 'disruptive' technology, they represent many opportunities for innovative GNSS applications. Some RPAS already incorporate GNSS for navigation and the intelligent use of position data to enable an automatic response to fixed and variable restrictions on airspace usage. The downside of the very rapid growth of this segment is the time-lag and lack of international homogeneity in current RPAS regulations.



CROSS SECTOR TECHNOLOGY REQUIREMENTS

The following areas are of significance for focused R&D:

- Improvement of EGNOS continuity;
- Flexible landing approach paths to ensure wake-vortex-free separation for mixed aircraft categories;
- Approaches to lower minima and taxiing guidance using SBAS and EVS/SVS (Enhanced/Synthetic Vision System);
- The development of Localizer Performance with Vertical Guidance (LPV) and Ground Based Augmentation System (GBAS) for Cat II/III, especially GBAS GAST-F[1] with DFMC- dual- frequency multi-constellation (CAT II/III approaches);
- Solutions and standards for Automatic Dependent Surveillance – Broadcast (ADS-B) working with Traffic Collision Avoidance System (TCAS);
- Minimum Aviation System Performance Standards (MASPS) for remote Emergency Locator Transmitter (ELT) activation for autonomous distress tracking;
- Development of RPAS-specific applications;
- Provide robust navigation applications, such as detect and avoid, based on EGNOS and Galileo, geofencing and authenticated communication link, so drones can be used in urban areas.

1 GBAS Approach Service Type

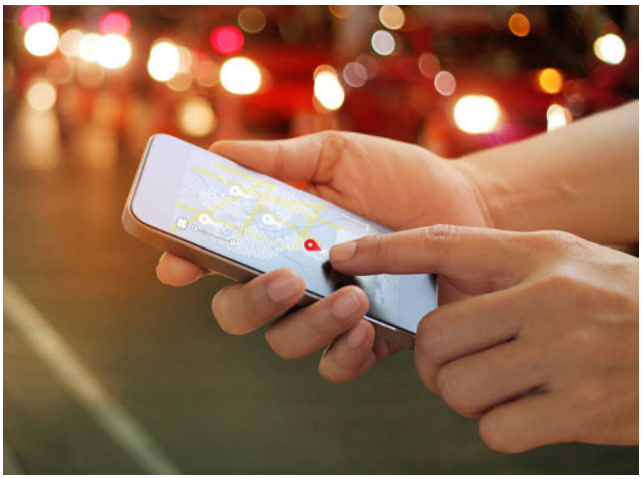
LOCATION BASED SERVICES

The Asia-Pacific region accounted for over 50 % of global LBS shipments in 2016, with a total of almost 1 billion devices shipped. North America and the EU accounted for more than 320 million and 200 million respectively.

Smartphones greatly outnumber other LBS devices in terms of shipments. Driven by the growing context-aware smartphone application market, revenues attributable to GNSS grew from EUR 150 million in 2010 to EUR 5 billion in 2016.

GNSS-enabled LBS comprise a multitude of applications designed to satisfy different uses and needs. These applications are supported by several categories of devices: mainly smartphones and tablets, but also by such specific equipment as personal tracking devices, wearables, digital cameras and portable computers.

Over 90 % of context-aware smartphone applications now rely on GNSS, with Galileo smartphones now entering the market. A growing number of premium smartphones now integrate MC GNSS chipsets, thus further increasing accuracy and availability and reducing time to fix. LBS in mHealth (mobile health) are driving the diversification and sophistication of 'wearables' and smartphone apps for healthcare. The availability of GNSS raw measurements on smartphones opens new possibilities for application developers.



CROSS SECTOR TECHNOLOGY REQUIREMENTS

The most promising and strategic applications for the mass market are:

- Seamless switch in outdoor/indoor navigation;
- RPAS applications;
- Logistics/asset tracking as part of the Internet of Things (IoT).
- Development of augmentation infrastructure for higher accuracy.

The most urgent challenges to be solved by R&D are:

- Commercial competitiveness of European industry;
- Bridging gaps between GNSS and IT communities;

The main technical barriers to be solved by R&D will be:

- Security of anti-spoofing;
- Power management and consumption.

The most important technology challenges for LBS applications are:

- Hybridisation;
- Multi-frequency;
- Ubiquity;
- Transparency (for augmentation services);
- Machine to Machine (M2M) communication;
- IoT connectivity.

MAPPING & SURVEYING

This segment includes both land and maritime surveying.

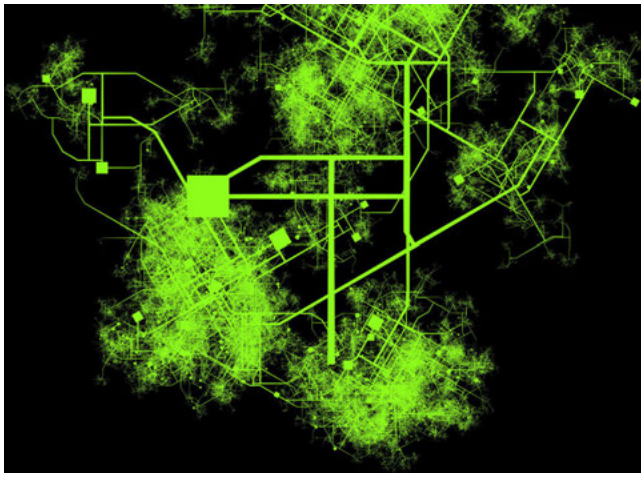
GNNS penetration of the global mapping and surveying market is defined as the proportion of all potential users that use GNSS. For land surveying, GNSS penetration is approximately 60 % (2017) and expected to reach almost 90 % by 2020. For the global marine surveying market, GNSS penetration is 100 % (2017).

The EU holds a 36 % market share of the global production of components and receivers manufactured for high precision surveying. In comparison, the North America region has a 40 % share and Asia Pacific a 24 % share.

The systems integration market is more evenly balanced between Europe (37 %), North America (34 %), and Asia (29 %).

Land surveying and mapping includes cadastral, construction and mine surveying and infrastructure monitoring. To counterbalance Asian manufacturers' competitive pricing strategies, European manufacturers are shifting their focus to customer support, offering new services and assistance. The integration of GNSS with complementary technologies in land surveying, mapping and construction activities represents a major push towards interoperability. However, GNSS remains the backbone technology in increasingly sophisticated applications, such as the move from 2D to 3D mapping.

Maritime surveying applications include a wide range of activities, such as seabed mapping and exploration and offshore and hydrographic surveying, all of which are important for maritime and waterway navigation.



CROSS SECTOR TECHNOLOGY REQUIREMENTS

The most promising strategic applications for the mapping and surveying sector are:

- Infrastructure monitoring;
- Digital transformation;
- Corrections for autonomous cars;
- Anti-spoofing and security-related issues;
- Augmented Reality (AR);
- Bathymetry survey for Inland Water Ways (IWW), e.g. streambed and IWW obstruction mapping):
  - Real-Time Kinematics (RTK) for specialist surveying vessels;
  - Unmanned vessels for regular surveys requiring position accuracy of 1m.
- Standardisation of the data format for easier information sharing and hybridisation;
- Flexible MF/MC[2] (software) receiver for multiple applications.

The main technical barriers to be solved by R&D are:

- Troposphere modelling;
- Software receiver developments;
- Hybridisation with multiple sensors and different technologies (incl. mass-market).

2 Multi-Frequency / Multi-constellation

MARITIME

The global GNSS maritime market, which is defined as the proportion of all possible vessels that are equipped with GNSS, is approximately 30 % (2017). It is expected to reach almost 40 % by 2020.

Over the next decade, North America, followed by Asia-Pacific and the EU, will remain the largest markets in terms of shipments and the number of GNSS devices in use. Global revenues are expected to grow by a Compound Annual Growth Rate (CAGR) of 5.2 % between 2015 and 2025, achieving total revenues of EUR 1.4 billion.

The EU holds a 43 % share of the maritime component and receiver manufacturing market, just behind the Asia-Pacific region (47 %). However, the EU holds an equal share (35 %} of the systems integration market with North America. [1]

The International Maritime Organisation (IMO) Resolution A.915(22) divides maritime GNSS applications into two groups: navigation and positioning applications.

GNSS is the primary means of obtaining Position, Navigation and Timing (PNT) information at sea. In May 2016, the IMO recognised Galileo's ability to meet the carriage requirements for position-fixing equipment for its World-Wide Radio-navigation System (WWRNS).

GNSS is a key enabler for both traditional and innovative maritime applications and operations, including the development of the 'smart ship' and the use of RPAS.

When its Return Link service becomes functional in 2018, Galileo will offer a unique contribution to the maritime GNSS applications industry.

In addition, the manufacturers of SAR beacons are preparing for multi-constellation GNSS, opening the door for Galileo penetration into all types of these beacons.

CROSS SECTOR TECHNOLOGY REQUIREMENTS

Seven areas have been identified for further R&D activity:

- **Complementary terrestrial systems.** Complementary territorial systems for resilience.
- **Autonomous vessels.** Focus areas include:
  - Detailed user requirements elicitation;
  - Horizontal Alert Limits (HAL);
  - Spoofing resistance;
  - Autonomous navigation, including collision risk modelling;
  - Resilience requirements.
- **Dynamic positioning.** Focus areas include:
  - Multi-system control;
  - System authentication;
  - Anti-spoofing;
  - Signal interference;
- **Oil & Gas positioning services.** Focus on 10cm positioning.
- **Sensor fusion.** Timing systems with 1 microsecond precision.
- **Accident investigation for IWW.** Automatic Information System (AIS) monitoring and tracking integrity.
- **SAR.** Return Link Service (RLS) and beacon positioning accuracies.

RAIL

Globally, signalling and train control applications represent 10 % of the market (2017), and are expected to reach 15 % by 2020. Similarly, non-safety critical applications currently hold 12 % of the market and are expected to reach almost 20 % by 2020.

EU rail systems with embedded GNSS elements, including signalling and train control, Driver Advisory Systems (DAS) and Asset Management, are experiencing strong growth. In 2017, some 100,000 systems were operational – a figure that is expected to rise to approximately 170,000 in 2020 and to nearly 290,000 by 2025. [1]

The exploitation of GNSS is central to the European Train Control System (ETCS), which is a core component of the European Rail Traffic Management System (ERTMS), the principal driver of developments in the rail sector. Already widely used in non-safety rail applications, GNSS can significantly reduce track-side infrastructure, such as Virtual Balise (VB) and operational costs, provided the relevant Safety Integrity Levels (SIL) can be met.

CROSS SECTOR TECHNOLOGY REQUIREMENTS

The focus areas for EGNSS R&D applications are:

- Developing aspects of:
  - Virtual Balise (VB);
  - Odometry;
  - Cold movement detector.
- Automatic Train Operation (ATO) for Main Line Railway applications;
- ERTMS Level 3;
- Predictive maintenance;
- Track surveys.

The challenges are:

- Demonstrate safety and availability according to CENELEC and user needs;
- Interoperable solutions based on GNSS;
- Development of cost-effective solutions.

ROAD

In the road sector, EU companies lead the GNSS component and receiver manufacturers market with a 51 % share, ahead of Asia Pacific (27 %) and North America (22 %). EGNSS system integrators generated 30 % of global turnover, trailing behind Asia (48 %).

Connected and Automated Vehicles (CAV), enabled by the uptake of connectivity solutions, represent the evolution of vehicles towards becoming integrated platforms capable of supporting smart mobility services and a range of safety applications.

GNSS, together with other technologies, satisfies the autonomous vehicles' need for accurate and reliable positioning. Although Original Equipment Manufacturers (OEM) and technology companies are leading these developments, opportunities to test CAV on public roads remains a limiting factor.

Business models continue to evolve, with OEMs moving towards the ownership of GNSS data, while aftermarket companies are increasingly specialising in data collection, analysis and added-value data products.

CROSS SECTOR TECHNOLOGY REQUIREMENTS

In terms of EGNSS, Connected and Automated Vehicles (CAV) applications are a priority. In particular, it will be important to support:

- Actions for standardisation to achieve performance requirements at the PNT level;
- Research and Innovation actions that develop new low-cost, high-performance antennas for GNSS and satellite communications;
- Fuse GNSS with other sensors and systems;
- Innovation actions for large scale pilots to evaluate GNSS performance and appraise business models.

Support will also be required for the testing and simulation of chipset development. Stable certification schemes needed at early stages of the technology life cycle are also a priority. This will enable the early integration of Galileo components in vehicles, which are subject to long integration cycles.

The key technical challenges for the sector include:

- Reducing the Time To First Fix (TTFF) and convergence time for Precise Point Positioning (PPP).

TIMING & SYNCHRONISATION OF CRITICAL INFRASTRUCTURES

The Timing and Synchronisation (T&S) capabilities offered by satellite navigation systems are core to such critical infrastructures as telecom networks operation, energy distribution, financial transactions and TV broadcast.

EGNSS provides a unique offering to the T&S user communities by delivering a global, free, stable and very accurate time and frequency source.

CROSS SECTOR TECHNOLOGY REQUIREMENTS

ACHIEVING PNT INTEGRITY AND ROBUSTNESS TO INTERFERENCES TO COMPLY WITH CAV

The main EGNSS R&D activities are:

- Increased receiver resilience to interference (intentional, non-intentional radio-frequency interference and intentional data spoofing), which is very important for critical infrastructure applications;
- Timing for financial organisations, as driven by MiFID II regulation[3];
- Tighter, more accurate time/phase requirements in many applications, 4G & 5G telecoms, power and scientific and measurement applications.

Providing an authenticated time system is seen as a significant application. However, although an encrypted system is not necessarily needed, a digital signature with a Public Key Infrastructure (PKI) system would be extremely useful. The introduction of the Open Service Navigation Message Authentication (OS-NMA) feature will differentiate Galileo from other GNSS services, such as GPS and GLONASS.

The top three challenges to address are:

- Resilience and reliability in reception of GNSS signals;
- GNSS equipment costs – usually higher cost to implement and maintain than LAN/WAN based timing;
- Making Galileo timing capabilities more visible to users. GPS/GLONASS currently have greater consumer confidence due to the longevity of availability and receiver manufacturer support. Galileo needs to establish a track record.

To overcome these challenges, the following technical barriers must be addressed:

- Reception in areas of poor or no sky view, e.g. urban canyon, or indoors;
- Holdover technology giving required accuracy at a feasible cost in cases where Galileo signals are lost;
- Capability of the service provider to commit to a Service Level Agreement (as done for EGNOS in aviation);
- Confidence in the integrity of the Galileo (and other GNSS) signals – e.g. identification and subsequent user notification of error conditions within the constellation that affect timing quality.

3 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0065

2.2 INTERNATIONAL COOPERATION

International cooperation is vital for the spread of EGNSS outside Europe. With this purpose in mind, the priority for EGNSS is to leverage industrial cooperation across continents, providing market entry support that is tailored to:

- The needs of the various engaged companies, up-to-date content (e.g. market information, cooperation opportunities, company profiles, etc.) via both offline and online communication channels;
- Supporting institutional relations and economic diplomacy activities, mainly through the creation of links between associations and research institutions, between the EC and the GSA and between foreign GNSS-affiliated institutions;
- Organising and sponsoring educational exchanges on EGNSS related matters between European university students and those of other continents;
- Driving EGNSS adoption abroad, e.g. through the adoption of Galileo receivers on the most internationally-diffused mobile devices;
- Raising awareness through the promotion of EGNSS abroad, fostering relationships with local media and communication channels;
- Supporting EU companies by promoting their EGNSS solutions abroad.

2.3 START-UPS AND SCALE-UP INITIATIVES

The EGNSS industry is fragmented. To increase European competitiveness, as well as attract investments from outside Europe, it is necessary to boost capacity building and create a critical mass. This can be achieved, in part, by creating a strong bond between science and industry, which will encourage, inter alia, the exploitation of innovative research.

In addition, support for innovative ideas in all market sectors can be promoted through the organisation of business competitions, such as the Galileo Masters, and the distribution of vouchers. Accelerators can play an important role by giving small companies access to the necessary facilities, including instruments and laboratories. Also, EGNSS Excellence Centres can act as catalysts at the regional/country level.

GSA-sponsored workshops – with the active participation of business angels, venture capitalists and other financing entities – would provide financial and practical assistance to start-ups and small enterprises. The events could be supplemented through coaching and mentoring of young start-ups by, for example, universities and with the support of the GSA.

Hackathons can promote new EGNSS-based systems to the development community, as well as nurture new applications.

2.4 CHALLENGES AND ISSUES FACING EGNSS

The significant challenges and issues facing EGNSS include:

- **Security and safety:** an improved level of robustness of authentication and integrity at system and user levels.
- **Certification** and **standardisation:** complete independent GNSS signals monitoring (e.g. EGNOS) to provide real time information on GNSS signal quality at the user reception level.
- **Non-technical issues:** several aspects of application and service development are impacted by non-technical issues. These include liability, ethics and General Data Protection Regulation (GDPR), all of which influence technical design. In some sectors, such as aviation, compliance with regulations is hampered by the involvement of more than one regulator.

2.5 CONTRIBUTION TO EU POLICIES

New applications not only enhance the continuing development of the EGNSS industry, they also endorse EU policies:

- **Sustainable development.** The EU made a positive and constructive contribution to the development of the UN 2030 Agenda for Sustainable Development, with several EGNSS related applications supporting the policy's goals. In particular, Precision Agriculture, which relies on accurate location data, is key to the first two goals of reducing poverty and hunger, while mHealth underpins the 3rd goal of ensuring healthy lives and promoting well-being for all ages.
- **Integrating digitisation in all industrial technologies and societal challenges.** LBS applications directly support the EU's Digital Single Market Strategy, which combines digital technologies, such as IoT, 5G and high-performance computing, with other advanced technologies and service innovations to increase industrial competitiveness.
- **Strengthening international Research & Innovation (R&I) cooperation.** All R&D proposals for EU funding are required to be implemented by an international consortium. This is means to encourage, and sustain, strong international R&I cooperation.
- **Societal resilience.** Europe faces a number pressures on several fronts, such as large-scale economic migration, cyber-crime and terrorism. Such pressures require a coordinated EU response based on reliable, accurate data, for which EGNSS applications make a basic contribution.
- **Market creating innovation.** EGNSS-based applications are innovation driven and developed by European companies, which contributes to and strengthens Europe's industrial base.

ALL R&D PROPOSALS FOR EU FUNDING ARE REQUIRED TO BE IMPLEMENTED BY AN INTERNATIONAL CONSORTIUM TO ENCOURAGE, AND SUSTAIN, STRONG INTERNATIONAL R&I COOPERATION.

03 BEST PRACTICES FOR EGNSS R&D APPLICATIONS PROGRAMMES

The R&D community views the Horizon 2020 programme as an effective and solid reference from which to build. However, a number of improvements could be introduced for the next Work Programme.

3.1 PRIORITY TECHNICAL RESEARCH THEMES

Although a wide variety of GNSS applications exist in the eight market sectors, the key R&D themes are often similar across the entire EGNSS market.

3.1.1 GENERAL ISSUES

The further development of receiver technology, including the antennae, is important. For example, power consumption, acquisition time and TTFF can still be improved for some applications.

Multi-frequency (MF) capability is expected to migrate to low-cost devices, which will require, inter alia, miniaturised MF antennae. The availability of new, low TRL-level technologies will stimulate further higher-level research and, in the long-term, strengthen the EU's EGNSS market position.

3.1.2 APPLICATIONS

3.1.2.1 ACCURACY AND INTEGRITY

For many applications, the requirement for high accuracy is becoming increasingly important, especially in the LBS and transport sectors. Furthermore, more and more applications in the transport market sector require service integrity. For instance, 20-cm (95 %) accuracy is required by the automotive sector to enable connected and autonomous vehicles (although the accuracy requirements and integrity relax with less demanding applications). A similar situation is seen in the maritime sector, where centimetre-level accuracy is required for certain in-port operations, whereas Search and Rescue locators must attain accuracy of tens of metres only.

The accuracy and integrity requirements are not limited to only some GNSS sectors, but are demanded by particular applications across all sectors.

3.1.2.2 GNSS-BASED SYSTEMS

As the GNSS market matures, the emphasis is moving towards GNSS hybridisation. Here, the integration of PVT with new sensor developments, such as Inertial Measurement Units (IMU), magnetometers, radar and LIDAR, creates new business opportunities.

Moreover, the integration of information from multiple sensors could enable GNSS receivers to identify and suppress undesirable multipath signals or bridge signal outages.

3.1.2.3 SECURITY AND SAFETY

Authentication, a key Galileo differentiator, provides a clear market advantage for EGNSS. Signal authentication, which is relevant to all the market sectors, will enable applications that require system robustness and trusted Position, Velocity, Time (PVT). The challenge is to provide the trustworthy measurement at the user level, not just at the system level, as is currently the case.

3.1.2.4 EXCHANGE OF KNOWLEDGE AND TECHNOLOGIES

User requirements, which may already be satisfied by GNSS technology in one sector, are not always exploited in another. For example, the maritime segment requires a precise 1 microsecond signal and 50 Hz reference, which could be easily

derived from GNSS-disciplined oscillators, which typically offer 10 MHz and 1-pulse-per-second references.

While the transfer of knowledge and technologies between market sectors should be encouraged, the technical solutions from one project may not be readily available to another, for reasons of Intellectual Property Rights (IPR), regulation, standardisation or ethics. However, a call procedure that enables such non-technical issues to be effectively managed will yield both temporal and economic benefits.

3.2 ATTRACTING THE RIGHT PROJECTS

3.2.1 CALL PERIODICITY

For maximum effectiveness, the periodicity of EU R&D calls should match the R&D "dynamics" of the market sector. Typically, in sectors where the product development phase is long, with rigorous regulations and standards (i.e., Aviation, Rail and Maritime), the two-year call-period is considered optimal. However, for fast developing sectors, such as LBS and low-TRL research, a flexible, open-call would be optimal. For other sectors, an annual call would be appropriate.

3.2.2 GRANT APPLICATION PROCESS

There is a strong demand for *simplifying* the grant application process. SMEs and start-ups are discouraged from applying because of the significant workload involved (e.g. studying 700-page guidelines), the lag between submission and acceptance and the modest chance of success, which for EGNSS in H2020 is in the range of 20 %. Small companies, which are typically entrepreneurial and innovative, lack the capacity and resilience to wait. There are companies that offer assistance with grant applications, but at a cost. With these services, even though the end product may be competently written, the submission is less then convincing because it has been prepared by a third party whose primary skills are in presentation, not technology.

A simplification of the application process, such as reducing the guidelines to 10 pages, would make the grant application process more attractive for SMEs and start-ups and negate the need for 'commercial' assistance.

3.3 EVALUATION PROCESS TO SELECT THE BEST PROJECTS

While the proposal evaluation process is regarded as sound, users are concerned about the elapsed time between submission and notification of the results, which is typically nine months. When added to the periodicity of the call and the duration of the average Innovation Action, some five years could easily 'slip by' before what was deemed by independent experts to be a fund-worthy application is ready for market.

As noted earlier, a flexible approach to announcing calls for particular applications and market sectors, together with a 'remote' evaluation process, could significantly reduce the time-to-grant by three to four months.

The removal of the Grant Agreement negotiation phase from the overall process was not unanimously welcomed. Although it was agreed that its withdrawal would lead to a faster funding process, some users recognised that the negotiations led to a more focused proposal, as well as potential time and budget savings on both sides. Moreover, the consequent cooperation between the proposer, the GSA and the EC improved the overall management of the project, resulting in a potentially better exploitation of its outcome.

3.4 PROGRAMME AND INDIVIDUAL PROJECT BUDGETS TO ACHIEVE TARGETED IMPACTS

The number of projects and their budgets are typically related to the targeted market sector. It is recommended, therefore, that the next Work Programme aim to better match these parameters to the needs of each sector.

Thus, the current number of LBS sector projects should optimally be doubled and their budgets raised above EUR 1M.

Similarly, the budgets for Mapping and Surveying projects should also be more than EUR 1M, although the amount would be moderated by consortium size. On the other end of the spectrum, the Rail sector should be limited to three major projects with budgets of approximately EUR 5M.

The Timing and Synchronization sector warrants more projects, albeit with lower budgets. Innovative projects proposed by smaller consortia, which include universities, should also be promoted.

The budget for user-side R&D projects should be in the range of EUR 150k - EUR 1M, although higher budgets would be required for service development projects.

3.5 THE MANAGEMENT OF PROJECTS

The current project management within the H2020 scheme is generally acceptable and well-regarded by users.

04 FUNDING INSTRUMENTS TO INCENTIVISE RESEARCH OUTPUTS

Public funding of R&D activities by EU institutions is essential to:

- Complement the design and development of the space and ground segments of EGNSS infrastructures with a specific focus on user segment technologies;
- Foster EGNSS market uptake;
- Strengthen the competitiveness of EU industry;
- Unleash public utility benefits (environmental and societal) generated by an efficient use of EGNSS;
- Remove technology barriers and foster innovation at the application layer level;
- Contribute to EU Policy objectives.

Many funding instruments have already been trialled, with some having proved to be efficient and thus could be restored. Nevertheless, some of these instruments need refining and new ones need to be proposed to reflect the continuous evolution of the EGNSS environment and its operational status.

The first step is to specify the ultimate objective. Next, one needs to consider which part of the value chain, which TRL and what kind of stakeholders are to be targeted to achieve this objective.

The Fundamental Elements programme, which is being implemented by the GSA over the 2015 – 2020 period, is proving to be relevant because it takes into consideration several elements not considered elsewhere in the design of the EGNSS programmes. In view of the continuing evolution of EGNSS services and market sector technologies and requirements, a similar programme should be implemented after 2020. This programme could:

Fundamental Elements

- Emphasise the transition to Galileo 2nd Generation (G2G) and G2G services, as well as EGNOS v3;
- Continue to optimise the market uptake opportunities generated by Galileo's differentiators, for instance with projects fostering the use of the high-accuracy service in all markets and in particular mass markets;
- Ensure the presence of EGNSS in emerging and promising applications, such as robotics;

- Reinforce research in such crucial matters as navigation and timing services robustness for aerial, maritime, road, rail and autonomous vehicles;
- Tackle the synergy of Galileo with other current and future EU space programmes (Copernicus, Govsatcom, Space Surveillance and Tracking, etc);
- Address the combination of EGNSS services with the ubiquitous positioning technologies that are emerging and could provide some redundancy and support in indoor navigation.

Grants, which are valued by industry, lead to meaningful results and have demonstrated that they can initiate the commercial success of an innovative application. Their benefits are manifold for: the user/EU citizen; the EGNSS programmes favouring their uptake; business; and EU industry's competitiveness. In particular, grants support the product/application developer by sharing the financial risk and allowing the developer to focus on the project and take a more daring approach, vis à vis the technical risks.

Demonstrations and pilot projects have been shown to have a direct and positive impact on market uptake, in particular for innovative services enabled by Galileo. Where the intention is to promote an EGNSS service or application, consideration should be given to promoting such projects through the Fundamental Elements or grants process.

International cooperation projects provide a singular opportunity to extend the uptake of EGNSS and EU technologies to non-EU countries, as well enhance EU business opportunities. Accordingly, a call for projects partnering with non-EU stakeholders could be profitable. However, these projects may become detrimental in the longer term, notably through uncontrolled technology transfer. It is therefore crucial to carefully avoid participation of non-EU enterprises that could enhance their own competitiveness at the expense of the EU.

Pre-Commercial Procurement (PCP) and Public Procurement of Innovation Solutions (PPI) have been trialled in several domains within the H2020 framework, but not yet for EGNSS applications. Nevertheless, these may be promising methods for fostering EGNSS market penetration, supporting EU public buyers and contributing to EU policies. They may create a critical mass, which leads to price reduction/cost savings, and could provide an opportunity for SMEs to commercialise their innovative applications and services. In particular, PCP/PPI initiatives could foster the uptake of EGNSS in many domains, such as fleet management of public vehicles and border control mobile radios. They could be particularly beneficial for PRS market uptake. However, the administrative burden of PCP/PPI projects can discourage applicants. This could be offset by launching preparatory actions to promote PCP and/or PPI initiatives to public procurement agencies or buyer's groups from different countries and creating networks of public stakeholders ready for coordinated procurements.

Innovation vouchers could provide a researcher with a small investment from the public purse. However, this instrument would be more effective if combined with an incubation and/or business accelerator.

Venture capital is often necessary for the commercialisation phase. Although venture capitalists do invest in new technologies, their primary targets are large market opportunities. Relatively small domains, such as EGNSS, are less attractive, especially when it is an SME or start-up seeking a sponsor. GSA sponsored 'EGNSS applications finance' workshops could provide a platform for selected H2020 entrepreneurs to present their applications and products to a small group of venture capitalists.

SMEs and start-ups are not only flexible, responsive and innovative, they also account for more than two thirds of total EU employment. Their capacity to generate 'success stories' can be multiplied through financial support and business advice.

The Grant Agreement includes a commitment to the exploitation of the project's output. However, bringing an innovative product or service to market represents a significant challenge, particularly for SMEs and start-ups. Support from public institutions during the early post-project phase could be crucial for the successful marketing of the innovative application and, incidentally, could result in an initial ROI from the project funding. A new post-project funding instrument could provide decisive support, with a form of PPI as part of the instrument.

It is also important not to overlook low-TRL research, with its potential to develop breakthrough technologies. While these may not lead to immediate, tangible results, their long-term impact, for example in terms of patent rights, could be substantial.

4.1 IPR CONSIDERATIONS

R&D activities typically involve the development of Intellectual Property (IP), which is valuable in and of itself and therefore must be 'protected'. Moreover, it plays a crucial role in the subsequent exploitation and commercialisation phases. This was recognised by the H2020 programme, which identified the management of Intellectual Property Rights (IPR) as a sub-criterion in the proposal evaluation process. In addition, management procedures are specifically required to address innovation management, while the obligatory Consortium Agreement, inter alia, describes how the IP generated within the project will be managed, protected and 'shared'.

This approach, with the GSA's oversight, has worked well and is recommended to be adopted for the next Work Programme.

4.2 EXPLOITING PROJECT OUTPUTS

Although the evaluation process explicitly addresses 'exploitation' as a sub-criterion, this topic does not appear to attract sufficient attention from either the proposers or the evaluators, probably because it is an activity that occurs after the project is 'completed'.

In addition, or alternatively, the project may only be declared 'finished' say 6 - 12 months after the 'Final Review', when a contractual deliverable, which addresses all the exploitation measures defined by the Grant Agreement, has been prepared by the consortium and 'accepted' by the Project Officer. Specific support beyond the end of an R&D project will be necessary to:

- Appraise the project's level of success;
- Learn lessons from what has contributed to or prevented complete success;
- Adapt the support tools accordingly;
- Maximise this success, perhaps by promoting products/services and business recommendations.

However, it may be administratively and/or contractually difficult to review a post project deliverable after the final review. One possible solution is to set up a Support Action to assess the exploitation actions of specified EGNSS projects and make recommendations on how the potential for successful exploitation can be strengthened.

05 CONCLUSION

R&D is a building block for many European policy objectives. Investing in R&D is essential to achieve European merited growth and leadership in a worldwide arena where other regions have very aggressive strategies to support their GNSS services and downstream development. More specifically, R&D directly fosters EGNSS market uptake and infrastructure investment recoveries. Learning form the past (FP7, H2020 and FE programmes), we should leverage the funding tools that proved to be efficient. In particular, the H2020 grant format is appreciated and recognised by experts as working well and thus provides a solid reference to build upon.

Nevertheless, it is worth considering the setting up of complementary funding tools to further develop EGNSS products and applications, innovative technologies and new business while increasing EGNSS adoption worldwide. For example, an FE programme addressing elements in the value chain beyond the EGNSS ground and space segment is considered necessary. Although international cooperation projects can facilitate business extension beyond EU markets, they need to be carefully considered so as not to be counterproductive by strengthening non-EU competitors. PCP/PPI tools could be promising for EGNSS market uptake and help achieve a critical mass for EU industry, but may need preparatory actions to attract public buyers. Although less ambitious, innovation vouchers, hackathons and contests, especially if combined with incubation and/or business accelerators, will complete the funding tools panorama by addressing different stakeholders.

Start-ups and scale-up initiatives must be encouraged and benefit from particular attention and support because they are currently weak but hold a lot of promise. Nevertheless, big companies able to compete with international leaders and capable of catching huge market shares worldwide must not be forgotten.

IT IS WORTH CONSIDERING THE SETTING UP OF COMPLEMENTARY FUNDING TOOLS TO FURTHER DEVELOP EGNSS PRODUCTS AND APPLICATIONS, INNOVATIVE TECHNOLOGIES AND NEW BUSINESS WHILE INCREASING EGNSS ADOPTION WORLDWIDE.

Low TRL research is also fundamental and should not be overshadowed, even though the results are not directly applicable to the market. Thus, academies and universities should contribute to the EGNSS R&D effort. Encouraging EGNSS business and market champions – e.g. universities or centres of excellence with proven track records – to share their experience and provide advice and mentorship to newcomers in terms of best practices, research support, business incubation and education and training in GNSS, could act as a catalyst.

The need for positioning and timing information is expected to continue to rapidly progress. From transport to agriculture and the surveying of critical infrastructures; the advent of smart cities; the progress of Internet of Things; the emergence of self-driving cars and drones for agriculture and border control; and autonomous solutions for ships and trains… The list of developments goes on, but they all represent new opportunities for the uptake of EGNSS. Whether it be needing a high level of robustness and reliability or security and integrity, an extended seamless availability, increased accuracy or a faster acquisition time – they all need EGNSS.

To meet these opportunities, EGNSS will have to be combined with other GNSS, use several frequencies, be hybridised with other sensors and be prepared to use signals of opportunity.

Besides the innovation work, standardisation and certification are also often necessary, which requires the development of adequate testing and simulation tools. Demonstrations and pilot projects are also required to advertise EGNSS technologies and services, promote their differentiators and foster adoption. They can also support the business development of European players and thus maximise socio-economic benefits.

Non-technical issues must not be forgotten, as they can have a great impact on the technical design of an application or service. Liability is a major one, but depending on the application, it could also include insurance policies, ethics, privacy, etc. Capacity building activities, for instance to educate the next generation of researchers and entrepreneurs in EGNSS, could also include awareness and training actions geared towards the users. Promotion actions to attract buyers and venture capitalists would also be appreciated.

Size and frequency of the calls for proposal must be adapted to the application domain. For instance, because regulated transport application projects that require multimillion Euros projects evolve slowly, bi-yearly calls could be adequate. In contrast, small projects of several hundreds of thousands of Euros or even innovation vouchers or prizes can serve many LBS projects well. However, time to grant must be very fast and calls very frequent - ideally continuously open. Low TRL research needs can be used in between.

CAPACITY BUILDING ACTIVITIES, FOR INSTANCE TO EDUCATE THE NEXT GENERATION OF RESEARCHERS AND ENTREPRENEURS IN EGNSS, COULD ALSO INCLUDE AWARENESS AND TRAINING ACTIONS GEARED TOWARDS THE USERS.

06

LIST OF ACRONYMS

ADS-B	Automatic Dependent Surveillance-Broadcast
AIS	Automatic Information System
AR	Augmented Reality
ATO	Automatic Train Operation
CAA	Civil Aviation Authority
CAGR	Compound Annual Growth Rate
CAV	Connected and Automated Vehicles
CBA	Cost Benefit Analysis
DAS	Driver Advisory System
DFMC	Dual Frequency Multi Constellation
EASA	European Aviation Safety Agency
EDAS	EGNOS Data Access Service
EGNOS	European Geostationary Overlay Service
EGNSS	European GNSS
ELT	Emergency Locator Transmitter
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
EU	European Union
EVS	Enhanced Vision System
FP7	Seventh Framework Programme
GAST	GBAS Approach Service Type
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
H2020	Horizon 2020
HAL	Horizontal Alert Limit
IMO	International Maritime Organisation
IoT	Internet of Things
IPR	Intellectual Property Rights
IWW	Inland Water Way
LBS	Location Based Services
LPV	Localiser Performance with Vertical Guidance

M2M	Machine to Machine
MASPS	Minimum Aviation System Performance Standard
MC	Multi-Constellation
MF	Multi-Frequency
OEM	Original Equipment Manufacturer
OS	Open Service
PA	Precision Agriculture
PBN	Performance Based Navigation
PCP	Pre-Commercial Procurement
PKI	Public Key Infrastructure
PNT	Position Navigation and Timing
PPI	Public Procurement of Innovation
PRS	Public Regulated Service
PVT	Position Velocity Time
R&I	Research and Innovation
RLS	Return Link Service
ROI	Return on Investment
RPAS	Remotely Piloted Aircraft System
RTK	Real Time Kinematic
SAR	Search and Rescue
SBAS	Space Based Augmentation System
SIL	Safety Integrity Level
SMEs	Small and Medium Enterprises
SVS	Synthetic Vision System
T&S	Timing and Synchronisation
TCAS	Traffic Collision Avoidance System
TTFF	Time To First Fix
TV	Television
VB	Virtual Balise
VFR	Visual Flight Rules
WWRNS	World-Wide Radio Navigation System

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