REPORT ON LOCATION-BASED SERVICES USER NEEDS AND REQUIREMENTS

OUTCOME OF THE EUSPA USER CONSULTATION PLATFORM

GALILEO EGNOS Copernicus

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1.0	First issue	18/10/2018
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3.0	Refer to Annex 5	01/08/2021

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01 INTRODUCTION AND CONTEXT OF THE REPORT

Applications relying on position have become part of everyday life leading to an increasing variety of location-based services (LBS). Smartphones, tablets, tracking devices, digital cameras, portable computers, fitness gear all use GNSS positioning (along with network-based or hybrid positioning techniques) for navigation, mapping, gaming and geoadvertising. Moreover, safety applications benefit from accurate emergency caller location tracking. LBS also assist enterprises by providing mobile workforce management and tracking solutions.

The User Consultation Platform (UCP) is a periodic forum organised by the European Commission and the EUSPA involving end users, user associations and representatives of the value chain, such as receiver and chipset manufacturers, application developers and the organisations and institutions dealing, directly and indirectly, with Galileo and EGNOS. The event is a part of the process developed at the EUSPA to collect user needs and requirements and take them as inputs for provision of user driven Galileo and EGNOS services. In this context, the objective of this document is to provide a reference for the European GNSS Programmes and for the mass market community reporting periodically the most up-to-date GNSS user needs and requirements in the LBS market segment. This report is considered a "living document" in the sense that it will serve as a key input to the next UCP event where it will be reviewed and subsequently updated. The UCP will be held periodically (e.g. once per year) and this report will be also periodically updated, to reflect the evolution in the user needs, market and technology captured during the UCP.

The report aims to provide the EUSPA with a clear and up-to-date view of the current and potential future user needs and requirements in order to serve as an input to the continuous improvement of the services provided by the European GNSS systems and their evolutions.

Finally, as the report is publicly available, it serves also as a reference for users and industry, supporting planning and decision-making activities for those concerned with the use of location technologies.

It must be noted that the listed user needs and requirements cannot usually be addressed by a single technological solution but rather by combination of several signals and sensors. Therefore the report does not represent any commitment of the European GNSS Programmes to address or satisfy the listed user needs and requirements in the current or future versions of the EGNSS services.

1.1 METHODOLOGY

The following figure details the methodology adopted for the analysis of the LBS user requirements.

The analysis is split into two main steps: a *"desk research"* to gather main insights, and a *"stakeholders' consultation"* to validate main outcomes.

APPLICATIONS RELYING ON POSITION HAVE BECOME PART OF EVERYDAY LIFE LEADING TO AN INCREASING VARIETY OF LOCATION-BASED SERVICES

In more detail, *"desk research"* was based on a secondary research and aimed at providing a preliminary structured analysis:

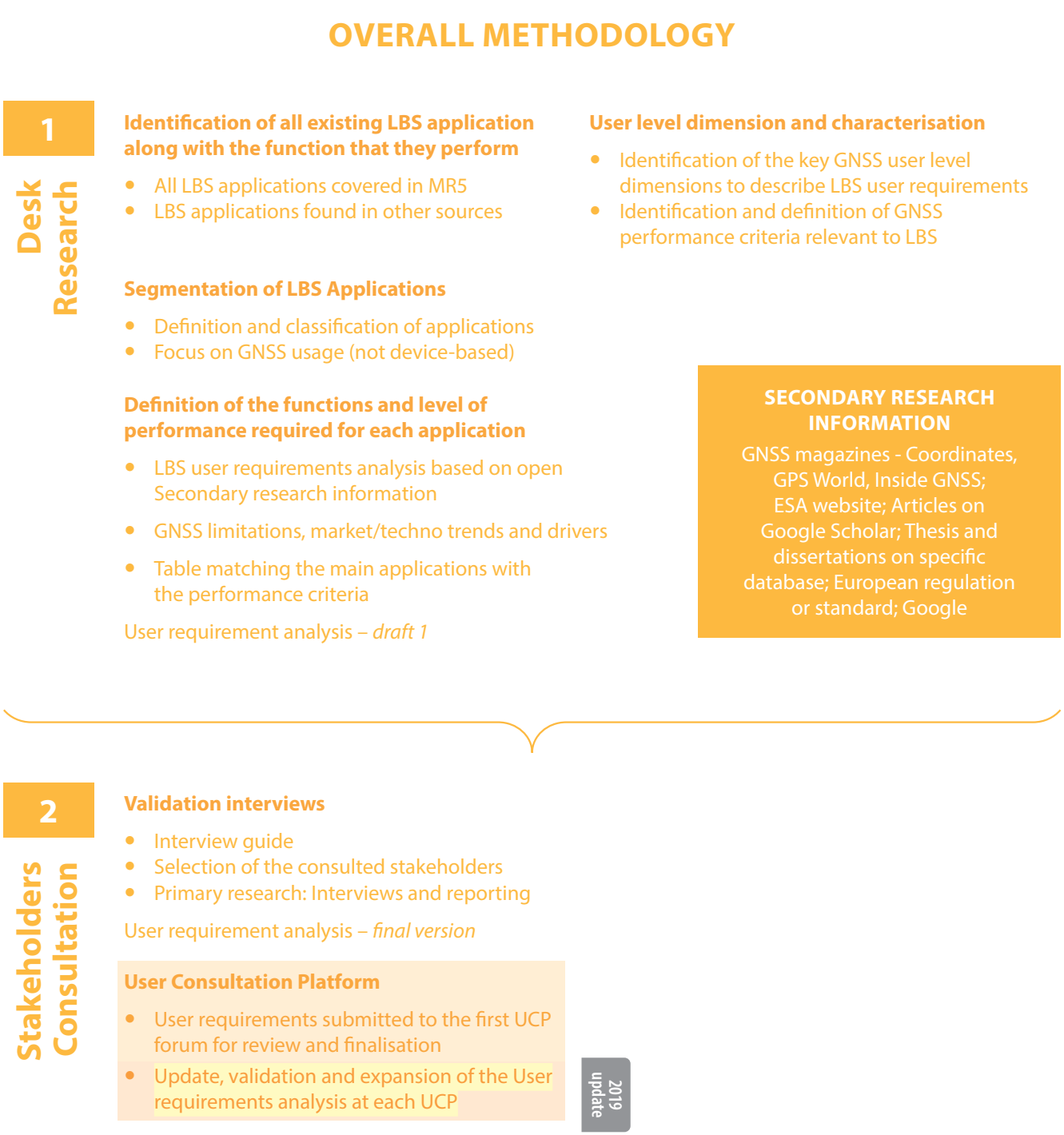
- Leveraging on the LBS applications' segmentation as included in the GSA GNSS market report, additional relevant applications have been identified and included; and
- For each application identified, the function and level of performance required has been determined.

As a result of this activity, a first draft of the *LBS User Requirements* document has been produced.

In the second step, the "*stakeholder consultation*", the main outcomes included in the document have been validated and updated. In this regard, preliminary validation interviews with selected stakeholders have produced the first document version that was used as an input for the first UCP where it was reviewed and finalised. 2019 update

The current document implements all the comments received during the UCP 2018 and thus it constitutes a validated version of LBS user requirements. 2019 update

Figure 1: LBS User requirements analysis methodology



1.2 SCOPE

This document is part of the User Requirements documents issued by the European GNSS Agency for the Market Segments where Position Navigation and Time (PNT) play a key role. Its scope is to cover user requirements for PNT solutions from the strict user perspective and the market conditions that drive them. Therefore, the document includes an analysis of the market trends in this particular segment, then performs a detailed analysis, including the prospective uses of GNSS in this market, finalising with a specification of user requirements in a format that can be used for System Engineering activities.

In more detail, the document is laid out as follows: it starts with a summarised market overview for LBS **(section 4)**, where market evolution and key trends, the main market players and user groups are presented.

Then it moves on to the analysis of GNSS user requirements for LBS **(section 5)**. Section 5 is organised as follows:

- Section 5.1.1 identifies and defines the GNSS performance parameters that are relevant in the analysis of the user requirements for LBS.
- Section 5.1.2 presents an overview of LBS applications extracted from GSA Market Report 5 but also from other sources. It also provides definitions of these applications. They have been split into different categories according to their GNSS usage.
- Sections 5.1.3 to 5.1.18 provide a detailed overview of GNSS user requirements in LBS for each application and category. They are derived from extensive desk research, validation interviews with key LBS stakeholders and discussions during the UCP.

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- Prospective use of GNSS in LBS is addressed in section 5.2. It assesses GNSS technology trends, along with the other positioning technologies that may be used in LBS.
- GNSS limitations for LBS are described in section 5.3.
- Section 5.4 identifies the main evolving criteria (drivers) for user requirements in LBS.
- Standardisation activities are covered in section 5.5.

Finally, a section summarising specification of the main GNSS user requirements for LBS is covered **(section 6)**.

The document is intended to serve as an input to more technical discussions on Systems Engineering and evolution of the European GNSS systems, so that space infrastructures are effectively linked to user needs.

SMARTPHONES, TABLETS, TRACKING DEVICES, DIGITAL CAMERAS, PORTABLE COMPUTERS, FITNESS GEAR ALL USE GNSS POSITIONING

02 EXECUTIVE SUMMARY

This report aims at enhancing the understanding of market evolution, strong points, limitations, key technological trends and main drivers related to the uptake of GNSS solutions across the different LBS applications. These elements are essential in order to frame the appropriate technology and service offering developments vis-à-vis the requirements of the respective users.

To that end the report starts with an overview of the GNSS LBS market trends. The increasing popularity of context-aware LBS applications and the continuously growing usage of GNSS devices are driving the rising GNSS use in LBS, an evolution forecasted to continue over the next years. It is particularly the case in the Asia-Pacific, which has been consolidating its position as the largest regional LBS market in terms of devices. In a context of global urbanisation and smart city GNSS-enabled LBS addresses some of the most immediate economic and societal concerns such as improvement of work productivity, ease of movement, tracking of people and resources and use of effective services to facilitate consumer interactions. To better understand market dynamics, the report provides a brief description of the landscape of market players. The LBS segment is dominated by non-EU players, with North American companies leading the chipset market and Asian companies accounting for the majority of handset revenues. European companies continue to perform strongly in app development.

> OVER RECENT YEARS, A BURGEONING GROUP OF NEW APPLICATIONS HAS EMERGED THAT REQUIRES FAR MORE STRINGENT HORIZONTAL AND VERTICAL ACCURACY LEVELS

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GNSS-enabled solutions cover a wide range of applications that can be divided into 16 main categories according to their usage: navigation, mapping and GIS, geomarketing and advertising, safety and emergency, enterprise applications, sports, games, health, tracking, augmented reality for leisure, social networking, infotainment, commercial, augmented reality for professional applications, robotics (high GNSS use) and robotics (high GNSS use). The user requirements of many established LBS applications, such as turn-by-turn navigation, infotainment and social networking apps have remained relatively constant since their inception and continue to be satisfied by levels of GNSS accuracy of more than 5 meters. Over recent years, a burgeoning group of new applications has emerged that requires far more stringent horizontal and vertical accuracy levels. These range from innovative safety-critical m-Health technologies such as guidance applications for the visually impaired, to mapping and GIS applications which are among the most demanding types of smartphones apps. Moreover, application categories such as geomarketing and advertising, fraud management and location-based billing require authentication of the position to protect app users or service providers from malicious signal interference such as spoofing. A synopsis of the user requirements is provided on page 9 for the key performance parameters[1] with the exception of availability where almost all applications require PNT in urban canyons under canopy and indoors.

The LBS user requirements are affected by standardisation activities related to signalling, definition of performance requirements for positioning including GNSS and A-GNSS, as well as definition of testing procedures for both of the previous areas. The main standardisation bodies here are the 3rd Generation Partnership Project (3GPP), the Open Mobile Alliance (OMA), ETSI TC SES, and CEN-CENELEC. As it comes to performance requirements for A-GNSS in a cellular environment, they are based on the US E911 performance requirements as a guideline. Therefore, it is assumed that GPS is always used for initial signal acquisition, so Galileo, in common with GLONASS and Beidou, is considered as a GNSS of secondary choice. There is a similar situation in case of testing requirements. At the same time, it is important to mention that Russian regulations dictate that smartphones sold on the Russian market must rely on GLONASS to avoid penalty taxes. A new European Union Regulation approved on 12 December 2018 making GNSS and Wi-Fi location mandatory in all new smartphones. The GNSS chip must be compatible and interoperable with at least the Galileo system [RD81].

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1 A qualitative characterisation of parameters is provided in section 5.1.1

	Performance parameters				
	Accuracy	**Time to First Fix**	**Power consumption**	**Resilience**	**Integrity message**
Navigation	Low/Medium (High for smart parking)	Low/Medium	Low/Medium	Susceptibility to interferences	-
Mapping & GIS	High	Low	Low	Susceptibility to interferences	Required
Geo marketing and advertising	Low/Medium	-	Low	Susceptibility to spoofing	-
Safety and emergency	Medium	Low/Medium	Low	Susceptibility to interferences	-
Enterprise applications	Low/Medium	Low/Medium	Low	Susceptibility to interferences and spoofing	-
Sports	Medium	Low/Medium (High for fitness and performance monitoring)	Medium	-	-
Games	High	High	Low	Susceptibility to interferences and spoofing	-
Health	High	High	Low	Susceptibility to interferences	-
Tracking	Medium	Medium/High	Low/Medium	Susceptibility to interferences and spoofing	-
Augmented reality for leisure	High	Medium	TBC	Susceptibility to interferences and spoofing	-
Social networking	Low/Medium	High	Low	-	-
Infotainment	Low	Low/Medium (High for points of interest)	Low	-	-
Commercial	High	High	High	Susceptibility to interferences and spoofing	Required
Augmented reality for professional applications	High	Medium	TBC	Susceptibility to interferences and spoofing	-
Robotics – High GNSS use	High	Low	TBC	Susceptibility to interferences and spoofing	-
Robotics – High GNSS use	High	Medium/High	TBC	Susceptibility to interferences and spoofing	-

THIS REPORT AIMS AT ENHANCING THE UNDERSTANDING OF MARKET EVOLUTION, STRONG POINTS, LIMITATIONS, KEY TECHNOLOGICAL TRENDS AND MAIN DRIVERS

Despite the large penetration of GNSS in the LBS segment, its use has some limitations: power consumption, availability in challenging environments (such as urban canyons), indoor availability, susceptibility to multipath, interference, jamming and spoofing. Such hurdles are typically overcome by employing hybrid solutions using additional complementary positioning technologies when necessary or by following best practices regarding the type of GNSS equipment used.

GNSS techno trends respond to the current and future expectations of the domain which are to provide increasingly accurate and available position, faster fix but constrained by low power consumption as most of LBS devices are battery powered (implying that they must remain small and lightweight).

Taking all these above aspects into account, the report presents a user requirement analysis across the different GNSS-enabled or supported applications in LBS, based on performance requirements.

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[RD90]	Augmented Public Safety	*Augmented Public Safety: AR Technology Gives Emergency Services Second Set of Eyes*, URL: https://www.sealevel.com/2018/07/27/augmented-public-safety-ar-technology-gives-emergency-services-second-set-of-eyes/	27.07.2018
[RD91]	The Multiple Uses of Augmented Reality in Education	*The Multiple Uses of Augmented Reality in Education*, URL: https://www.emergingedtech.com/2018/08/multiple-uses-of-augmented-reality-in-education/	-
[RD92]	The Benefits of AR in education and learning process	*The benefits of augmented reality in education and learning process*, URL: https://www.talk-business.co.uk/2018/07/09/the-benefits-of-augmented-reality-in-education-and-learning-process/	-
[RD93]	The Ultimate Guide to Agricultural Robotics	*The Ultimate Guide to Agricultural Robotics*, URL:	
[RD94]	TeleRetail Delivery Robot	*TeleRetail Delivery Robot – Feasibility Study for an Automated Urban On-demand Courier Service*, URL: https://business.esa.int/projects/teleretail-delivery-robot	Updated 17.05.2018
[RD95]	Law Enforcement Robotics and Drones	*Law Enforcement Robotics and Drones*, URL: https://emerj.com/ai-sector-overviews/law-enforcement-robotics-and-drones/	Updated on 9.11.2018
[RD96]	Personal Robots for your Home	*12 Personal Robots for Your Home*, URL: https://tech.co/news/personal-robots-for-your-home-2017-09	11.09.2017
[RD97]	What You Need to Know About Industrial Painting Robots	*What You Need to Know About Industrial Painting Robots*, URL: https://conceptsystemsinc.com/what-you-need-to-know-about-industrial-painting-robots/	-
[RD98]	Autonomous Vehicles in Logistics	*Autonomous Vehicles in Logistics*, URL: https://cerasis.com/2017/05/24/autonomous-vehicles-in-logistics/	-
[RD99]	Intelligent Marking	*https://www.intelligentmarking.com/#*	-

04 GNSS MARKET OVERVIEW AND TRENDS

4.1 MARKET EVOLUTION AND KEY TRENDS

4.1.1 KEY MARKET TRENDS

The global macro socio-economic and demographic trends have a big impact on the way people use technology and LBS applications and what kind of requirements they therefore have for GNSS.

- **Growth of global population and shipments of GNSS devices**

The mobile phone coverage is now near-ubiquitous in urban areas, with an estimated 95% of the global population living in an area covered by a basic 2G mobile-cellular network. Overall, **the total number of mobile-broadband subscriptions was expected to reach 3.6 bln by the end of 2016**, compared with 3.2 bln at the end of 2015 [RD35].

The global population growth, increasing **average standard of living** and purchase power, as well as **decreasing prices for electronics** and mobile services have led to a booming growth in the use of LBS devices. The global installed base of GNSS-enabled handsets was 4.1 bln in 2016, with an expected rise to 6.1 bln in 2019 [RD1]. The regional distribution is not homogenous and many users own more than one device, especially in developed countries. Continuous economic growth led **Asia-Pacific** to consolidate its position as the largest regional LBS market in terms of devices, with a total of 1 bln shipments in 2016. North America and **the EU** accounted for 320 mln and **200 mln** shipments respectively. **Smartphones** represent the majority of shipments, with more than 1.7 bln smartphones shipped in 2016. Other GNSS-enabled devices accounted for around 175 mln units in 2016 (tablets represented the second largest number of shipped device) [RD1]. At the same time, it is predicted that personal tracking devices will be the fastest growing market in LBS between 2016 and 2025, with a CAGR of 17.9% [RD1].

- **LBS has a key role to play in the context of global urbanisation and the smart city**

Driven by global **urbanisation**, more than 50% of the world population already lives in cities and it is forecasted to grow up to 66% by 2050 [RD34]. This results in the need for better services to be provided as an integral part of cities' infrastructure. At the centre of these changes lies the **smart city concept, enabled by ICT services**. Smart cities concept relies on an integrated system for collecting, measuring, collating and broadcasting data from different sensors and for making it easily accessible to stakeholders for efficient governance, effective development and management of resources. It is a field of uptake of GNSS-enabled IoT devices, used among others in connected vehicles, healthcare solutions, water and waste management, energy management etc.

The increasing density of resources due to urban sprawl and suburbanisation force a dynamic way of life, in which **time becomes a scarce resource**. People work, commute, consume, socialise and look for entertainment using LBS applications. Business users seek to improve work productivity, ease movement, track their resources and use effective services to facilitate consumer interactions.

- **Boom of context-aware applications**

The development of successful apps continues to drive the global growth of the smartphone market, with high-end devices now commonly making use of multi-constellation and hybrid positioning. Technological advancements in indoor positioning will further fuel the development of new applications. The app market is in a sustained booming phase, with total app revenues projected to grow from €40.9 bln in 2015 to €73.4 bln in 2017. The average annual growth rate of app revenues between 2011 and 2017 will therefore be at a staggering rate of 45% [RD9], [RD10].

AN ESTIMATED 95% OF THE GLOBAL POPULATION LIVES IN AN AREA COVERED BY A BASIC 2G MOBILE-CELLULAR NETWORK

Context-aware applications are a category of mobile LBS applications that is gaining greater importance in the whole segment. The app market is moving beyond **pull applications** - in which users manage and control the information provided to them via the app - **to a proliferation of push services**, which determine the timing and content of displayed information based on the

user's context. The context can depend on various aspects, such as individuals' location, activity status, movement patterns, past preferences, calendar appointments, blood pressure and many other factors [RD37]. With the share of context-aware apps relying on GNSS exceeding 90% in 2016, GNSS and location information is truly becoming a key enabler of context-aware applications [RD1]. Context-aware apps are a growing driver of the app market, with revenues expected to rise from €11.7 bln in 2014 to almost €30.6 bln in 2019. The high GNSS penetration in context-aware apps is also reflected in the revenues coming from the GNSS apps. Around 28% of global app revenues will be generated by context-aware apps, out of which GNSS-attributable app revenues will represent almost 90% of the total global app revenues in the upcoming years until 2019 [RD1].

4.1.1 MARKET EVOLUTION

The increasing popularity of context-aware LBS applications and the continuously growing usage of GNSS devices are driving rising GNSS use in LBS, a trend forecasted to continue over the next years.

- **Continuous growth of GNSS penetration in LBS devices**

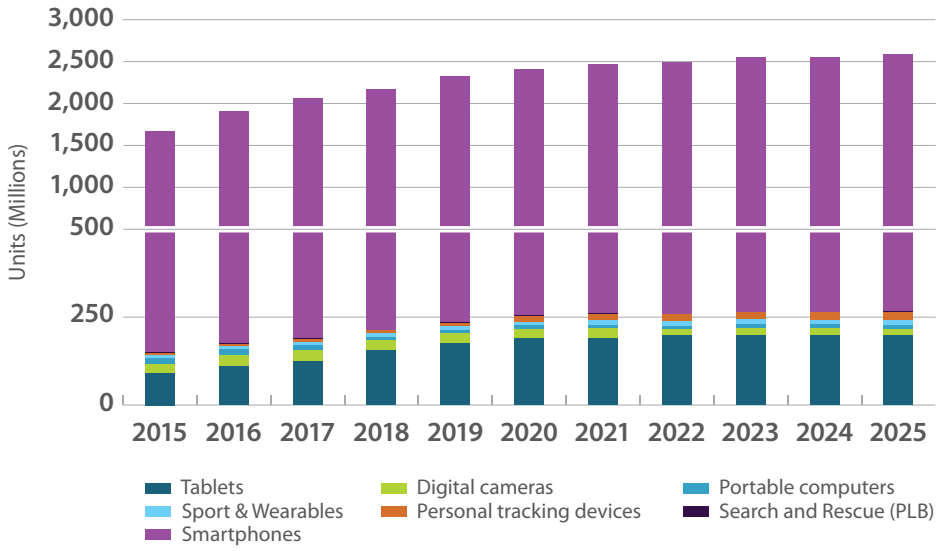
In 2020, more than 2.4 bln units of GNSS devices are forecasted to be shipped, reaching more than 2.5 bln units in 2025. By then, the total installed base of GNSS devices will exceed 8 bln units, with an estimated overall GNSS revenue from LBS forecasted to be more than € 80 bln[2]. Asia-Pacific will continue to play a major role in driving growth in smartphone shipments. The device market will further be dominated by smartphones that have already become multi-functional devices, used also for applications in other GNSS segments (e.g. Road). As premium smartphones increasingly approximate the performance of low-end professional-grade receivers, the technological evolution of multi-constellation smartphones could in the future lead to an even larger democratization of some professional activities, such as rural cadastral surveying, and the further "cannibalisation" of dedicated devices. With a CAGR of 15% between 2012 and 2016, shipments of GNSS enabled wearables, including GNSS fitness devices, smart watches and glasses, will increase to 14.4 mln units by 2025 [RD1]. Also, a considerable share of the non-GNSS wearables will be leveraging on GNSS by being paired with a smartphone.

Personal tracking devices represent an interesting market niche and will gain prominence, as technological advancements will enable devices to hit the mass market and to increase the competitiveness of available solutions. The shipments of such devices are foreseen to increase from 4.2 mln units in 2015 to 23.6 mln units in 2025 [RD1]. In the context of LBS, Personal Locator Beacons (PLBs) assist rescue authorities in their search to locate people in distress, such as hikers and other adventurers on land and employees working in remote areas. In 2015, around 18 000 PLBs destined for land applications were produced worldwide [RD1].

- **The app market will continue to grow into "ubiquitous" reality**

As elaborated in the previous section, the market for apps that rely on positioning data is forecasted to grow in terms of revenues and diversification over the upcoming years. The

Figure 2: Shipments of GNSS devices by type



2 Only data revenue arising from the use of location based services considered.

app market will continue to grow into "ubiquitous" reality. The integration of outdoor and indoor LBS is ushering in the era of **hybrid positioning**, which includes all services that use both outdoor and indoor LBS technologies to enable a **seamless navigation experience** between outdoor and indoor environments.

- **The success of businesses will increasingly depend on location-based marketing**

Location-based marketing is forecasted to become one of the industry standards, especially for companies that offer services in different physical locations. Restaurants, hotels, shops and other points of interest will become increasingly dependent on LBS users. With the rise of context-aware apps, more and more business users are profiting from services such as location-based aggregation services, geolocation social media monitoring and proximity-based marketing applications to drive sales and customer retention.

The success of context-aware applications assumes that the devices are continuously location-aware (seamless indoor/outdoor), are tracking the activity of the user and are analysing the "location+motion/activity history" of the user. As the awareness and tracking need to be done on the device, the market needs solutions are mostly independent of the cloud and can be executed in the device with minimal use of the device resources. This will also largely solve the privacy issues as the device is not expected to stream all the raw data to the cloud, but the user can control the exposure from his/her device or account.

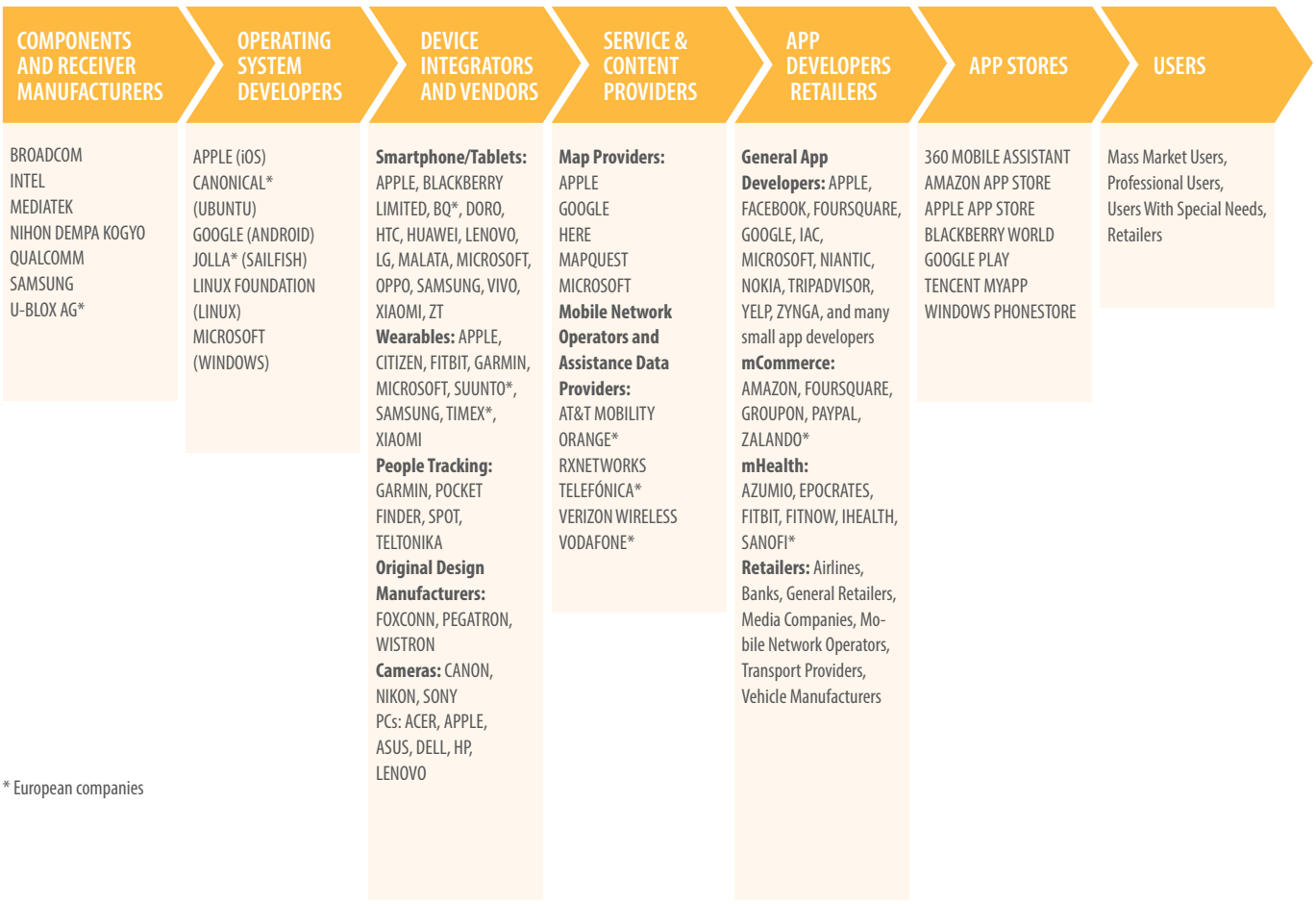
There will be a further market consolidation amongst the service providers and applications developers, with big players gaining ever greater importance. Many start-ups have business models that rely on selling the app to established companies once a certain user-base is reached. This trend is likely to continue over the next years.

4.2 MAIN MARKET PLAYERS

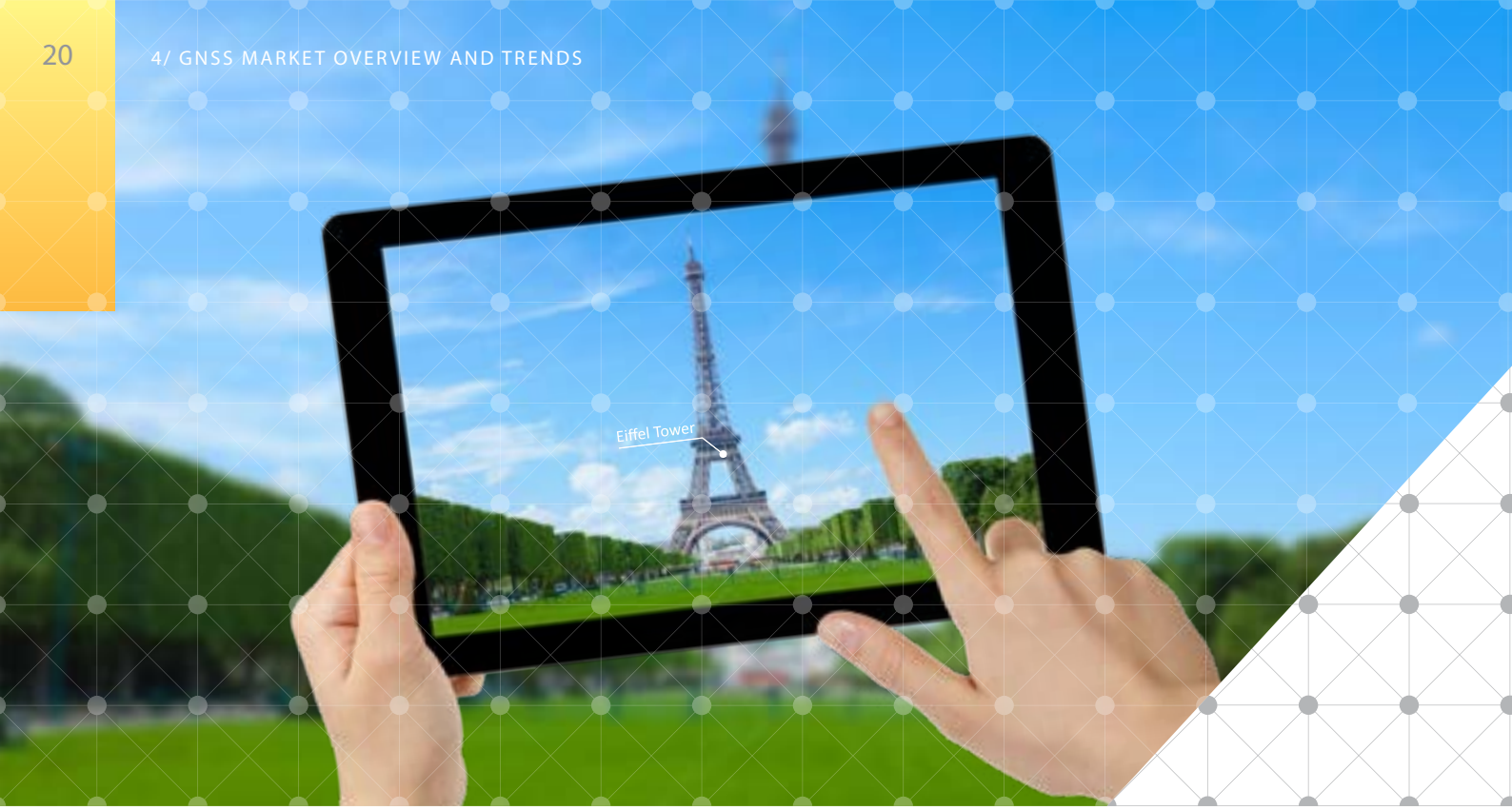
The LBS segment is dominated by non-EU players, with North American companies leading the chipset market and Asian companies accounting for the majority of handsets revenues (with the significant exception of Apple). European companies continue to perform strongly in app development but their global share is limited.

The main industry stakeholders in the LBS GNSS market value chain are **components manufacturers, device integrators and vendors, service and content providers, app developers/retailers** and **app stores**.

Figure 3: LBS Value Chain



* European companies



The value chain with main players is provided in figure 3 [RD1]:

The value chain considers the key global and European companies involved in the GNSS downstream activities.

4.3 MAIN USER GROUPS

Mobile application users, including LBS and digital innovations in general, can be characterised by two important criteria: the digital capability of users and their trust in the applications they use [RD41]. Digital capability takes into account the user's ability to fully use all the latest technology features, functions and services available to improve their overall effectiveness and quality of life. Trust involves the willingness of users to share personal data and, in some cases, to renounce privacy in exchange of a perceived benefit.

At the same time, the user groups for LBS applications, as for any other target group, can be segmented based on four different criteria or combinations of them:

- Geographic, based on users' region, city size, density, climate. This segmentation describes regional differences between LBS users.
- Demographic, which is based on users' age, family size, family life cycle, gender, income, occupation, education, religion, race, generation, nationality, social class.
- Psychographic, which analyses users' lifestyle, personality, values, often connected with degree of trust to technology.
- Behavioural segmentation, which categorises occasions, benefits, usage rate, loyalty status, readiness stage, and attitude toward LBS applications and technology in general.

LBS app users' motivations greatly depend on which user group(s) they belong to and represent different levels of requirements within the app:

- To provide basic location-based information or how to get somewhere (usually users with low digital capability and/or low trust in apps);
- To provide a discovery experience of new items and offers available in a user's physical space (medium digital capability and/or medium trust in apps);
- To "think for the user" in an integrated way, to have pushed individualised and personalised services with location-specific recommendations and information (high digital capability and/or high trust in apps).

Table 1 summarises different groups of users based on their psychographic and behavioural characteristics. This user segmentation is used in Chapter 5.1 as a characterisation criterion for the different LBS application categories considered in this study.

Table 1: LBS Applications User Segments. Source: Based and adapted on GNSS opportunities in Location Based Services [RD39], [RD40], [RD41]

Group	Description	Primary LBS needs and motivations to use apps	Primary applications
Enthusiasts	• Early adopters, such as hipsters who would like to be trendsetters. They are aware users and can accept to give up some privacy in order to benefit the most from LBS applications. Have high demands towards applications. • Mass adopters, who are the large group of unaware enthusiasts heavily using LBS applicatins. They do not have have deep knowledge about LBS and privacy issues, however can be sensitive towards possible privacy issues when hearing news in media.	Exploring new and innovative services. LBS apps are the way to express themselves, socialise and are natural part of their life.	All
Traditionalists	Have limited interest or trust in technology and high privacy concerns. Use LBS applications only when really needed.	Safety, convenience, saving of time	Navigation Safety and emergency Health Infotainment: Points of interest (POI)
Pragmatists	Working professionals, career-oriented, have limited time and spend a lot of time at work. Like having control and use the apps with awareness.	Productivity growth, time savings, self-expression, socialising, getting discounts and offers.	Navigation Sports Social networking Infotainment Commercial Geomarketing and advertising Augmented reality
Professional and business users	Require specific LBS applications for day-to-day use at work. Have high requirements towards reliability of applications.	Productivity at work	Tracking services Navigation Safety and emergency Health Enterprise applications Commercial Geomarketing and advertising GIS and Mapping Augmented reality
Users with special needs	People concerned about other people with special needs or having special needs themselves. Have high requirements towards reliability of applications.	Safety and care for other people (kids, patients, elderly people) and themselves	Tracking services Health Augmented reality
Bulk users	Service POI providers and owners, advertisers, marketing companies	Commercial success, building marketing strategies and consumer insights	Commercial Geomarketing and adverstising Infotainment Augmented reality

05 GNSS USER REQUIREMENTS ANALYSIS

A table entitled *"Synthesis of LBS User Requirements"* summarises all GNSS user requirements for every LBS application covered in this report. It is provided in Annex 1.

5.1 GNSS USE IN LBS

5.1.1 GNSS USER LEVEL CRITERIA

The performance of GNSS may be evaluated/perceived according to several criteria. **Each criterion** may include **several performance parameters** or non-measurable parameters. Only those criteria and performance parameters that are relevant for the analysis of LBS user requirements have been retained, i.e. **accuracy, service area, availability, resilience, integrity and power consumption**.

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Accuracy is given in terms of horizontal and vertical position accuracy, but timing accuracy is not considered in this report. **Service area** is defined in terms of geographical coverage. **Availability** covers both physical environmental conditions such as urban canyon and canopy (natural obstruction caused by a layer of branches of trees), and the time required to make a first fix (TTFF) and the fix update type.

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Resilience, or robustness, covers susceptibility to interference and susceptibility to spoofing. **Integrity** provides the user with a probability that the position provided is (or is not) correct and it also provides the time required before an incorrect position can be determined and signalled to the user. Integrity is considered only for liability critical applications that is those applications in which the consequences of an undetected GNSS-generated position error can generate significant legal or economic consequences (e.g. fraud management, billing, smart parking, parolees monitoring, etc.). **Power consumption** is not strictly a GNSS performance parameter, however it is also considered in this analysis. Most LBS devices are battery powered (which implies that they must remain small and lightweight) and GNSS is considered one of the heaviest drain on smartphones batteries.

More details on the definitions of the above criteria are given in Annex 2.

Note that **Accuracy, availability** and **power consumption** are consistent with parameters that Google uses in its geolocation API which is the main interface for the application developers, accessing the location information on smartphones today.

The proportion of GNSS use in each application category has also been assessed in this analysis.

Table 2: List of criteria / performances relevant to users

Criterion	Performance	Characterisation
Accuracy	Horizontal	Low: 5 to 10 m Medium: 1 to 5 m High: <1 m
	Vertical	Low: 5 to 20 m (95%) Medium: 1 to 5 m (enabling floor recognition) High: <1 m
Service area	Geographical Coverage	Global / Regional / Local
Availability	Urban canyon Canopy Indoors	Yes/No
	Light Indoor (Below 5 meters from window) Deep indoor	2019 update
	TTFF (hot start)	Low: More than 30 s Medium: 2 to 30 s High: < 2 s
	Fix update type	Continuous (with a given update rate) On Request
Resilience	Susceptibility to interference	Yes/No
	Susceptibility to spoofing	Yes/No 2019 update
Integrity	Risk	Low: < 95% probability Medium: 95 to 99% probability High: 99.5% probability
	Time to alert	In seconds
Power consumption		Low: < 2mA Medium: 2 to 10mA High: > 10mA

5.1.2 OVERVIEW OF LBS APPLICATIONS

The LBS applications that are considered in this analysis are consistent with GSA Market Report 5 [RD1]. They have been completed with additional applications and applications categories found in other sources (in italics in the following table).

Road navigation applications that are supported by **smartphones** have also been included in the following analysis.

Table 3: LBS applications and definitions

Application categories	Applications	Applications description
Navigation	Route planning and turn-by-turn navigation	Route planning and turn-by-turn instructions based on GNSS positioning. Includes driving, walking, riding bicycles and recreational sailing [RD1], [RD5], [RD11]. Il also delivers real-time information such as traffic updates or weather reports so the user can plan accordingly.
	Real-time public transport	Informs about transport vehicles position, when the next one should arrive and provides the user with service updates [RD5].
	Eco-driving and carbon emission footprint	GNSS-enabled application that helps drivers optimise their car journeys to reduce greenhouse gas emissions [RD17].
	Smart parking	Provides drivers with information on empty parking slots [RD16].
Mapping and GIS	Mapping and GIS	GIS applications can generate contour maps from analysed data and present these maps in a digital form [RD96]. Smartphones enable users to become map creators thanks to the democratisation of digital mapping [RD1].
Geomarketing and advertising	Geomarketing and advertising	Consumer preferences are combined with positioning data to provide personalised offers to potential customers and create market opportunities for retailers [RD1].
Safety and emergency	Search and rescue	Alerts search and rescue services and provides them with accurate emergency caller location [RD1], [RD3].
	E112	Emergency phone number that can be dialled free of charge from most mobile telephones in order to reach emergency services (ambulance, fire and rescue, police). The telecom operator transmits the location information to the emergency centre [RD1].
Enterprise applications	Mobile workforce management	Aims to manage employees working outside the company premises and to improve operational efficiency [RD1], [RD21].
Sports	Fitness and performance monitoring	Records data such as real-time distance, speed/pace, location, elevation, travelled distance, step counters to monitor users' performance. Speed and elevation charts are provided (includes running, biking, hiking, swimming, etc.) [RD1], [RD5], [RD12], [RD13].
	Sports gear retrieval: golf balls	GNSS-enabled application that helps locate sports gear [RD19].
	Fishing assistance	GNSS-enabled application that helps locate fish [RD20].
Games	LBS games	GNSS enables a wide range of location-based games on smartphones and tablets [RD1].
Health	Guidance for visually impaired	Provides turn-by-turn instructions based on GNSS positioning that help visually-impaired get around more easily [RD1], [RD4].
	Vulnerable people tracking	Tracks elderly, people with cognitive disabilities. Includes the deployment of local geofences that trigger an alarm when a user leaves the perimeter [RD3], [RD5].
	Fall detection	Alerts when a fall event has occurred [RD22].
	Lone worker protection	Ensures the security of employees through features such as two-way communications and automatic location. Sends alarm to supervisors or to alarm receiving centres in case of emergency [RD21].

Application categories	Applications	Applications description
Tracking	Children locators	Allows parents to track their children. Includes the deployment of local geofences that trigger an alarm when a user leaves a perimeter or approaches a dangerous area (e.g. swimming pool) [RD5], [RD21].
	Parolees monitoring	Monitors parolees. Includes local geofences that trigger an alarm when a parolee leaves the perimeter (if this is a stipulation of their parole conditions) [RD21].
	Pets locators	Allows masters to track their pets. Some of them also enable to track pets' physical activity levels [RD5], [RD18].
	Tracking of valuable and stolen goods	Allows owners to locate valuable goods and assets such as luggage, bikes, jewellery, etc. [RD5], [RD23]. Identifies the location of cargo or containers equipped with GNSS receivers whilst in transit by road, rail or ships [RD5].
Augmented reality for leisure	Gaming	Augmented reality gaming is the integration of game visual and audio content with the user's environment in real time [RD82].
	Broadcast and live events	Augmented reality enhances spectators' experience during broadcast and live events by the overlaying content [RD85].
	Navigation	These applications use a smartphone's GNSS and camera to implement an augmented reality-powered GNSS navigation system. With the AR feature, the driver no longer needs to follow a map on their phone. Instead, they are guided by a virtual path on the smartphone camera preview [RD83].
	Travel applications	Augmented reality applications contribute to improve travellers' experience regarding accommodation, transport, catering and tourist attractions [RD84].
	Sports/adventure	AR applications help athletes assess their techniques and improve their performances [RD89].
Social networking	Friend locator	Provides on-demand information to end users about the location of friends relative to themselves [RD1].
	Dating	GNSS-enabled apps that use participants' current locations to connect people, allowing them to chat and to possibly meet up [RD24].
	Chat and instant messaging services	Location information used in chat and instant messaging services allows the user to estimate how far they are from each other at the time of communication
Infotainment	Points of interest	Provides content relative to the end user's location. Such location may include location-based landmarks, restaurants, petrol stations, banks, ATMs, hospitals, etc. [RD5], [RD8].
	Photos and videos geotagging	Adds geospatial metadata to digital media such as photographs, videos, messages, blogs and web pages [RD5]
	Geolocated news	Application that sends users a push notification on their mobile device when news breaks near them [RD15].
Commercial	Fraud management	Creates another level of security during a credit card transaction by checking the customer's location through his/her smartphone [RD7].
	Billing	Payment processing based on location or activity duration for public transport, gyms, theme parks, parking [RD5], [RD17]

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Application categories	Applications	Applications description
Augmented Reality for Professional applications	Emergency and Public Safety	Augmented reality can be useful for both law enforcement and emergency forces. Police officers' benefit from enriched training sessions using augmented reality. They also benefit from enhanced vision of the city when chasing suspects [RD90].
	Customer Experience & Marketing	Augmented reality applications can enhance customers' experience by displaying real-time digital information in conjunction with the real word [RD80].
	Training and Education	Augmented reality applications can be used for training purposes to bridge the gap between theory and practice and to make workers operational more quickly. AR applications are also used by teachers when organising field trips [RD80].
Robotics High GNSS use	Gardening robots	Gardening robots are able to perform gardening labour autonomously [RD80].
	Delivery robots	Delivery robots are used to support the last mile deliveries in cities and delivery in remote areas [RD80].
	Security and surveillance	Security and surveillance robots are used for the security and surveillance of areas [RD80].
Robotics Low GNSS use	Personal assistant robots	Personal assistant robots help individuals with their day-today household tasks. They are mainly used indoor and they interact with humans [RD80].
	Painting robots	Painting robots are meant to paint autonomously a defined surface [RD80].
	Automated guided vehicle/logistics	Automated guided vehicles/logistics deal with logistics tasks indoor and outdoor [RD80].

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The sections 5.1.3 to 5.1.18 gather all available information on GNSS user requirements for each LBS application listed in Table 3.

5.1.3 NAVIGATION

5.1.3.1 ROUTE PLANNING AND TURN-BY-TURN NAVIGATION

Turn-by-turn navigation is an application that provides drivers, riders and pedestrians with directions for a selected route on a continuous basis in the form of spoken and/or visual instructions. Thanks to data collected from mobile GNSS devices on traffic flows, crashes and travel time, the system keeps the user up-to-date about the best route to the destination [RD8]. This application usually combines precision location technologies with geographical maps that are shown on the handset display along with instructions.

GNSS is the main source of outdoor positioning for such applications. Pedestrian navigation is more challenging than road navigation. Indeed, the slower movement speed is an issue for the map-matching algorithms, which results in higher likelihood of drifts in the position [RD17]. Moreover, in contrast to motorised vehicles, a large part of pedestrian movement takes place indoors or in light indoor environment. Therefore, complementary navigation methods need to be sought to assist in these environments. The use of Assisted GNSS (A-GNSS), network positioning and inertial/motion sensors can be considered as three of these additional methods.

Common devices enabling this application are smartphones, portable navigation devices (PNDs) and in-vehicle navigation systems.

The main GNSS user requirements are:

- **The reported position accuracy:**
  - Horizontal: medium for road navigation, low/medium for pedestrian navigation [RD79]

- Vertical: low for road navigation, low for pedestrian navigation

- **Geographical coverage:** Global [RD47]

- **Availability / Timeliness:**
  - Availability in urban canyons [RD17], under canopy [RD17] and indoors for road and pedestrian navigation [RD48]
  - TTFF: low [RD79]
  - Need for continuous positioning once the operation has started [RD31]

- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD79]
  - Susceptibility to spoofing: Yes [RD79]

- **Power consumption:** medium to low consumption [RD6]

5.1.3.2 REAL-TIME PUBLIC TRANSPORT

The use of GNSS technology in public transportation such as buses and taxis is increasing rapidly. By equipping public transport vehicles with GNSS receivers and cellular or other modems, their location and speed can be constantly tracked and this information is in turn used to display estimated time of arrivals at street-side bus stops or tracking taxi cabs [RD73].

Common devices enabling this application are on-board units.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal accuracy: medium [RD79]
  - Vertical accuracy: N/A

- **Geographical coverage:** Global [RD47]

- **Availability / Timeliness:**
  - Availability in urban canyons [RD73] and indoors [RD71]
  - TTFF: 10 seconds [RD71]
  - Need for continuous positioning once the operation has started [RD73]

- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No

- **Power consumption:** low [RD79]

5.1.3.3 ECO-DRIVING AND CARBON EMISSION FOOTPRINT

Eco-driving applications allow drivers to improve their driving techniques and reduce their emissions while saving money on fuel. The use of GNSS systems is a key enabler for this application. Position, Velocity and Time (PVT) are used in the calculations related to the eco-driving module in order to implement measures that will have an impact in the fuel and CO2 production in the road domain.

Common devices enabling this application are smartphones and portable navigation devices (PNDs).

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal accuracy in the tens of meters [RD71]
  - Vertical accuracy: <10 meters [RD71]
- **Geographical coverage**: Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD17] and under canopy [RD71]
  - TTFF: 15 seconds [RD71]
  - Need for continuous positioning [RD31]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** medium to low consumption [RD6]

2019 update

5.1.3.4 SMART PARKING

Smart parking applications provide real-time parking availability to the drivers. GNSS is then used to guide the driver to the best available space with turn-by-turn instructions. The GNSS user requirements in this application are the same as those of route planning and turn-by-turn navigation applications, except for the horizontal accuracy which should be higher in order to enable the parking assistance feature

Common devices enabling this application are smartphones, portable navigation devices (PNDs) and in-vehicle navigation systems.

The main GNSS user requirements are:

- **The reported position accuracy:**
  - Horizontal: high [RD79]
  - Vertical: medium [RD79]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD17], under canopy [RD17]
  - TTFF: 10 seconds [RD71].
  - Need for continuous positioning once the operation has started [RD31]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** medium to low consumption [RD6]

2019 update

The following table summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Navigation. Whenever two or more applications in this category have different requirements for a performance parameter the most stringent one has been included in this table.

Table 4: Main GNSS user requirements, proportion of GNSS and main user groups for Navigation

Accuracy	**Horizontal**	High [RD79]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD17]
	Canopy	Yes [RD17] [RD71]
	Indoors	Yes [RD79]
	TTFF	Medium [RD71]
	Fix update	Continuous [RD31]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD79]
	Susceptibility to spoofing	Yes [RD79]
Power consumption		Low [RD79]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Traditionalists Pragmatists Professionals and business users

2019 update

5.1.4 MAPPING AND GIS

A geographic information system (GIS) captures, stores, analyses, manages and presents all types of geographically referenced data. GIS technology combines database, mapping and statistical methods to integrate georeferenced data into visual displays such as maps where the relationships, patterns and trends in the data can be more easily identified [RD61], [RD62]. The position associated with the data can be provided by a GNSS receiver.

Common devices enabling this application are smartphones and tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal accuracy: between 10 centimetres and 50 centimetres [RD71]
  - Vertical accuracy: between 10cm and 50 cm [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD71], under canopy [RD71] and indoors [RD71]
  - TTFF: a few minutes [RD71].
  - Need for continuous positioning [RD71]. Update rate: comprised between 1Hz and 5 Hz [RD71]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Integrity:** Integrity could be considered for liability risk maps [RD79]
- **Power consumption:** low (smartphone-based) [RD79]

The following table summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Mapping and GIS.

5.1.5 GEOMARKETING AND ADVERTISING

Geomarketing and advertising use a combination of customers' preferences and positioning data to provide personalised offers to potential customers and create market opportunities for retailers [RD1].

At first geo-fencing emerged that uses only geographical location for advertisement. However, in marketing strategies, geo-targeting now also incorporates other data from mobile devices, such as the user's demographics, behaviour and purchase history. Geo-targeting allows to create detailed consumer profiles and businesses can better segment their audience [RD29]. Messages can be sent to customers who are likely to be interested, enabling them to get greater engagement. Geo-targeting can also incorporate the user's language, ensuring that the message is sent to the right one. The offers can be sent to LBS users in real-time (push messages), when they are in the certain physical space, e.g.

Table 5: Main GNSS user requirements, proportion of GNSS and main user groups for Mapping and GIS

Accuracy	**Horizontal**	High [RD71]
	Vertical	High [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD17]
	Canopy	Yes [RD71]
	Indoors	Yes [RD71]
	TTFF	Low [RD71]
	Fix update	Continuous 1-5Hz [RD71]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	No
Power consumption		Low [RD79]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Professionals users

in form of discounts coupons to certain shops or recommendations for best food in restaurants in the area.

Common devices enabling this application are smartphones and tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: hundreds of meters [RD6]
  - Vertical: 3 meters [RD71].
- **Geographical coverage:** Global [RD47]
- **Availability:**
  - Availability in urban canyons [RD47], under canopy [RD71] and indoors [RD32]
  - TTFF: N/A [RD79]
  - There is no need for continuous positioning computation. There is an intermittent "push-to-fix" requirement that helps save battery power [RD32]
- **Resilience (Robustness / Trust)**: 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** very low consumption [RD6]

Table 6 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Geo marketing and advertising.

5.1.6 SAFETY AND EMERGENCY

5.1.6.1 SEARCH AND RESCUE

Such applications alert search and rescue services and allow them to quickly locate people in the event of an emergency [RD3]. Under this category no mobile coverage is assumed.

Modern beacons contain three crucial elements: a five-watt radio transmitter working at a frequency of 406 megahertz, a 0.25-watt radio transmitter working at 121.5 MHz and a GNSS receiver. Beacons can be triggered manually or automatically – such as when they become submersed in water or experience a strong impact. When the beacon is activated, it sends out a radio signal (depending on the specific model, it may also emit an audio and/or visual signal). Upon activation, both of the radio transmitters in the beacon turn on. Above the Earth, a weather satellite detects the 406-MHz signal. Part of the information conveyed in the signal is the device's serial number, which can tell marine patrols back on Earth who owns the beacon. If the beacon has on-board GNSS, the satellite can also determine the device's exact geographic location. The information is shared by COSPAS-SARSAT, the international satellite-based search-and-rescue detection and distribution system.

Common devices enabling this application are personal locator beacons (PLBs).

Table 6: Main GNSS user requirements, proportion of GNSS and main user groups for geomarketing and advertising

Accuracy	**Horizontal**	Low [RD6]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD47]
	Canopy	Yes [RD71]
	Indoors	Yes [RD32]
	TTFF	N/A [RD79]
	Fix update	On request [RD32]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD47]
Power consumption		Very low [RD6]
Proportion of GNSS		Low [RD71]
Main user groups		Enthusiasts Pragmatists Professional and business users

2019 update

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: medium [RD79]
  - Vertical: 3 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD71], under canopy [RD47] and indoors [RD32]
  - TTFF: low [RD79]
  - Need for on-request positioning [RD71]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- **Power consumption:** low consumption [RD6]

2019 update

5.1.6.2 E112

The EU Directive E112 (2003) requires mobile phone networks to provide emergency services with whatever information they have about the location a mobile call was made [RD51]. This application places stringent requirements on position accuracy, availability and response time [RD32]. Yet for the time being there is no regulation requirement for a minimum accuracy within the European Union. Such clear requirement (E911) has been in place for a long time in the US. There is also a gap between citizens' expectations of **location accuracy (5-10 m)** and the current emergency location solutions available in EU Member States using mobile cell or sector ID (100m- 40 km). To close this gap the European Commission approved on 12 December 2018 a Regulation making GNSS and Wi-Fi location mandatory in all new smartphones. The GNSS chip must be compatible and interoperable with at least the Galileo system, thus being able to automatically send more accurate location data as part of any emergency call to 112. The Regulation however does not apply to other portable devices such as tablets [RD81].

2019 update

It is of interest to note that it is widely acknowledged that the E911 requirement in the US was the initial main driver for the rapid and widespread adoption of GPS (actually A-GPS) technology in mobile phones, without this driver the uptake would certainly have been slower. Furthermore, other governmental pressure (whether by regulation or simply by unofficial encouragement) has meant that the additional adoption of other GNSSs, GLONASS and Beidou, has been initially prioritised by chipset providers over that of Galileo for which no such pressure existed.

2019 update

Common devices enabling this application are smartphones and tablets. The main GNSS user requirements are:

Table 7: Main GNSS user requirements, proportion of GNSS and main user groups for Safety and emergency

Accuracy	**Horizontal**	Medium [RD56]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47] Regional for E112
Availability / Timeliness	**Urban canyon**	Yes [RD71]
	Canopy	Yes [RD47]
	Indoors	Yes [RD32]
	TTFF	Medium [RD80]
	Fix update	On request [RD71]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD79]
Power consumption		Low [RD6]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Pragmatists Professional and business users

2019 update

2019 update

- **Accuracy:**
  - Horizontal: between 5 and 10 meters [RD52]
  - Vertical: between 3 and 4 meters [RD71]
- **Geographical coverage:** Regional [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoors [RD32]
  - TTFF: 10 seconds [RD80]
  - Need for on-request fix update [RD79]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]
- **Power consumption:** low [RD79]

The table 7 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Safety and Emergency. Whenever the two applications in this category have different requirements for a performance parameter the most stringent one has been included in this table.

5.1.7 ENTERPRISE APPLICATIONS

5.1.7.1 MOBILE WORKFORCE MANAGEMENT

Mobile workforce management revolves around tracking and navigation services that enable workers to plan their routes more efficiently and to support dispatch services.

This application for corporate clients is mainly marketed as a productivity enhancement service. It relies on GNSS and mobile communication technologies to determine the location of a worker and transmit the data to the workforce manager. The latter can view workers on a map, send them messages and give route to new sites. Security functions such as alarms are also part of the service. Mobile workforce management is frequently part of fleet management solutions for light commercial vehicle fleets. Many companies now adopt more or less standardized workforce management apps for smartphones. Industry sectors leading the adoption of workforce management solutions include construction, distribution and field services [RD21].

Common devices enabling this application are smartphones and on-board units.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: low [RD79]
  - Vertical: 5 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD54], under canopy [RD71], [RD54] and indoors [RD17], [RD54].
  - TTFF: 1 minute [RD71]
  - Need for continuous positioning once the operation has started. Update rate is 5 seconds [RD71]

Table 8: Main GNSS user requirements, proportion of GNSS and main user groups for Enterprise

Accuracy	**Horizontal**	Medium / High [RD79]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD54]
	Canopy	Yes [RD71]
	Indoors	Yes [RD17]
	TTFF	Low [RD71]
	Fix update	Continuous 5s [RD71]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD71]
Power consumption		Low [RD71]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Professional and business users

2019 update

- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]
- **Power consumption:** low consumption [RD71]

5.1.7.2 LONE WORKER PROTECTION

Lone worker protection services primarily focus on ensuring the security of employees through features such as two-way communication and automatic location. Many lone worker protection services rely on dedicated location devices featuring alarm buttons and man down detection sensors. These devices are typically programmed to send alarms to supervisors or alarm receiving centres in case of emergency [RD21].

Common devices enabling this application are dedicated portable devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: medium/ high [RD79]
  - Vertical: 3-4 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability**
  - Availability in urban canyons, under canopy and indoors [RD48]
  - TTFF: response in a few seconds [RD6]
  - Continuous positioning once the operation has started.

2019 update

- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** low consumption [RD6]

Table 8 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Enterprise applications. Whenever there two or more applications in this category have different requirements for a performance parameter the most stringent one has been included in this table.

5.1.8 SPORTS

5.1.8.1 FITNESS AND PERFORMANCE MONITORING

Fitness monitoring applications are collecting records data such as real-time distance, speed/pace, location, vertical oscillation, vertical drop (for skiing), travelled distance, number of steps and calories burned for outdoor activities. The use of GNSS in these applications depends on the environment the type of sport is practiced in. For the outdoor activities, such as jogging, biking, hiking, swimming, skiing, GNSS is the basic enabling location technology in these devices (smartphones, smart watches, activity trackers, biking computers, GNSS handhelds and other wearables) together with altimeter, barometer and compass (ABC) sensors.

For the indoor fitness monitoring the applications that perform activity tracking, (counting the steps, distance, sleep, heart rate, calories burn) rely on other sensors than

GNSS. The data and information provided by these devices is intended to be a close estimation of a user activity and metrics tracked, but may not be completely accurate. In short, fitness trackers measure motion: most of today's wearables come with a 3-axis accelerometer to track movement in every direction, and some come with a gyroscope too to measure orientation and rotation. This data allows to estimate steps and activity of a user; and from that into calories and sleep quality. Altimeters can measure a user's altitude and barometer the atmospheric pressure. The more sensors are used in a fitness tracker application, the more data can be generated.

The average battery life in GNSS mode in current smartwatch models is about 10-50 hours [RD45]. In case of a smartphone in a run tracking mode, the battery would last much shorter, for about 4-10 hours. So, in any case, e.g. for longer hiking (1 or 2 days), spare batteries might be needed. It is possible to set the watch to longer GNSS intervals, so the battery life may be enhanced, but the accuracy may be then worsened [RD46]. In general, battery life is a crucial factor when choosing an altimeter watch.

Common devices enabling this application are smartphones and dedicated wearable devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: medium [RD79]
  - Vertical: 5 meters [RD71]
- **Geographical coverage**: Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD47], under canopy [RD47] and indoors [RD47]
  - TTFF: A few seconds [RD71]
  - Need for continuous positioning once the operation has started, with an update rate from 1 to 2 Hz [RD79].
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption**: medium consumption [RD79]

2019 update

5.1.8.2 SPORTS GEAR RETRIEVAL: GOLF BALLS

In the new generation of golf products, a user can capture all stats about their performance in real-time, on a smartphone or smart watch. The balls are installed with a microchip and a locating handheld uses GNSS technology that synchronises to the chip.

Table 9: Main GNSS user requirements, proportion of GNSS and main user groups for Sports

Accuracy	**Horizontal**	Medium [RD71]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD47]
	Canopy	Yes [RD47]
	Indoors	Yes [RD47]
	TTFF	High [RD71]
	Fix update	Continuous [RD71] Update rate from 1 to 2 Hz [RD79]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	N/A
Power consumption		Low [RD44]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Pragmatists Lifestyle users Yuppies

2019 update

Common devices enabling this application are smartphones and wearable devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: within a range of 9 meters to 30 meters [RD19]
  - Vertical: N/A
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability under canopy [RD19]
  - TTFF: medium [RD79]
  - Need for on-request positioning [RD19]
- **Resilience (Robustness / Trust):** (2019 update)
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** medium consumption [RD19]

5.1.8.3 FISHING ASSISTANCE

Fishing assistance applications help to locate the best fishing spots and share it with other users, as well as locate marinas, bait shops or other anglers. They include e.g. also databases with the preferred habitats of fish and tips and suggestions for catching each different creature. The apps are based on GNSS that guarantees tracking and mapping for fishermen [RD20].

Common devices enabling this application are smartphones and dedicated portable computers.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: low [RD79]
  - Vertical: N/A [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - TTFF: 1 minute [RD71]
  - Need for continuous positioning once the operation has started [RD71]
- **Resilience (Robustness / Trust):** (2019 update)
  - Susceptibility to interference: Yes [RD79]
  - Susceptibility to spoofing: No
- **Power consumption:** low (on-board equipment) [RD79]

Table 9 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Sports. Whenever there two or more applications in this category have different requirements for a performance parameter the most stringent one has been included in this table.

5.1.9 GAMES

Mobile Location Based Gaming (MLBG) is a growing trend among LBS. MLBG integrates elements of traditional open-air field games (e.g. Hide-and-seek, Paper Chase) with new technologies available on mobile devices including positioning technologies (such as GNSS receivers), wireless fast speed internet/permanent internet connection, image recognition, maps and augmented reality among others.

Currently, the most frequently used **methods to determine the location** of a mobile device are: GNSS, Wi-Fi, cell tower triangulation and single cell tower. Determining the location using a GNSS sensor is still one of the most popular approaches due to its high accuracy and availability in areas with no phone coverage or Internet. However, GNSS suffers a few drawbacks: the poor performance of GNSS user equipment in indoors, in urban canyons both in terms of accuracy and availability [RD53], high TTFF and power consumption. In order to determine the location of players at all times, some solutions could include using triangulation from mobile phone masts (GSM) or wireless networks (WPS), radio-frequency identification (RFID) or Bluetooth or a combination thereof [RD53]. To decrease the required time to adjust to the satellites, A-GNSS can be used.

Location based games will use a **large amount of power** as they use many features including GNSS and sometimes highly complicated graphics. There are several ways to increase battery longevity:

- Some games choose to trade accuracy off for battery longevity by performing fewer calculations.
- Another way to improve power consumption is to turn off power hungry sensors when the user is standing still.
- **Cloud processing** reduces power consumption at device level. Instead of using the host device's processing capabilities, cloud GNSS receivers utilise cloud-based processing services, thus offloading most of the processing and energy-consuming tasks to the cloud – where such resources are virtually unlimited. UBISCALE's 'UBIGNSS Solutions empowered by GNSS' is an example of the use of cloud-processing significantly reducing power consumption [RD47].

Common devices enabling this application are smartphones and tablets.

The main GNSS user requirements are:

- **Accuracy**[3]**:**
  - Horizontal: high [RD79]
  - Vertical: 10m [RD71]

3 For augmented reality games higher accuracy may be needed. See section 5.1.12

- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD53], under canopy [RD47] and indoors [RD48]
  - TTFF: A few seconds [RD71]
  - Need for continuous positioning once the operation has started [RD6]. Update rate to be determined.
- **Resilience (Robustness / Trust):** 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- **Power consumption:** low consumption [RD6]

The following table summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Games. Whenever there two or more applications in this category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.1.10 HEALTH

5.1.10.1 GUIDANCE FOR VISUALLY IMPAIRED

Portable devices with their associated mobility services dedicated to visually impaired people have appeared on the market. However, GNSS standalone solutions cannot provide the level of positioning accuracy and integrity needed by visually impaired people for assisting them efficiently in their mobility. The acquisition time appears to take too long and people are not confident enough in the reliability of the information they receive [RD56].

Common devices enabling this application are dedicated portable devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: high [RD79]
  - Vertical: 3-4 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD17], under canopy [RD17] and indoors [RD48]
  - TTFF: <15s [RD56]
  - Need for continuous positioning once the operation has started. Need to locate visually-disabled pedestrians 95% of the time [RD56].
- **Resilience (Robustness / Trust):** 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- **Integrity:**
  - Risk: yes [RD79]
  - Time to alert: yes [RD79]
- **Power consumption:** low consumption [RD6]

Table 10: Main GNSS user requirements, proportion of GNSS and main user groups for Games

Accuracy	**Horizontal**	High [RD79]
	Vertical	Low [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD53]
	Canopy	Yes [RD47]
	Indoors	Yes [RD48]
	TTFF	High [RD71]
	Fix update	Continuous [RD6]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD79]
Power consumption		Low [RD6]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts

2019 update

5.1.10.2 VULNERABLE PEOPLE TRACKING

Vulnerable people tracking can be very useful for people with dementia but also for old people to prevent troubles and to improve speed of response in case of troubles. A related functionality is geofencing – the defining of virtual geographical boundaries that will generate an automatic alert when crossed by someone under supervision. There are projects to connect wheelchairs with embedded GNSS for example [RD5]. According to Satsafe Limited's Stuart Millward, location-aware, multi-sensing devices could provide a radically lower cost monitoring solution for senior citizens and other vulnerable groups and has the potential to significantly reduce avoidable hospital admissions [RD3].

Common devices enabling this application are personal tracking devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: a few meters or less [RD6]
  - Vertical: 3-4 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD17], under canopy [RD17] and indoors [RD48]
  - TTFF: <15 seconds [RD71]
  - Need for continuous positioning once the operation has started [RD6][RD71]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- **Power consumption:** low consumption [RD6]

2019 update

5.1.10.3 FALL DETECTION

Having the capability to monitor human activity and detect a fall can save a life. For that purpose there are now fall detection apps that can be used with mobile devices [RD57].

Fall detection devices or applications usually combine fall sensor and GNSS. The fall sensor automatically contacts a monitoring centre after a sudden change in motion (indicating a fall). If there is no movement or change in tilt within 10 seconds, it is assumed that the patient is unconscious. GNSS provides the patient's location, thus enabling family, friends, or emergency personnel to intervene [RD58].

Common devices enabling this application are dedicated wearable devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: tens of meters or less [RD58]
  - Vertical: 3-4 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoors [RD48]
  - TTFF: a few seconds [RD71]
  - Need for continuous positioning once the operation has started [RD71] [RD75]

2019 update

- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- **Power consumption:** low consumption [RD75]

The table 11 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Health. Whenever there two or more applications in this category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.1.11 TRACKING

5.1.11.1 CHILDREN LOCATORS

Satellite navigation is particularly useful to allow parents to locate their children at any time. Most child-trackers rely on GNSS and some of them are also provided with mobile communication technologies.

Safety wearables come in a wide variety of designs and formats (disposable plastic band, rechargeable watch that doubles a cell phone, watches/wristband, necklaces, mobile phones, devices that can be clipped onto a belt, shoes, etc.). The ones that use RF technology provide for short distance monitoring. Others are more sophisticated and use a **GNSS system** to pinpoint exactly on parents' smartphone map the position of their child. Some devices use a blend of GNSS, GSM, and Wi-Fi to help parents locate their children both indoors and outdoors [RD49]. Most of the devices are now lightweight.

Crucial performance requirements include a positioning accuracy in the order of a few meters or less [RD6] and high availability of the service indoors [RD32]. Continuity of the coverage throughout the service area is also indispensable [RD32]. Devices must also be robust to survive rough handling [RD32].

Common devices enabling this application are dedicated wearable devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: a few meters or less [RD6]
  - Vertical: 5 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD32], under canopy [RD32] and indoors [RD48]

Table 11: Main GNSS user requirements, proportion of GNSS and main user groups for Health

Accuracy	**Horizontal**	High [RD79]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD17]
	Canopy	Yes [RD17]
	Indoors	Yes [RD32]
	TTFF	High [RD6] [RD71]
	Fix update	Continuous [RD71]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD79]
Integrity	**Risk**	Yes [RD79]
	Time to alert	Yes [RD79]
Power consumption		Low [RD75]
Proportion of GNSS		Medium [RD71]
Main user groups		Enthusiasts Traditionalists Professional and business users Users with special needs

2019 update

- TTFF: a few seconds [RD6]
- Need for on-request fix updates [RD79]

2019 update

- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]

- **Power consumption:** medium to low consumption [RD6]

5.1.11.2 PAROLEES MONITORING

Electronic monitoring (EM) of parolees is gradually being adopted globally [RD21]. They use two types of monitoring: RF monitoring and GNSS monitoring. The most common forms of EM equipment in use today are **RF systems** that comprise a transmitter worn by the person being monitored, often in the form of an ankle bracelet. The RF transmitter sends out a signal to a receiver unit that communicates with a monitoring centre to report signal interruptions during curfews or any attempts to tamper with the equipment [RD21]. **Systems using GNSS** location allow near real-time location of the parolee and the creation of geographic inclusion and exclusion zones are being used [RD21].

The following requirements are US national standards. No specific requirement has been found for the European Union. The US National Standard for Offender Tracking System calls for OTS to provide a location that is accurate within 10 meters 90 percent of the time in an open-air environment with no obstructions [RD50]. The draft standard calls for OTS to be able to provide an on-demand location within 3 minutes of a request. Two out of five US agencies that were interviewed specified that they require the ability to instantly receive a parolee's location and status. Yet OTS manufacturers have stated that their OTSs cannot provide "instant" location updates because of limitations including GNSS and cellular technology, and that while quicker response times are possible, the 3-minute time frame is a reasonable requirement for the minimum performance standard [RD50]. GNSS integrity is another important user requirement [RD77].

Common devices enabling this application are dedicated tracking devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: 10 meters (90% of the time) in an open-air environment with no obstruction (US standards) [RD50]
  - Vertical: 5 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoors
  - TTFF: medium [RD79]
  - Need for on-demand positioning [RD50]

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- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]

- **Integrity:**
  - Risk: N/A [RD79]
  - Time to alert: N/A [RD79]
- **Power consumption:** low [RD79]

5.1.11.3 PETS LOCATORS

An increasing number of companies are crafting wearables devices using GNSS to keep track of animals. Some of these wearables even combine GNSS tracking and pet fitness monitoring in one band. They can be clipped to the pets' collar. Most of them connect to a smartphone app and can get real-time location, set a geo-fenced area and receive an alert if a pet moves out of the zone.

Continuous (active tracking) and on-demand (roam) positioning are possible with some pet trackers. Active tracking allows owners to monitor their pet's activity in real-time. In this mode the collar transmitter constantly monitors the pet's movements and automatically refreshes location data every few seconds. By using the roam mode owners can receive their pet's location only when they request it. In this case the collar transmitter is in a low power state and not tracking until it receives a 'wake-up' notification to begin sending its location data [RD76].

Common devices enabling this application are wearable tracking devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: a few meters or less [RD6]
  - Vertical: 5 meters [RD71]
- **Geographical coverage:** Global [RD47]
  - Availability / Timeliness:
  - Availability in urban canyons [RD32], under canopy [RD32] and indoors [RD48]
  - TTFF: 15 seconds [RD71]
  - Need for continuous and/or on-request positioning [RD76]. Research has not permitted to determine the update rate. However, it is worth noticing that some manufacturers propose tracking devices that have an update rate of 4 seconds [RD76].
- **Resilience (Robustness / Trust):** 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]
- **Power consumption:** medium to low consumption [RD6]

Table 12: Main GNSS user requirements, proportion of GNSS and main user groups for Tracking

Accuracy	**Horizontal**	Medium [RD6]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD32]
	Canopy	Yes [RD32]
	Indoors	Yes [RD48]
	TTFF	High [RD6]
	Fix update	Continuous [RD6] [RD71] Update rate of 4s [RD76] and On-request [RD76]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD71]
Integrity	**Risk**	N/A [RD79]
	Time to alert	N/A [RD79]
Power consumption		Low [RD79]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Professional and business users Users with special needs

2019 update

5.1.11.4 TRACKING OF VALUABLE AND STOLEN GOODS

There are numerous systems available to monitor asset location based on GNSS or mobile network location. Vehicle-tracking solution companies are introducing new products that provide multiple functions including location, security etc. Another popular function is geo-fencing. Companies are implementing some or all of the above solutions, which all have one thing in common – they all need wide area mobile connectivity to link the information generated by these devices to head office. Indoor coverage is also useful. Tracking services are also marketed towards consumers, for instance for tracking of stolen vehicles [RD36]. For tracking of stolen cars, their systems are usually separate from the car navigation systems, as these ones tend to be disconnected in such situations.

GNSS is also used in suitcases, jewellery pieces, such as rings, necklaces, bracelets, hair clips etc. GNSS has mostly a tracking functionality, which can be used as a detection tool in case of losing jewellery or tracking a life partner or other close people. "Wearable jewellery" is still a niche market segment and **GNSS is not a standard technology in these pieces** [RD25].

Particular case of containers carrying dangerous/hazardous/sensitive cargoes:

If containers carry dangerous, precious and/or sensitive cargoes, the requirements are more stringent. The objective is to obtain a reliable position estimate for this application where position is a key driver for security or safety. The main driver here is **the confidence level** associated to the application figure of merit, which can be the **reported position**. For such applications it becomes paramount to be informed of the probability that reported information is inaccurate. Reliable geo-localisation therefore covers all sources of positioning uncertainty in order to bring confidence not only in the position authenticity, but also in position accuracy. Reported **position accuracy** and **service availability** remain important drivers [RD17].

Common devices enabling this application are dedicated tracking devices.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: a few meters or less [RD71]
  - Vertical: 5 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoors [RD48]
  - TTFF: a few seconds [RD6]
  - Need for continuous positioning once the operation has started [RD71]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]
- **Integrity:** needed for the tracking of containers carrying dangerous/hazardous/sensitive cargoes [RD17]
  - Risk: N/A [RD79]
  - Time To alert: N/A [RD79]
- **Power consumption:** medium [RD79]

The table 12 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Tracking. Whenever there two or more applications in this category have different requirements for a performance parameter, the most stringent one has been included in this table.

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5.1.12 AUGMENTED REALITY FOR LEISURE

5.1.12.1 GAMING

Augmented reality gaming is the integration of game visual and audio content with the user's environment in real time. The aim is to expand the playing field, taking advantage of the diversity of the real-world environment to keep the games interesting. The position, potentially coming from a GNSS receiver is used in combination with the camera images [RD82].

Common devices enabling this application are smartphones, tablets and portable gaming systems.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter. For some applications a 2cm accuracy is required but for "relative" positioning, not "absolute" positioning, for instance when the distance between two persons or objects is more relevant than the position of these persons or objects. The notion of "relative" navigation should therefore be introduced in particular knowing that better performances could easily be achieved [RD80]
  - Vertical: <1 meter, a 2cm accuracy is required for some applications [RD80]
- **Geographical coverage:** Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: 30 seconds [RD80]
  - Update rate: 15 Hz [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

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5.1.12.2 BROADCAST AND LIVE EVENTS

Augmented reality can enrich spectators' experience during broadcast and live events by overlaying content. It can be used to tailor advertising and marketing to the geographical location of the spectator. GNSS is used to determine the spectator's location [RD85].

Common devices enabling this application are smartphones or tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: 50 cm [RD80]
  - Vertical: up to 50 cm [RD80]
- **Geographical coverage:** Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: Not critical [RD80]
  - Update rate: 1 Hz [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

5.1.12.3 NAVIGATION

Some major companies are on their way to add augmented reality to their navigation applications to improve navigation (e.g. Google maps). The smartphone's GNSS and camera information are combined and additional augmented reality content is added to guide the user with virtual path on the smartphone camera preview. This way the user no longer needs to follow a map on their phone [RD86].

Common devices enabling this application are smartphones, tablets or PNDs.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: 50 cm [RD80]
  - Vertical: 2 meters [RD80]
- **Geographical coverage:** Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: 1 minute [RD80]
  - Update rate: 1 Hz [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

Table 13: Main GNSS user requirements, proportion of GNSS and main user groups for Augmented Reality

Accuracy	**Horizontal**	High [RD80]
	Vertical	High [RD80]
Service area	**Geographical coverage**	Global [RD80]
Availability / Timeliness	**Urban canyon**	Yes [RD80]
	Canopy	Yes [RD80]
	Indoors	Yes [RD80]
	TTFF	Medium [RD80]
	Fix update	Continuous 15Hz [RD80]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD80]
	Susceptibility to spoofing	Yes [RD80]
Power consumption		TBC
Proportion of GNSS		TBC
Main user groups		TBC

2019 update

5.1.12.4 TRAVEL APPLICATIONS

There is an increased interest by the tourism industry to implement augmented reality into the travellers' experience. Augmented reality applications enable hotels and other businesses operating in this field to enhance the physical environments they are promoting to potential customers, including local sights and hotel rooms. They also enrich tourists' experience by allowing users to point their smartphones to a point of interest (buildings, etc.) to learn more about it in real-time or at maps to view extra information about some of the local places of interest [RD87] [RD88]. To access this digitally created information, these applications use GNSS in combination with image recognition technology.

Common devices enabling these applications are smartphones and tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: It shall be comprised between 1 and 5 meters [RD80]
  - Vertical: It shall be comprised between 1 and 5 meters [RD80]
- **Geographical coverage:** Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: 1 minute [RD80]
  - Update rate: 1 Hz [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

5.1.12.5 SPORTS/ADVENTURE

Augmented reality applications are increasingly employed by professional and – sometimes- amateur athletes to get real-time data about every hit, run distance, push, throw, jump. With this information, they can improve their abilities by correcting their actions, enhance the technique and make better decisions [RD89]. GNSS is used in combination with other sensors to track the location of the athlete when exercising.

For the sport industry, common devices enabling this application are smart glasses and smartphones.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: It depends on the considered sport: <1 meter [RD80]
  - Vertical: It depends on the sport; 2 meters [RD80]
- **Geographical coverage:** Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: 30 seconds [RD80]
  - Update rate: 15 Hz [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

Table 13 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for augmented reality for leisure applications. Whenever two or more applications in the category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.1.13 SOCIAL NETWORKING

5.1.13.1 FRIEND LOCATOR

Friend locator applications and services inform a user about their friend's location when they are nearby. This feature can be also used to track a user's friend's location in real time.

The most popular service used for these features is Facebook Nearby Friends, which is a built-in option to enable by Facebook users. The Facebook Nearby Friends also has an option to set the time of a user's traceability via this feature. The proximity can be shared with all friends, or a specific friend list or group. There are also timestamps of when someone's location was last queried. A similar popular app is Apple Find my Friends, which allows to locate friends and family from the Apple devices.

Common devices enabling this application are smartphones and tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: 10 meters or more [TBD].
  - Vertical: N/A [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons [RD28], under canopy [RD71] and indoors [RD48]
  - TTFF: a few seconds [RD6]
  - Need for on-request positioning [RD28]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** low power consumption [RD6]

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5.1.13.2 DATING

Dating applications use GNSS user's current location to connect people in their area, allowing them to chat and possibly meet up. Currently, the most popular dating app in the world is Tinder, with over 100 million active users, of which 1 million pay for the extra in-built services (data for May 2016 [RD27]). What is interesting, one of the paid functions of Tinder is to 'fake your location' to increase the matching options or mislead the potential matching partners. Other popular dating apps include Grindr, Bumble or Happn. For privacy reasons, the location of a user in an app is often shared as a proximity and not the most accurate. GNSS is a key enabler for these kinds of apps.

Common devices enabling this application are smartphones.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: 10 meters or more [TBD]
  - Vertical: N/A [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy [RD71] and indoors [RD48]
  - TTFF: a few seconds [RD71]
  - Need for on-request positioning. The location information is updated when a user is logging into the application and does not need to be re-calculated on a continuous basis, as these services work intentionally with bigger location identification proximity
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes
- **Power consumption:** low consumption [RD6]

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5.1.13.3 CHAT AND INSTANT MESSAGING SERVICES

Location information used in chat and instant messaging services allows the user to estimate how far they are from each other at the time of communication. As the most general, a user can pre-define manually their location in a software menu. For more accurate location information, the apps use cellular triangulation, Wi-Fi and then GNSS for the most accurate calculation (but with a higher cost of energy). The GNSS user requirements for these applications can be defined as high accuracy and availability, low power consumption and real-time response.

Common devices enabling this application are smartphones.

Table 14: Main GNSS user requirements, proportion of GNSS and main user groups for Social networking

Accuracy	**Horizontal**	Medium [RD6]
	Vertical	N/A [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD28]
	Canopy	Yes [RD71]
	Indoors	Yes [RD32]
	TTFF	High [RD71]
	Fix update	On request [RD26]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	Yes [RD78]
Power consumption		Low [RD6]
Proportion of GNSS		Medium [RD71]
Main user groups		Enthusiasts Pragmatists

2019 update

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: in the order of tens of meters [RD6]
  - Vertical: N/A [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy [RD71] and indoors [RD48]
  - TTFF: a few seconds [RD71]
  - Need for on-request positioning
- **Resilience (Robustness / Trust):** 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** low consumption [RD6]

Table 14 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Social networking. Whenever there two or more applications in this category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.1.14 INFOTAINMENT

5.1.14.1 POINTS OF INTEREST

GNSS is a key enabler of Point-of-Interest (POI) applications. Such applications allow a user to find places, such as restaurants, shops, banks, petrol stations and specific services based on his location or searched location.

As a standard, these apps are built into applications using maps (e.g. Google Maps) or include also maps as their built-in function. Also, car navigation services are offering now more and more built-in apps with POIs. For instance, Google Local Search, Yelp and Expedia are in-built apps for TomTom services [RD26]. The applications are free to download and developers are making money cooperating with local points of interest that pay for adding them to the database. A big advantage for the users is the possibility to download the maps and database for a specific city in advance and to use it offline with location function enabled in a phone, which is working with GNSS. The data about users and their searchers is also used for consumer insights and for building companies' marketing strategies.

Common devices enabling this application are smartphones, portable navigation devices (PNDs) and in-vehicle infotainment systems.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: low [RD79]
  - Vertical: N/A [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy [RD71] and indoors [RD48]
  - TTFF: a few seconds [RD6]
  - Need for on-request positioning. This helps save battery power [RD32]
- **Resilience (Robustness / Trust):** 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** low consumption [RD6]

5.1.14.2 PHOTOS AND VIDEOS GEOTAGGING

Geotagging is defined as adding geospatial metadata to digital media such as photographs, videos, messages, blogs, web pages and GeoRSS (a specification for encoding location as part of a Web feed). Significant amount of the social media content is created by users through location-aware mobiles devices.

Common devices enabling this application are smartphones and digital cameras.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: low [RD79]
  - Vertical: N/A
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoors
  - TTFF: 10 seconds [RD71]
  - Need for on-request positioning [RD71]
- **Resilience (Robustness / Trust):** 2019 update
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** low [RD79]

5.1.14.3 GEOLOCATED NEWS

The geolocated news apps send users a push/pull notification on their mobile device when news breaks near them - no matter how far from home they may be [RD15]. The type of news can be also personalised with an alert system based on a particular user's interests, from politics and sports to weather. The news is collected from different sources, including social media.

GNSS works here in a simple way to locate a user. The required accuracy, availability and time to first fix can be defined as low.

Table 15: Main GNSS user requirements, proportion of GNSS and main user groups for Infotainment

Accuracy	**Horizontal**	Low [RD79]
	Vertical	N/A [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD47]
	Canopy	Yes [RD71]
	Indoors	Yes [RD32]
	TTFF	High [RD6]
	Fix update	Continuous [RD79]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD71]
	Susceptibility to spoofing	No
Power consumption		Low [RD6]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Traditionalists (Points of interest) Pragmatists Bulk users

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Common devices enabling this application are smartphones and tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: the required horizontal accuracy is low. Usually the news is generated for proximity of a city or neighbourhood area, so even a few kilometres range is enough to make use of applications benefits.
  - Vertical: N/A [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoors
  - TTFF: low – Quantified information to be determined
  - Need for continuous positioning [RD79]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- **Power consumption:** low [RD79]

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Table 15 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Infotainment. Whenever there two or more applications in this category have different requirements for a performance parameter the most stringent one has been included in this table.

5.1.15 COMMERCIAL

When using GNSS, most of the LBS commercial applications often require the **high level of accuracy and authentication**, as these are especially commercially sensitive applications for both users and companies. These include banking services (mobile payments) and other fraud management applications, in which a **precise location** of a user (centimetres accuracy) can be crucial to protect the assets. These applications are the most exposed to GNSS spoofing and jamming and fraud, as a result.

5.1.15.1 FRAUD MANAGEMENT

Establishing someone's immediate whereabouts is emerging as a key element in preventing fraud. The technique uses location data, derived from GNSS and other sources, to estimate the likelihood that the person making a request to use an access card for example is actually who they say they are. Fraud management applications can also include control of the computer system or building access [RD7].

Fraud management applications with mobile payments require high levels of **accuracy, availability** and continuity, as well as **authentication** parameters [RD14]. At the same time TTFF should be only a few seconds and power consumption low. It is still quite difficult to fulfil all these

parameters for GNSS. The barriers are also indoor usage, as they need to rely on antennas installed outside the target buildings to reproduce the GNSS signal. This requirement causes additional costs, challenging the economic viability of GNSS-based positioning as a means to reinforce the security of access and transactions [RD30].

Common devices enabling this application are smartphones.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: high. No quantitative information available [RD14]
  - Vertical: 3 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy [RD71] and indoors [RD32]
  - TTFF: a few seconds [RD14]
  - Need for on-request positioning [RD7]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD68]
  - Susceptibility to spoofing: Yes [RD67] [RD69]
- **Integrity:**
  - Risk: high [RD79]
  - Time to alert: 10 seconds [RD71]
- **Power consumption:** low consumption [RD14]

2019 update

5.1.15.2 BILLING

Location Based Billing (LBB) also called Location Based Charging (LBC) refers to the ability to dynamically charge users of a particular service depending on their location when using or accessing the service. Payment processing based on location or activity duration can include e.g. public transport, gyms, theme parks, parking [RD17], [RD5]. LBS can be also combined with location-based advertisements or coupons [RD32].

So far, the primary industry that uses this LBS application are cellular network companies. A mobile operator can charge different rates to mobile subscribers based on their physical location, e.g. abroad charging roaming rates or recognize whether their clients are at home or at work with rates comparable to wire line and with standard rate when they leave (home zone billing). However, LBS based billing is not the standard method used by network operators for this but instead the mobile phone service provider networks are used.

Table 16: Main GNSS user requirements, proportion of GNSS and main user groups for Commercial

Accuracy	**Horizontal**	High [RD14] [RD32]
	Vertical	Medium [RD71]
Service area	**Geographical coverage**	Global [RD47]
Availability / Timeliness	**Urban canyon**	Yes [RD47]
	Canopy	Yes [RD71]
	Indoors	Yes [RD32]
	TTFF	High [RD14]
	Fix update	On request [RD79]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD68]
	Susceptibility to spoofing	Yes [RD68]
Integrity	**Risk**	High [RD79]
	Time to alert	10s [RD14]
Power consumption		Low [RD14]
Proportion of GNSS		Medium [RD71]
Main user groups		Enthusiasts Pragmatists Professional and business users Bulk users

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According to ETSI, the key requirement for LBS billing applications are the **reliability of check point detection** and the **service availability**. The reliability of check point detection is the risk that a user's reported position triggers a charging event when it is actually in a position free of charge. This risk is generally very low [RD17]. The service availability is the percentage of cases when a user's actual position is able to trigger a charging event, but the system is not properly informed. In this application service unavailability is generally low [RD17].

InsideGNSS reports that these applications demand above all high quality of service (QoS), including short time to first fix and indoor availability. High accuracy and robustness are also important to the service providers so that customers are charged the correct tariffs [RD32].

Common devices enabling this application are smartphones.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: high. No quantitative information available [RD32]
  - Vertical: 3 meters [RD71]
- **Geographical coverage:** Global [RD47]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy [RD71], indoors [RD32]
  - TTFF: a few seconds [RD32] [RD71]
  - Need for on-request positioning [RD79].
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD68]
  - Susceptibility to spoofing: Yes [RD67] [RD69]
- **Integrity:**
  Risk: high [RD79]
  Time to alert: 10 seconds [RD71]
- **Power consumption:** high [RD79]

The table 16 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Commercial. Whenever there two or more applications in this category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.1.16 AUGMENTED REALITY FOR PROFESSIONAL APPLICATIONS

5.1.16.1 EMERGENCY AND PUBLIC SAFETY

Augmented reality can be useful for both law enforcement and emergency forces.

Police officers benefit from enriched training sessions using augmented reality. Law enforcement agencies use staged crisis (pandemic, hostage situations, street gun battle, etc.) to train their people. It is however expensive and difficult to recreate everything a police officer may encounter. As a result, police have turned to augmented and virtual reality scenario training. Virtual reality headsets totally immerse officers in the projected world. GNSS is used in conjunction with other sensors to provide information on device orientation and position. It is used in combination with the device camera to display digitally-created content.

When chasing suspects on foot, or investigating unfamiliar areas of town, officers can use enhanced vision of a city system (correct turns or potential hide outs) to ensure personal safety as well as mission success. The officer's device GNSS and camera information are combined and additional augmented reality content is added to guide the officer with virtual path [RD90].

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter [RD80]
  - Vertical: It shall be comprised between 1 and 5 meters. It mostly refer to floor detection. [RD80]
- **Geographical coverage:** Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: It shall be comprised between 2 and 30 seconds [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

5.1.16.2 CUSTOMER EXPERIENCE & MARKETING

Augmented reality helps bridge the gap between offline and online shopping, creating a more cohesive experience (gather in-store information, look at 3D products in home, virtually try on 3D products, use virtual fitting rooms…).

Such applications are also designed to enhance customers' experience by displaying real time digital information in conjunction with the real world. It uses the customer's

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mobile camera and GNSS location feature to retrieve data based on where the customer is and displays this data on his/her mobile screen.

Common devices enabling this application are smartphones or tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter [RD80]
  - Vertical: it shall be comprised between 1 and 5 meters when it refers to a shop. It shall be <1 meter when it refers to an object [RD80]
- **Geographical coverage:** Urban and suburban areas [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: It shall be comprised between 2 and 30 seconds. The responsiveness of the application to a change of position is critical [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

5.1.16.3 TRAINING & EDUCATION

Augmented Reality applications may be used of training purposes. In some professions (factory workers, workers in the construction industry, landscapers, etc.), theoretical knowledge is not enough to obtain proper skills. Students need practice and hands-on experience in their areas. Through interaction, AR applications help students perform a virtual practice – with augmented tutorials, digital modelling, and simulations – and acquire some experience. The position provided by GNSS is used in combination with the camera pictures to physically guide students' gestures during the training. Such applications also help make workers operational more quickly.

When organising field trips, teachers can use AR applications to create additional educational content related to pre-determined locations. When students arrive at any of the pre-determined locations, GNSS is used in combination with cameras to trigger an augmented information on their mobile devices [RD91] [RD92].

Common devices enabling this application are smartphones or tablets.

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter [RD80]
  - Vertical: it shall be comprised between 1 and 5 meters when it refers to a building. It shall be <1 meter when it refers to an object [RD80]
- **Geographical coverage**: Global [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: It shall be comprised between 2 and 30 seconds [RD80]

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Table 17

Accuracy	**Horizontal**	High [RD80]
	Vertical	High [RD80]
Service area	**Geographical coverage**	Global [RD80]
Availability / Timeliness	**Urban canyon**	Yes [RD80]
	Canopy	Yes [RD80]
	Indoors	Yes [RD80]
	TTFF	Medium [RD80]
	Fix update	Continuous [RD80]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD80
	Susceptibility to spoofing	Yes [RD80]
Power consumption		**TBC**
Proportion of GNSS		**TBC**
Main user groups		**TBC**

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- Need for continuous positioning [RD80]

- **Resilience (Robustness / Trust)**:
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

Table 17 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for augmented reality for leisure applications. Whenever two or more applications in the category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.1.17 ROBOTICS – HIGH GNSS USE

5.1.17.1 GARDENING ROBOTS

Gardening robots are used either by particular or professional farmers to maintain a lawn, harvest a field or spread products autonomously. They allow to improve production yield while reducing human and resources required. These robots embed a GNSS receiver for precise guidance, sometimes coupled with mapping techniques [RD93].

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter [RD80]
  - Vertical: <1 meter [RD80]
- **Geographical coverage:** Regional [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons and under canopy [RD80]
  - TTFF: It shall be comprised between 30 seconds and 1 minute [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: No [RD80]
  - Susceptibility to spoofing: No [RD80]

5.1.17.2 DELIVERY ROBOTS

Delivery robots have the objective of supporting the last mile deliveries in cities. Their ability to autonomously deliver goods within their assigned territory enables them to fulfil the rapidly growing need for cost effective, energy preserving, space efficient urban and sub-urban logistics. Thanks to the sensor-fusion platform that collect the data from different sensors like GNSS receiver, Lidar or camera for instance, they can drive fully autonomously [RD94].

The main GNSS user requirements are:

- **Accuracy**:
  - Horizontal: <1 meter [RD80]
  - Vertical: <1 meter [RD80]
- **Geographical coverage:** Regional [RD80]
- **Availability / Timeliness**:
  - Availability in urban canyons and under canopy [RD80]
  - TTFF: It shall be comprised between 30 seconds and 1 minute [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

5.1.17.3 SECURITY AND SURVEILLANCE

Autonomous robots are intelligent machine which operate by making decisions based on programming and sensory feedbacks. They can have different degree of autonomy but they always operate without direct intervention from a human operator during the course of their mission. They can handle missions of transportation, surveillance and reconnaissance or search & rescue even in risky or difficult to access areas. For such applications, the GNSS position information is used to precisely control the navigation and the movements of the operated robot. The GNSS equipment is always hybridized and is part of a complex navigation system [RD95].

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter [RD80]
  - Vertical: <1 meter [RD80]
- **Geographical coverage:** Regional [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons and under canopy. Indoor availability is required if the surveillance also includes indoor areas [RD80]
  - TTFF: It shall be comprised between 2 and 30 seconds[RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

Table 18 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for augmented reality for leisure applications. Whenever two or more applications in the category have different requirements for a performance parameter, the most stringent one has been included in this table.

Table 18

Accuracy	**Horizontal**	High [RD80]
	Vertical	High [RD80]
Service area	**Geographical coverage**	Regional [RD80]
Availability / Timeliness	**Urban canyon**	Yes [RD80]
	Canopy	Yes [RD80]
	Indoors	Yes [RD80]
	TTFF	Low [RD80]
	Fix update	Continuous [RD80]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD80
	Susceptibility to spoofing	Yes [RD80]
Power consumption		**TBC**
Proportion of GNSS		High [RD80]
Main user groups		**TBC**

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5.1.18 ROBOTICS – LOW GNSS USE

5.1.18.1 PERSONAL ASSISTANT ROBOT

Personal assistant robots help individuals with their day-to-day household tasks. They can be particularly useful for elderly or disable people. They are programable and can be parametrized according to the user needs. Their action can be either to vacuum the floor, to carry objects, to turn light, music or heating on or to remind you of an appointment as they are able to interact with humans. Assistant robots are mainly used indoor and use cameras, lidars or various sensors for navigation. GNSS is used for navigation in light indoor environment and outdoor and ensures a smooth functioning of these robots when used outdoor [RD96].

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: <1 meter [RD80]
  - Vertical: N/A [RD80]
- **Geographical coverage:** Local [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: <10 seconds [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

5.1.18.1 PAINTING ASSISTANT ROBOT

Painting robots are meant to paint autonomously a defined surface. They are for instance used by manufacturers to do detailing work on their products in a consistent and systematic way. Their use allows to improve safety in hazardous painting work environments, to significantly reduce waste by performing consistent painting and to higher speed and productivity [RD97]. More specifically robots are being used to mark or maintain the lines of sports fields, such as American football, soccer or lacrosse. These robots use RTK-GNSS system to record coordinates [RD99].

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: Centimetre [RD80]
  - Vertical: Centimetre [RD80]
- **Geographical coverage:** Local [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyons, under canopy and indoor [RD80]
  - TTFF: >30 seconds [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

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5.1.18.1 AUTOMATED GUIDED VEHICLE/LOGISTICS

Automated guided vehicles deal with logistics tasks indoors and outdoors. They can facilitate maintenance operations that require a high level of precision and access in hazardous or hard-to-access areas like undergrounds for instance. The precision of interventions allows to reduce the overall maintenance costs and the use of autonomous robots minimizes economic and social impacts of vast surface work. GNSS receivers allow self-driving vehicles to navigate without human input. When integrated into other techniques, such as laser light, radar, odometry, and computer vision, robotic cars can automatically sense, store, and retrieve data about the surrounding environment. Automated guided vehicles may also be used for transportation in the future, reducing human resources needs [RD98].

The main GNSS user requirements are:

- **Accuracy:**
  - Horizontal: Centimetre [RD80]
  - Vertical: N/A [RD80]
- **Geographical coverage:** Local [RD80]
- **Availability / Timeliness:**
  - Availability in urban canyon, under canopy and indoor [RD80]
  - TTFF: <10 seconds [RD80]
  - Need for continuous positioning [RD80]
- **Resilience (Robustness / Trust):**
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: Yes [RD80]

Table 19 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for augmented reality for leisure applications. Whenever two or more applications in the category have different requirements for a performance parameter, the most stringent one has been included in this table.

5.2 PROSPECTIVE USE OF GNSS IN LBS

5.2.1 FUTURE TRENDS

There is an emerging premium mass market, driven by a growing number of premium smartphones with multi-constellation GNSS chipsets [RD1]. It is a category which can evolve over time, being very much exposed to market and technology trends and development. Premium mass market technology needs to satisfy high-end consumers having more demanding requirements than those satisfied by mass market products but, in turn, less stringent than the demands of the professional market. Such needs encompass both **technical performance** – i.e. high-level performance, availability in critical environments and more robustness to interference and **qualitative aspects** such as ease of use, interoperability, after-sales services and assistance.

Another key recent trend in the LBS segment is a consequence of the **PokemonGo** success, which shed light on the need for GNSS Authentication in the mass market: **GNSS spoofing** has been easily demonstrated by the players'

Table 19

Accuracy	**Horizontal**	High [RD80]
	Vertical	High [RD80]
Service area	**Geographical coverage**	Local [RD80]
Availability / Timeliness	**Urban canyon**	Yes [RD80]
	Canopy	Yes [RD80]
	Indoors	Yes [RD80]
	TTFF	Medium/High [RD80]
	Fix update	Continuous [RD80]
Resilience (Robustness / Trust)	**Susceptibility to interference**	Yes [RD80
	Susceptibility to spoofing	Yes [RD80]
Power consumption		**TBC**
Proportion of GNSS		Low [RD80]
Main user groups		**TBC**

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community in their experiments to hack their smartphone location. The case for increased security and anti-spoof function is therefore expected to be made even in the LBS segment, and the Galileo OS-NMA service could provide significant benefits.

The extension of IoT concept to numerous objects such as connected helmets, bikes, mowers, etc. could provide a significant knock-on demand boost for GNSS capabilities in the LBS segment. It is expected that IoT will rely on GNSS now and in the future except for the lowest (cost, size) segments. It is possible to design and implement very low-CPU and low-memory single-frequency GNSS (GPS) receivers that are affordable and practical for low-cost IoT devices and the industry is already working on that.

5.2.2 GNSS TECHNOLOGICAL TRENDS

GNSS modules can be integrated in:

- Smartphones and tablets
- Wearables (including watches)
- Portable Navigation Devices
- Cameras
- Personal tracking devices
- Personal Locator Beacons
- Drones
- Robots

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The current GNSS modules used in LBS (except for tracking and wearables which are smaller but have a reduced number of channels) typically have the following characteristics:

- Weight: between 1 and 2 g
- Temperature range: -40° to +85°
- Frequency: L1/E1
- Number of channels: 80
- TTFF (cold start): 25-30 s
- TTFF (hot start): 1s
- Maximum navigation update rate: 5 Hz
- Horizontal accuracy (autonomous, which means using GNSS only for positioning): 2.5 m
- Number of GNSS constellations: up to 4
- Dimensions: 15 x 15 x 3 mm

WHEN USING GNSS, MOST OF THE LBS COMMERCIAL APPLICATIONS OFTEN REQUIRE THE HIGH LEVEL OF ACCURACY AND AUTHENTICATION

The LBS market is driven by the shortest lifecycle in the GNSS industry which favours innovation but also brings important constraints on cost. In addition, GNSS techno trends respond to the current and future expectations of the domain which are to provide increasingly accurate and available position with faster fix but also constrained by low power consumption, as most of LBS devices are battery powered (which implies that they must remain small and lightweight). The most important technology trends target the following areas:

- **Multi-constellation processing:** specific architectures are now available to favour the adoption of multi constellation in LBS while limiting the impact on cost, processing and power consumption. These new architectures allow a specific channel to process signals originating from different constellations, the choice of which constellation is used can ultimately be made at firmware level by the final product manufacturer (e.g. smartphone). The latest GNSS chipsets already have this multi-constellation capability and soon will become standard used on the market.

- **Multi-frequency processing:** new generation of LBS GNSS receivers are dual frequency which provides improved accuracy by removing ionospheric errors and also supports the development of PPP solutions.

- **Sensor fusion** / hybridisation (with Wi-Fi, Bluetooth, Cellular network positioning, MEMS sensors, etc.): this area is continuously progressing with new techniques and inclusion of new sensors (e.g. signals of opportunities).

- **Availability of raw measurements:** new versions of the Android operating system enable users to have access to raw pseudoranges, dopplers and carrier phase measurements. Phone makers can make use of this data for performance testing while developers have more resources to create innovative applications, under condition of compliant APIs.

- **Chip-based indoor location techniques:** location algorithms are running inside the chipset (e.g. Wi-Fi called 802 or motion sensors). This allows new generations of smartphones to be factory-ready for indoor positioning anywhere.

- **Innovative algorithms:** they include machine learning e.g. SLAM, satellite shadow matching, multipath mitigation, interference rejection etc. An important development happened recently to allow the development of new algorithms with Google opening access to raw GNSS measurements: Nougat (Android Version 7.0 and later releases) is being developed and the API allows app developer and smartphone manufacturers to compute pseudoranges Dopplers and Carrier Phase – potentially implementing PPP algorithms in smartphones.

- **Miniaturisation** and integration of GNSS and communications into a single chip.

- **Cloud processing** techniques for computing PVT outside of the host devices, putting some of the power consumption and processing constraints onto the server side. This type of solution responds to applications requiring 'on demand' rather than continuous location information.

5.2.3 OTHER LBS POSITIONING TECHNOLOGIES

Clearly GNSS is not the only technology that can be used to compute a position. In particular GNSS suffers from poor or non-existent performance in indoor environments and can also suffer from R F interference, multipath etc. Moreover, even when available, GNSS has some power consumption issues. This is why LBS devices often also use other technologies in combination with GNSS. In particular, indoor LBS uses a number of positioning technologies based on WLAN, ultra-wide band (UWB), Bluetooth, MEMS sensors, etc. and other hybrid technologies that cover smaller areas to determine location [RD68].

A number of these other technologies compute the position by evaluating the distance between the device and terrestrial transmitters of one type or another. They include:

- **Cellular/Network-based:** cellular-based positioning technologies rely on the cellular telecommunications network. They generally use one of two positioning techniques: so-called enhanced Cell-ID (ECID), where the timing advance in use in the serving cell is used to calculate the distance from the cell tower, or variations of Time Difference of Arrival (TDOA), such as OTDOA used in LTE, where the differences of the times of arrival of the signals from a number of cell towers is used to triangulate the position. Accuracy for TDOA depends critically on cell density but can be in the region of 50 metres.

- **WLAN (Wireless Local Area Network) or Wi-Fi Positioning:** Determines the location fix by reference to the known location of Wi-Fi access points maintained on a reference database. Dependent on access point density, but high accuracy of 10-20 metres is possible in dense urban environments and indoors.

- **WPAN** (Wireless Personal Area Network) such as Bluetooth or Zigbee. These techniques are similar to WLAN, but can be more accurate (about 2-5 m) but with a lower range (15m). Bluetooth Low Energy (BLE) is now in place and is aimed at healthcare, sports and fitness applications in particular. It uses so-called BLE beacons that are small and have a long battery life and do not require an external energy source. The device detects the signals from the beacons and can calculate roughly the distance to the beacons and hence estimate the location.

- **LPWAN** (Low Power Wide Area Network) such as SigFox or LoRa. They have a similar range to cellular but are designed to allow wireless communication over a long range at a low and very low data rate (not real-time). It enables medium-accuracy geolocation of devices through different time of arrival that is carried out by the network itself, which sends back the location informa-

tion to the device (one-way only). The device requires no additional hardware or power to become a location-aware end node. Base stations (gateways) share a common time-base; end-device transmits a packet and algorithms compare the time of arrival. Accuracy depends on the network density.

- **RFID** (Radio Frequency Identification) accuracy can be below 1m. RFID tags need a reader that scan a tag and determine position as long as it is within frequency range. The readers can scan items simultaneously and work automatically. They do not have any line-of-sight limitations. Although costs are falling, RFID systems are still relatively expensive to install for smaller operations.
- **UWB** (Ultra-Wide Band) short-range radio technology can provide better than 30 cm accuracy and be used for indoor positioning. Only special UWB receivers can detect the signal and still there is lack of UWB hardware on the smartphone, so a user or object needs to have a special UWB tag. There might be issues with synchronisation, which can be time consuming and therefore limits the user experience. UWB solutions are still relatively expensive but like in case of RFID, the prices of hardware and software have been rapidly decreasing.

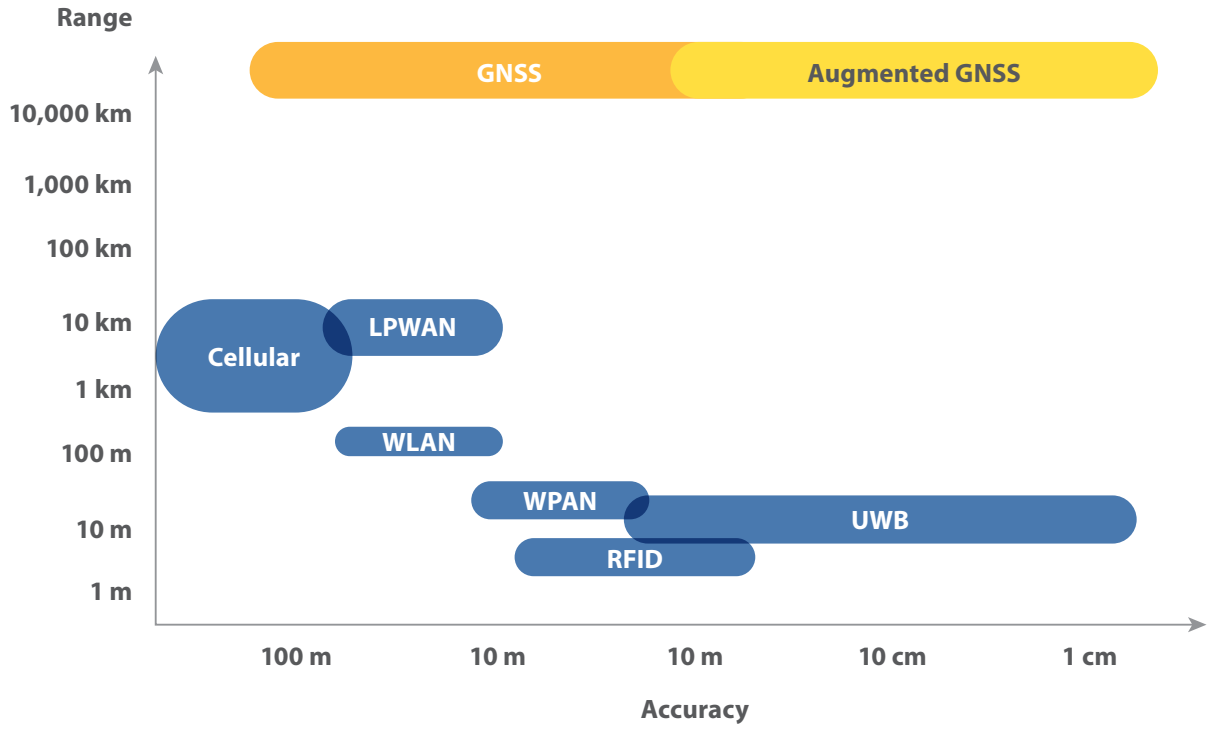
THE LBS MARKET IS DRIVEN BY THE SHORTEST LIFECYCLE IN THE GNSS INDUSTRY WHICH FAVOURS INNOVATION BUT ALSO BRINGS IMPORTANT CONSTRAINTS ON COST

Figure 4 summarises the range and accuracy of the described technologies compared to GNSS (adapted to LBS from the GSA Technology report). Note that Augmented GNSS refers to satellite-based augmentation systems (SBAS) such as EGNOS in Europe, WAAS in North America or GAGAN in India. SBAS compensate for certain disadvantages of GNSS in terms of accuracy, continuity and availability.

Finally, the **Microelectromechanical Systems** (MEMS) technology should be mentioned. MEMS and other types of sensors do not provide a position per se due to their generally poor absolute accuracy and high drift rates but they can complement GNSS, for example to improve indoor performance using dead-reckoning algorithms or to provide additional robustness against spoofing and jamming. Different classes of MEMS and other sensors include for instance:

- Accelerometer detecting change in position
- Gyroscope computing an angular rate sensor (it detects rotation around one or more axis)
- Pressure (altitude)
- Magnetic (compass)

Figure 4: Comparison of GNSS vs. other LBS positioning technologies



It is also possible to use the cameras in the Smartphones to complement GNSS similarly to motion sensors. Visual gyro and visual odometer are practically "off-the-shelf" technologies that will capture the motion and heading of the user with very high precision. High-end smartphones typically have even stereo cameras, cameras able to operate in darkness and cameras to both directions.

5.3 GNSS LIMITATIONS FOR LBS

In spite of all possibilities, GNSS use in LBS applications has some limitations, which are typically overcome by employing the complementary technologies described in the previous sections or by following best practices regarding the type of GNSS equipment used.

POWER CONSUMPTION

GNSS can lead to a **battery life** issue: when running in background on a permanent basis it requires a considerable amount of energy. Therefore, it is preferable to use it only when relatively high precision positioning is required [RD33], [RD69]. Several techniques exist to optimise power consumption, such as setting the receiver in idle or sleep mode and cloud processing.

THERE IS A GREAT DIVERSITY OF APPLICATIONS CATEGORIES IN LBS FOR WHICH GNSS IS EITHER THE MAIN ENABLER OR A KEY COMPONENT

INDOOR/OUTDOOR AVAILABILITY

Although GNSS remains the main source of outdoor positioning information, GNSS signals can be partially or totally blocked by solid walls and ceilings. It thus complicates the positioning of users indoors. **Ubiquitous** indoor/outdoor positioning is one of the critical limits of current LBS applications.

It is difficult (if not impossible) to find a positioning technology which can provide real-time position of users at low cost, seamlessly indoors and outdoors, with a very high level of accuracy, with very low power consumption [RD48]. The current trend is to adopt sensor and systems fusion techniques to respond to the ubiquity requirement.

AVAILABILITY IN CHALLENGING ENVIRONMENTS

One of the factors affecting the performance of positioning systems depends on line-of-sight to satellites [RD9]. The poor performance of GNSS user equipment in urban canyons in terms of both accuracy and solution availability is a well-known problem that arises where there are tall buildings or narrow streets [RD68].

SUSCEPTIBILITY TO MULTIPATH

Multipath occurs when a GNSS signal is reflected off an object, such as the wall of a building, to the GNSS antenna. Because the reflected signal travels further to reach the antenna, the reflected signal arrives at the receiver slightly delayed. This delayed signal can cause the receiver to calculate an incorrect position [RD62].

JAMMING AND SPOOFING OF GNSS SIGNALS

The impacts of intentional **jamming** and **spoofing** are numerous but of different consequences to different LBS users. One consequence of jamming is the inconvenience that results from the service unavailability, which can lower the overall satisfaction of LBS users with the application or the service. The impact can be more consequential for professionals using location-based services for productivity purposes, since it may lead to mismanagement of resources and loss of revenues. The impacts can be also important for users of applications such as navigation of the visually-impaired, lone workers protection, search and rescue, etc. Spoofing can have disastrous effects for users of applications such as children tracking, parolees monitoring, etc.

5.4 MAIN EVOLVING CRITERIA RELATED TO USER REQUIREMENTS

As presented in the table summarising the LBS user requirements, there is a great diversity of applications categories in LBS for which GNSS is either the main enabler or a key component. These categories include: navigation, mapping and GIS, safety and emergency, games, tracking and infotainment. In the future, mass market technology will be used more and more for professional applications (e.g. prospects) and for "citizen science" (e.g. crowd sourcing and cloud sharing). Each of the categories has its own GNSS performance requirements. From the user point of view, these requirements must be satisfied in order to accept the proposed technology.

LBS applications users increasingly seek **ubiquitous availability** (outdoors, in challenging environments such as urban canyons and indoors), **lower power consumption** towards always "the best", **a short TTFF** and **seamless service** (i.e. outdoor to indoor transitions).

There is also a growing demand for **better location accuracy**. Nowadays the main driver pushing the GNSS technological development in smartphones is accuracy. Developments both at the software and hardware levels will soon enable smartphones to be capable of providing such accurate location that they will be used for a range of applications now served by high-end dedicated devices. In May 2016

Google announced that it would make available raw GNSS measurements, making pseudoranges, carrier phase and Doppler accessible from smartphones and tablets using the Google Location Services API. This opens up possibilities for higher accuracy and deployment of algorithms currently restricted to more advanced GNSS receivers.

Integrity of the position will be increasingly requested being a key enabler for LBS liability-critical applications: parolees monitoring, fraud management and billing.

Also, **authentication** and **robustness** are becoming key parameters to mitigate the risks in critical applications such as billing and fraud management but also safety and emergency, parolee monitoring and even gaming.

There will be also an increasing demand for GNSS high consistency. The "red circle" around the GNSS location must also be as accurate as the "red dot", so GNSS receiver must be able to indicate when it is not certain about the quality of the PNT fix. This is extremely important from the autonomous driving/guidance perspective, but also for navigation.

It is nevertheless important to note that the consumer market is more susceptible to the perception of a product or a service [RD67]. Users do not make decision purely on performance criteria. This is different for industrial applications where the fulfilment of quantitative user requirements definitely impacts the adoption of GNSS solutions. But this is rarely the case for consumer applications [RD67].

5.5 STANDARDISATION

Standardisation activities related to Location Based Services can be divided into three areas:

- Definition of the protocols or **signalling** necessary between a positioning server and a device to request and supply a calculated position (or related positioning data). For LBS this can also include the protocols or signalling required for the transfer of the necessary assistance data for the support of Assisted GNSS (A-GNSS). Other positioning protocols may be required internally within networks but these are not considered here.

- Definition of **performance** requirements for positioning including GNSS and A-GNSS. These requirements may be simple position or time accuracy requirements, or may include other performance criteria such as position authenticity and robustness to interference. These requirements may take the form of a series of suggested performance levels or a single minimum performance requirement.

- Definition of **testing** procedures for both the above areas. These procedures can be used generally by the industry, as well as by **certification** bodies for the certification of relevant devices.

Signalling protocols for LBS are mainly developed by the 3rd Generation Partnership Project (3GPP) and the Open Mobile Alliance (OMA). 3GPP is concerned solely with cellular devices and networks but as such still represents the most important LBS area for standardisation. The protocols developed by the OMA are bearer-agnostic and therefore

can be used over any network (e.g. cellular, Wi-Fi, etc.) but are considered to be complementary to those developed by 3GPP. The main protocols of interest are:

- 3GPP: three positioning protocols for the three main generations of cellular networks including the LTE Positioning Protocol (LPP), which is likely to also be used for 5G. 3GPP is currently working on additions to LPP to allow the support of high-accuracy positioning to include potentially both PPP and RTK.

- OMA: Secure User Plane Location (SUPL) which is used extensively in smartphones, as well as LPP Extensions (LPPe) which add additional capability to LPP from 3GPP.

All the above protocols cater for a number of positioning technologies as well as GNSS and A-GNSS, including full support for Galileo and A-Galileo.

Performance requirements for LBS are mainly developed by 3GPP and ETSI TC SES, with CEN-CENELEC also working in this area for the automotive sector, which will not be discussed further here (the OMA does not develop performance requirements). The main performance requirements of interest are:

- 3GPP: so-called "minimum performance" requirements for the position accuracy and TTFF for A-GNSS in a cellular environment (and also similar requirements for other 3GPP-supported positioning technologies). These were originally developed for A-GPS using the US E911 performance requirements as a guideline but were later modified for A-GNSS with slightly tighter requirements. It is of note that these requirements assume that GPS is always used for initial signal acquisition, so Galileo, in common with GLONASS and Beidou, is considered currently as a GNSS of secondary importance. The 3GPP work on the support of high-accuracy positioning may potentially include some additional performance requirements in this same area.

- ETSI TC SES: a number of performance requirements covering a range of performance criteria including position accuracy, time accuracy, TTFF, position authenticity, robustness to interference, position integrity and position repeatability. These requirements take the form of a series of suggested performance levels rather than one "minimum performance" requirement. These requirements are aimed at the complete LBS market, rather than just the cellular sector, however industry uptake of these requirements has so far been slow.

- ETSI TC SES: this group has also recently released a Harmonised European Standard covering the adjacent frequency band selectivity performance and spurious emissions performance for GNSS receivers required to meet the European RED, although it has not yet been adopted by the EC. This standard applies to all commercial GNSS receivers and not just those designed for the LBS market.

All the above requirements, with the exception of the issue mentioned above under 3GPP, include full support for Galileo and A-Galileo where appropriate.

Testing requirements for LBS based on the above signalling and performance requirements are mainly developed by 3GPP, OMA and ETSI TC SES. The main testing requirements of interest are:

- 3GPP: testing requirements are in place for both signalling and minimum performance requirements. However, again the requirements assume that GPS is always present and is used for signal acquisition, so Galileo, in common with GLONASS and Beidou, is considered in the current version as a GNSS of secondary choice. In addition, the tests for A-Galileo, unlike those for other GNSSs, have not yet been officially proven as working correctly (so-called verification).

- OMA: testing requirements are in place for both SUPL and LPPe. Some of the test requirements for A-Galileo are not complete and those tests for A-Galileo that do exist have not yet been officially proven as working correctly.

- ETSI TC SES: testing requirements are in place for a number of the performance requirements, all of which include full support for Galileo, where appropriate.

- ETSI TC SES: testing requirements are in place for the Harmonised European Standard, all of which include full support for Galileo.

There are two main **certification** bodies that cover the certification of cellular devices based on 3GPP technology. These are the Global Certification Forum (GCF), and the PTCRB which mainly covers North America and is therefore not considered further here. For GCF certification of A-GNSS functionality in cellular devices, all the above signalling and minimum performance testing from both 3GPP and OMA is required, however, again, testing for A-Galileo, unlike for other GNSSs, is not performed due to insufficient industry interest formally expressed.

5.6 CONCLUSIONS

GNSS-enabled LBS comprise a multitude of applications tailor-made to satisfy different usages and needs. Whether used for navigation, games or mobile workforce management, LBS creates a more dynamic user experience that

adds value and convenience and changes the way people organise their activities, spend free time and increase productivity at work. This report has provided an overview of GNSS-enabled LBS applications, shed light on the current market and technology trends and outlined the key user requirements for GNSS.

The industry is investing in GNSS, A-GNSS and High-precision GNSS to overcome the challenges with spoofing, indoor/outdoor functionality and high-accuracy. GNSS has become the backbone for LBS and the weaknesses in the existing designs and systems are becoming real threats. It is virtually impossible to change/modernize the satellites and GNSS signals, so the innovations and improvements need to be done in the chipsets, chipset drivers and assistance data services.

There is a growing demand for indoor LBS applications, ubiquitous availability, seamless service, low power consumption and short TTFF. Although not traditionally considered as a high priority in the LBS segment, users have also been increasingly pushing for better location accuracy, which is in turn supporting the GNSS technological development in smartphones.

06 USER REQUIREMENTS SPECIFICATION

6.1 SYNTHESIS OF UR ANALYSIS

The requirements have been gathered according to the groups of applications described in paragraph 5.1.2. When a requirement is common to one or two groups the same nomenclature, reference is used.

6.1.1 REQUIREMENTS FOR NAVIGATION APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0010	The PNT solution shall provide the user position with a horizontal accuracy better than 1 meter with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD79] [RD80]
GSA-MKD-USR-REQ-LBS-0020	The PNT solution shall provide the user position with a vertical accuracy within a range of 1-5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0030	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0040	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD17] [RD80]
GSA-MKD-USR-REQ-LBS-0050	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD17] [RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0060	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD79]
GSA-MKD-USR-REQ-LBS-0070	The PNT solution shall provide a TTFF (hot start) of 30 seconds or less.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-0080	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD31]
~~GSA-MKD-USR-REQ-LBS-0090~~	~~The PNT solution shall provide medium robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0100	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD79]
GSA-MKD-USR-REQ-LBS-0101	The PNT solution shall provide robustness against spoofing.	Performance (Susceptibility to spoofing)	[RD79]

6.1.2 REQUIREMENTS FOR MAPPING AND GIS APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0110	The PNT solution shall provide the user position with a horizontal accuracy better than 1 meter with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0120	The PNT solution shall provide the user position with a vertical accuracy of 1 meter or more with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0130	(Vertical Accuracy)	[RD71] [RD80]	[RD47]
GSA-MKD-USR-REQ-LBS-0140	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0150	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0160	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD71]
GSA-MKD-USR-REQ-LBS-0170	The PNT solution shall provide a TTFF (hot start) better than 1 minute.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-0180	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD71]
GSA-MKD-USR-REQ-LBS-0190	The PNT solution shall have an update rate within a range of 1-5Hz.	Performance (Timeliness: Update rate)	[RD71]
~~GSA-MKD-USR-REQ-LBS-0200~~	~~The PNT solution shall provide medium robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0210	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]

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6.1.3 REQUIREMENTS FOR GEOMARKETING AND ADVERTISING APPLICATIONS

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0220	The PNT solution shall provide the user position with a horizontal accuracy within a range of 10-100 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD6] [RD80]
GSA-MKD-USR-REQ-LBS-0230	The PNT solution shall provide the user position with a vertical accuracy within a range of 1-5 meters. with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0240	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0250	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-0260	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0270	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
GSA-MKD-USR-REQ-LBS-0290	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD32]
~~GSA-MKD-USR-REQ-LBS-0300~~	~~The PNT solution shall provide low robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0310	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-0320	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD47]

6.1.4 REQUIREMENTS FOR SAFETY AND EMERGENCY APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0330	The PNT solution shall provide the user position with a horizontal accuracy within a range of 1-5 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD74] [RD80]
GSA-MKD-USR-REQ-LBS-0340	The PNT solution shall provide the user position with a vertical accuracy within a range of 1-5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0350	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0360	The geographical coverage of the PNT solution shall be regional for E112.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0370	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0380	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-0390	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
GSA-MKD-USR-REQ-LBS-0400	The PNT solution shall provide a TTFF od less than 10 seconds.	Performance (Timeliness: TTFF)	[RD80]
GSA-MKD-USR-REQ-LBS-0410	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD71]
~~GSA-MKD-USR-REQ-LBS-0420~~	~~The PNT solution shall provide high robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0430	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-0440	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD79]

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6.1.5 REQUIREMENTS FOR ENTERPRISE APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0450	The PNT solution shall provide the user position with a horizontal accuracy better than 5 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD79] [RD80]
GSA-MKD-USR-REQ-LBS-0460	The PNT solution shall provide the user position with a vertical accuracy within a range of 1-5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0470	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0480	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD54] [RD80]
GSA-MKD-USR-REQ-LBS-0490	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD17]
GSA-MKD-USR-REQ-LBS-0510	The PNT solution shall provide a TTFF (hot start) of 1 minute or less.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-0520	The PNT solution shall provide continuous positioning.	Performance (Timeliness: Update rate)	[RD71]
GSA-MKD-USR-REQ-LBS-0530	Maximum time between usable fixes shall be 5 seconds	Performance (Timeliness: Update rate)	[RD71].
~~GSA-MKD-USR-REQ-LBS-0540~~	~~The PNT solution shall provide high robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0550	The PNT solution shall provide high robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-0560	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD71]
GSA-MKD-USR-REQ-LBS-0570	The PNT solution shall provide the user position with a horizontal accuracy within 1-5 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0580	The PNT solution shall provide the user position with a vertical accuracy within a range of 1-5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0590	PPP data shall be available via terrestrial links	Availability	[RD79]

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6.1.6 REQUIREMENTS FOR SPORTS APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0570	The PNT solution shall provide the user position with a horizontal accuracy within 1-5 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0580	The PNT solution shall provide the user position with a vertical accuracy within a range of 1-5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0590	The geographical area of operation of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0600	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-0610	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-0620	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD47]
GSA-MKD-USR-REQ-LBS-0630	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-0640	The PNT solution shall provide continuous positioning with an update rate from 1 to 2 Hz	Performance (Timeliness: Update rate)	[RD79]
GSA-MKD-USR-REQ-LBS-0650	Update rate shall be within a range of 5-10Hz.	Performance (Timeliness: Update rate)	[RD71]
~~GSA-MKD-USR-REQ-LBS-0660~~	~~The PNT solution shall provide high robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD68]~~
GSA-MKD-USR-REQ-LBS-0670	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]

2019 update

6.1.7 REQUIREMENTS FOR GAMES APPLICATIONS

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0680	The PNT solution shall provide the user position with a horizontal accuracy better than 1 meter with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD79] [RD80]
GSA-MKD-USR-REQ-LBS-0690	The PNT solution shall provide the user position with a vertical accuracy better than 5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0700	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0710	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD53] [RD80]
GSA-MKD-USR-REQ-LBS-0720	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-0730	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD48]
GSA-MKD-USR-REQ-LBS-0740	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-0750	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD6]
~~GSA-MKD-USR-REQ-LBS-0760~~	~~The PNT solution shall provide medium robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0770	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-0780	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD79]

6.1.8 REQUIREMENTS FOR HEALTH APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0790	The PNT solution shall provide the user position with a horizontal accuracy better than 1 meter with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD79] [RD80]
GSA-MKD-USR-REQ-LBS-0800	The PNT solution shall provide the user position with a vertical accuracy within 1-5 meters with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0810	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-0820	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD17] [RD80]
GSA-MKD-USR-REQ-LBS-0830	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD17] [RD80]
GSA-MKD-USR-REQ-LBS-0840	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
GSA-MKD-USR-REQ-LBS-0850	The PNT solution shall provide a TTFF (hot start) of less than 15 seconds.	Performance (Timeliness: TTFF)	[RD56]
GSA-MKD-USR-REQ-LBS-0860	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD71]
~~GSA-MKD-USR-REQ-LBS-0870~~	~~The PNT solution shall provide high robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0880	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-0890	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD79]
GSA-MKD-USR-REQ-LBS-0891	The PNT solution shall be able to provide timely warnings to the user when data provided by the solution should not be used.	Performance (Integrity)	[RD79]

2019 update

6.1.9 REQUIREMENTS FOR TRACKING

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-0900	The PNT solution shall provide the user position within a range of 1-5 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD6] [RD80]
GSA-MKD-USR-REQ-LBS-0910	The PNT solution shall provide a position with a vertical accuracy of 5 meters or less with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0920	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD32]
GSA-MKD-USR-REQ-LBS-0930	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD32] [RD80]
GSA-MKD-USR-REQ-LBS-0940	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-0950	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD48]
GSA-MKD-USR-REQ-LBS-0960	The PNT solution shall provide a TTFF (hot start) of less than 15 seconds.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-0970	The PNT solution shall provide continuous positioning once the operation has started. Update rate shall be 4 seconds.	Performance (Timeliness: Update rate)	[RD71] [RD76]
~~GSA-MKD-USR-REQ-LBS-0980~~	~~The PNT solution shall provide high robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-0990	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-1000	The PNT solution shall provide robustness against spoofing.	Performance (Resilience: Susceptibility to spoofing)	[RD71]

6.1.10 REQUIREMENTS FOR AUGMENTED REALITY FOR LEISURE

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-1200	The PNT solution shall provide the user position with a horizontal accuracy of 50 centimetres.	Performance (Horizontal Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-1201	The PNT solution shall provide a relative positioning with an accuracy of 2 centimetres.	Performance (Horizontal Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-1300	The PNT solution shall provide the user position with a vertical accuracy of a few centimetres.	Performance (Vertical Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-1301	The PNT solution shall provide a relative positioning with an accuracy of 2 centimetres.	Performance (Vertical Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-1400	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD80]
GSA-MKD-USR-REQ-LBS-1500	The PNT solution shall be available in urban canyons.	Performance (Availability in urban canyon)	[RD80]
GSA-MKD-USR-REQ-LBS-1600	The PNT solution shall be available under canopy.	Performance (Availability under canopy)	[RD80]
GSA-MKD-USR-REQ-LBS-1700	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD80]
GSA-MKD-USR-REQ-LBS-1800	The PNT solution shall provide a TTFF (hot start) of 30 seconds or less.	Performance (Timeliness: TTFF)	[RD80]
GSA-MKD-USR-REQ-LBS-1900	The PNT solution shall provide continuous positioning once the operation has startedUpdate rate shall be of 15Hz.	Performance (Timeliness: Update rate)	[RD80]
GSA-MKD-USR-REQ-LBS-2100	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD80]
GSA-MKD-USR-REQ-LBS-2200	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD80]

2019 update

6.1.11 REQUIREMENTS FOR SOCIAL NETWORKING APPLICATIONS

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-2300	The PNT solution shall provide the user position with a horizontal accuracy of better than 10 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD6] [RD28] [RD80]
GSA-MKD-USR-REQ-LBS-2400	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-2500	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD28] [RD80]
GSA-MKD-USR-REQ-LBS-2600	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-2700	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
GSA-MKD-USR-REQ-LBS-2800	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-2900	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD28]
~~GSA-MKD-USR-REQ-LBS-3000~~	~~The PNT solution shall provide medium robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-2900	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-3000	The PNT solution shall provide robustness against spoofing.	Performance (Resilience: Susceptibility to spoofing)	[RD78]

6.1.12 REQUIREMENTS FOR INFOTAINMENT APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-3100	The PNT solution shall provide the user position with a horizontal accuracy within a range of 10-100 meters with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD79] [RD80]
GSA-MKD-USR-REQ-LBS-3200	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-3300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-3400	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-3500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
GSA-MKD-USR-REQ-LBS-3600	The PNT solution shall provide a TTFF (hot start) of less than 2 seconds.	Performance (Timeliness: TTFF)	[RD71]
GSA-MKD-USR-REQ-LBS-3700	The PNT solution shall provide continuous positioning.	Performance (Timeliness: Update rate)	[RD79]
~~GSA-MKD-USR-REQ-LBS-3800~~	~~The PNT solution shall provide medium robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	[RD71]
GSA-MKD-USR-REQ-LBS-3900	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]

2019 update

6.1.13 REQUIREMENTS FOR COMMERCIAL APPLICATIONS

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-4000	The PNT solution shall provide the user position with a high horizontal accuracy with a 95% confidence level.	Performance (Horizontal Accuracy)	[RD14] [RD32] [RD80]
GSA-MKD-USR-REQ-LBS-4100	The PNT solution shall provide a position with a vertical accuracy of 3 meters or less with a 95% confidence level.	Performance (Vertical Accuracy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-4200	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
GSA-MKD-USR-REQ-LBS-4300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
GSA-MKD-USR-REQ-LBS-4400	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
GSA-MKD-USR-REQ-LBS-4500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
GSA-MKD-USR-REQ-LBS-4600	The PNT solution shall provide a TTFF (hot start) of less than 2 seconds.	Performance (Timeliness: TTFF)	[RD14]
GSA-MKD-USR-REQ-LBS-4700	The PNT solution shall provide on request positioning.	Performance (Timeliness: Update rate)	[RD79]
~~GSA-MKD-USR-REQ-LBS-4800~~	~~The PNT solution shall provide high robustness against environmental conditions.~~	~~Performance (Resilience: Susceptibility to environmental conditions)~~	~~[RD71]~~
GSA-MKD-USR-REQ-LBS-4900	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-5000	The PNT solution shall provide robustness against spoofing.	Performance (Resilience: Susceptibility to spoofing)	[RD68]
GSA-MKD-USR-REQ-LBS-5100	The PNT solution shall be able to provide timely warnings to the user when data provided by the solution should not be used.	Performance (Integrity)	[RD71]
GSA-MKD-USR-REQ-LBS-5200	The maximum allowable time between the occurrence of the failure in the PNT solution and its presentation to the user shall be less than 10 seconds.	Performance (Time to alter)	[RD71]

6.1.14 REQUIREMENTS FOR AUGMENTED REALITY FOR PROFESSIONAL APPLICATIONS

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-6050	The PNT solution shall provide the user position with a horizontal accuracy of less than 1 meter.	Performance (Horizontal Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-6100	The PNT solution shall provide the user position with a vertical accuracy of less than 1 meter.	Performance (Vertical Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-6200	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD80]
GSA-MKD-USR-REQ-LBS-6300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performan (Availability in urban canyon)	[RD80]
GSA-MKD-USR-REQ-LBS-6400	The PNT solution shall be available under canopy with a confidence level between 90% and 95%.	Performance (Availability under canopy)	[RD80]
GSA-MKD-USR-REQ-LBS-6500	The PNT solution shall be available indoors with a confidence level between 90% and 95%.	Performance (Availability indoors)	[RD80]
GSA-MKD-USR-REQ-LBS-6600	The PNT solution shall provide a TTFF (hot start) in the range 2-30 seconds.	Performance (Timeliness: TTFF)	[RD80]
GSA-MKD-USR-REQ-LBS-6700	The PNT solution shall provide continuous positioning once the operation has started	Performance(Timeliness: Update rate)	[RD80]
GSA-MKD-USR-REQ-LBS-6800	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD80]
GSA-MKD-USR-REQ-LBS-6900	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD80]

2019 update

6.1.15 REQUIREMENTS FOR ROBOTICS – HIGH GNSS USE

2019 update

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-7000	The PNT solution shall provide the user position with a horizontal accuracy of less than 1 meter.	Performance (Horizontal Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-7100	The PNT solution shall provide the user position with a vertical accuracy of less than 1 meter.	Performance (Vertical Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-7200	The geographical coverage of the PNT solution shall be regional.	Performance (Geographical coverage)	[RD80]
GSA-MKD-USR-REQ-LBS-7300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD80]
GSA-MKD-USR-REQ-LBS-7400	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD80]
GSA-MKD-USR-REQ-LBS-7500	The PNT solution shall be available indoors with a 95% confidence level.	Performance (Availability indoors)	[RD80]
GSA-MKD-USR-REQ-LBS-7600	The PNT solution shall provide a TTFF (hot start) in the range 2-30 seconds.	Performance (Timeliness: TTFF)	[RD80]
GSA-MKD-USR-REQ-LBS-7700	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD80]
GSA-MKD-USR-REQ-LBS-7800	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD80]
GSA-MKD-USR-REQ-LBS-7900	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD80]

6.1.16 REQUIREMENTS FOR ROBOTICS – LOW GNSS USE

Id	Description	Type	Source
GSA-MKD-USR-REQ-LBS-8000	The PNT solution shall provide the user position with a horizontal accuracy of a centimetre.	Performance (Horizontal Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-8100	The PNT solution shall provide the user position with a vertical accuracy of a centimetre.	Performance (Vertical Accuracy)	[RD80]
GSA-MKD-USR-REQ-LBS-8200	The geographical coverage of the PNT solution shall be local.	Performance (Geographical coverage)	[RD80]
GSA-MKD-USR-REQ-LBS-8300	The PNT solution shall be available in urban canyons.	Performance (Availability in urban canyon)	[RD80]
GSA-MKD-USR-REQ-LBS-8400	The PNT solution shall be available under canopy.	Performance (Availability under canopy)	[RD80]
GSA-MKD-USR-REQ-LBS-8500	The PNT solution shall be available indoors.	Performanc (Availability indoors)	[RD80]
GSA-MKD-USR-REQ-LBS-8600	The PNT solution shall provide a TTFF (hot start) of less than 10 seconds.	Performance (Timeliness: TTFF)	[RD80]
GSA-MKD-USR-REQ-LBS-8700	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD80]
GSA-MKD-USR-REQ-LBS-8800	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
GSA-MKD-USR-REQ-LBS-8900	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD71]

2019 update

07 ANNEXES

ANNEX 1 – SYNTHESIS OF LBS USER REQUIREMENTS

Application categories	Applications	Applications description	Accuracy		Service area		
			Horizontal	Vertical	Global	Regional	Urban canyon
Navigation	Route planning and turn-by-turn navigation	Plans route and provides turn-by-turn instructions based on GNSS positioning. Includes road, bike, pedestrian, sailing navigation [RD2], [RD5], [RD18]. Il also delivers real-time information, such as traffic updates or weather reports so the user can plan accordingly [RD5].	Low for road navigation Low/ Medium for pedestrian navigation	Low	Yes	No	Yes
	Real-time public transport	Informs about transport vehicles position, when the next one should arrive and provides the user with service updates [RD5].	Medium	N/A	Yes	No	Yes
	Eco-driving and carbon emission footprint	Optimises journey to reduce greenhouse gas emissions [RD25]	Low	Medium	Yes	No	Yes
	Smart parking	Provides drivers with information on empty parking slops [RD24].	High	Medium	Yes	No	Yes
Mapping & GIS		A geospatial information system (GIS) captures, stores, analyses, manages, and presents data that is linked to location. GIS applications can generate contour maps form the data and present these maps in a digital form. Smartphones enable users to become map creators thanks to the democratisation of digital mapping [RD2].	High	High	Yes	No	Yes
Geo marketing and advertising	Geomarketing and advertising	Consumer preferences are combined with positioning data to provide personalised offers to potential customers and create market opportunities for retailers [RD5].	Low	Medium	Yes	No	Yes
Safety and emergency	Search and rescue	Alerts search and rescue services and provides them with accurate emergency caller location [RD3].	Medium	Medium	Yes	No	Yes
	E112	Emergency phone number that can be dialled free of charge from most mobile telephones in order to reach emergency services (ambulance, fire and rescue, police). The telecom operator transmits the location information to the emergency centre [RD1], [RD2].	Medium	Medium	No	Yes	Yes

Availability / Timeliness				Resilience (Robustness/Trust)			Integrity		Power consumption	Proportion of GNSS in the application category
Canopy	Indoors	TTFF	Fix update	Susceptibility to environmental conditions	Susceptibility to interferences	Susceptibility to spoofing	Risk	Time to alert		
Yes	Yes for road and pedestrian navigation	Low	Continuous	Medium	High	low	N/A	N/A	Medium to low	High
No	Yes	Medium	Continuous	Medium	Medium	N/A	N/A	N/A	Low	
Yes	No	Medium	Continuous	Medium	Medium	N/A	N/A	N/A	Medium to low	
Yes	No	Medium	Continuous	Medium	Medium	N/A	N/A	N/A	Medium to low	
Yes	Yes	Low	Continuous 1-5Hz	Medium	High	N/A	Yes	TBD	Low	High
Yes	Yes	N/A	on-request	Low	Low	Yes	N/A	N/A	Very low	Low
Yes	Yes	Low	On-request	High	High	Medium	N/A	N/A	Low	High
Yes	Yes	Medium	On-request	High	High	Medium	N/A	N/A	Low	

Application categories	Applications	Applications description	Accuracy		Service area		
			Horizontal	Vertical	Global	Regional	Urban canyon
Enterprise applications	Mobile workforce management	Aims to manage employees working outside the company premises and to improve operational efficiency [RD30].	Low	Medium	Yes	No	Yes
	Lone worker protection	Ensures the security of employees through features such as two-way communications and automatic location. Sends alarm to supervisors or to alarm receiving centres in case of emergency [RD30].	Medium/ High	Medium	Yes	No	Yes
Sports	Fitness and performance monitoring	Records data such as real-time distance, speed/pace, location, elevation, traveled distance, step counters to monitor users' performance. Speed and elevation charts are provided (inc. running, biking, hiking, swimming, etc.) [RD2], [RD19], [RD20].	Medium	Medium	Yes	No	Yes
	Sports gear retrieval: golf balls	GNSS-enabled application that helps locate sports gear [RD28].	Medium	N/A	Yes	No	No
	Fishing assistance	GNSS-enabled application that helps locate fish [RD29].	Low	N/A	Yes	No	No
Games	LBS games	GNSS enables a wide range of location-based games on smartphones and tablets [RD1].	High	Low	Yes	No	Yes
Health	Guidance for visually impaired	Provides turn-by-turn instructions based on GNSS positioning that help visually-impaired get around more easily [RD2], [RD4].	High	Medium	Yes	No	Yes
	Vulnerable people tracking	Tracks elderly, people with cognitive disabilities. Includes the deployment of local geofences that trigger an alarm when a user leaves the perimeter [RD3], [RD5].	Medium	Medium	Yes	No	Yes
	Fall detection	Alerts when a fall event has occurred [RD31].	Low	Medium	Yes	No	Yes
Tracking	Children locators	Allows parents to track their children. Includes the deployment of local geofences that trigger an alarm when a user leaves a perimeter or approaches a dangerous area (e.g. swimming pool) [RD30].	Medium	Medium	Yes	No	Yes
	Parolees monitoring	Monitors parolees. Includes local geofences that trigger an alarm when a parolee leaves the perimeter (if this is a stipulation of their parole conditions) [RD30].	Medium	Medium	Yes	No	Yes
	Pets locators	Allows masters to track their pets. Some of them also enable to track pets' physical activity levels [RD26].	Medium	Medium	Yes	No	Yes
	Tracking of valuable and stolen goods	Allows owners to locate valuable goods and assets such as luggage, bikes, etc. [RD5], [RD32].	Medium	Medium	Yes	No	Yes
Augmented reality		Positioning and virtual information are combined to entertain the user and to improve everyday life [RD5].	High	Medium	Yes	No	Yes

Availability / Timeliness				Resilience (Robustness/Trust)			Integrity			
Canopy	Indoors	TTFF	Fix update	Susceptibility to environmental conditions	Susceptibility to interferences	Susceptibility to spoofing	Risk	Time to alert	Power consumption	Proportion of GNSS in the application category
Yes	Yes	Low	Continuous	High	High	High	N/A	N/A	Low	Low
Yes	Yes	Medium	Continuous	High	High	N/A	N/A	N/A	Low	Low
Yes	Yes	High	Continuous 1-2Hz	High	Medium	N/A	N/A	N/A	Medium	High
Yes	No	Medium	On-request	High	Medium	N/A	N/A	N/A	Medium	
No	No	Low	Continuous	High	Low	N/A	N/A	N/A	Low	
Yes	Yes	High	Continuous	High	High	High	N/A	N/A	Low	High
Yes	Yes	High	Continuous	High	High	Low/ Medium	Yes	TBD	Low	Medium
Yes	Yes	High	Continuous	High	High	Low	N/A	N/A	Low	
Yes	Yes	High	Continuous	High	High	Low	N/A	N/A	Low	
Yes	Yes	High	On-request	High	Medium	Medium	N/A	N/A	Medium to low	High
Yes	Yes	Medium	On-request	High	High	High	N/A	N/A	Low	
Yes	Yes	Medium	Continuous and on-request	High	Medium	low	N/A	N/A	Medium to low	
Yes	Yes	High	Continuous	Hgh	High	High	N/A	N/A	Medium	
Yes	Yes	High	Continuous 1Hz	High	Medium	Medium	N/A	N/A	Low	Medium

Application categories	Applications	Applications description	Accuracy		Service area		
			Horizontal	Vertical	Global	Regional	Urban canyon
Social networking	Friend locator	Provides on-demand information to end users about the location of friends relative to themselves [RD2].	Medium	N/A	Yes	No	Yes
	Dating	GNSS-enabled apps that use participants' current locations to connect people, allowing them to chat and to possbily meet up [RD33].	Medium	N/A	Yes	No	Yes
	Chat and instant messaging services	Location information used in chat and instant messaging services allows the user to estimate how far they are from each other at the time of communication	Low	N/A	Yes	No	Yes
Infotainment	Points of interest	Provides content relative to the end user's location. Such location may include location-based landmarks, restaurants, gas stations, banks, ATMs, hospitals, etc. [RD12].	Low	N/A	Yes	No	Yes
	Photos and videos geotagging	Adds geospatial metadata to digital media such as photographs, videos, messages, blogs and web pages [RD5]	Low	N/A	Yes	No	Yes
	Geolocated news	The app will send users a push notification on their mobile device when news breaks near them [RD23].	Low	N/A	Yes	No	Yes
Commercial	Fraud management	Creates another level of security during a credit card transaction by checking the customer's location through his/her smartphone [RD7].	High	Medium	Yes	No	Yes
	Billing	Payment processing based on location or activity duration for public transport, gyms, theme parks, parking [RD5], [RD25].	High	Medium	Yes	No	Yes

Availability / Timeliness				Resilience (Robustness/Trust)			Integrity		Power consumption	Proportion of GNSS in the application category
Canopy	Indoors	TTFF	Fix update	Susceptibility to environmental conditions	Susceptibility to interferences	Susceptibility to spoofing	Risk	Time to alert		
Yes	Yes	High	A few seconds	Medium	Low	N/A	N/A	N/A	Low	Medium
Yes	Yes	High	On-request	Medium	Medium	Yes	N/A	N/A	Low	
Yes	yes	High	On-request	Medium	Low	N/A	N/A	N/A	Low	
Yes	Yes	High	On-request	Medium	Low	N/A	N/A	N/A	Low	High
Yes	Yes	Medium	On request	Low	Low	N/A	N/A	N/A	Low	
Yes	Yes	Low	Continuous	Low	Low	N/A	N/A	N/A	Low	
Yes	Yes	High	On-request	High	High	High	High	10 seconds	Low	Medium
Yes	Yes	High	On-request	High	High	High	High	10 seconds	High	

ANNEX 2 – DEFINITION OF KEY GNSS PERFORMANCE PARAMETERS

This Annex provides a definition of the most commonly used GNSS performance parameters, taken from [RD47] and not specifically focused on the LBS community.

Availability: the percentage of time the position, navigation or timing solution can be computed and supplied to the user. Values vary greatly according to the specific application and services used, but typically range from 95-99.9%. There are two classes of availability:

- System: the percentage of time the (GNSS) system allows the user to compute a position – this is what is referred to in the GNSS Interface Control Documents (ICDs).
- Overall: takes into account the receiver performance and the user's environment (for example if they are subject to shadowing).

Accuracy: the difference between the true and the computed position (absolute positioning). This is expressed as the value within which a specified proportion of samples would fall if measured. Typical values for accuracy range from tens of meters to centimeters for (typically) 95% of samples. Accuracy is typically stated as 2D (horizontal) or 3D (horizontal and height) and/or time.

Continuity: ability to provide the required performance during an operation without interruption once the operation has started. Continuity is usually expressed as the risk of a discontinuity and depends entirely on the timeframe of the application (e.g. an application that requires 10 minutes of uninterrupted service has a different continuity figure than one requiring two hours of uninterrupted service, even if using the same receiver and services). A typical value is 1x10-4 over the course of the procedure where the system is in use.

Integrity: the measure of trust that can be placed in the correctness of the position and/or time estimate provided by the receiver. This is usually expressed as the probability of a user being exposed to an error larger than alert limits without warning. The way integrity is ensured and assessed, and the means of delivering integrity related information to the user are highly application dependent. For safety-of-life-critical applications such as passenger transportation, the "integrity concept" is generally mature, and integrity can be described by a set of precisely defined and measurable parameters. This is particularly true for civil aviation. For less critical or emerging applications, however, the situation is different, with an acknowledged need for integrity but no unified way of quantifying or satisfying it. Throughout this report, "integrity" is to be understood at large, i.e. not restricted to safety-critical or civil aviation definitions but also encompassing concepts of quality assurance/quality control as used by other applications and sectors.

Resilience or Robustness: the ability of the receiver to continue to perform satisfactorily under conditions of interference or attack. This can take the form of any or all of: susceptibility to interference, susceptibility to spoofing, susceptibility to jamming, susceptibility to environmental conditions. Robustness is a qualitative, rather than quantitative, parameter that depends on the type of attack or interference the receiver is capable of mitigating. It can include authentication information to ensure users that the signal comes from a valid source (enabling sensitive applications).

Note: for some users robustness may have a different meaning, such as the ability of the solution to respond following a severe shadowing event. For the purposes of this document, robustness is defined as the ability of the solution to mitigate any form of interference, either accidental or deliberate.

- Susceptibility to interference: interference can refer to any form of problem experienced by a receiver and can generally be accidental or deliberate, but for the purposes of this document the term interference is used for RF conditions that interfere with the performance of the receiver (i.e. degrade or completely deny the performance) and are accidental and not deliberate.
- Susceptibility to spoofing: spoofing is a deliberate act to try to force the receiver to provide an incorrect position (or time) to deceive the user or the system provider.
- Susceptibility to jamming: jamming is a deliberate act to try to prevent the receiver from providing any output of position (or time).
- Susceptibility to environmental conditions: susceptibility to environmental conditions such as weather, day/night, ionosphere etc.

Indoor penetration or availability: ability of a signal to penetrate inside buildings (e.g. through windows). Indoor penetration does not have an agreed or typical means of expression. In GNSS, this parameter is dictated by the sensitivity of the receiver, whereas for other positioning technologies there are vastly different factors that determine performance (for example, availability of Wi-Fi access points for Wi-Fi-based positioning).

Time to first fix (TTFF): a measure of a receiver's performance covering the time between activation and output of a position within the required accuracy bounds. Activation means subtly different things depending on the status of the data the receiver has access to:

- Cold start: the receiver has no knowledge of the current situation (that is satellite orbits and current time) and thus has to systematically search for and identify signals before processing them – a process that typically takes 15 minutes.
- Warm start: the receiver has estimates of the current situation – typically taking 45 seconds.
- Hot start: the receiver knows accurately what the current situation is – typically taking 20 seconds.

Power consumption: the amount of power a device uses to provide a position. The power consumption of the positioning technology will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing position. Typical values are in the order of tens of mW (for smartphone chipsets).

ANNEX 3 – LIST OF ACRONYMS

3GPP	3rd Generation Partnership Project
A-GNSS	Assisted GNSS
A-GPS	Assisted GPS
BLE	Bluetooth Low Energy
EC	European Commission
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EM	Electronic Monitoring
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
G2G	Galileo Second Generation
GAGAN	GPS and GEO Augmented Navigation
GCF	Global Certification Forum
GDP	Gross Domestic Product
GeoRSS	Geo Rich Site Summary
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System (Russian)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European GNSS Agency
ICD	Interface Control Document
IoT	Internet of Things
LBS	Location Based Services
LPP	LTE Positioning Protocol
LPWAN	Low Power Wide Area Network

LTE	Long-Term Evolution (4G)
M2M	Machine to Machine
MEMS	Microelectromechanical Systems
MKD	Market Development
MLBG	Mobile Location Based Gaming
N/A	Not Applicable
OMA	Open Mobile Alliance
OTDOA	Observed Time Difference of Arrival
OTS	Offender Tracking System
OS-NMA	Open Service Navigation Message Authentication
PLB	Personal Locator Beacon
PNT	Positioning, Navigation, and Timing
PPP	Precise Point Positioning
PVT	Position, Velocity, Time
RED	Radio Equipment Directive
RF	Radio Frequency
RFID	Radio Frequency IDentification
RTK	Real Time Kinematic
SUPL	Secure User Plane Location
TTFF	Time To First Fix
UCP	User Consultation Platform
UWB	Ultra-Wide Band
WAAS	Wide Area Augmentation System
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network

ANNEX 4 – UPDATES FOLLOWING THE USER CONSULTATION PLATFORM 2018

As per EUSPA document reference GSA-MKD-LBS-UREQ-251690 available here.

ANNEX 5 – UPDATES FOLLOWING THE USER CONSULTATION PLATFORM 2020

As per EUSPA document reference EUSPA-MKD-LBS-UREQ-251690 available here.

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