2023

Report on Consumer Solutions

User Needs and Requirements

#EUSpace

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European Union Agency for the Space Programme

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1 INTRODUCTION AND CONTEXT OF THE REPORT

The User Consultation Platform (UCP) is a periodic forum organised by the European Union Agency for the Space Programme (EUSPA), where users from different market segments meet to discuss their needs and application-level requirements relevant for Position, Navigation and Timing (PNT), Earth Observation (EO) and secure telecommunications. The event is involving end users, user associations and representatives of the value chain, such as receiver and chipset manufacturers and application developers. It also gathers organisations and institutions dealing, directly and indirectly, with the two European satellite navigation systems, Galileo and EGNOS and newly since 2020, also with the EU Earth Observation system, Copernicus, and with GOVSATCOM, the upcoming system for secure governmental satellite communications. The UCP event is a part of the process developed at EUSPA to collect user needs and requirements and take them as inputs for the provision of user driven space data-based services by the European Space Programme.

In this context, the objective of this document is to provide a reference for the European Space Programme and for the *Consumer Solutions, Tourism & Health* community, reporting periodically the most up-to-date user needs and requirements in the *Consumer Solutions, Tourism & Health* market segment. This report is a living and evolving document that will periodically be updated by EUSPA. It serves as a key input to the UCP, where it will be reviewed and subsequently updated and expanded in order to reflect the evolutions in the user needs, market and technology captured during the event.

During the 2022 UCP edition, a special session of the discussion has been dedicated to EO platform developers, who include service and content providers and app developers (last-mile). These players are strategically relevant stakeholders within the value chain since they make the richness and complexity of EO data accessible, understandable and usable also for non-expert users, driving the development of the downstream market of consumer solutions. On this occasion, the aim will be to gather first-hand information on needs and offers, the consequent convergence points as well as gaps that will need bridging, which might concern data, processing, accessibility, end user readiness and capabilities. All this is meant to enable all the actors within the industry to communicate and collaborate in a mutually profitable way.

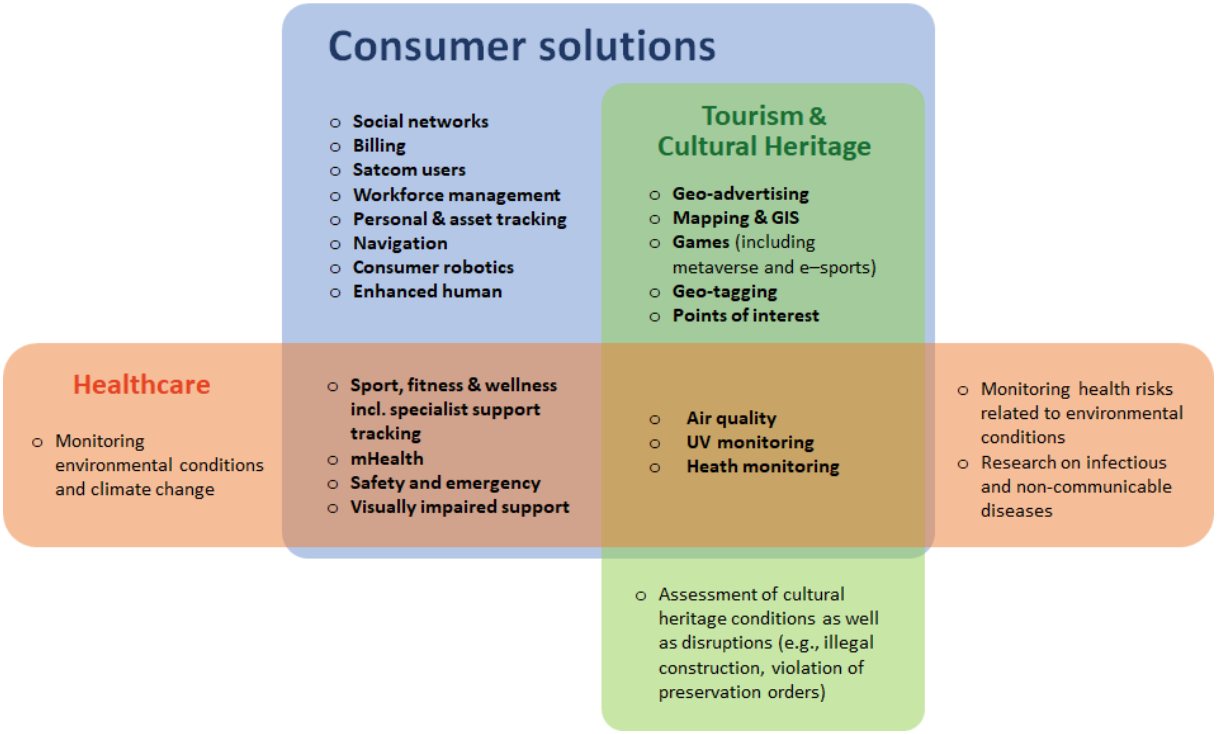
The report aims to provide EUSPA with a clear and up-to-date view of the current and potential future user needs and requirements in order to serve as an input to the continuous improvement of the development of the space downstream applications and services provided by the European Space Programme components. In line with the extended mandate of EUSPA, the Report on User needs and Requirements (RURs) previously focused on GNSS, have been revamped in order to also encompass the needs of Earth Observation (EO) commercial users and is now organised according to the market segmentation of the EUSPA EO and GNSS Market Report.

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

It must be noted that the listed user needs and requirements cannot usually be addressed by a single technological solution but rather by space downstream applications which combine several signals and sensors. Therefore, the report does not represent any commitment of the European Space Programme to address or satisfy the listed needs and requirements in the current or future versions of the services and/or data delivered by its different components.

In this report the focus is specifically to applications of GNSS and EO technologies in the Consumer Solutions, Tourism & Health market segment, which encompasses all those consumer services that include a multitude of applications, tailored to meet different conditions and usage needs about lifestyle, sports activities, health, etc. These applications are supported by different categories of connected devices; mainly

Figure 1 - Consumer solutions. Tourism and Healthcare segments synergies



smartphones and tablets, but also specific devices such as personal tracking devices, wearables, digital cameras, and laptops. Today, thanks to the combination of technologies such as GNSS, EO, 5G, Wi-Fi, Internet of Things (IoT), any physical device can become a connected device, enabling new applications to facilitate the well-being and lifestyle of the end user. Technological advances and substantial cost reductions associated with the operation and supporting infrastructure for satellites have led to a dramatic increase in the availability of satellite imagery for civilian use in recent years. This significant amount of information on Earth conditions, often available on a (at least) daily basis, has allowed application developers to create service and information layers that enable dozens of apps for various purposes. The Consumer Solutions, Tourism and Health segment include a very wide array of applications that support activities in many domains which can be very similar, and even partially overlap, or be quite different from each other. There are services that can be leveraged for mass market use but at the same time meet needs of other related segments as well. Specifically, Consumer Solutions intersects with two others segments: Healthcare, Tourism & Cultural Heritage. For example, sports activity-related applications are personal and wearable applications also associated with the concept of health. Air Quality and UV monitoring applications are usable by the individual user through their own devices, but these offered services are related to personal health. Even, applications for mapping and geo-tagging can be linked to the segment of Tourism. The Figure 1 can better show the relationships across those different market segments. It is evident that the Consumer Solutions, Tourism & Health segment is extremely varied in its application modes and complementary with several fields of great social importance.

It is also important to talk about the EO platforms developers that play a particularly crucial role in this market segment. These actors of the value chain are service providers for EO data management, analytical information and insights on specific applications, (e.g. mapping and GIS, air quality, UV monitoring, etc.), and some platforms directly provide data on specific topics, e.g. tourism and environmental indicators. EUSPA is

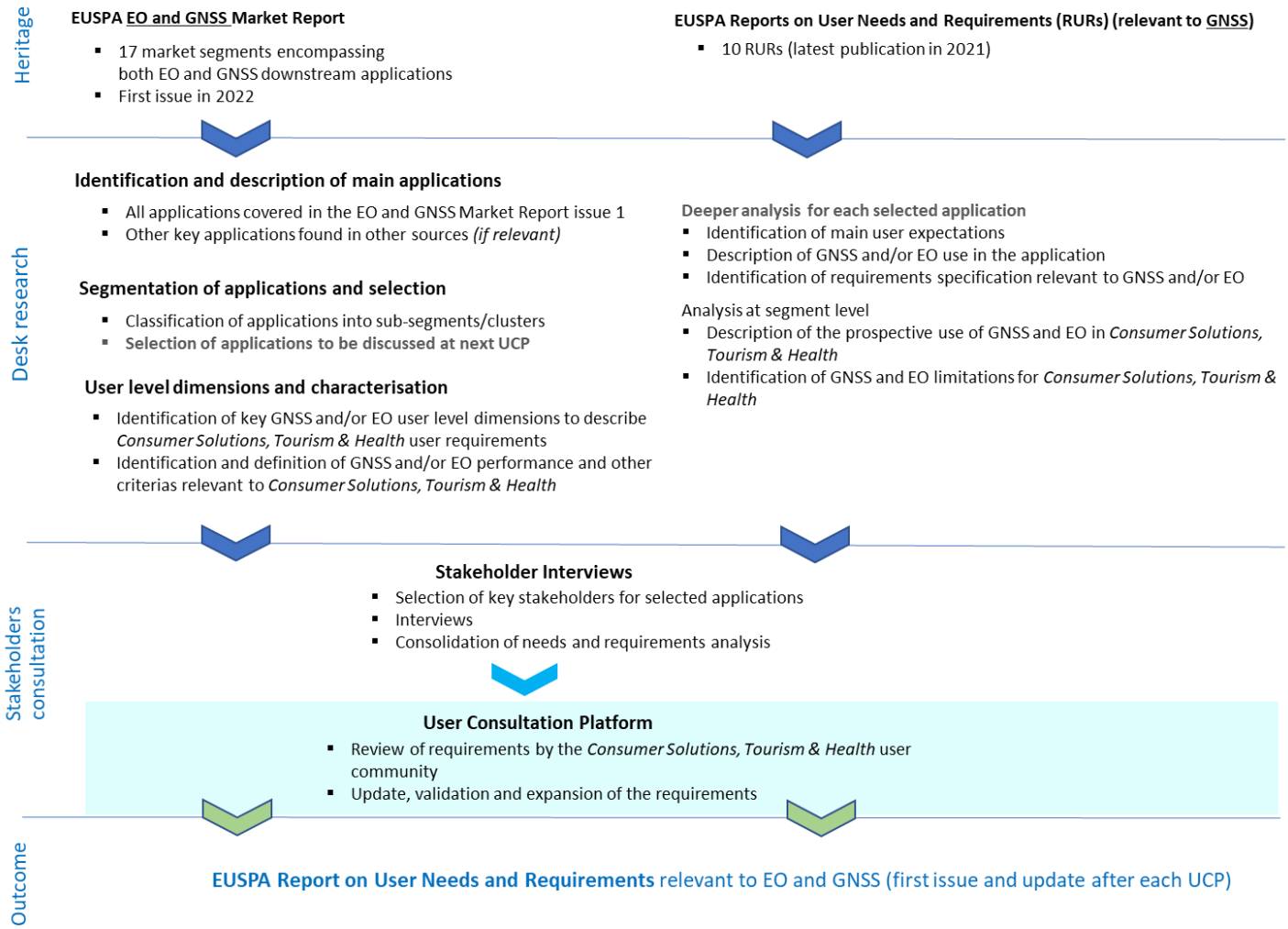
promoting and building, starting with UCP 2022, a community of EO platforms developers that includes service and content providers, app developers and app retailers, EO content providers for the terrestrial segment (e.g. Copernicus DIAS), multiple data/mapping providers (e.g. UP42, Sinergise), but also platforms about specific information providers for certain market segments (e.g. Kayrros, Satelligence, EOMAP). At the UCP 2022 event in Prague, a discussion session was dedicated to EO platform developers. The aim was to bring these together with application developers, who are the ones who make use of the EO data offered in the platforms. The prolific discussion that emerged will be reported in Chapter 3.3 of this document.

The current document implements all the comments received during the UCP 2022 and thus it constitutes a validated version of user requirements for Consumer Solutions, Tourism and Health.

1.1 Methodology

Figure 2 shows the methodology adopted for the analysis of the *Consumer Solutions, Tourism & Health* user requirements at application level.

Figure 2 - Consumer Solutions, Tourism & Health user requirements analysis methodology



The performed analysis leverages on the latest EUSPA EO and GNSS Market Report Issue 1 (2022), adopting as starting point the market segmentation for EO and GNSS downstream applications and takes on board the baseline of user needs and requirements relevant to GNSS compiled in the previous RURs published by the agency.

The analysis is split into two main steps, including desk research, aiming at refining and extending the heritage inputs and at gathering new relevant insights, and a stakeholders' consultation to validate main outcomes.

More in details, the desk research was carried out to consolidate when required the list of applications and their classification, to identify the key parameters driving their performances or other relevant requirements together with the main requirements specification, etc. A deeper analysis was conducted for a set of applications prioritised for discussion at the last UCP event. The outcomes of this preliminary analysis were shared and consolidated prior to the UCP with a small group of key stakeholders, operating in the field of the selected applications.

These requirements analysis results were then presented and debated at the UCP with the *Consumer Solutions, Tourism & Health* user community. The outcomes of the *Consumer Solutions, Tourism & Health* forum discussions were finally examined in order to validate and fine-tune the study findings.

The steps described above have resulted in the outcomes that are presented in detail hereafter.

1.2 Scope

This document is part of the User Requirements documents issued by the European Union Agency for the Space Programme for the Market Segments where Position Navigation and Time (PNT) and Earth Observation (EO) data play a key role. Its scope is to cover requirements on PNT and Earth Observation-based solutions from the strict user perspective and considering the market conditions, regulations, and standards that drive them.

The RUR is intended to serve as an input to more technical discussions on systems engineering and to shape the evolution of the European Union's satellite navigation systems, Galileo and EGNOS and the Earth Observation system, Copernicus.

The document starts with a market overview for *Consumer Solutions, Tourism & Health* (Section 3), focusing on the market evolution and key trends applicable to the whole segment or more specific ones relevant to a group of applications or to the use of GNSS or EO. This Section also presents the main market players and user communities. The report then provides a panorama of the applicable policies, regulations and standards (Section 4). It then moves to the detailed analysis of user requirements (Section 5). This Section first presents an overview of the market segment downstream applications, and indicates for each application, the depth of information available in the current version of the report: i.e. broad specification of needs and requirements relevant to GNSS and EO, partial specification limited at this stage to needs and requirements relevant to GNSS, or limited to an introduction to the application and its main use cases at operational level. The content of this Section will be expanded and completed in the next releases of the RUR.

Finally, Section 6 summarises the main User Requirements for *Consumer Solutions, Tourism & Health* in the applications domains analysed in this report.

The current version of the report will be expanded and completed through its future releases.

2 EXECUTIVE SUMMARY

This report aims to enhance the understanding of market evolution, strengths, limitations, technology trends, and key drivers related to the adoption of GNSS and EO solutions in the different applications of the *Consumer Solutions, Tourism & Health* segment. These elements are essential to frame the technological developments required in the near future and how the supply can be adapted with respect to the demands of the corresponding users.

Key trends and market evolution

The main key market trend characterising Consumer Solutions applications include:

- **Increasing focus on health, including public health, personal health and mental wellbeing.** After Covid pandemic many patterns of exercise for sports enthusiasts have changed, and also the interest in personal health and wellbeing, have encouraged more people to begin exercise routines.
- **Location data to fight digital fraud**. The increased use of online financial services, including mobile banking and online shopping, have lead also a rise of digital fraud. To combat these digital frauds, fraud monitoring based on user authentication has become a key role for online financial services.
- **Sustainable devices**. The rising consumer interest in sustainability is driving the market toward more repairable phones and longer replacement cycles.
- **Digital and Sustainable Tourism**. One of the emerging trends in the use of satellite data in sustainable tourism is the combination of satellite data with other sources of data, such as social media data or tourist evaluations. This allows for a more comprehensive understanding of the impact of tourism on destinations and local communities, and to develop more effective strategies for tourism management. Furthermore, there is an increasing use of satellite data in sustainable tourism to monitor and prevent phenomena such as desertification, deforestation, and climate change, which can have a significant impact on touristic destinations. This requires greater collaboration between tourism agencies, environmental organizations, and local authorities to develop sustainable tourism management strategies that consider long-term environmental impacts [RD113].

In terms of **shipments**, smartphones continued to greatly outnumber other consumer devices, while sports & wearable devices represent the second largest demand of consumer solutions devices and applications. Concerning the **revenues**, the biggest share derives from Navigations applications and Social Networks, followed by Health and Lifestyle applications.

These evolutions are expected to continue in the coming years since the mentioned categories of applications respond to some of the most immediate economic and social problems of citizens, such as improving work productivity, ease of movement, tracking people and resources, and using effective services to facilitate consumer interactions.

Current and prospective use of GNSS and EO in Consumer Solutions, Tourism and Health

The user requirements for many **GNSS technology applications** have remained relatively **constant** since their inception and continue to be satisfied by GNSS offer. In recent years, however, a growing group of new applications has emerged that require much **more stringent levels of horizontal and vertical accuracy**. In addition, categories of applications such as geo-marketing and advertising, **fraud management**, and location-based billing and invoicing require location authentication to protect application users or service providers from malicious signal interference signal interference, such as spoofing.

In this research, there are five applications using EO data that are presented and investigated, and they are the following: **Air quality monitoring, Sport, fitness and wellness, UV monitoring, Geo-advertising, Mapping & GIS**.
What emerged from the analysis of the use of EO data in the listed applications is that user needs are

generally met by the current data offer. In some cases, however, there is a **gap between spatial resolution and acquisition time** that would be crucial to address, in particular for applications providing health services, among others. Another important future challenge concerns the need to integrate data from different sources. This, in the first place, will require the creation of new **data processing techniques in the cloud**. Following this, issues related to the **privacy** of used data, **copyrights** and online **authentication systems** will for sure be discussed and developed in the near future. In the meantime, critical points of these issues were collected from various stakeholders during UCP 2022 and reported in the final sections of Chapter 5.

Drivers for user requirements

For both technologies, one of the main drivers that will characterize the future market is the increase in the **number of satellites**, combined with the consequent optimization of data production and processing costs. This will lead to an increase in the availability of data and an increasing number of services that will be requested and offered. Another important driver is the pursuit and **integration of data collected from different sources**, not only the combination of GNSS and EO data, but also data from ground-based sensors or archive data. This will consequently lead to more precise and personalized services.

Finally, a key role will be played by **data platform developers**. In particular, it emerged from the discussions at UCP 2022, that within the EO technology value chain, EO platform developers are a strategic group of players for the future. They act as intermediaries between raw data and app developers or end users, and could become strategic drivers by meeting the needs of the market.

3 MARKET OVERVIEW & TRENDS

3.1 Market Evolution and Key Trends

Consumer Solutions, Tourism & Health segment is comprehensive of three different but synergic market segments. They can briefly described as follow.

Consumer solutions

Consumer Solutions comprise a **multitude of applications**, tailor-made to satisfy different usage conditions and needs. These applications are supported by several categories of **connected devices**: **mainly smartphones and tablets, but also specific equipment such as personal tracking devices, wearables, digital cameras and portable computers**.

Nowadays, with a combination of technologies such as GNSS, EO, 5G, Wi-Fi and Internet of Things (IoT), any physical device can become a connected device, enabling new applications to facilitate the end user's wellness and lifestyle. On top of this, Artificial Intelligence (AI) provides an additional layer to this connectivity enabling greater capabilities and sophistication to these devices. Technological advances and substantial reductions in the costs associated with operation and supporting infrastructure (e.g., data storage) for satellites, have led to a dramatic rise in the availability of satellite imagery for civilian use in recent years. This significant amount of information on Earth's condition, often available on (at least) a daily basis, has enabled application developers to create service and information layers that enable dozens of apps for various purposes.

Tourism

Tourism market segmentation is the strategic instrument for the need of **cultural heritage or touristic sites managers to understand their audience** (i.e. collection of info from them) on one hand, and their need to **provide information to optimise their experience** and ensure sustainable fruition, on the other hand. As such, stakeholders need to inform visitors on current seasonal climatic conditions that could impact their health and quality of their experience. Tourist sites want to ensure that specific audiences can be reached out in order to advertise their products/services. Moreover, providers try to enhance the user experience as well by using an extra layer of geographical metadata to develop better online content.

Cultural heritage is a specific cluster of applications within Tourism. The enhancement of Cultural Heritage assets aims at creating the link between a Cultural Heritage site and the relevant audience (e.g. general public, the education field, research field, private companies) for purposes that go beyond conservation and preservation. This includes mapping of surrounding infrastructure, mapping of frequentation patterns, identification of previously searched sites in the area and the creation of database products for Cultural Heritage communities. All this delivered to the visitors through **smartphone apps**, often also augmented and or/virtual reality experiences. On top of this, with the increase of visitors, there is a growing need to raise awareness on sustainable tourism practices. This can be achieved by either notifying certain pollution levels in the area or re-routing their guide planning, in accordance to less crowded areas. Sustainable and environmental-friendly activities are growing in interest, as we will see this demand is satisfied by some applications as will be seen later (Chapter 5), such as when seeking cleaner air quality as an added value even in a tourism service.

Healthcare

Healthcare application are widely used in many contexts and by many types of users. **Citizens, fitness & sport enthusiasts** need support in identifying certain atmospheric conditions in order know where and when it is possible to perform a certain activity. **People with specific health conditions, such as**

allergies, asthma, hearth diseases or specific skin conditions, are dependent on information related to air quality (e.g. pollution, dust particles or pollen concentrations), UV rays (e.g. skin allergies), heath concentration, especially around cities, or even mosquito surveillance (e.g decline malaria infections). The information provided allows the induvial to take informative decisions such as staying at home or dress appropriately according to the forecasts.

Some applications can also be useful for **public health surveillance** through the systematic and continuous collection, analysis, and interpretation of data on environmental factors hazardous to society. The main users are national and local authorities, national and international health organizations, and NGOs, that make informative decisions on the planning, implementation, and evaluation of health practices. A clear example are applications that monitor air quality or the amount of UV radiation hazardous to human health, but some geo-advertising information can also be used for such purposes.

Finally, **insurance companies** play a role as well, since the findings of new diseases or new dangerous environmental factors can contribute to new forms of financing and contracting between insurers, health service providers and final clients.

Key Market Trends

COVID-19 has heavily impacted day-to-day life, leading to increased adoption of context-aware apps to solve societal problems introduced by the virus. The importance of context-aware services has increased during the COVID-19 pandemic. New apps such as DiAry and Zostaň Zdravý, have taken the approach of using location data, shared in an anonymised format with public authorities, to help map and track the spread of the virus. Context-aware apps have played an essential role in dealing with issues that have arisen in the era of social distancing. Filaindiana handles queue management at shops, FreMEn Adviser allows users to avoid crowds and peak visit times in public places such as parks, Coronamadrid helps people to access nearby medical services, UberEats allows contact-less deliveries and Swishd provides help with grocery deliveries for vulnerable people. These context-aware apps are expected to stay post-COVID, boosting re-integration and the returning of lives to 'normal', particularly for individuals from vulnerable groups [RD9], [RD10], [RD35].

- **Renewed focus on health, including public health, personal health and mental wellbeing**

All those renewed interested will drive uptake of personal fitness mobile apps and wearables. The COVID-19 pandemic and related social distancing requirements have changed patterns of exercise for sports enthusiasts. It has also renewed interest in personal health and wellbeing, encouraging more people to begin exercise routines. The result is an increased uptake of cycling, running, walking and other outdoor activities. The increased popularity of outdoor exercise has aligned well with green initiatives of many regions and cities, with more than €1billion spent on cycling-related infrastructure worldwide since the pandemic began [RD110]. The public health investment and personal health focus have been reflected in a boost in uptake of fitness tracking apps, with providers such as Strava reporting one million new users each month of the pandemic. New to fitness apps and wearables are the improved functions offered through Augmented Reality (AR). Google Live AR Navigation combines GNSS localisation and visual mapping providing floating arrows on your camera feed, making it easier to follow directions or find a way out of unfamiliar areas whilst out on a run. For sport enthusiasts looking for a stronger motivation and some competition with their former self, the AR glass manufacturer Ghost Pacer is introducing an AR holographic running partner for you to keep pace with.

- **Location data to fight digital fraud**

Online purchasing behaviour is causing changes in fraud patterns, with location data becoming a key tool to fight digital fraud. The 'new normal' introduced by the COVID-19 pandemic has led to an increased use of

online financial services, including mobile banking and online shopping. However, as mobile banking and eCommerce increases, digital fraud also rises. To combat the growth in digital fraud, fraud monitoring based on user authentication has become a key role for online financial services.

In today's complex world, anti-fraud strategies require a layered approach, where the user's true identity is verified using various contextual factors. GNSS positioning data plays a role as a layer of security against fraudulent purchases as purchases and money transfers from unusual locations can immediately be flagged as suspicious and require additional authentication. Many financial technology providers move beyond two-factor authentication and are now using geolocation data as part of a 'context-aware' authentication approach, including Venmo, Mastercard, Visa and Revolut. When unusual activity occurs, other attributes like time/date and the device used to make the purchase can be used to verify the user's identity [RD37].

• **Sustainable devices**

Consumer interest in sustainability is driving growth in repairable phones and longer replacement cycles. Sustainable phones which ensure easy maintenance, either through long warranties which include all repairs (Teracube), and user replaceable modules (Fairphone 3) are beginning to take off, although are still niche products in the smartphone market. With a consumer focus on sustainability, longer replacement cycles are demanded phones designed to be long-lasting will bolster this trend. Premium phone prices continue to rise over the years, ensuring higher value for producers to offset longer device lifetimes.

GNSS Market Evolution

With roughly 90% of a 1.5-billion-unit market, smartphones continued to greatly **outnumber other consumer devices** in terms of shipments. Nevertheless, the number of smartphones shipments has been decreasing significantly for the first time with the 2019-2020 year-on-year growth becoming negative (-9%). This can be explained by the increasing saturation of the market (mature EU, North American and China markets), the COVID-19 pandemic and consumer interest in sustainability, which drives growth in repairable phones and longer replacement cycles.

Other GNSS-enabled devices accounted altogether for around 161 million units in 2020. With 64 million units shipped that year, **sports & wearable devices** represented the second largest group of consumer solutions. Their shipments saw an annual increase of 30% between 2015 and 2020, with Chinese manufacturers dominating the smart wearables market. Driven by reducing device prices and growing consumer awareness, personal tracking devices continue to witness the highest growth rate across all Consumer Solution applications, with a CAGR of 79% between 2010 and 2020.

The remaining devices, like digital cameras, tablets, and personal tracking devices, all saw their share shrink over the last couple of years. Shipments for personal and low-power asset tracking devices have been decreasing the most in 2020, mainly due to the general slowdown caused by the global pandemic. The declining shipments for tablets, digital cameras and portable computers are due to the maturity of these devices and their market, as well as a general decline in the use of GNSS for said devices [RD103].

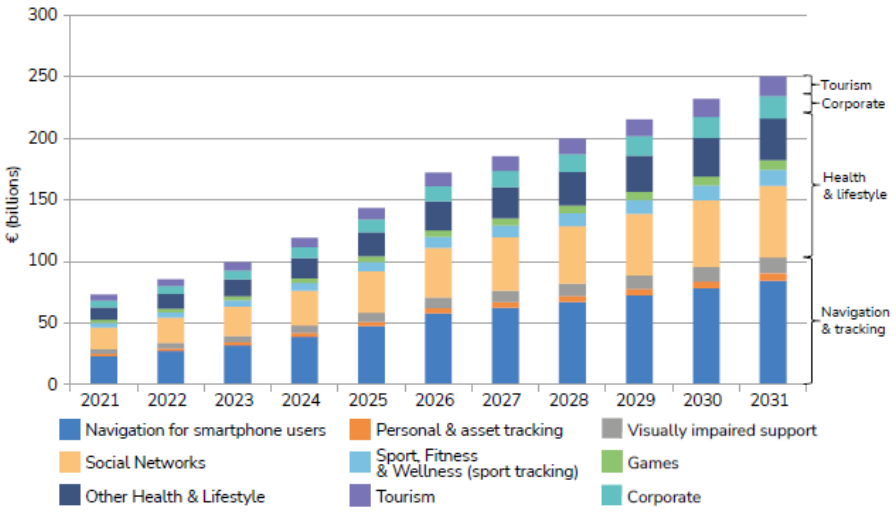
Whereas the market for GNSS-enabled devices has been maturing over the past decade, **GNSS-enabled revenues generated by apps are expected to soar from roughly €73 billion in 2021 to €250 billion by 2031**, growing by a CAGR of 15%. The chart below focuses on biggest categories as well as the largest individual applications. **The largest group covers,** for a total market of €34 billion in 2021, Social Networks (roughly €18 billion in 2021), Sport-related apps (almost €4 billion) and Games (over €2 billion), while the remaining 'Other Health & Lifestyle' in the chart add up to almost €10 billion.

'Navigation & Tracking' apps combine for almost €29 billion in 2021, and the **Navigation apps themselves have global revenues worth €23 billion.** Although a niche category, the revenues of the Visually Impaired Support apps have an estimated revenue of almost €4 billion. Personal & Asset Tracking follow at almost €2 billion.

The remaining app categories, namely, 'Tourism' and 'Corporate', generate a combined €10 billion GNSS-enabled revenues in 2021.

Over the next decade, it is forecasted that global GNSS-enabled revenues from apps in the 'Navigation & Tracking' category will reach €103 billion, remaining the second largest category behind 'Health & Lifestyle' which is expected to generate a total of €113 billion. Combined, these two app categories would dominate the global revenues with a share of 86% of the market.

Figure 3 – GNSS revenues



EO Market Evolution

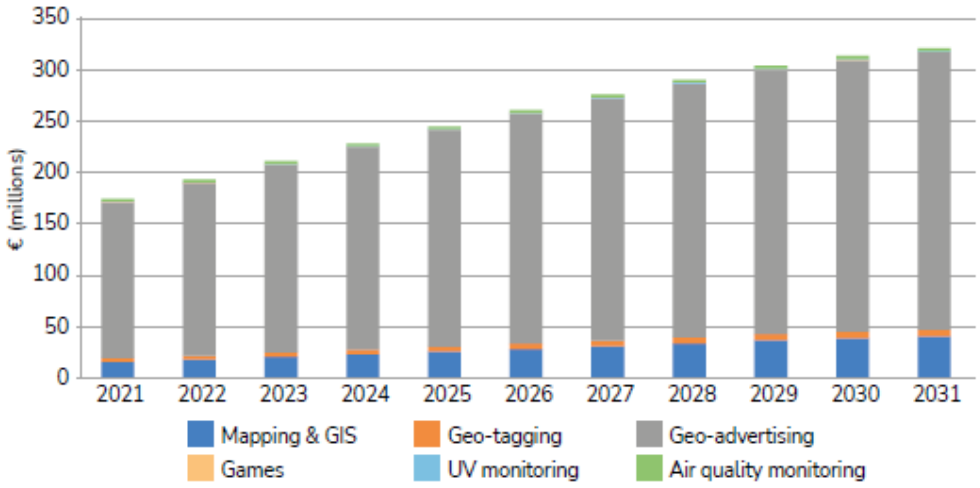
With an estimated CAGR of 6%, the global EO market of data and service revenues in consumer solutions, tourism and health will grow progressively from roughly €175 million in 2021 to almost €321million in 2031.

As is possible to see in the chapter below, the largest EO service in the consumer market belongs to Geo-advertising. The associated revenue will increase from €152 million in 2021 to €270 million in 2031. Mapping & GIS is foreseen to remain the second most important revenue-generator, with annual growth rates of around 10%, which is higher than the CAGR% of geo-tagging (7%).

With the lowest CAGR of 2% between 2021 and 2031, UV monitoring (from €764,000 in 2021 to €959,000 in 2031) and air quality (from €2 million in 2021 to almost €3 million in 2031) are the two applications expected to see the slowest growth over the next decade. However, this can be explained by looking at the nature of the applications which are clearly serving less a commercial role and more an informative one for the end users.

Finally, despite having the fastest growth forecasts of all EO applications (13% CAGR), EO-enabled games remain a niche amongst the mobile games. Whilst games themselves generate large revenues, the share associated to actual EO contributions is negligible compared to, for example, in-game purchases for in-game content.

Figure 4 – EO revenues



3.2 Main User Communities

The user groups for Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health applications, and technology in general."

Consumer solutions is strongly characterised by a non-specialised user audience, covering all demographic and geographic groups, as it relates to the worldwide mass market.

Consequently, it makes sense to create a categorisation based on apps exploitation, so primarily on the last two criteria, psychography and behaviour. In particular, mobile application users, including Consumer Solutions, Tourism & Health and digital innovations in general, can be characterised by two keys aspects: digital capability and trust. The **digital capability** of users concerns 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 uptake a technological solution, like a smartphone app can be, to perform activities for which she or he previously relied on more traditional means, undertake new activities or improve their experience through the use of technology. This typically also implies users need to share personal data and, in some cases, to renounce privacy in exchange of a perceived benefit.

Consumer Solutions, Tourism & Health app users' motivations greatly depend on which user group(s) they belong to and represent different levels of requirements within the app. The first categorization, done on their psychographic and behavioural characteristics, have three different groups with growing level of digital capability and/or trust in the apps:

- **Enthusiasts** (high digital capability and/or high trust in apps), they look for apps that are "designed for the user" in an integrated way, to have personalized and pushed services with location-specific recommendations and information;
- **Pragmatists** (medium digital capability and/or medium trust in apps), they look for apps that offer a discovery experience of new items and opportunities available in a user's physical space;
- **Traditionalists** (low digital capability and/or low trust), they are just looking for basic information, like for example the location or how to get somewhere.

Often, there are just few differences among applications adopted by these three groups. The real important difference is *when* these new technologies are embraced. The *Enthusiasts* are the early adopters, those who will use them first. While, at the opposite there are the *Traditionalists*, who lag behind in their use as much as possible, because they are diffident and reluctant, and sometimes only adopt new technologies because they are forced to. Finally, the *Pragmatists*, are in-between and they can adopt new technologies sooner or later according to their needs.

- The **subcategorization** of each group is based on the application background of the apps, that is, the context and main purpose that drives the use of the apps. Thus, each group is divided into the following three subgroup:
- **Commercial user**, those use apps for insights and indicators provided by apps/dashboards/platforms, in the perspective of work optimisation, but also, e.g. for decision-making, reporting, etc.;
- **Citizens**, people who use apps in their daily lives to express themselves, socialize, and integrate them into many different aspects of their lives;
- **Public users/Public authorities**, public figures that use apps in their public administration or in the projects and services they support.

Finally, included in the list of users is the "**users with special needs**" category, so those users with special needs resulting from particular health conditions, who take advantage of applications created specifically for their needs.

Table 1 summarises different groups of users.

Table 1 – User groups for Consumer Solutions, Tourism & Health applications

Group	Subgroup	Description	Primary EO and GNSS needs and motivations to use apps	Primary applications		
				EO	Synergetic	GNSS
Enthusiasts	*Commercial users*	Require specific Consumer Solutions, Tourism & Health applications for day-to-day use at work. Have high requirements towards reliability of applications.	- Productivity at work - Commercial success, building marketing strategies and consumer insights	- Air quality monitoring - UV monitoring	- Games - Geo-tagging - Geo-advertising - Mapping & GIS	- mHealth - Safety and emergency - Social networks - Billing - Workforce management - Navigation - Personal & asset tracking - Visually impaired support - Consumer robotics - Points of interest - IoT
	Citizens	- 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 Consumer Solutions, Tourism & Health applications. Have high demands towards applications. - Mass adopters, who are the large group of unaware enthusiasts heavily using Consumer Solutions, Tourism & Health applications. They do not have deep knowledge about Consumer Solutions, Tourism & Health and privacy issues, however can be sensitive towards	Exploring new and innovative services. Consumer Solutions, Tourism & Health apps are the way to express themselves, socialise and are natural part of their life.	- Air quality monitoring - UV monitoring	- Sport, fitness and wellness - Games - Geo-tagging - Geo-advertising - Mapping & GIS	- mHealth - Safety and emergency - Social networks - Navigation - Personal & asset tracking - Visually impaired support - Consumer robotics - Points of interest - Augmented reality for leisure - IoT

Group	Subgroup	Description	Primary EO and GNSS needs and motivations to use apps	Primary applications		
				EO	Synergetic	GNSS
		possible privacy issues when hearing news in media.				
	Public users/Public authorities	Institutions that want to take full advantage of the benefits of new technologies and propose projects or initiatives that not only use apps, but also promote and spread them	- Access the large number of users and data to be more efficient - Give an innovative and smart picture of public institutions	- Air quality monitoring - UV monitoring	- Geo-tagging - Geo-advertising - Mapping & GIS	- Safety and emergency - Billing - Workforce management - Navigation - Personal & asset tracking - Visually impaired support - Points of interest
Pragmatists	*Commercial users*	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.		- Geo-tagging - Geo-advertising - Mapping & GIS	- Safety and emergency - Personal & asset tracking - Billing - Workforce management - Navigation - Consumer robotics - IoT
	Citizens	Citizens who use apps to better optimize and organize their time, their daily tasks.	Saving of time	- Air quality monitoring - UV monitoring	- Sport, fitness and wellness - Geo-advertising - Mapping & GIS	- mHealth - Safety and emergency - Social networks - Billing - Navigation - Personal & asset tracking - Consumer robotics - Point of interest - IoT

Group	Subgroup	Description	Primary EO and GNSS needs and motivations to use apps	Primary applications		
				EO	Synergetic	GNSS
	Public users/ Public authorities	Institutions adopting new technological applications to provide more efficient services	They want access to large numbers of data and users in order to be more efficient in the services they deliver.	- Air quality monitoring - UV monitoring	- Geo-tagging - Geo-advertising - Mapping & GIS	- Safety and emergency - Billing - Navigation - Workforce management - Visually impaired support
Traditionalists	*Commercial users*	They adopt new technologies only when necessary to be competitive in the market, they imitate other businesses and do not take any personalized initiative.			- Geo-advertising - Mapping & GIS	- Safety and emergency - Workforce management - Navigation - Personal & asset tracking
	Citizens	Have limited interest or trust in technology and high privacy concerns. Use Consumer Solutions, Tourism & Health applications only when really needed.	Safety, convenience, saving of time		- Mapping & GIS	- mHealth - Safety and emergency - Navigation - Personal & asset tracking
	Public users/ Public authorities	Public institutions that, because of the types of service they provide, struggle to adopt new technologies in their daily activities.	Exploit the most basic advantages, adopt new technologies when forced.	- Air quality monitoring - UV monitoring	- Mapping & GIS	- Safety and emergency - Workforce management - Navigation
Users with special needs	*Citizens*	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	- Air quality monitoring - UV monitoring	- Sport, fitness and wellness - Geo-advertising - Mapping & GIS	- mHealth - Safety and emergency - Visually impaired support - Consumer robotics[1]

[1] Based on LBS Applications User Segments. Source: Based and adapted on GNSS opportunities in Location Based Services [RD39], [RD40], [RD41], [RD42], [RD43]

3.3 Main Market Players

The Consumer Solutions, Tourism & Health 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.
With STmicroelectronics, Infineon Technologies and U-Blox, Europe held three of the top 10 positions among GNSS Component and Receiver manufacturers in 2019. Europe had a share of turnover of 7%, behind North America (47%) and Asia (45%). European GNSS system integrators (e.g.. smartphone and wearable manufacturers) generated 3% of the turnover in 2019, trailing behind Asia (63%) and North America (34%).

Consistently with the EUSPA EO and GNSS Market Report, the main industry stakeholders in the *Consumer Solutions, Tourism & Health* GNSS market value chain are *components manufacturers, device integrators and vendors, EO platform developers, service and content providers, app developers/retailers and app stores*.

Figure 5 - Consumer Solutions, Tourism & Health Value Chain (incl. both EO and GNSS)

The value chain with main players is provided in Figure 5: the value chain considers the key global and European companies involved in the GNSS and EO downstream activities.

- ***Component and receiver manufacturers*** are the factories that supply some of the semiconductor components that are essential for the creation of portable devices.
- ***Operating system developers*** are the companies involved in developing the operating systems through which it is possible to exploit the technologies and services provided by portable electronic devices. From these players of the value chain, the software functioning is designed, that has strategic importance both a priori and ex post for the creation of applications.
- ***Device integrators and vendors*** are value chain actors who take care of integration of different semiconductor parts in order to create the final products. Those products can have the form of smartphones, tablet, cameras, pc and other popular portable devices, or have an original design for a specific purpose. They also take care of selling phase in the mass market.
- ***EO platform developers*** is a broad category of stakeholders that includes both the actors who reprocess raw data coming out from satellites and those who organise data and information necessary to create a specific application. Two sub-categories are therefore belonging to this group:
    - ***Service and content providers*** are companies responsible for the sale of data for the creation of applications, this data is reprocessed in an intermediate (not final) way and sold according to the services they can fulfil.
    - ***App developers/resellers*** are those who develop the application software needed to reprocess the data from satellites together with other information and present it to users in a form that can provide intuitive and useful information. They provide a commercial

services (e.g. EO apps tailored for specific market segment) so they are also referred to as 'last mile' because they are more towards the end of the value chain.

In brief, EO platforms developers are considered as service providers in the Consumer Solutions, Tourism and Health Value chain. While applications are instead considered as the step after, processing tailored Copernicus and EO data.

- ***App stores*** are the online stores where you can find and purchase the software applications that provide the services described in the various applications.
- ***Users*** are the end users of the applications, who, as we saw in the previous chapter, may differ depending on their purposes and needs.

EO platform developers

EO platform developers are actors of the value chain that provide service for EO data management, analytical information and insights on specific applications, and some platforms directly provide insights on specific topics. On one side there are *Service and content providers* offering raw data, or barely reprocessed data, for developing applications. On the other side there are *App developers/resellers* developing the application software that reprocess data from satellites together with other information, to provide final commercial services.

During the discussion session dedicated to EO developer at UCP 2022 event in Prague, one of the most important point was about the availability of data. It clearly emerged that EO developers and users struggle to understand how to obtain data. The fragmentation of data offered over multiple different platforms, the lack of homogeneity in data formats, and the difficult merging with non-space-based complementary data and metadata are perceived as an issue and an obstacle hindering the potential on this market. Dealing with such fragmentation leads to higher costs for developers. Coordination and collaboration between EO platform providers and application developers is a crucial future aim, to align needs and expectations. As main outcome of this discussion, there was the request to provide data taking more into account the point of view of the end-users.

Another finding of application developers is that they often prefer to download data in order to integrate them into the application systems, rather than process and integrate different sets of data in an online cloud. This is because data formats are not always compatible with each other, and thus some require more than one elaboration to be handled. Other difficulties were reported in terms of access to IPR-protected data, since the authentication process for accessing data through the API is rather complex, and in terms of the maximum amount of data that can be downloaded for each account created, which might be insufficient to fulfil the user's purpose.

Another interesting point of discussion was regarding the traceability and transparency of data. It emerged that data trust levels, and reliability are among the most important prerequisites, but the use of EO data presents a high level of uncertainty. This uncertainty is mainly related to the processing chain and the lack of standards to refer to.

Finally, the source of the data (ownership) can also be a problem. For instance, when there are many companies working on a single dataset, only one of them can retain ownership of the dataset. Data sharing can also become a problem due to intellectual property rights.

These were some of the major discussion points that emerged from the UCP 2022 live meeting with EO and GNSS data-based application and platform. Co-operation and co-ordination with this key stakeholder group has only just begun. EUSPA is promoting the creation of a EO key market players networking, in which to also involve them, with the aim of creating a useful tool to sustain and harmonise different needs within the market.

4 POLICY, REGULATION AND STANDARDS

4.1 Regulations towards GNSS user requirements

As per last RUR [RD105]: "Standardisation activities" 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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.

4.2 Regulations towards EO user requirements

While there is no legislating directly addressing EO user requirements in Consumer Solutions, Tourism & Health, the privacy concerns play a role. With the emergence of high-resolution commercial remote sensing and improving data enrichment and dissemination methods, worries about data privacy and potential reputation danger may rise. International laws governing the use of data gathered by remote sensing technologies, however, are still being developed and may differ by market.

This may increase uncertainties about the ability of insurance solutions to scale across markets.

4.2.1 The Full Free and Open (FFO) License of Copernicus data and service

The European Commission is responsible for coordinating and managing the Copernicus program in line with Regulation (EU) No. 377/2014 of the European Parliament and of the Council of April 3, 2014, establishing the Copernicus program and repealing Regulation (EU) No. 911/2010. The European Commission leaves access to this service free of access fees and licenses in order to promote the widest possible use of Copernicus data and information. What the European Commission has requested, however, is the registration of Copernicus word and figurative marks in relation to specific classes of goods and services. The license to use and manage the Copernicus trademarks gives interested parties the necessary rights to use the trademark in their activities related to the Copernicus Program. The use of EO data are permitted under certain conditions, providing some communication about the Copernicus ownership, following activities related and compatible with the aims and principles of the EU, maintaining the integrity of Copernicus Trade Marks, and some other requirements. The users shall submit to the European Commission the Registration Form that requests information from the User to allow the use of the Copernicus Trade Marks, to gather and archive information on use and market definition[RD111].

4.2.2 Principles relating to remote sensing of the earth from outer space

According to the United Nations guidelines on the resolution “Principles Relating to Remote Sensing of the Earth from Outer Space” recommend that remote sensing by one country should not be conducted in a manner detrimental to the legitimate rights of another country. Albeit, not legally binding and countries do not have any veto power to stop themselves from being monitored, it can pose issues for foreign insurers using locally generated images of insured assets.

4.2.3 GDPR

It is currently not possible to spy on people or monitor their movements on a large-scale using satellite resolutions. However, putting this data in a geographical context may help identify insured assets in some cases. The General Data Protection Regulation (GDPR) in Europe has clauses that may expose a remote sensing enterprise to data protection and privacy legislation. However, there is currently no international law governing the regulation of personal data collected through remote sensing.

4.2.4 Open Geospatial Consortium (OGC)

The Open Geospatial Consortium (OGC) was founded in 1994 for the purpose of making geographic information an integral part of the global information infrastructure. Both technology providers and users can be members of the OGC, and the work they collaboratively do is to develop open interface standards and associated coding standards, but also best practices, so that developers can make information systems able to easily exchange "geospatial" information and instructions with other information systems. The requirements developed relate primarily to: complex programming, control of Earth observation satellites, display of simple map images on the Web, and encoding of location in a few bytes for geo-tagging and messaging.

5 USER REQUIREMENTS ANALYSIS

This chapter offers a detailed analysis of user needs and requirements pertaining to *Consumer Solutions, Tourism & Health* applications introduced before, describing the different roles and needs covered by GNSS and EO and, ultimately, identifying the corresponding requirements from a user perspective.

In this segment, EO performs several interesting functions. By monitoring air quality and UV radiation it promotes special attention to some important aspects of human health, which are contemporary issues of rising interest in the consumer domain. The information about meteorological conditions of locations used for sports or tourist facilities, make these services usable not only by the individuals, but more and more even by business activities that want to fully exploit their potential. Finally, some data are useful to policy creation and decision-making public actors, in charge of providing public services and ensure environmental health.

GNSS technology is adapted to a great number of sub-segments in the *Consumer Solutions, Tourism & Health* segment, position and navigation data are the central feature for the existence of many applications. The essential functions that are fulfilled are the increasing accuracy with which it is possible to link activities, points of interest, useful and interactive information, services, etc. to a specific location. Also, the capacity to monitor objects and people and the consequences that can result from this, is gaining in importance for businesses and for personal health services.

In general, it is important to emphasize, that data from the GNSS system and data from the EO, can be strategically combined and integrated, to achieve better results in terms of the service offered through the application.

Table 2 below depicts the main applications making use of GNSS and/or EO technologies in *Consumer Solutions, Tourism & Health.* The list of applications is non-exhaustive and is expected to potentially grow and adapt according to the expected adoption of space technologies in the coming years and the innovations that should come with it. The current report being the first version of the *Consumer Solutions, Tourism & Health* report on User Needs and Requirements relevant to EO in addition to GNSS, it is a living and evolving document that will periodically be updated and expanded by EUSPA in its next releases.

Therefore, even if the applications considered in this analysis are consistent with EUSPA EO and GNSS Market Report [RD103], a significant number of new applications have been added to complement the picture. These come from a comprehensive desk research of the segment's state-of-the-art together with the ideas and innovations generated in R&D projects.

The current issue the RUR does not cover in detail the needs and requirements of all applications. A categorisation was performed prioritising some applications based on their maturity level and relevance to the market trends and drivers. Other applications are foreseen to be covered in more detail in future versions of this RUR.

The following applications categorisation reflects the depth of information available in Section 5:

Application Type A: these applications correspond to those for which an in-depth investigation is presented and for which needs and requirements relevant to GNSS and EO have been identified and validated with *Consumer Solutions, Tourism & Health* user community at the UCP.

Application Type B: these applications correspond to those not selected for in-depth investigation in the current version of the RUR, for which a partial specification of needs and requirements is provided, limited at this stage to the ones relevant to GNSS.

Application Type C: these applications correspond to EO-based applications, not selected for in-depth investigation in the current version of the document. A high-level description

of the application is included considering that they will be further analysed and developed in next versions of the RURs.

The Table 2 maps the **21** *Consumer Solutions, Tourism & Health*-related applications, as well as 10 dedicated IoT applications, to the three above-mentioned types. **The following** list of **applications and their** categorisation are **expected to evolve in the next versions of the document.**

Legend

EO only application
GNSS only application
Hybrid/synergetic application (combined use of EO and GNSS)

Table 2 - Consumer Solutions, Tourism & Health Applications

Sub-segments	Applications	Types of Application/ Level of Investigation	
Health & Lifestyle	Air quality monitoring	A	
	Games	B	
	Augmented reality for leisure	B	
	Geo-tagging	B	
	mHealth	B	
	Safety and emergency	B	
	Social networks	B	
	Sport, fitness and wellness	A	
	UV monitoring	A	
Corporate	Billing	B	
	Geo-advertising	A	
	Mapping & GIS	A	
	Satcom users	C	
	Workforce management	B	
Navigation & Tracking	Navigation	B	
	Personal & asset tracking	B	
	Visually impaired support	B	
Robotics	Consumer robotics – High GNSS use	B	
	Consumer robotics – Low GNSS use	B	
	Enhanced human	B	
IoT	IoT - High-end sport tracker (Elite sport/rugby man tracking)	B	
	IoT - Low-end sport tracker	B	
	IoT - Asset tracker for logistics	B	
	IoT - Tracking of trailers	B	

Sub-segments	Applications	Types of Application/ Level of Investigation	
	IoT - Tracking of containers	B	
	IoT - Tracking of packages	B	
	IoT - Tracking of staff	B	
	IoT - Artisanal Fisheries	B	
	IoT - Livestock Monitoring	B	
	IoT - Smart Farming	B	
Tourism	Points of interest	B	

The next Section 5.1 addresses first "type A" applications, then "type B" applications and finally "type C" applications, for which the level of provided information is currently the less developed.

Each Type A application will cover the user needs and requirements for potentially several operational scenarios. For each scenario, a table summarises the needs and requirements relevant to EO. The table template is illustrated below in

Table 3 and explains the various inputs.

Table 3 - Description of EO User Requirements Table[2]

ID	Identifier
Application	Application covered
Users	Common users of the product/service
User Needs	
Operational scenario	**Describes the operational scenario faced by the user, which requires a solution**
Size of area of interest	Describes the area of interest
Scale	Describes the scale of interest
Frequency of information	How often the user requires the information
Other (if applicable)	Other user needs such as contextual information (weather data) or file formatting requirements
Service Provider Offer	
What the service does	Description of the service that satisfies the user's needs
How does the service work	(Technical) description of how the service works
Service Provider Satellite EO Requirements	
Spatial resolution	The satellite image ground sampling distance (GSD) required by the service provider to realise the service
Temporal resolution	Frequency of satellite data (revisit time) over the area of interest
Data type / Spectral range	Type of data (e.g. RGB, SAR) and spectral range (if relevant)
Other (if applicable)	Other data requirements
Service Inputs	

[2] See key EO performance parameters (detailed) definition in annex A1.2.

Satellite data sources	Type of required data and examples of operational satellites that can provide these data
Other data sources	Other sources of data that the service provider uses to realise the service

Type “B” applications reports GNSS requirements that were already available in the previous GNSS UCP Report [RD105].

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, ser- vice area, availability, resilience, integrity and power consumption.

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. 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 drains on smartphones batteries.

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.

For each type B application, a table summarises the needs and requirements relevant to GNSS. The table template is illustrated below in Table 4 - Description of GNSS User Requirements Table and explains the various inputs. More details on the definitions of the above criteria are given in the A1.1.

Table 4 - Description of GNSS User Requirements Table

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 Light Indoor (Below 5 meters from window) Deep indoor	Yes/No
	TTFF (hot start)	Low: More than 30 s

Criterion	Performance	Characterisation
		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
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 Current GNSS/EO use and requirements per application

The *Consumer Solutions, Tourism & Health* applications that are considered in this analysis are consistent with EUSPA Market Report 7 [RD103]. They have been completed with additional applications and applications categories found in other sources.

5.1.1 Air quality monitoring

EO enables *air quality applications* which measure the presence of harmful substances and particulate matter in the air (e.g., sulphur dioxide and PM 2.5). Measurements of air quality are used to inform analytics, such as air quality indexes, and to provide recommendations to users (e.g., to stay indoors and keep windows closed if air quality is very poor).

Air pollution causes about 350.000 premature deaths in Europe each year [RD112]. It is recognized as one of the biggest environmental health risks. The effects of air pollution affect the respiratory & cardiovascular system. Air quality is a complex issue, as there are many different pollutants, and it varies a lot in time and space.

For persons (e.g. pedestrian, bicyclist) in general but especially for those suffering from air pollution and allergies, it is of relevance to have information on air quality for outside activities (like walking, sporting, cycling, etc.), at the right location (where I am) and real-time (now). This is true especially in locations with lots of traffic or air polluting industry (e.g. Breezometer API). Based on the location of the individual person (delivered via smartphone position), easy to understand information needs to be provided (e.g. in form of textual recommendations or coloured maps).

In addition, there are many other types of scenarios in which air quality information can be useful and relevant.

Information on air quality is useful for governments / local authorities / city planners / traffic planners: since cities become more polluted (more cars, more buildings blocking natural air ventilation), there is significant negative impact on human health. High quality modelled air quality data are vital to inform policy creation and decision making, e.g. on new buildings, traffic flow, congestion control, revegetation with trees and plants, differentiating e.g. in high emission zones, low emission zones, clean air zones). In the real estate market, a clear indication on the air quality status can be a sales argument. Air quality can be one of the parameters that impacts the real estate price in the urban areas (e.g. certain parts of the city with the better air quality can achieve higher prices, for buying, but also for renting). In ventilation applications for buildings, air quality information can be integrated as an additional

parameter in the automation of ventilation systems (ventilation is on when the air is of good quality) (e.g. project Aircheckr).

Medical care providers require air quality data for providing services and recommendations to their patients, informing policies for employee health and workplace sustainability (e.g. projects SAQM, Air-Portal, Urban Green Quality Tracker, SAIUDMA, FreeBreeth, etc.). Information on the air quality, especially pollutants like PM2.5 that poses a great risk to human health, can be included in the models of medical insurance companies (e.g. people living in the areas with low air pollution will be less prone to the lung and respiratory diseases).

The monitoring of air pollution caused by maritime shipping is of high and growing interest (e.g. project SAMBA). Maritime fuels traditionally used are a residual of petroleum distillation, and therefore contain a lot of pollutants, like Sulphur. The consequence is a high amount of sulphur oxide emissions and particulate matter components along maritime routes and within port areas, often close to urban areas, leading to environmental and public health problems like acid rains, asthma, and cardiopulmonary cancers.

Air quality is impacted by events like fires or volcanic eruptions. Effects of such large-scale natural events can only be properly assessed by using satellite data.

In tourism air quality is becoming one of relevant elements for visitors when selecting the destination of visit and on the other side tourism is also one of the causes of pollution. Touristic destination with excellent air quality can increase their marketing potential (market themselves as respiratory-friendly). At the same time, it is often that during the touristic periods (e.g. in summer in Mediterranean region) there could be a ten-fold or higher influx of people and vehicles which could on a local level increase the air pollution. Local administrative units, as well as destination, regional and national management organisations are tasked with preparing tourism development plans and strategy: they would need to understand what kind of impact would e.g. 1 million more overnight stays, or a new tourist attraction or the additional traffic have on their air quality.

Examples of this application are Tourism Impact Model (TIM) and SD4TIM project (founded by ESA) in which the goal is to automatically integrate satellite air quality data in the solution and connect with other tourism indicators.

Common users of *Air Quality Monitoring* application can be individual people, medical care/services, medical insurance companies, stakeholders in real estate market, city/traffic planners, governments/local authorities – LAUs (Local administrative units), maritime authorities / shipping companies, DMOs (destination management organisations), national tourist boards, tourist service providers, urban mobility planning in sustainable coastal tourism.

The EO requirements are summarised in the Table 5.

Table 5 - Air Quality Monitoring EO user requirements

ID	EUSPA-EO-UR-CSO-0001
Application	***Air Quality Monitoring***
Users	Enthusiasts, citizens and public users Pragmatists, citizens and public users Traditional, public users Users with special needs
User Needs	
Operational scenario	a. Personal advice for people living in locations and environments prone to air pollution. b. Information for policy creation and decision making (especially in urban environment, or in touristic area during busy periods). c. Marketing element for: e.g. real estate market, medical care providing services (e.g. recommendations to their patients), tourist destinations.

	d. Parameter in automation technology systems (e.g. of ventilation systems). e. Detection of matter components coming from maritime fuels, along maritime routes and within port areas. f. Assess large-scale natural events impact.
Size of area of interest	- From few square kilometres range (up to 1000 km² for megacities), from a specific location within the city up to the size of the whole city. - Maps of the entire regions, or even countries can be valuable.
Scale	Range from few meters (street level)* up to 1:5000 meters **Air quality information in cities is usually required on street level because there can be significant differences already from one street to the next, parallel street.*
Frequency of information	- Instantaneously or few minutes range - Hourly - Weekly - Monthly
Other (if applicable)	- Challenge in this environment is the coverage: Air Quality Indicators need accurate and consistent data while covering large areas - Air quality also needs to be correlated with weather data and topography data since they both have a significant effect on it
Service Provider Offer	
What the service does	The service collects the air quality data in a form of maps. These data are resampled, if necessary, and put into the mathematical model, which can include various other inputs. The results are visualised in a form of maps that show the index of higher or lower property value based on all parameters. This allows final users to get useful and clear information about air quality: e.g. visual maps, indexes, app notifications, etc.
How does the service work	The service collects data from different data sources (Meteo, Copernicus CAMS, air and ground-based data, others) and integrates them into information in a spatial resolution that is adequate for the application. In cities, the information usually needs to be provided on street level (at least 100m). In outdoor/rural environments lower resolutions are sufficient, as they are not so much influenced by local traffic. The information (data, reports, information on pollutants, actionable recommendations) is then provided via web (dashboard) and mobile applications to the users. Depending on the type of application, different atmosphere components can be used by users. For example, CAMS provides estimates of climate forcings for carbon dioxide, methane, tropospheric ozone, stratospheric ozone, interactions between anthropogenic aerosols and radiation, and interactions between anthropogenic aerosols and clouds. While, for air quality, CAMS provides daily analyses and forecasts of worldwide long-range transport of atmospheric pollutants as well as the background air quality for the European domain (taking into account some air elements like, i.e. PM, O3, No2, SO2, BaP).
Service Provider Satellite EO Requirements	
Spatial resolution	- The spatial resolution of relevant services must be at least on 100 meters level. - Earth Observation derived information usually cover large areas with limits in acquisition time and accuracy (several kilometres resolution).
Temporal resolution	- Instantaneously or few minutes range - Hourly

	- Daily - Monthly
Data type / Spectral range	- UV (250-310 nm) - VIS (310 - 500 nm) - NIR (675 - 775 nm) - SWIR (2305-2385 nm)
Other (if applicable)	- Availability of relevant data (EO, ground) with sufficient spatial and temporal resolution is usually the critical aspect. - Currently, there are many companies trying to include small air quality stations into their smart city products (e.g. smart benches etc.), or even downscale the sensors to a human wearable items. The data gathered in this way could be shared and used to refine the satellite models to achieve higher-resolution products. - Historical data would help AI solutions to discover patterns and allow development of forecasts. - In situ stations could provide real-time air quality monitoring status, but satellites can pride the info, ideally, on hourly level (Sentinel-4, which is expected to launch in 2023).

Service Inputs	
Satellite data sources	- Sentinel-1 (e.g. city structure, buildings, roads). - Sentinel-2 (e.g. vegetation in urban areas). - Sentinel-5P (e.g. air pollutants, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, formaldehyde and methane). - Sentinel-3 (Fire detection). - GNSS/Galileo (e.g. geolocalisation of local sensor networks, determination of user position). - Future satellite missions: Sentinel-4 (2023), Sentinel-5, Copernicus Carbon Dioxide Monitoring mission -CO2M (2025).
Other data sources	- Meteo data (MSG, METOP, etc.) provide low resolution information on air pollutants as well as on the local meteorological situation (e.g. Air quality after rainfall improves significantly, as the pollutants are washed out). - The Copernicus Atmosphere Monitoring Service (CAMS) is delivering valuable air quality data at European scale for several relevant pollutants. - Air quality data from ground-based sensor networks (they provides the most accurate and high spatial resolution data). - VDC (ESA Atmospheric Validation Data Centre). - Sensors for measuring black carbon (e.g. Aerosol.si) which allow a very accurate correlation between sources of pollution (traffic, heating) and the level of pollution. - Advanced IT technologies (e.g. AI) these sensors can be used in a short time period for acceptable cost (renting) to provide very detailed snapshot of the situation (e.g. Measuring air quality at an event). - Land cover maps produced from EO imagery, such as the Copernicus 'Urban Atlas'. It provides pan-European comparable land use and land cover data for Large Urban Zones with more than 100.000 inhabitants. - Geolocalised, locally collected data from air (e.g. drones) or ground (e.g. sensor networks)

5.1.2 Sport, fitness and wellness

❖ ***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 [RD2], [RD19], [RD20]. 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 [RD1], [RD5], [RD12], [RD13].

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 users' 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]

❖ ***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.** 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):
    - Susceptibility to interference: Yes [RD71]
    - Susceptibility to spoofing: No
- Power consumption: medium consumption [RD19]

❖ ***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):
  - Susceptibility to interference: Yes [RD79]
  - Susceptibility to spoofing: No
- Power consumption: low (on-board equipment) [RD79]

Table 6 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.

Table 6 - Sport, fitness and wellness applications GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	High [RD71]
	Fix update type	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, citizens Pragmatists, citizens Users with special needs

Sports applications also rely on *EO* data in various applications. Let's look at the main characteristics and market needs involved.

In the 'participant sports' segment, services related to **information on local effects for specific sports** are of interest for planning, preparation, execution of sports activities. Many operational scenarios can be listed, and the following are the most popular services available:

- MetOcean conditions and weather, information for surfers on ocean conditions such as wave characteristics and occurrence influenced by underwater terrain and local weather conditions (e.g. project SeaUrchin);
- Information for outdoor swimmers (on MetOcean) like sea conditions, waves, local weather (e.g. project Swimtraxx);
- information for mountaineers, mountain bikers, winter sport athletes on terrain information, route characteristics, snow conditions (e.g.ski conditions monitoring for the availability of snow on tracks),

avalanche risk, and local weather conditions (e.g. projects MiLoW-RRS, SIS-SREM, Fatmap live, AAF Avalanche Forecast Service);
- information for canoeists on river bed, water level, streams/current and local weather conditions, information for runners, hikers on air quality, local weather phenomena.

Sports medicine is a branch of medicine that deals with physical fitness and the treatment and prevention of injuries related to sports and exercise. The assistance of sports medicine is also recommended either when being untrained and starting completely new with a sport as well as following rehabilitation after sustained injuries in order not to overload the body. Data collection (including information on surrounding conditions and environment), transmission and analysis will allow the medical personnel to provide tailored advice regarding the sport program to be followed. Nowadays, for any sport activity the utilisation of wearables is taken for granted, providing individual information on location, routing, tracking, medical data, etc. As such, any application in the sport domain will be in combination with such wearables.

Also in wellness tourism, overlaps with sports medicine regarding information required which are part of tourist products attracting persons after the medical treatment/support (e.g. iWellness/Parsek) with local and international potential (e.g. Arabic countries). Information services for sports tourism on local geographical conditions combined with local weather phenomena and air quality, such as information for leisure sailors, divers, etc. are very useful.

Common users for Sport, fitness and wellness applications are: sports tourists (athletes, tourist organisations, logistics organisations, tourist accommodations, sport event organisers), wellness tourists (tourists, wellness accommodations, wellness experiences providers), sports facilities (sport clubs, local authorities, land owners, construction organisations, facility management), individual sporters (athletes, sport coaches, technology providers, medical care takers), sports medicine (athletes, coaches, sport clubs, medical care, sport insurances), emergency/rescue service providers.

The EO requirements are contained in

Table 7.

Table 7 - Sport fitness and wellness EO user requirements

ID	EUSPA-EO-UR-CSO-0002
Application	***Sport, fitness and wellness***
Users	Enthusiasts citizens Pragmatists citizens Users with special needs
User Needs	
Operational scenario	a. Information services on local geographical conditions combined with local weather phenomena and air quality, related to specific outdoors sports. b. Sports medicine c. Wellness tourism d. Sport tourism
Size of area of interest	The area of interest is the area where the sport or outdoor activity takes place: - linear routes of few (e.g. jogging route) up to many kilometres (e.g. long distance trails, recreational cycling or canoeing routes along rivers); - some square kilometres for oceans, mountains, touristic territories conditions.
Scale	1:1000 - 1:25000 range: - usual outdoor map apps are scaled 1:1000, - for paper trail maps best resolution is 1:25000.
Frequency of information	- Weather and related information (forecasts) are usually provided every 6 hours with a forecast range up to 10 days (up to 3 days with hourly resolution, 4-10 day with 3 hourly resolution)

	- Weather induced effects (e.g. snow presence/absence, tree wind breaks, flooding,) need to be communicated upon appearance. - Time of sports activity (minutes, hours), when processing information to supply an outcome of an outdoor activity.
Other (if applicable)	The most common tool used are smartphones and therefore mobile applications. For post-processing data must be integrated with analytic tools.
Service Provider Offer	
What the service does	When it comes to B2C services, then these are usually provided in Apps to a smartphone or a dedicated tracker/device. E.g. for mountaineering a hiking tour is selected by the mountaineer (suggested by the service provider like Fatmap, OutdoorActive). The App asks for the starting day and time, then the App provides back information on the expected weather conditions along the tour together with warnings on specific conditions (e.g. heavy rainfall, storm, snow conditions). When data are created for B2B services, they can be even provided in aggregated manner or database, able to be elaborated and be merged with other services.
How does the service work	The service collects data from different data sources (Meteo, Copernicus, ground based data) and integrates them into maps with actionable recommendations (e.g. maps on terrain information and routes, potential threats from weather events ahead / warnings). The information can be either stored locally (e.g. terrain information) or called up via web services (e.g. regular updates on weather), information in a spatial resolution that is adequate for the application. The information can be downloaded for integration into analyses tools and post-processing.

Service Provider Satellite EO Requirements	
Spatial resolution	- Terrain characteristics for outdoor sports information with a spatial resolution of 10m is considered sufficient (e.g. mountaineering, mountain biking, winter sports). - MetOcean conditions for sailors' resolutions in the km range are sufficient. - Sports bound to specific locations (e.g. surfers, divers, spatial resolution of 10m would be required). - Weather information is usually available with a spatial resolution in km range. - For specific activities, e.g. mountaineering, this is often insufficient, as mountains can act as meteorological divide. Information would be required with higher resolution (e.g. valley by valley) in the 100m range.
Temporal resolution	- Real time information and on forecasts for the near future, in needed for local phenomena (e.g. MetOcean, Weather, NRT). - Information should be available for the time of the sports activity for information output after an outdoor activity (e.g. analyses by athletes, coaches, medical providers). - Weather and related information (forecasts) are usually provided every 6 hours with a forecast range up to 10 days (up to 3 days with hourly resolution, 4-10 day with 3 hourly resolution).
Data type / Spectral range	N/A
Other (if applicable)	

Service Inputs	
Satellite data sources	- Sentinel-1 - Sentinel-2 - Sentinel-3 - Sentinel-5P - Meteo (MSG/METOP) for local weather information, nowcasting and forecasting - GNSS/Galileo. - Copernicus Atmosphere Monitoring Service (CAMS) is delivering valuable air quality data at European scale for several relevant pollutants. Urban heat maps for sport activities in cities.
Other data sources	- Urban heat maps. - Optical data on land cover, vegetation information, terrain information, ground pollution, etc.

5.1.3 UV monitoring – Type A application

Earth observation (EO)-based system is capable of operationally estimating and continuously monitoring the ultraviolet index (UVI) in Europe. Those *EO* data are used in consumer UV monitoring applications to provide UV exposure measurements for particular geolocations, to inform analytics about safe levels of UV exposure and to make recommendations for user behaviour (e.g. recommendations to remain indoors when the UV index is very high).

UV radiation can provoke health disorders and diseases, such as sunburn, skin cancer, or cataracts, and alter the immune response of the human body. The incidence of skin cancers has been markedly increased in fair-skinned populations since the 1970s, which is strongly associated with personal habits in relation to UV radiation exposure, and the societal view that a tan is desirable and healthy. The UVI is highly variable in time and space, mainly influenced by sun elevation, ozone, cloud cover, aerosols, ground reflection and altitude. Though there are about 160 stations in 25 European countries monitoring UVI, those sites are not equally distributed, and a proportion of the European population is still uninformed about UV radiation and the involved health risks. In addition, it is complicated for people/tourists getting information about their holiday destination, to find UVI for a specific region or country. For a further promotion of UVI, satellite and ground-based measurements can be combined, to provide easily accessible information of UVI not only as a forecast, but also as a UV index climatology.

For end-users a decision support system as a "Sunlight Healthcare Assistant"(UVI classes low-moderate-high-very high-extreme) needs to be provided, delivering delocalised, personalized and actionable information on a daily basis about solar radiation exposure and allowing for personal dosimetry control. Such a system can be integrated as an app in smartphones or in wearable devices which themselves are capable of measuring other relevant parameters (e.g. Ajuma UV Bodyguard).

Receiving relevant UVI information on local, regional level allows local, regional organisations and businesses to provide tailored recommendations and products (e.g. sunscreen, sunglasses, clothes). The feedback of collection of individually collected data (under observation of data privacy regulations) from wearable devices and smartphone apps allows concerned organisations and businesses the further evolution and improvements of such products (e.g. sun cream, protective clothing).

Tourists can be a higher risk group since they often do not have the same innate knowledge on how to correctly deal with the UV radiation of the visiting destinations and are spending a lot of the time outside. It is important that they have the correct knowledge on the current dangers of the UV radiation and how to protect themselves from it.

UV radiation also has an effect on the heritage sites since it can increase the deterioration rate of certain materials (wood, textile, colours...). It is important that we know the actual impact of UV radiation so the custodians can make the correct steps in heritage conservation. (e.g. Murmuration company is exploring those effects).

Individual people, tourism organisations, medical care/services, equipment providers, pharmaceutical industry, are common users of this type of application.

The EO requirements are contained in

Table 8.

Table 8 - UV monitoring applications EO user requirements

ID	EUSPA-EO-UR-CSO-0003
Application	***UV monitoring***
Users	Enthusiasts, citizens and public users Pragmatists, citizens and public users Traditional, public users Users with special needs
User Needs	
Operational scenario	a. Provision of localised, personalized, and actionable information on a daily basis about solar radiation exposure. b. Creation of historical UVI information, at local and regional level, to provide tailored recommendations and products for local and regional organisations and businesses. c. Provision of UV radiation of the visiting destinations for tourists. d. Measurement of UV radiation effect on the heritage sites increasing the deterioration.
Size of area of interest	- Area of interest is the whole globe, with information to be broken down on individual locations. - Minimum: single spots for outdoor activities (individual beaches, hotel resorts or entire city regions). - High interest on areas with increased UV radiations, like desert areas, water areas, mountain areas, areas in the range of reduced ozone layers (e.g. Australia).
Scale	- For the regions with highly variable environment a higher resolution is desirable (<100 meters resolution). - For non-urban areas higher resolution of up to several kilometres can be enough.
Frequency of information	- Near-real time information are needed for some applications. - Hourly is important for detailed studies and correlations. - Daily or weekly UV indexes results are good enough for the overall evaluation, however the most important are the peaks and not just the average value. - Low temporal resolution UV data (daily, weekly, monthly) can be analysed and used in assessment and planning with information about the expected UV over different regions.
Other (if applicable)	The estimation of UVI derived from satellite measurements has the advantage of spatial comprehensive coverage, although it must be considered that the lack of detailed knowledge of influencing parameters at specific locations limits accuracy. Therefore, other observations (from space, air, ground) are required to complement a UVI forecast model.
Service Provider Offer	
What the service does	For forecasting, the service should collect all relevant input parameters for a precise determination of the UV radiation at the place of the user. Such information would then be provided in maps including information on the radiation class. As the effect of UV is also dependent on the sensitivity of the user (e.g. pale skin vs. dark skin), the possibility

	for individual settings should be able to be included into any personal device/wearable (e.g. wristbands, skin patches, etc.). App uses satellite data together with the user input (daily hours exposure, possibly obtained from GPS locations, skin type etc.) and provides the user with the risk of skin cancer and the optimal time exposure needed for the synthesis of vitamin D.
How does the service work	Application downloads the satellite data on a cloud and performs calculations to obtain UVI. Together with the user input it calculates from the mathematical model the risk for developing skin cancer and the daily vitamin D synthesis.
Service Provider Satellite EO Requirements	
Spatial resolution	Resolution of 100 meters would be of interest but cannot be achieved today. One of the best instruments in orbit today is the TROPOMI instrument on board of S5P. In such applications, the higher the resolution the better. However, there is a trade-off between EO instruments and related cost of these instruments.
Temporal resolution	As data from satellites need to be processed which takes time, there is no chance to provide real-time information on UV. Satellite data are mainly used for forecast models (like weather models, e.g. MetOffice). As the processing also requires time, the temporal resolution requirement depends on the capabilities of the models. In current weather models, data are provided on 6-hourly basis which then can generated hourly forecasts. Therefore, it is assumed that a similar temporal resolution is sufficient. . Also EUMETSAT Meteorological satellites (e.g. MSG), which are geostationary satellites, are used to model UV radiation and they provide information every 10 minutes[3]. On the contrary, the revisit time of LEO satellites carrying relevant instruments for UV monitoring, is in the range of days rather than hours
Data type / Spectral range	280 - 400 nm for the detection for the surface UV (this covers UV-A (400 - 315 nm) and UV-B (315 - 280 nm)) *UV-C is absorbed by the atmospheric ozone and does not reach the Earth's surface*
Other (if applicable)	Any UV related information or warning service has to be reliable, and especially avoid false negatives.
Service Inputs	
Satellite data sources	- Copernicus Land Monitoring Service - Sentinel-2 (e.g. land cover, vegetation) - Sentinel-3 (e.g. cloud cover, aerosols and water vapour, other atmospheric parameters) - Sentinel-5P (e.g. solar irradiance)
Other data sources	- MetServices (e.g. ECMWF) and Satellite Application Facility on Ozone Monitoring (EUMETSAT O3M SAF) (for global UV index forecasts for clear sky and clouded weather forecasts updated daily). - EUMETSAT CM-SAF (Satellite Application Facility for Climate Monitoring): it provides continuous climate data records containing the Surface Incoming Solar radiation (SIS), - the Surface incoming Direct Irradiation (SDI), spectrally resolved irradiation (SRI) and the effective cloud albedo (CAL). - Tropospheric Emission Monitoring Internet Service (TEMIS; temis.nl) for initial clear-sky UVIs (hosted by the Royal Netherlands Meteorological Institute (KNMI)). - UV index forecast by the Copernicus CAMS service. - Other air quality parameters (aerosols, clouds, total ozone, etc.). - Digital elevation models, as well as vegetation and surface maps.

[3] https://publications.jrc.ec.europa.eu/repository/handle/JRC32976

5.1.4 Geo-advertising – Type A application

Geo-marketing 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. 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):
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- Power consumption: very low consumption [RD6]

Table 9 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Geo marketing and advertising.

Table 9 - Geo-advertising application GNSS user requirements

Criterion	Performance	Characterisation
Accuracy	Horizontal	Low [RD6]
	Vertical Medium [RD71]	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 Traditional, commercial users Users with special needs

EO represents an additional layer of geospatial information contributing to better audience targeting. The most widespread means of using information obtained from satellite imagery is traffic analysis for big retailers (e.g. car density counting). This involves analysing the utilization of car parks around shopping centres. To expand this type of analysis, additional characteristics are used such as infrastructure, remoteness from highways, availability of public transport, nearby nonindustrial buildings.

Another application is the generation of an economic index of trading areas to provide an in-depth understanding of marketing processes in a city or region, e.g. by estimating mall sizes (e.g. EOS services). The combination of land use information obtained from satellites (object classification) with population and demographic data allows the provision of location-based information on the current and future distribution of the population by age groups, education level, and other socio-economic parameters relevant for marketing (e.g. presence of ageing population in relation to available pharmacies, hospitals, doctors in a city district or region, presence of younger people in relation to electronic stores or perfumeries). This allows private and public organizations to determine where to offer certain services and how to adapt their supply chain to the local demands depending on the demographic structures (e.g. project 'AgeSpot').

Another example is the service 'EO4Belmap' which combines information from satellites with local, cadastral, road information and classifies areas and buildings in cities according to various characteristics such as greenfield, gardens, rooftops, swimming pools, building age. Accordingly, such information can be taken up by various organisations such as insurance and finance, utilities and telecommunications, renewable energy organisations, etc.

Tourism related activities (e.g. local recreational areas, cultural events or buildings) can be complemented with local information about the surroundings (e.g. parking situation, public transport, air/water quality). For example H-Benchmark allows an objective measurement of past and future tourist flows for a territory. Helps identify the best times of the year in which to create new opportunities and events to attract tourist flows. It also provides targeted information to plan communication and marketing strategies more effectively.

Combination of satellite data showing the changes in landscape (constructions), data from platforms such as Airbnb and paid tourist taxes help identify the illegal overnight stays. This phenomenon can lead to uncontrolled over tourism. First attempts in this direction were done in Tourism 4.0 for the Black Sea project (with TIM and satellite images).

Additionally green Infrastructure is based on the principle that protecting and enhancing nature and natural processes should be consciously integrated into spatial planning and territorial development. Satellite data can help us measure the presence and characteristics of different green infrastructure such as public parks, flood retention areas e.g. water meadows, green walls or roofs on buildings, swimming pools, building age, the "quality"/ development rate of the area etc. This is also an indicator in TIM. The positive impact of these data is when not only measured, but used in the smart way to influence the behaviour of people to become more sustainable, this can be done for visitors (tourists) as well as local inhabitants (e.g. Collaboration Impact token solution).

The main users for such services are: advertising/marketing companies, retail businesses, tourism, culture, consumers, DMOs, local municipalities (overlap with urban mobility applications).

The EO requirements are contained in the Table 10.

Table 10 - Geo-advertising application EO user requirements

ID	Identifier EUSPA-EO-UR-CSO-0004
Application	***Geo-advertising***
Users	Enthusiasts Pragmatists Traditional, commercial users Users with special needs
User Needs	
Operational scenario	a. traffic analysis for big retailers b. generation of an economic index of trading areas to provide an in-depth understanding of marketing processes in a city or region c. to create new opportunities and events to attract tourist flows d. help identify the illegal overnight stays
Size of area of interest	- The size of the area of interested is in the range of few km ² (for shopping and touristic activities, the focus is usually on city districts where the number of shops as well as of passing buyers/shoppers is relatively high, touristic outdoor activities may be considered for geo-advertising, pointing) - City level which can reach a size in the range of 1000 km² for megacities (for other public and business organisations, e.g. Planning of education facilities, hospitals, pharmacies, telecommunication infrastructure, infrastructure services)
Scale	- The requirements for spatial resolution are usually quite high going up to meter level (e.g. car counting, classification of small buildings). - For larger buildings like malls, a resolution of 10m might be sufficient. - For dynamic aspects like environmental parameters, the requirement on spatial resolution varies. - For shopping advertising, the scale has to allow to identify individual shops, in combination with usual map features (i.e. scale 1:1.000). - For other applications lower resolutions are sufficient (i.e. 1:10.000 to 1:50.000).
Frequency of information	- The temporal resolution is not critical for the classification of buildings or specific places. - More dynamic information requires ideally high temporal resolutions (e.g. continuous observation, on hourly basis, daily frequency).
Other (if applicable)	Space data and imagery usually has to be combined with contextual data, e.g. use of buildings, cadastral information, road layers, in order to provide a proper classification.
Service Provider Offer	
What the service does	The service provides the user with easily understandable (e.g. colouring) classification information on the subject of interest. E.g. analysing traffic and customer habits in mall areas, the service could provide information on the occupation of the local parking spaces over day/week to indicate busy / not so busy periods.
How does the service work	The service collects data from archives and/or from satellites. Automated land change and object classification algorithms are applied involving AI/ML processes. The process usually starts with collection of imagery covering large areas. Then potential hotspots or interesting zones are identified. For these hotspots or zones, additional imagery is collected with high spatial resolution. The produced maps/reports including the classification information are then provided to the users.

Service Provider Satellite EO Requirements	
Spatial resolution	It is usually quite high going up to meter and sub-meter level (e.g. car counting, classification of small buildings).
Temporal resolution	It depends on the application needs. Also the balance between spatial and temporal reposition accuracy is crucial. E.g. data can be collected with lower spatial resolution over a longer period of time to create information over a day, a week, a season.
Data type / Spectral range	Data types are optical and radar images to create the underlying maps as well as to detect specific aspects. E.g. radar images could be used to identify vehicles. E.g. optical images could be used to identify the type of buildings (industrial, housing, utilities, etc.).
Other (if applicable)	As the information is used for management or investment decisions, the provided information has to be as precise as possible.
Service Inputs	
Satellite data sources	- Sentinel-1 (e.g. land cover, land use) - Sentinel-2 (e.g. land cover, land use) - Sentinel-3 - Sentinel-5P (e.g. air quality) - NASA / USGS - A mix of radar and optical satellites generating images with various spatial and temporal resolutions (up to very high spatial and very high temporal resolution).
Other data sources	- Local information about the utilisation of buildings and cadastral information. - Demographic information and models. - Very High Resolution (VHR) data with spatial resolution ≤ 1m (e.g. Copernicus Contributing missions)

5.1.5 Mapping & GIS – Type A application

Smartphones enable users to become map creators as a result of the democratisation of digital mapping. Mapping services comprise all consumer applications that draw on GNSS and EO information for map features, which includes location or navigational services, including navigation, tracking and local search & discovery applications.

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]. GIS technology combines database, map- ping 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 Table 11 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Mapping and GIS.

Table 11 - Mapping & GIS application GNSS user requirements

Criterion	Performance	Characterisation
Accuracy	Horizontal	High [RD71]
	Vertical	High [RD71]
Service area	Geographical coverage	Global
Availability/timeliness	Urban canyon	Yes [RD17]
	Canopy	Yes [RD17]
	Indoors	Yes [RD17]
	TTFF (hot start)	Low [RD17]
	Fix update type	Continuous 1-5Hz [RD71]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD17]
	Susceptibility to spoofing	No
Power consumption		Low [RD79]
Proportion of GNSS		High [RD71]
Main user groups		Enthusiasts Pragmatists Traditionalists Users with special needs

The simplest way of utilisation of EO data is the provision of maps by specific organisations (e.g. for outdoor activities) offering to their user community the possibility to provide an individual feedback loop reporting about actual observations during their activity (e.g. Apps from Fatmap and Outdooractive). E.g. during an outdoor activity like hiking on a given trail, reporting about a hiking route blocked by a landslide or tree, or reporting about a beautiful spot at a specific location (GNSS position) and evidenced by pictures taken with the smartphone. Such information is then taken up in the related app and made available to other users.

More advanced users can create their own maps with existing tools (e.g. ArcGIS) where basic maps are available for further input generation depending on the individual aspects. Many application examples can be listed, as following.

An organisation that carries out inspections in a city can provide to their employees' maps including the information on the buildings to be inspected, the travel modes, the travel route by foot, bicycles or cars.

A forester can to geolocalize trees which are infested with bark beetle. After a check of tailored maps including potential hotspot areas (e.g. taken from satellite imagery), he/she walks through the forest and marks the infested trees with their location in the map. This map is then made available to the forest workers for extraction of the trees (e.g. project Waldcursor).

GIS service delivers plans for expansion or reduction of green areas to foster the visibility of particular touristic region as 'eco-friendly', or 'sustainable'. Apps for end users (tourists) provided either by local municipality (B2G and B2C – Business to Government and to Consumers) or directly from private companies (B2C).

Infrastructure evaluation for urban cycling, vegetation and terrain evaluation are requirements to complement cycling and (in latter) hiking apps so that end users have a tool which can serve as basis to prevent collisions and other injuries relate to objects present on/near tracks.

Additional users are for example also from up--down like hiking associations (or those responsible for management of flows in the mountains), where the above-mentioned information can be combined with person counters (and weather, holiday, …) in order to redirect the hiker flows (an emerging issue in Covid time), e.g. Mountaineering 4.0 project. Similar use is the combination of road/ parking slot counters showing the available capacity of the destination to prevent road congestions in valleys, e.g. Tourism 4.0 TRL 3-6 project was studying among others the patterns for smaller villages organizing big events once per year.

Common users for this application are: consumers, businesses, outdoor and travel tourism, transport/logistics users, , local municipalities in charge of planning and maintaining green areas and forestry (overlap with urban mobility), creating accurate cycling and hiking maps, monitoring the average occupancy or the beaches by tourists needed for spatial planning for B2B (Business to Business) and B2G (Business to Government) sectors, cyanobacteria monitoring for public and private beaches.

The Table 12 - Mapping & GIS application EO user requirements summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Mapping and GIS.

Table 12 - Mapping & GIS application EO user requirements

ID	Identifier EUSPA-EO-UR-CSO-0005
Application	***Mapping & GIS***
Users	Enthusiasts Pragmatists Traditionalists Users with special needs
User Needs	
Operational scenario	a. Provide an individual feedback loop reporting about actual observations during activity. b. Creation of users' own personalised maps with existing tools (e.g. ArcGIS), starting from basic maps available for further input generation depending on the needed aspects.
Size of area of interest	It depends on the specific applications (without specifications, the area of interest can be characterised in general as global).
Scale	The scale depends on the specific application.
Frequency of information	The update rate needed depends on the specific application.
Other (if applicable)	Remote sensing and digital image processing research is focused mainly on information extraction from images (thematic maps) but orthoimage usage for cartographical purposes is rarely investigated.
Service Provider Offer	
What the service does	The service provides information tailored to the user and to the related utilisation/operation to help the user finding objects, routes, etc. as well as to improve efficiency of operational processes. E.g. optimised route of a parcel delivery service. E.g. for emergency services in a disaster to notate still functional installations or services like bridges, hospitals; for maintenance service people to show the specific operational location).

How does the service work	The generator of the maps takes either pre-existing maps (e.g. ArcGIS, GoogleMaps) or uses processed satellite topographic image maps with the most recent information. He/she then creates an own thematic layer for the intended operational use (e.g. routes, points of interest, additional relevant information). The map is made available to the user in the field on his/her smartphone. Depending on the type of usage, the user in the field can provide feedback information (including some evidence for verification) refining the map content and information for other users.
Service Provider Satellite EO Requirements	
Spatial resolution	Usually in the meter range: online maps can go down to 1:1.000 (highest resolution level).
Temporal resolution	- Not critical for detecting slow changes (e.g. changes in land use). - In case of modifications (e.g. tree breaks in forests, landslides on hiking routes) relevant for the operational use, updates of the maps should be available as soon as possible.
Data type / Spectral range	For NDVI in most cases NIR and IR spectral bands are used.
Other (if applicable)	Reliability should be guaranteed, and false information especially on reporting of recent changes should be avoided.
Service Inputs	
Satellite data sources	- Sentinel-2 - Worldview - Planet Skysat - Pleiades - Pleiades Neon - Planet Lab - BlackSky
Other data sources	- Existing official or self-made maps - Imagery from optical satellites - Combination with local data, such as person, road, parking slot counters, mobile user data (reliable only areas with good coverage)

5.1.6 Games – Type B application

Mobile Location Based Gaming (MLBG) is a growing trend among Consumer Solutions, Tourism & Health market segment. **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 [RD11], 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 [RD11]. 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 [RD12].

Common devices enabling this application are smartphones and tablets.

The main GNSS user requirements are:

- Accuracy:
  - Horizontal: high [RD79]
  - Vertical: 10m [RD71]
- 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):
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- Power consumption: low consumption [RD6]

Table 13 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.

Table 13 - Games application GNSS user requirements

Criterion	Performance	Characterisation
Accuracy	Horizontal	High
	Vertical	Low [RD71]
Service area	Geographical coverage	Global
Availability/timeliness	Urban canyon	Yes [RD53]
	Canopy	Yes [RD47]
	Indoors	Yes [RD48]
	TTFF (hot start)	High [RD71]
	Fix update type	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, commercial users and citizens

5.1.7 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. 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]

❖ ***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]

❖ ***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 [RD83].

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]

❖ ***Travel applications***

There is an increased interest by the tourism industry to implement augmented reality into the travellers' experience [RD84]. 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 smart- phones 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]

❖ ***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 14 - Augmented reality for leisure applications GNSS user requirements 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 14 - Augmented reality for leisure applications GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	Medium [RD80]
	Fix update type	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		

5.1.8 Geo-tagging – Type B application

❖ ***Photos and videos geotagging***

Geotagging means adding geographical metadata to online content with the purpose of identifying the physical location of where the content was posted from.

Common geospatial metadata are 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):
    - Susceptibility to interference: Yes [RD71]
    - Susceptibility to spoofing: No
- Power consumption: low [RD79]

❖ ***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. 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]

The Table 155 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Geo-tagging applications.

Table 15 - Geo-tagging application GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	High [RD6]
	Fix update type	Continuous [RD79]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD71]
	Susceptibility to spoofing	No
Power consumption		Low [RD6]
Proportion of GNSS		N/A
Main user groups		Enthusiasts, commercial users, citizens and public users Pragmatists, commercial users and public users

5.1.9 mHealth – Type B application

In combination with other technologies, GNSS enables a vast array of applications from patient monitoring to guidance systems for vulnerable groups (people with reduced mobility, visual impairment and seniors). Some sub-applications are described in detail below. They have distinct purposes and users but are all examples of how GNSS technology is used for personal health needs.

❖ ***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 super- vision. 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 [RD101]. 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]

❖ ***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 [RD22], [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]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: Yes [RD71]
    - Susceptibility to spoofing: Yes [RD79]
- Power consumption: low consumption [RD75]

The

Table 16 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.

Table 16 - mHealth application GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	High [RD6][RD71]
	Fix update type	Continuous [RD71]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD71]
	Susceptibility to spoofing	Yes [RD79]
Integrity	Risk	Yes [RD79]
	Time to alert	In seconds [RD79]
Power consumption		Low [RD75]
Proportion of GNSS		Medium [RD71]
Main user groups		Enthusiasts, commercial users and citizens Pragmatists, citizens Traditional, citizens Users with special needs

5.1.10 Safety and emergency – Type B application

GNSS, in combination with network-based methods, provides accurate emergency caller location. Under this type of application stand two different sub-applications, specific for particular demands and users: search and rescue, E112.

❖ ***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).

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]

❖ ***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]. 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]. 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]. 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. Common devices enabling this application are smartphones and tablets.

- The main GNSS user requirements are:
- 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 17 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.

Table 17 - Safety and emergency application GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	Medium [RD80]
	Fix update type	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 Traditional Users with special needs

5.1.11 Social networks – Type B application

GNSS technology is also used in some specific functions of social networks, to facilitate keeping in touch, for sharing travel information and providing new networking services to users [RD2]. The most popular applications are described below:

❖ ***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 Face- book 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]

❖ ***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 [RD24].

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].

❖ ***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.

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] indoors [RD48]
    - TTFF: a few seconds [RD71]
    - Need for on-request positioning
- Resilience (Robustness / Trust):
    - Susceptibility to interference: Yes [RD71]
    - Susceptibility to spoofing: No
- Power consumption: low consumption [RD6]

Table 18 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 cate- gory have different requirements for a performance parameter, the most stringent one has been included in this table.

Table 18 - Social networks application GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	High [RD71]
	Fix update type	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, commercial users and citizens Pragmatists, citizens

5.1.12 Billing – Type B application

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.** Under this type of application stand two different sub-applications: billing and fraud management.

❖ ***Billing***

This application use GNSS to process payments based on location or activity duration for public transport, gyms, theme parks, parking. 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. 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]. Inside GNSS 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]

❖ ***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]

Table 19 - Billing application GNSS user requirements summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Billing applications. Whenever there two applications in this category have different requirements for a performance parameter, the most stringent one has been included in this table.

Table 19 - Billing application GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	High [RD14]
	Fix update type	On Request [RD79]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD68]
	Susceptibility to spoofing	Yes [RD68]
Integrity	Risk	High [RD79]
	Time to alert	10 seconds [RD14]
Power consumption		Low [RD14]
Main user groups		Enthusiasts, commercial users and public users Pragmatists, commercial users, citizens and public users

5.1.13 Navigation – Type B application

Navigation app is a route planning and turn-by-turn instructions enabled by GNSS for both pedestrian and road users through a smartphone. The following are some specific sub-applications of this technology.

❖ ***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 [RD2], [RD5], [RD18]. 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 [RD18]. 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]

❖ ***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 [RD19]. 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]

❖ ***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]

❖ ***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 [RD16].

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]

Table 20 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 20 - Navigation application GNSS user requirements

Criterion	Performance	Characterisation
Accuracy	Horizontal	High [RD79]
	Vertical	Medium [RD71]
Service area	Geographical coverage	Global [RD47]
Availability/timeliness	Urban canyon	Yes [RD17]
	Canopy	Yes [RD17]
	Indoors	Yes [RD79]
	TTFF (hot start)	Medium [RD71]
	Fix update type	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 Pragmatists Traditionalists

5.1.14 Personal & asset tracking – Type B application

In personal & asset tracking applications, GNSS facilitates innovative tracking solutions, including the deployment of local geofences that trigger an alarm when users and/or goods leave a specific perimeter.

❖ ***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]
  - TTFF: a few seconds [RD6]
  - Need for on-request fix updates [RD79]
- Resilience (Robustness / Trust):
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]
- Power consumption: medium to low consumption [RD6]

❖ ***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 inter- viewed 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]
- 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].

❖ ***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):
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD71]
- Power consumption: medium to low consumption [RD6].

❖ ***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]. 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].

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].

Table 21 - Personal & asset tracking application GNSS user requirements 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.

Table 21 - Personal & asset tracking application GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	High [RD6]
	Fix update type	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 Pragmatists Traditionalists, commercial users and citizens

5.1.15 Visually impaired support – Type B application

GNSS can be used for solutions providing turn-by-turn instructions based on positioning that help visually impaired people get around more easily [RD2], [RD4]. **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):
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: Yes [RD79]
- Integrity:
  - Risk: yes [RD79]
  - Time to alert: yes [RD79]
- Power consumption: low consumption [RD6]

The Table 22 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Visually impaired support applications.

Table 22 - Visually impaired support application GNSS user requirements

Criterion	Performance	Characterisation
Accuracy	Horizontal	High [RD79]
	Vertical	3-4 meters [RD71]
Service area	Geographical coverage	Global [RD47]
Availability/timeliness	Urban canyon	Yes [RD17]
	Canopy	Yes [RD17]
	Indoors	Yes [RD48]
	TTFF (hot start)	<15 seconds [RD56]
	Fix update type	Continuous [RD56]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD71]
	Susceptibility to spoofing	Yes [RD79]
Integrity	Risk	Yes [RD79]
	Time to alert	In seconds [RD79]
Power consumption		Low [RD6]
Proportion of GNSS		High
Main user groups		Enthusiasts Pragmatists, public users Users with special needs

5.1.16 Consumer robotics – Type B application

GNSS signals are used along with other sensors integrated in consumer electronics for localisation and navigation purposes; e.g., gardening robots, delivery robots, security and surveillance robots, personal assistant robots, painting robots, automated guided vehicle/logistics.

5.1.16.1 ROBOTICS – HIGH GNSS USE

❖ ***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, some- times 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]

❖ ***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]

❖ ***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 23 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 appli- cations in the category have different requirements for a performance parameter, the most stringent one has been included in this table.

Table 23 - Consumer robotics application GNSS user requirements – High GNSS use

Criterion	Performance	Characterisation
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 (hot start)	Low [RD80]
	Fix update type	Continuous [RD80]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD80]
	Susceptibility to spoofing	Yes [RD80]
Power consumption		TBD
Proportion of GNSS		Low [RD80]
Main user groups		Enthusiasts, commercial users and citizens Pragmatists, commercial users and citizens

5.1.16.2 ROBOTICS – LOW GNSS USE

❖ ***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].

❖ ***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].

❖ ***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 24 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 24 - Consumer robotics application GNSS user requirements – Low GNSS use

Criterion	Performance	Characterisation
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 (hot start)	Medium/High [RD80]
	Fix update type	Continuous [RD80]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD80]
	Susceptibility to spoofing	Yes [RD80]
Power consumption		TBD
Proportion of GNSS		Low [RD80]
Main user groups		Enthusiasts, commercial users and citizens Pragmatists, commercial users and citizens

5.1.17 Points of interest – Type B application

Thanks to GNSS data is possible to create online points of interest, this means to provide content relative to the user's location. Such location may include location-based landmarks, restaurants, petrol stations, banks, ATMs, hospitals, etc.
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):
  - Susceptibility to interference: Yes [RD71]
  - Susceptibility to spoofing: No
- Power consumption: low consumption [RD6]

The main GNSS user requirements are summarised in the Table 25 - Point of interest application GNSS user requirements.

Table 25 - Point of interest application GNSS user requirements

Criterion	Performance	Characterisation
Accuracy	Horizontal	Low [RD79]
	Vertical	N/A [RD71]
Service area	Geographical coverage	Global [RD47]
Availability/timeliness	Urban canyon	Yes [RD71]
	Canopy	Yes [RD71]
	Indoors	Yes [RD48]
	TTFF (hot start)	A few seconds [RD6]
	Fix update type	On request. This helps save battery power [RD32]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD71]
	Susceptibility to spoofing	No
Power consumption		Low [RD6]
Proportion of GNSS		n/a
Main user groups		Enthusiasts, commercial users and citizens Pragmatists, citizens

5.1.18 Workforce management – Type B application

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

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

Table 26 summarises the main GNSS user requirements, the proportion of GNSS and the main user groups for Workforce management applications. Whenever there two applications in this category have

different requirements for a performance parameter the most stringent one has been included in this table.

Table 26 – Workforce management application GNSS user requirements

Criterion	Performance	Characterisation
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 [RD71]
	TTFF (hot start)	Low [RD71]
	Fix update type	Continuous 5s [RD71]
Resilience (Robustness / Trust)	Susceptibility to interference	Yes [RD71]
	Susceptibility to spoofing	Yes [RD71]
Power consumption		Low [RD71]
Proportion of GNSS		n/a
Main user groups		Enthusiasts, commercial users and public users Pragmatists, commercial users and public users Traditionalist, public users

5.1.19 IoT

The IoT applications have been discussed during the Mass Market Panel at the User Consultation Platform (UCP) 2020 held virtually on the 2nd of December 2020. These findings are recorded in the Mass Market panel meeting minutes [RD100] and are reported are Annex 5 2020 Updates to the Location-Based Services User Needs and Requirements Report [RD112]. The diversity of IoT applications presented at the UCP led to significant disparities in terms of performance requirements. A single table of requirements for this application category cannot represent accurately all applications. To accurately transmit the requirements discussed at the UCP [RD100] this section will provide a detailed table of requirements per application.

❖ ***High-end sport tracker (Elite sport/rugby man tracking)***

The positioning information is used in sport to assess athletes' performances and manage their rest time according to the covered distance and maximum speed for example.

The main GNSS user requirements are:

- Accuracy:
  - Horizontal: 2 meters [RD100]
  - Vertical: 2.5 meters [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
  - Availability in urban canyons, indoor and under canopy [RD100]
  - TTFF: No specific requirement [RD100]
  - Update rate: 10 Hz [RD100]
- Resilience (Robustness / Trust):
  - Susceptibility to interference: Yes [RD100]
  - Susceptibility to spoofing: No [RD100]

❖ ***Low-end sport tracker***

For this use-case to grow even further, the comfort, efficiency and pricing of the devices have the highest impact on consumer adoption. Those drivers push for lower-end sport devices with smaller size, cheaper price and higher accuracy. Additionally, long-range connectivity brings added value to sport trackers by adding social interaction such as position sharing.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 2.5 to 10 meters. [RD100]
    - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - Availability in urban canyons and under canopy [RD100]
    - TTFF: <2 seconds [RD100]
    - Update rate: <5min [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: 'nice-to-have' [RD100]
    - Susceptibility to spoofing: 'nice-to-have' [RD100]

❖ ***Asset tracker for logistics***

Many different vectors are used in logistics to transport goods from factory to consumers or between factories. It ranges from small boxes, especially in retail, up to containers for international carriage. The geolocation of the vector is always a valuable information that is used to increase logistics process by monitoring the transport efficiency, informing the final destinate or anticipating delays.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: Variable [RD100]
    - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - Availability in urban canyons, indoor and under canopy [RD100]
    - TTFF: Low (>30 sec) [RD100]
    - Update rate: >240 min [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: 'nice-to-have' [RD100]
    - Susceptibility to spoofing: 'nice-to-have' [RD100]

❖ ***Tracking of trailers***

This application aims at maximising the use of trailers. Indeed, tracking trailers allows to locate them and optimise their usage. Finally, the tracking enhances supply chain management transparency and traceability.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 20m [RD100]
    - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - Availability in urban canyons [RD100]
    - TTFF: No requirement - Time out within a minute [RD100]
    - Update rate: 6 to 8 per day [RD100]

- Resilience (Robustness / Trust):
    - Susceptibility to interference: May be needed on the long run but no threat identified yet [RD100]
    - Susceptibility to spoofing: May be needed on the long run but no threat identified yet [RD100]

❖ ***Tracking of containers***

The primary objective of this application is to inform the end customer when he will be delivered. The tracking of containers allows to locate and protect valuable assets, to save time and to optimise their usage. It also promotes safety when managing assets in isolated and rugged work sites. Finally, the tracking enhances supply chain management transparency and traceability.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 10m [RD100]
    - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - Availability in urban canyons [RD100]
    - TTFF: No requirement - Time out within a minute [RD100]
    - Update rate: 6 to 8 per day [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: May be needed on the long run but no threat identified yet [RD100]
    - Susceptibility to spoofing: May be needed on the long run but no threat identified yet [RD100]

❖ ***Tracking of packages***

The primary objective of this application is to improve the efficiency of the logistic chain. Indeed, the tracking of packages allows to locate and protect them but also to save time and optimise their transit through the logistic chain. Finally, the tracking allows to enhance supply chain management transparency and traceability.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 10m [RD100]
    - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - Availability in urban canyons and indoor [RD100]
    - TTFF: No requirement - Time out within a minute [RD100]
    - Update rate: 1 every 15 min and one each time it moves [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: May be needed on the long run but no threat identified yet [RD100]
    - Susceptibility to spoofing: May be needed on the long run but no threat identified yet [RD100]

❖ ***Tracking of staff***

The tracking of staff aims at reinforcing the safety of workers. It allows to locate to save time and optimise their tasks as well as protecting them. It also promotes safety when managing employees in isolated and rugged work sites.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 20 m [RD100]
    - Vertical: N/A [RD100
- Geographical coverage: Regional [RD100]
- Availability / Timeliness:
    - Availability in urban canyons [RD100]
    - TTFF: No requirement - Time out within a minute [RD100]
    - Update rate: 1 every 5 min during 12 hours [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: May be needed on the long run but no threat identified yet [RD100]
    - Susceptibility to spoofing: May be needed on the long run but no threat identified yet [RD100]

❖ ***Artisanal Fisheries***

This application helps control the fishing activity to protect the fishing resources. Fishermen can use it to send alerts and receive weather notifications. Moreover, the application provides them with analytics on the uptime and downtime of their assets.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 10m [RD100]
    - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - TTFF: Not critical [RD100]
    - Update rate: 1 PVT per hour [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: Yes [RD100]
    - Susceptibility to spoofing: Yes [RD100]

❖ ***Livestock Monitoring***

This application helps to monitor the animals wandering around. By get the position and health data of the animals, Farmers improve productivity and automate, which is much needed.

The main GNSS user requirements are:

- Accuracy:
    - Horizontal: 100m [RD100]
    - Vertical: 100m [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
    - Availability in under canopy [RD100]
    - TTFF: Not critical [RD100]
    - Update rate: 1 PVT per day [RD100]
- Resilience (Robustness / Trust):
    - Susceptibility to interference: No [RD100]
    - Susceptibility to spoofing: No [RD100]

❖ ***Smart Farming***

Smart farming is a major evolution that can be defined as data management that supports farming decision. It aims at improving production quality, animals' health, sustainability goals, activity

competitiveness and operational cost. Geolocation based on GNSS is already one of the key data at the heart of smart farming, but it is limited to applications where cost of GNSS system is not critical (such as cm-level guiding systems). Thanks to affordable long-range connectivity, a broad range of environmental connected probes (collecting temperature, soil moisture or other local data) are getting widespread but they miss geolocation capability due to price constraints. Accordingly, an affordable GNSS capability could become a valuable option for this class of probes.

The main GNSS user requirements are:

- Accuracy:
  - Horizontal: 2.5 to 10 m [RD100]
  - Vertical: N/A [RD100]
- Geographical coverage: Global [RD100]
- Availability / Timeliness:
  - Availability in urban canyons and under canopy [RD100]
  - TTFF: Low (>30 sec) [RD100]
  - Update rate: >240 min [RD100]
- Resilience (Robustness / Trust):
  - Susceptibility to interference: 'nice-to-have' [RD100]
  - Susceptibility to spoofing: 'nice-to-have' [RD100]

5.1.20 Enhanced human – Type B application

Human enhancement application refers to methods for altering the human body to enhance mental or physical performance. The most developed examples are untethered mixed reality devices: in the future, GNSS position and EO data could be combined with optical feedback and 3D mapping to give users full situational awareness and the most accurate navigation.

❖ ***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 refers 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]

❖ ***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 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]

❖ ***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 per- form 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]
  - Need for continuous positioning [RD80]
- Resilience (Robustness / Trust):
  - Susceptibility to interference: Yes [RD80]
  - Susceptibility to spoofing: No [RD80]

Table 27 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 27 - Enhanced human applications GNSS user requirements

Criterion	Performance	Characterisation
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 (hot start)	Medium [RD80]
	Fix update type	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

5.1.21 Satcom users – Type C application

GNSS is typically used in Satellite Control Stations and Telecommunications Gateways, mostly for frequency control. When focusing on the user segment, we look into the end user markets that use handheld SATCOMs.

5.2 Limitations of GNSS and EO

In spite of all possibilities, GNSS use in Consumer Solutions, Tourism & Health 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. As per last RUR for Consumer Solutions, Tourism & Health, these are the main limitations: power consumption, indoor/outdoor availability, availability in challenging environments, Susceptibility to Multipath, Jamming and Spoofing of GNSS signals.

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.

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 Consumer Solutions, Tourism & Health 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 the line-of-sight to satellites. 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 Consumer Solutions, Tourism & Health users. One consequence of jamming is the inconvenience that results from the service unavailability, which can lower the overall satisfaction of Consumer Solutions, Tourism & Health 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.

The main limitations in the use of EO data concern the **accuracy** of the images that satellites are able to provide, **in relation to scale, area of interest and update time**.

For example, for air quality information, it is important to have very frequent data updates, but this is difficult to have at a high level of scale accuracy. At the same time, air quality indicators need accurate and consistent data while covering large areas. When information on air quality in cities are needed, them are usually required at street level (there can already be significant differences from one street to another, a parallel street) and they can change within minutes because of traffic, congestion, pollen, and other pollutants moving and changing rapidly. Therefore, it can be said that information derived from Earth observation usually covers large areas but has limitations in acquisition time and accuracy. For example, CAMS (Copernicus Atmosphere Monitoring Service) provides air quality forecast over Europe every hour, which is a notable achievement in terms of timely and consistent information. However, despite this effort, it may not always meet the demands of users due to the dynamic and rapidly changing nature of air quality, and one hour update could result insufficient accurate.

Accurate and continuous information could be provided by ground stations, but their spatial coverage is limited, and implementation and operation are usually quite expensive.

Another problem concerns data deriving from **ground-based sources**, which are fundamental to complement EO data, tend to be quite expensive, and often also difficult to collect and offering insufficient geographical coverage, usually limited to a neighbourhood or a city. This is a case that especially affects the estimation of UV derived from satellite measurements. It has the advantage of complete spatial coverage, but it must be considered that the lack of detailed knowledge of influential parameters at specific locations limits the accuracy of the final service. Furthermore, since UV poses a threat to people's health, any UV-related information or warning service must be reliable and avoid false negatives. So, those data need to be **integrated with spatial data and images with contextual data**, e.g. use of buildings, cadastral information, street layers, in order to provide an adequate classification.

In applications related to maps, movement tracking around economic activities, and geo-advertising analysis, some **conflicts could arise concerning personal privacy regulations** [RD107]. Moreover, from the point of view of the application provider (especially for larger companies), this compliance with the regulations on data sharing and disclosure, administrative and legal constraints for the use of space data, can become significant obstacles in terms of human resources, time and cost.

On another side, also EO data accessing, and processing requires **highly skilled (and therefore expensive) workforce. Support services, data processing and administration** are often financial issues not affordable for all application providers, with the smaller ones struggling the most.

During UCP 2022 event in Prague, some **human barriers** were identified. For example, the lack of developers able to combine all the needed technology (machine learning, AI, EO) and domain/application specific knowledge. Another issue hindering the full exploitation of EO data in tourism and health applications is identified in the unbalanced regional development, especially. in terms of education and expertise, which generates a lack of interest in the adoption of EO data, especially in the tourism sector.

Finally, during UCP 2022 discussion, a concern was raised regarding the role the European Commission should take in the field of EO data. The current role as a data provider was welcomed, but the idea that the **European Commission would play a growing role in the development of EO-based products and services** was identified as a potential threat to commercial companies already developing their own EO products and services. Technical and scientific support is identified by the participants as the most important element offered by the public institutions, and it still can be improved. While financial support, it is considered very relevant, but sometimes not sufficient. In order to support the testing, the following refinement and uptake of EO-based solutions, early adopters play a crucial role since they allow the developers to collect first-hand feedback and they often play an informative role in the community, spreading awareness and best practices. In this regard, according to the discussion at UCP, public institutions should be early adopters themselves, especially of the solutions they funded in the first place, on top of supporting the engagement of other early adopters.

5.3 Prospective use of GNSS and EO

5.3.1 Prospective use of GNSS

There is an emerging premium mass market, driven by a growing number of premium smartphones with multi- constellation GNSS chipsets [RD101]. 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.

The case for increased security and anti-spoof function is therefore expected to be made even in the Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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.

- **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

The current GNSS modules used in Consumer Solutions, Tourism & Health (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

The Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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 Consumer Solutions, Tourism & Health 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.

5.3.2 Prospective use of EO

The principal trends that will characterize the EO technology can be summarized as the following. The list does not focus on the technical trends that are going to be developed, but many of the following considerations are useful in understanding the market changes and user needs examined in the previous chapters.

- **Exponential growth in number of satellites**, which will be mainly driven by the increase in number of satellites. Among all, the smaller satellites, which are cheaper and easier to launch, will increase exponentially and will make a direct impact in the EO data available as a result.
- **Cost optimization**: satellites and the materials to manufacture them will become progressively cheaper. It is a virtuous circle in which, decreasing costs promote an increase in satellite launches which increases the sources of data available. In turn, more data, the greater the spread, the greater the demand and the greater the possibility of lowering production and maintenance costs.
- **Reduction in update time**: the availability of data at higher time intervals has also become a key trend for EO technology. As we have seen, in many applications, the need for data updated at short intervals, or even in real time, is crucial for operation and service provision.
- **Rise of artificial intelligence**: machine learning algorithms have proven to be a powerful tool to analyse satellite imagery of any resolution and demonstrate better, more nuanced information [RD108].
- **Changes in business model**: traditionally EO service providers relied on government-supported business models with large lucrative contracts and supplied mostly very high-resolution data. In recent years, the business model is more industry-focused, providing low-resolution data but with a high level of review and analysis, leveraging the added value that can be provided to services. During UCP 2022, the participants agreed on the existing challenges to deploy a sustainable business model, especially at large (global level) in this domain, since the acquisition of data at local level is typically affordable and relatively simple, while data at regional or wider level they tend to be more expensive due to the higher amount of data and consequent complexity.
- **Move up the service chain**: demand is changing toward the demand for usable information and solution-based products instead of just image. Here is where EO platform developers fit into the value chain, reshaping data and making them more accessible for final purposes. This process has already been on-going for a while, but it will keep growing and becoming more and more customised to meet the needs of the services demanded. During UCP 2022 event, two main future needs have been identified: (i) financial support to R&D is considered fundamental in this emerging market, especially for the initial development phase of innovative solutions; and (ii) adopting the perspective of the end user, rather than the technology developers, when elaborating new solutions to make sure they feet the market.
- **Multisource solutions**: now the unidimensional approach based on data from a single source is losing relevance. When end users require contextual solutions, a single data source is not enough and it is necessary to integrate information with other sources, heterogeneous and able to contextualize the data, creating a multidimensional solution of information that is integrated with each other proficiently [RD109].

5.4 Summary of drivers for user requirements

In the following Table 28 we present a summary of drivers common to the entire segment and sub-segments/groups of applications. Many drivers and needs for the future have been analyzed in previous chapters, within the specific applications of the Consumer Solutions, Tourism & Health segment. The following are the most important GNSS and EEO drivers allocated per specific sub-segment of the market:

- *Resilience and reliability*: data are needed with the ability to reprocess information by contextualizing it to the surrounding environment and with a high degree of reliability.
- *High resolution and availability*: the need for high-resolution and frequently updated data and the need to have a large amount of data, to develop useful and accurate information for end users (https://business.esa.int/newcomers-earth-observation-guide).
- *Miniaturization and integration*: the ability to process data and provide alerts to end-users requires the integration of specific technologies even in very small devices (e.g. wearable devices for sports activities or monitoring UV levels)
- *Multi-source solutions*: the need to integrate data from different types of sources (space, air, ground, sensors, etc.) in order to contextualize the data and provide timely information.
- *Data processing*: the increasing capacity and demand to add value to the information that can be obtained by reprocessing raw data coming from satellites.
- *Chip-based indoor localization techniques*: especially for GNSS technology, also require the availability of data in enclosed spaces.
- *Improved robustness to Interference*: the need for GNSS technologies to withstand signal interference.
- *GNSS continuity of service and traceability*: continuity in the receiving and delivering GNSS signals, also to ensure traceability purposes.

Table 28 - Future main drivers in the Consumer Solutions, Tourism & Health segment

Consumer solutions	***Healthcare***	***Tourism***
• Resilience and reliability • High resolution and availability • Miniaturisation and integration • Multisource solutions • Data processing • Improved robustness to Interference • Chip-based indoor location technique	• Resilience and reliability • Miniaturisation and integration • Multisource solutions • Data processing • Chip-based indoor location techniques • GNSS Continuity of service and traceability	• High resolution and availability • Multisource solutions • Data processing • GNSS Continuity of service and traceability

6 USER REQUIREMENTS SPECIFICATION

The chapter provides a synthesis of the user requirements described in Section 5.1 respectively on GNSS in section 6.1 and on EO in section 6.2. The content of this section will be updated, completed and expanded by EUSPA in the next releases of the RUR based on the results of further investigations discussed and validated in the frame of the UCP.

6.1 Synthesis of GNSS User Requirements

The GNSS-related requirements presented in this chapter are based on those presented in the Report on Location-Based Services user needs and requirements (and its annexes) [RD105]. The difference that these requirements have now been matched to the list of applications as presented under chapter 5.1.

Table 29 - Requirements for Sport, fitness and wellness applications

Id	Description	Type	Source
EUSPA-GN-UR-LBS-0600	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
EUSPA-GN-UR-LBS-0610	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD47] [RD80]
EUSPA-GN-UR-LBS-0620	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD47]
EUSPA-GN-UR-LBS-0630	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-0640	The PNT solution shall provide continuous positioning with an update rate from 1 to 2 Hz.	Performance (Timeliness: Update rate)	[RD79]
EUSPA-GN-UR-LBS-0650	Update rate shall be within a range of 5-10Hz.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0670	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-0671	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]
EUSPA-GN-UR-LBS-0672	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]
EUSPA-GN-UR-LBS-0673	The geographical area of operation of the PNT solution shall be global.	Performance (Geographical coverage)	[RD 47]

Table 30 - Requirements for geo-advertising applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-0240	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-0250	The PNT solution shall be available in urban canyons with a 95% confidence level	Performance (Availability in urban canyon)	[RD47] [RD80]
EUSPA-GN-UR-LBS-0260	The PNT solution shall be available under canopy with a 95% confidence level	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-0270	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
EUSPA-GN-UR-LBS-0290	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD32]
EUSPA-GN-UR-LBS-0310	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-0320	The PNT solution shall provide robustness against GNSS spoofing threats	Performance (Resilience Susceptibility to spoofing)	[RD47]

Table 31 - Requirements for Mapping and GIS applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR-LBS-0140	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD71] [RD80]
EUSPA-GN-UR-LBS-0150	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-0160	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD71]
EUSPA-GN-UR-LBS-0170	The PNT solution shall provide a TTFF (hot start) better than 1 minute.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-0180	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0190	The PNT solution shall have an update rate within a range of 1-5Hz.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0200	The PNT solution shall provide medium robustness against environmental conditions.	Performance (Resilience: Susceptibility to environmental conditions)	[RD71]
EUSPA-GN-UR-LBS-0210	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]

Table 32 - Requirements for games applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-0700	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-0710	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD53] [RD80]
EUSPA-GN-UR-LBS-0720	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD47] [RD80]
EUSPA-GN-UR-LBS-0730	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD48]
EUSPA-GN-UR-LBS-0740	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-0750	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD6]
EUSPA-GN-UR-LBS-0770	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-0780	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD79]

Table 33 - Requirements for augmented reality for leisure

Id	Description	Type	Source
EUSPA-GN-UR-LBS-1200	The PNT solution shall provide the user position with a horizontal accuracy of 50 centimetres.	Performance (Horizontal Accuracy)	[RD80]
EUSPA-GN-UR-LBS-1250	The PNT solution shall provide the user position with an accuracy of 2 centimetres.	Performance (Horizontal Accuracy)	[RD80]
EUSPA-GN-UR- LBS-1300	The PNT solution shall provide the user position with a vertical accuracy of few centimetres.	Performance (Vertical Accuracy)	[RD80]
EUSPA-GN-UR- LBS-1350	The PNT solution shall provide a relative positioning with an accuracy of 2 centimetres.	Performance (Vertical Accuracy)	[RD80]
EUSPA-GN-UR-LBS-1400	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD80]
EUSPA-GN-UR-LBS-1500	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD80]
EUSPA-GN-UR-LBS-1600	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD80]
EUSPA-GN-UR-LBS-1700	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD80]
EUSPA-GN-UR-LBS-1800	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD80]
EUSPA-GN-UR-LBS-1900	The PNT solution shall provide continuous positioning once the operation has started. Update rate shall be of 15Hz.	Performance (Timeliness: Update rate)	[RD80]
EUSPA-GN-UR-LBS-2100	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD80]
EUSPA-GN-UR-LBS-2200	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD80]

Table 34 - Requirements for mHealth and visually impaired support applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-0810	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-0820	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD17] [RD80]
EUSPA-GN-UR-LBS-0830	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD17] [RD80]
EUSPA-GN-UR-LBS-0840	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
EUSPA-GN-UR-LBS-0850	The PNT solution shall provide a TTFF (hot start) of less than 15 seconds.	Performance (Timeliness: TTFF)	[RD56]
EUSPA-GN-UR-LBS-0860	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0880	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-0890	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD79]
EUSPA-GN-UR-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]

Table 35 - Requirements for safety and emergency applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-0350	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-0360	The geographical coverage of the PNT solution shall be regional for E112.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR-LBS-0370	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD71] [RD80]
EUSPA-GN-UR-LBS-0380	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD47] [RD80]
EUSPA-GN-UR-LBS-0390	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
EUSPA-GN-UR-LBS-0400	The PNT solution shall provide a TTFF od less than 10 seconds.	Performance (Timeliness: TTFF)	[RD80]
EUSPA-GN-UR-LBS-0410	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0430	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-0440	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD79]

Table 36 - Requirements for social networks applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-LBS-2400	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-2500	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD28] [RD80]
EUSPA-GN-UR- LBS-2600	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-2700	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
EUSPA-GN-UR-LBS-2800	The PNT solution shall provide a TTFF (hot start) of less than 30 seconds.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-2900	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD28]
EUSPA-GN-UR-LBS-2910	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-3000	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD78]

Table 37 - Requirements for billing applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-4200	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-4300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
EUSPA-GN-UR-LBS-4400	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-4500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
EUSPA-GN-UR-LBS-4600	The PNT solution shall provide a TTFF (hot start) of less than 2 seconds.	Performance (Timeliness: TTFF)	[RD14]
EUSPA-GN-UR-LBS-4700	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD79]
EUSPA-GN-UR-LBS-4900	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-5000	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD68]
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]

Table 38 - Requirements for Navigation applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR-LBS-0030	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR-LBS-0040	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD17] [RD80]
EUSPA-GN-UR-LBS-0050	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD17] [RD71] [RD80]
EUSPA-GN-UR-LBS-0060	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD79]
EUSPA-GN-UR-LBS-0070	The PNT solution shall provide a TTFF (hot start) of 30 seconds or less.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-0080	The PNT solution shall provide continuous positioning once the operation has started.	Performance (Timeliness: Update rate)	[RD31]
EUSPA-GN-UR-LBS-0100	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD79]
EUSPA-GN-UR-LBS-0101	The PNT solution shall provide robustness against spoofing.	Performance (Susceptibility to spoofing)	[RD79]

Table 39 - Requirements for personal & asset tracking applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR-LBS-0920	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD32]
EUSPA-GN-UR-LBS-0930	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD32] [RD80]
EUSPA-GN-UR-LBS-0940	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-0950	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD48]
EUSPA-GN-UR-LBS-0960	The PNT solution shall provide a TTFF (hot start) of less than 15 seconds.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-0990	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-1000	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD71]

Table 40 - Requirements for robotics (high GNSS use)

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

Table 41 - Requirements for robotics (low GNSS use)

Id	Description	Type	Source
EUSPA-GN-UR-LBS-8000	The PNT solution shall provide the user position with a horizontal accuracy of a centimetre.	Performance (Horizontal Accuracy)	[RD80]
EUSPA-GN-UR-LBS-8100	The PNT solution shall provide the user position with a vertical accuracy of a centimetre.	Performance (Vertical Accuracy)	[RD80]
EUSPA-GN-UR- LBS-8200	The geographical coverage of the PNT solution shall be local.	Performance (Geographical coverage)	[RD80]
EUSPA-GN-UR- LBS-8300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD80]
EUSPA-GN-UR-LBS-8400	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD80]
EUSPA-GN-UR-LBS-8500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD80]
EUSPA-GN-UR-LBS-8600	The PNT solution shall provide a TTFF (hot start) of less than 10 seconds.	Performance (Timeliness: TTFF)	[RD80]
EUSPA-GN-UR-LBS-8700	The PNT solution shall provide continuous positioning once the operation has started	Performance (Timeliness: Update rate)	[RD80]
EUSPA-GN-UR-LBS-8800	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-8900	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience Susceptibility to spoofing)	[RD71]

Table 42 - Requirements for Point of Interest applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-LBS-3200	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR-LBS-3300	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD47] [RD80]
EUSPA-GN-UR-LBS-3400	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-3500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD32]
EUSPA-GN-UR-LBS-3600	The PNT solution shall provide a TTFF (hot start) of less than 2 seconds.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-3700	The PNT solution shall provide on-request positioning.	Performance (Timeliness: Update rate)	[RD79]
EUSPA-GN-UR-LBS-3900	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]

Table 43 - Requirements for Workforce Management applications

Id	Description	Type	Source
EUSPA-GN-UR-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]
EUSPA-GN-UR-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]
EUSPA-GN-UR- LBS-0470	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD47]
EUSPA-GN-UR- LBS-0480	The PNT solution shall be available in urban canyons with a 95% confidence level.	Performance (Availability in urban canyon)	[RD54] [RD80]
EUSPA-GN-UR-LBS-0490	The PNT solution shall be available under canopy with a 95% confidence level.	Performance (Availability under canopy)	[RD71] [RD80]
EUSPA-GN-UR-LBS-0500	The PNT solution shall be available indoors.	Performance (Availability indoors)	[RD17]
EUSPA-GN-UR-LBS-0510	The PNT solution shall provide a TTFF (hot start) of 1 minute or less.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0520	The PNT solution shall provide continuous positioning.	Performance (Timeliness: TTFF)	[RD71]
EUSPA-GN-UR-LBS-0530	Maximum time between usable fixes shall be 5 seconds.	Performance (Timeliness: Update rate)	[RD71]
EUSPA-GN-UR-LBS-0550	The PNT solution shall provide high robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD71]
EUSPA-GN-UR-LBS-0560	The PNT solution shall provide robustness against GNSS spoofing threats.	Performance (Resilience: Susceptibility to spoofing)	[RD71]
EUSPA-GN-UR-LBS-0590	PPP data shall be available via terrestrial links	Availability	[RD79]

The diversity of IoT applications presented at the UCP led to significant disparities in terms of performance requirements. A single table of requirements for this application category cannot represent accurately all applications. To accurately transmit the requirements discussed at the UCP [RD100] this section will provide a detailed table of requirements per application.

Table 44 - Requirements for IoT: High-end sport tracker

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9000	*A*	*The PNT solution shall provide the user position with a horizontal accuracy of 2 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR-LBS-9090	A	The PNT solution shall provide the user position with a vertical accuracy of 2.5 meters.	Performance (Vertical Accuracy)	[RD100]
EUSPA-GN-UR-LBS-9150	A	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR-LBS-9200	A	The PNT solution shall be available in urban canyons.	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR-LBS-9300	A	The PNT solution shall be available under canopy.	Performance (Availability under canopy)	[RD100]
EUSPA-GN-UR-LBS-9400	A	The PNT solution shall be available indoor.	Performance (Availability indoor)	[RD100]
EUSPA-GN-UR-LBS-9500	A	The PNT solution shall provide robustness against interference.	Performance (Resilience: Susceptibility to interference)	[RD100]
EUSPA-GN-UR-LBS-9600	A	The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be 10 Hz.	Performance (Timeliness: Update rate)	[RD100]

Table 45 - Requirements for IoT: Low-end sport tracker

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9010	A	*The PNT solution shall provide the user position with a horizontal accuracy within a range of 2.5 to 10m.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9200	A	*The PNT solution shall be available in urban canyons.*	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR- LBS-9300	A	*The PNT solution shall be available under canopy.*	Performance (Availability under canopy)	[RD100]
EUSPA-GN-UR- LBS-9700	A	*The PNT solution shall provide a TTFF (hot start) of less than 2 seconds.*	Performance (Timeliness: TTFF)	[RD100]
EUSPA-GN-UR- LBS-9610	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be less than 5 minutes.*	Performance (Timeliness: Update rate)	[RD100]

Table 46 - Requirements for IoT: Asset tracker for logistics

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9150	A	The geographical coverage of the PNT solution shall be global.	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9200	A	*The PNT solution shall be available in urban canyons.*	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR- LBS-9300	A	*The PNT solution shall be available under canopy.*	Performance (Availability under canopy)	[RD100]
EUSPA-GN-UR- LBS-9400	A	*The PNT solution shall be available indoor.*	Performance (Availability indoor)	[RD100]
EUSPA-GN-UR- LBS-9620	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be more than 240 minutes.*	Performance (Timeliness: Update rate)	[RD100]

Table 47 - Requirements for IoT: the tracking of trailers

Id	Action	Description	Type	Source

EUSPA-GN-UR-LBS-9020	A	*The PNT solution shall provide the user position with a horizontal accuracy better than 20 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9200	A	*The PNT solution shall be available in urban canyons.*	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR- LBS-9630	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be less than 5 minutes.*	Performance (Timeliness: Update rate)	[RD100]

Table 48 - Requirements for IoT: the Tracking of containers

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9030	A	*The PNT solution shall provide the user position with a horizontal accuracy better than 10 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9200	A	*The PNT solution shall be available in urban canyons.*	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR- LBS-9630	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be 6 to 8 positions per day.*	Performance (Timeliness: Update rate)	[RD100]

Table 49 - Requirements for IoT: the Tracking of packages

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9030	A	*The PNT solution shall provide the user position with a horizontal accuracy better than 10 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9200	A	*The PNT solution shall be available in urban canyons.*	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR- LBS-9400	A	*The PNT solution shall be available indoor*	Performance (Availability indoor)	[RD100]
EUSPA-GN-UR- LBS-9640	A	*The PNT solution shall provide continuous and on request positioning once the operation has started. The update rate of the PNT solution shall be 15 minutes. An additional positioning shall be provided by the PNT solution every time a movement occurs.*	Performance (Timeliness: Update rate)	[RD100]

Table 50 - Requirements for IoT: the Tracking of staff

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9040	A	*The PNT solution shall provide the user position with a horizontal accuracy better than 20 meters*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9160	A	*The geographical coverage of the PNT solution shall be regional.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9200	A	*The PNT solution shall be available in urban canyons.*	Performance (Availability in urban canyon)	[RD100]
EUSPA-GN-UR- LBS-9650	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be 5 minutes (during 12 hours).*	Performance (Timeliness: Update rate)	[RD100]

Table 51 - Requirements for IoT: Artisanal Fisheries

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9030	A	*The PNT solution shall provide the user position with a horizontal accuracy of 10 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9500	A	*The PNT solution shall provide robustness against interference.*	Performance (Resilience: Susceptibility to interference)	[RD100]
EUSPA-GN-UR- LBS-9510	A	*The PNT solution shall provide robustness against GNSS spoofing threats.*	Performance (Resilience: Susceptibility to spoofing)	[RD100]
EUSPA-GN-UR- LBS-9660	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be one position per hour.*	Performance (Timeliness: Update rate)	[RD100]

Table 52 - Requirements for IoT: Livestock Monitoring

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9060	A	*The PNT solution shall provide the user position with a horizontal accuracy of 10 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR-LBS-9100	A	*The PNT solution shall provide the user position with a vertical accuracy of 10 meters.*	Performance (Vertical Accuracy)	[RD100]
EUSPA-GN-UR- LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR- LBS-9300	A	*The PNT solution shall be available under canopy.*	Performance (Availability under canopy)	[RD100]
EUSPA-GN-UR- LBS-9670	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be 1 position per day.*	Performance (Timeliness: Update rate)	[RD100]

Table 53 - Requirements for IoT: Smart Farming

Id	Action	Description	Type	Source
EUSPA-GN-UR-LBS-9080	A	*The PNT solution shall provide the user position with a horizontal accuracy within a range of 2.5 to 10 meters.*	Performance (Horizontal Accuracy)	[RD100]
EUSPA-GN-UR-LBS-9150	A	*The geographical coverage of the PNT solution shall be global.*	Performance (Geographical coverage)	[RD100]
EUSPA-GN-UR-LBS-9200	A	*The PNT solution shall be available urban canyon.*	Performance (Availability urban canyon)	[RD100]
EUSPA-GN-UR-LBS-9300	A	*The PNT solution shall be available under canopy.*	Performance (Availability under canopy)	[RD100]
EUSPA-GN-UR-LBS-9680	A	*The PNT solution shall provide continuous positioning once the operation has started. The update rate shall be greater than 240 minutes.*	Performance (Timeliness: Update rate)	[RD100]

Table 54 - Requirements for enhanced human applications

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

6.2 Synthesis of Requirements Relevant to EO

Table 55 – EO requirement for Air Quality Monitoring

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	**Size of Area of Interest**	**Scale**	**Frequency of Information**	**Other (if applicable)** (e.g. non-functional, data format, contextual info...)	**What the service does**	**How does the service work**	**Spatial Resolution**	**Temporal Resolution**	**Data Type / Spectral Range**	**Other (if applicable)** (e.g. non-functional, latency, historical availability, reanalysis, pre-processing...)	**Satellite data sources**	**Other Data Sources**
EUSPA-EO-UR-CSO-001	Air Quality Monitoring	Enthusiasts, citizens and public users Pragmatists, citizens and public users Traditional, public users Users with special needs	a. Personal advice for people living in locations and environments prone to air pollution. b. Information for policy creation and decision making (especially in urban environment, or in touristic area during busy periods). c. Marketing element for: e.g. real estate market, medical care providing services (e.g. recommendations to their patients), tourist destinations. d. Parameter in automation technology systems (e.g. of ventilation systems). e. Detection of matter components coming from maritime fuels, along maritime routes and within port areas. f. Assess large-scale natural events impact.	- From few square kilometres range (up to 1000 km² for megacities), from a specific location within the city up to the size of the whole city. - Maps of the entire regions, or even countries can be valuable.	Range from few meters (street level)* up to 1:5000 meters *Air quality information in cities is usually required on street level because there can be significant differences already from one street to the next, parallel street.	- Instantaneously or few minutes range - Hourly - Weekly - Monthly	- Challenge in this environment is the coverage: Air Quality Indicators need accurate and consistent data while covering large areas - Air quality also needs to be correlated with weather data and topography data since they both have a significant effect on it	The service collects the air quality data in a form of maps. These data are resampled, if necessary, and put into the mathematical model, which can include various other inputs. The results are visualised in a form of maps that show the index of higher or lower property value based on all parameters. This allows final users to get useful and clear information about air quality: e.g. visual maps, indexes, app notifications, etc.	The service collects data from different data sources (Meteo, Copernicus CAMS, air and ground-based data, others) and integrates them into information in a spatial resolution that is adequate for the application. In cities, the information usually needs to be provided on street level (at least 100m). In outdoor/rural environments lower resolutions are sufficient, as they are not so much influenced by local traffic. The information (data, reports, information on pollutants, actionable recommendations) is then provided via web (dashboard) and mobile applications to the users. Depending on the type of application, different atmosphere components can be used by users. For example, CAMS provides estimates of climate forcings for carbon dioxide, methane, tropospheric ozone, stratospheric ozone, interactions between anthropogenic aerosols and radiation, and interactions between anthropogenic aerosols and clouds. While, for air quality, CAMS provides daily analyses and forecasts of worldwide long-range transport of atmospheric pollutants as well as the background air quality for the European domain (taking into account some air elements like, i.e. PM, O3, No2, SO2, BaP).	- The spatial resolution of relevant services must be at least on 100 meters level. - Earth Observation derived information usually cover large areas with limits in acquisition time and accuracy (several kilometres resolution).	- Instantaneously or few minutes range - Hourly - Daily - Monthly	- UV (250-310 nm) - VIS (310 - 500 nm) - NIR (675 - 775 nm) - SWIR (2305-2385 nm)	- Availability of relevant data (EO, ground) with sufficient spatial and temporal resolution is usually the critical aspect. - Currently, there are many companies trying to include small air quality stations into their smart city products (e.g. smart benches etc.), or even downscale the sensors to a human wearable items. The data gathered in this way could be shared and used to refine the satellite models to achieve higher-resolution products. - Historical data would help AI solutions to discover patterns and allow development of forecasts. - In situ stations could provide real-time air quality monitoring status, but satellites can pride the info, ideally, on hourly level (Sentinel-4, which is expected to launch in 2023).	- Sentinel-1 (e.g. city structure, buildings, roads). - Sentinel-2 (e.g. vegetation in urban areas). - Sentinel-5P (e.g. air pollutants, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, formaldehyde and methane). - Sentinel-3 (Fire detection). - GNSS/Galileo (e.g. geolocalisation of local sensor networks, determination of user position). - Future satellite missions: Sentinel-4 (2023), Sentinel-5.	- Meteo data (MSG, METOP, etc.) provide low resolution information on air pollutants as well as on the local meteorological situation (e.g. Air quality after rainfall improves significantly, as the pollutants are washed out). - The Copernicus Atmosphere Monitoring Service (CAMS) is delivering valuable air quality data at European scale for several relevant pollutants. - Air quality data from ground-based sensor networks (they provides the most accurate and high spatial resolution data). - VDC (ESA Atmospheric Validation Data Centre). - Sensors for measuring black carbon (e.g. Aerosol.si) which allow a very accurate correlation between sources of pollution (traffic, heating) and the level of pollution. - Advanced IT technologies (e.g. AI) these sensors can be used in a short time period for acceptable cost (renting) to provide very detailed snapshot of the situation (e.g. Measuring air quality at an event). - Land cover maps produced from EO imagery, such as the Copernicus 'Urban Atlas'. It provides pan-European comparable land use and land cover data for Large Urban Zones with more than 100.000 inhabitants. - Geolocalised, locally collected data from air (e.g. drones) or ground (e.g. sensor networks)

Table 56 - EO requirement for Sport, fitness and wellness

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	**Size of Area of Interest**	**Scale**	**Frequency of Information**	**Other (if applicable)** (e.g. non-functional, data format, contextual info...)	**What the service does**	**How does the service work**	**Spatial Resolution**	**Temporal Resolution**	**Data Type / Spectral Range**	**Other (if applicable)** (e.g. non-functional, latency, historical availability, reanalysis, pre-processing...)	**Satellite data sources**	**Other Data Sources**
EUSPA-EO-UR-CSO-002	Sport, fitness and wellness	Enthusiasts citizens Pragmatists citizens Users with special needs	a. Information services on local geographical conditions combined with local weather phenomena and air quality, related to specific outdoors sports. b. Sports medicine c. Wellness tourism d. Sport tourism	The area of interest is the area where the sport or outdoor activity takes place: - linear routes of few (e.g. jogging route) up to many kilometres (e.g. long distance trails, recreational cycling or canoeing routes along rivers); - some square kilometres for oceans, mountains, touristic territories conditions.	1:1000 - 1:25000 range: - usual outdoor map apps are scaled 1:1000, - for paper trail maps best resolution is 1:25000.	- Weather and related information (forecasts) are usually provided every 6 hours with a forecast range up to 10 days (up to 3 days with hourly resolution, 4-10 day with 3 hourly resolution) - Weather induced effects (e.g. snow presence/absence, tree wind breaks, flooding,) need to be communicated upon appearance. - Time of sports activity (minutes, hours), when processing information to supply an outcome of an outdoor activity.	The most common tool used are smartphones and therefore mobile applications. For post-processing data must be integrated with analytic tools.	When it comes to B2C services, then these are usually provided in Apps to a smartphone or a dedicated tracker/device. E.g. for mountaineering a hiking tour is selected by the mountaineer (suggested by the service provider like Fatmap, OutdoorActive). The App asks for the starting day and time, then the App provides back information on the expected weather conditions along the tour together with warnings on specific conditions (e.g. heavy rainfall, storm, snow conditions). When data are created for BTB services, they can be even provided in aggregated manner or database, able to be elaborated and be merged with other services.	The service collects data from different data sources (Meteo, Copernicus, ground based data) and integrates them into maps with actionable recommendations (e.g. maps on terrain information and routes, potential threats from weather events ahead / warnings). The information can be either stored locally (e.g. terrain information) or called up via web services (e.g. regular updates on weather), information in a spatial resolution that is adequate for the application. The information can be downloaded for integration into analyses tools and post-processing.	- Terrain characteristics for outdoor sports information with a spatial resolution of 10m is considered sufficient (e.g. mountaineering, mountain biking, winter sports). - MetOcean conditions for sailors' resolutions in the km range are sufficient. - Sports bound to specific locations (e.g. surfers, divers, spatial resolution of 100m would be required. - Weather information is usually available with a spatial resolution in km range. - For specific activities, e.g. mountaineering, this is often insufficient, as mountains can act as meteorological divide. Information would be required with higher resolution (e.g. valley by valley) in the 100m range.	- Real time information and on forecasts for the near future, in needed for local phenomena (e.g. MetOcean, Weather, NRT). - Information should be available for the time of the sports activity for information output after an outdoor activity (e.g. analyses by athletes, coaches, medical providers). - Weather and related information (forecasts) are usually provided every 6 hours with a forecast range up to 10 days (up to 3 days with hourly resolution, 4-10 day with 3 hourly resolution).			- Sentinel-1 - Sentinel-2 - Sentinel-3 - Sentinel-5P - Meteo (MSG/METOP) for local weather information, nowcasting and forecasting - GNSS/Galileo. - Copernicus Atmosphere Monitoring Service (CAMS) is delivering valuable air quality data at European scale for several relevant pollutants. Urban heat maps for sport activities in cities.	- Urban heat maps. - Optical data on land cover, vegetation information, terrain information, ground pollution, etc.

Table 57 – EO requirements for UV monitoring

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	**Size of Area of Interest**	**Scale**	**Frequency of Information**	**Other (if applicable)** (e.g. non-functional, data format, contextual info...)	**What the service does**	**How does the service work**	**Spatial Resolution**	**Temporal Resolution**	**Data Type / Spectral Range**	**Other (if applicable)** (e.g. non-functional, latency, historical availability, reanalysis, pre-processing...)	**Satellite data sources**	**Other Data Sources**
EUSPA-EO-UR-CSO-003	UV monitoring	Enthusiasts, citizens and public users Pragmatists, citizens and public users Traditional, public users Users with special needs	a. Provision of localised, personalized, and actionable information on a daily basis about solar radiation exposure. b. Creation of historical UVI information, at local and regional level, to provide tailored recommendations and products for local and regional organisations and businesses. c. Provision of UV radiation of the visiting destinations for tourists. d. Measurement of UV radiation effect on the heritage sites increasing the deterioration.	- Area of interest is the whole globe, with information to be broken down on individual locations. - Minimum: single spots for outdoor activities (individual beaches, hotel resorts or entire city regions). - High interest on areas with increased UV radiations, like desert areas, water areas, mountain areas, areas in the range of reduced ozone layers (e.g. Australia).	- For the regions with highly variable environment a higher resolution is desirable (<100 meters resolution). - For non-urban areas higher resolution of up to several kilometres can be enough.	- Near-real time information are needed for some applications. - Hourly is important for detailed studies and correlations. - Daily or weekly UV indexes results are good enough for the overall evaluation, however the most important are the peaks and not just the average value. - Low temporal resolution UV data (daily, weekly, monthly) can be analysed and used in assessment and planning with information about the expected UV over different regions.	The estimation of UVI derived from satellite measurements has the advantage of spatial comprehensive coverage, although it must be considered that the lack of detailed knowledge of influencing parameters at specific locations limits accuracy. Therefore, other observations (from space, air, ground) are required to complement a UVI forecast model.	For forecasting, the service should collect all relevant input parameters for a precise determination of the UV radiation at the place of the user. Such information would then be provided in maps including information on the radiation class. As the effect of UV is also dependent on the sensitivity of the user (e.g. pale skin vs. dark skin), the possibility for individual settings should be able to be included into any personal device / wearable (e.g. wristbands, skin patches, clip-ons). App uses satellite data together with the user input (daily hours exposure, possibly obtained from GPS locations, skin type etc.) and provides the user with the risk of skin cancer and the optimal time exposure needed for the synthesis of vitamin D.	Application downloads the satellite data on a cloud and performs calculations to obtain UVI. Together with the user input it calculates from the mathematical model the risk for developing skin cancer and the daily vitamin D synthesis.	Resolution of 100 meters would be of interest but cannot be achieved today. One of the best instruments in orbit today is the TROPOMI instrument on board of S5P. In such applications, the higher the resolution the better. However, there is a trade-off between EO instruments and related cost of these instruments.	As data from satellites need to be processed which takes time, there is no chance to provide real-time information on UV. Satellite data are mainly used for forecast models (like weather models, e.g. MetOffices). As the processing also requires time, the temporal resolution requirement depends on the capabilities of the models. In current weather models, data are provided on 6-hourly basis which then can generated hourly forecasts. Therefore, I would assume that here is a similar temporal resolution sufficient. As currently only LEO satellites carry instruments, the revisit time is in the range of days rather than hours.	280 - 400 nm for the detection for the surface UV (this covers UV-A (400 - 315 nm) and UV-B (315 - 280 nm)) *UV-C is absorbed by the atmospheric ozone and does not reach the Earth's surface*	Any UV related information or warning service has to be reliable, and especially avoid false negatives.	- Copernicus Land Monitoring Service - Sentinel-2 (e.g. land cover, vegetation) - Sentinel-3 (e.g. cloud cover, aerosols and water vapour, other atmospheric parameters) - Sentinel-5P (e.g. solar irradiance)	- MetServices (e.g. ECMWF) and Satellite Application Facility on Ozone Monitoring (EUMETSAT O3M SAF) (for global UV index forecasts for clear sky and clouded weather forecasts updated daily). - UMETSAT CM-SAF (Satellite Application Facility for Climate Monitoring): it provides continuous climate data records containing the Surface Incoming Solar radiation (SIS), - the Surface incoming Direct Irradiation (SDI), spectrally resolved irradiation (SRI) and the effective cloud albedo (CAL). - Tropospheric Emission Monitoring Internet Service (TEMIS; temis.nl) for initial clear-sky UVIs (hosted by the Royal Netherlands Meteorological Institute (KNMI)). - UV index forecast by the Copernicus CAMS service. - Other air quality parameters (aerosols, clouds, total ozone, etc.). - Digital elevation models, as well as vegetation and surface maps. - Geographical position of the heritage sites.

Table 58 - EO requirements for Geo-advertising

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	**Size of Area of Interest**	**Scale**	**Frequency of Information**	**Other (if applicable)** (e.g. non-functional, data format, contextual info...)	**What the service does**	**How does the service work**	**Spatial Resolution**	**Temporal Resolution**	**Data Type / Spectral Range**	**Other (if applicable)** (e.g. non-functional, latency, historical availability, reanalysis, pre-processing...)	**Satellite data sources**	**Other Data Sources**
EUSPA-EO-UR-CSO-004	Geo-advertising	Enthusiasts Pragmatists Traditional, commercial users Users with special needs	a. traffic analysis for big retailers b. generation of an economic index of trading areas to provide an in-depth understanding of marketing processes in a city or region c. to create new opportunities and events to attract tourist flows d. help identify the illegal overnight stays	- The size of the area of interested is in the range of few km ² (for shopping and touristic activities, the focus is usually on city districts where the number of shops as well as of passing buyers/shoppers is relatively high, touristic outdoor activities may be considered for geo-advertising, pointing) - City level which can reach a size in the range of 1000 km² for megacities (for other public and business organisations, e.g. Planning of education facilities, hospitals, pharmacies, telecommunication infrastructure, infrastructure services)	- The requirements for spatial resolution are usually quite high going up to meter level (e.g. car counting, classification of small buildings). - For larger buildings like malls, a resolution of 10m might be sufficient. - For dynamic aspects like environmental parameters, the requirement on spatial resolution varies. - For shopping advertising, the scale has to allow to identify individual shops, in combination with usual map features (i.e. scale 1:1.000). - For other applications lower resolutions are sufficient (i.e. 1:10.000 to 1:50.000).	- The temporal resolution is not critical for the classification of buildings or specific places. - More dynamic information requires ideally high temporal resolutions (e.g. continuous observation, on hourly basis, daily frequency).	Space data and imagery usually has to be combined with contextual data, e.g. use of buildings, cadastral information, road layers, in order to provide a proper classification.	The service provides the user with easily understandable (e.g. colouring) classification information on the subject of interest. E.g. analysing traffic and customer habits in mall areas, the service could provide information on the occupation of the local parking spaces over day/week to indicate busy / not so busy periods.	The service collects data from archives and/or from satellites. Automated land change and object classification algorithms are applied involving AI/ML processes. The process usually starts with collection of imagery covering large areas. Then potential hotspots or interesting zones are identified. For these hotspots or zones, additional imagery is collected with high spatial resolution. The produced maps/reports including the classification information are then provided to the users.	It is usually quite high going up to meter level (e.g. car counting, classification of small buildings).	It depends on the application needs. Also the balance between spatial and temporal reposition accuracy is crucial. E.g. data can be collected with lower spatial resolution over a longer period of time to create information over a day, a week, a season.	Data types are optical and radar images to create the underlying maps as well as to detect specific aspects. E.g. radar images could be used to identify vehicles. E.g. optical images could be used to identify the type of buildings (industrial, housing, utilities, etc.).	As the information is used for management or investment decisions, the provided information has to be as precise as possible.	Satellite data sources - Sentinel-1 (e.g. land cover, land use) - Sentinel-2 (e.g. land cover, land use) - Sentinel-3 - Sentinel-5P (e.g. air quality) - NASA / USGS - A mix of radar and optical satellites generating images with various spatial and temporal resolutions (up to very high spatial and very high temporal resolution).	- Local information about the utilisation of buildings and cadastral information. - Demographic information and models.

Table 59 - EO requirements for Mapping & GIS

ID	Application	User	User Needs					Service Provider Offer		Service Provider Satellite EO Requirements				Service Inputs	
			Operational Scenario	**Size of Area of Interest**	**Scale**	**Frequency of Information**	**Other (if applicable)** (e.g. non-functional, data format, contextual info...)	**What the service does**	**How does the service work**	**Spatial Resolution**	**Temporal Resolution**	**Data Type / Spectral Range**	**Other (if applicable)** (e.g. non-functional, latency, historical availability, reanalysis, pre-processing...)	**Satellite data sources**	**Other Data Sources**
EUSPA-EO-UR-CSO-005	Mapping & GIS	Enthusiasts Pragmatists Traditionalists Users with special needs	a. Provide an individual feedback loop reporting about actual observations during activity. b. Creation of users' own personalised maps with existing tools (e.g. ArcGIS), starting from basic maps available for further input generation depending on the needed aspects.	It depends on the specific applications (without specifications, the area of interest can be characterised in general as global).	The scale depends on the specific application.	The update rate needed depends on the specific application.	Remote sensing and digital image processing research is focused mainly on information extraction from images (thematic maps) but orthoimage usage for cartographical purposes is rarely investigated.	The service provides information tailored to the user and to the related utilisation/operation to help the user finding objects, routes, etc. as well as to improve efficiency of operational processes. E.g. optimised route of a parcel delivery service. E.g. for emergency services in a disaster to notate still functional installations or services like bridges, hospitals; for maintenance service people to show the specific operational location).	The generator of the maps takes either pre-existing maps (e.g. ArcGIS, GoogleMaps) or uses processed satellite topographic image maps with the most recent information. He/she then creates an own thematic layer for the intended operational use (e.g. routes, points of interest, additional relevant information). The map is made available to the user in the field on his/her smartphone. Depending on the type of usage, the user in the field can provide feedback information (including some evidence for verification) refining the map content and information for other users.	Usually in the meter range: online maps can go down to 1:1.000 (highest resolution level).	- Not critical for detecting slow changes (e.g. changes in land use). - In case of modifications (e.g. tree breaks in forests, landslides on hiking routes) relevant for the operational use, updates of the maps should be available as soon as possible.	For NDVI in most cases NIR and IR spectral bands are used.	Reliability should be guaranteed, and false information especially on reporting of recent changes should be avoided.	- Sentinel-2 (e.g. optical images) - Maxar - Airbus - Planet Lab	- Existing official or self-made maps - Imagery from optical satellites - Combination with local data, such as person, road, parking slot counters, mobile user data (reliable only areas with good coverage)

7 ANNEXES

A1.1 Definition of key GNSS performance parameters

This annex provides a definition of the most commonly used GNSS performance parameters, taken from [RD47] and includes additional details which are relevant for *Consumer Solutions, Tourism & Health* community.

Availability: the percentage of time the position, navigation or timing solution can be computed by 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 availability: the percentage of time the system allows the user to compute a position - this is what GNSS Interface Control Documents (ICDs) refer to.
- Overall availability: takes into account the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

Accuracy is the difference between true and computed solution (position or time). This is expressed as the value within which a specified proportion – usually 95% – of samples would fall if measured. This report refers to positioning accuracy using the following convention: centimetre-level: 0-10 cm; decimetre level: 10-100 cm; metre-level: 1-10 metres.

Continuity is the ability of a system to perform its function (deliver PNT services with the required performance levels) without interruption once the operation has started. It is usually expressed as the risk of discontinuity and depends entirely on the timeframe of the application. A typical value is around 1*10-4 over the course of the procedure where the system is in use.

Indoor penetration is the ability of a signal to penetrate inside buildings (e.g. through windows). Indoor penetration does not have an agreed or typical means for 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 WiFi base stations for WiFi-based positioning).

Integrity is a term used to express the ability of the system to provide warnings to users when it should not be used. It is the probability of a user being exposed to an error larger than the alert limits without timely warning. The way integrity is ensured and assessed, and the means of delivering integrity-related information to users are highly application dependent. Throughout this report, the "integrity concept" 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 in other applications and sectors.

Latency is the difference between the reference time of the solution and the time this solution is made available to the end user or application (i.e. including all delays). Latency is typically accounted for in a receiver, but presents a potential problem for integration (fusion) of multiple positioning solutions, or for high dynamics mobile devices.

Robustness relates to spoofing and jamming and how the system can cope with these issues. It is a more qualitative than quantitative parameter and depends on the type of attack or interference the receiver is capable of mitigating. Robustness can be improved by authentication information and services.

Authentication gives a level of assurance that the data provided by a positioning system has been derived from real signals. Radio frequency spoofing may affect the positioning system, resulting in false data as output of the system itself.

Power consumption is the amount of power a device uses to provide a position. It 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 a position. Typical values are in the order of tens of milliwatts (for smartphone chipsets).

Time To First Fix (TTFF) is a measure of time between activation of a receiver and the availability of a solution, including any power on self-test, acquisition of satellite signals and navigation data and computation of the solution. It mainly depends on data that the receiver has access to before activation: cold start (the receiver has no knowledge of the current situation and must thus systematically search for and identify signals before processing them – a process that can take up to several minutes.); warm start (the receiver has estimates of the current situation – typically taking tens of seconds) or hot start (the receiver understands the current situation – typically taking a few seconds).

A1.2 Definition of key EO performance parameters

This annex provides a definition of the most commonly used EO performance parameters and includes additional details which are relevant for *Consumer Solutions, Tourism & Health* community.

Spatial resolution relates to the level of detail that can be retrieved from a scene. In the case of a satellite image, which consists of an array of pixels, it corresponds to the smallest feature that can be detected on the image. A common way of characterising the spatial resolution is to use the Ground Sample Distance (GSD) which corresponds to the distance measured on the ground between the centres of two adjacent pixels. Thus, a spatial resolution of 1 meter means that each pixel corresponds to a 1 by 1 meter area on the ground.

Temporal resolution relates to the time elapsed between two consecutive observations of the same area on the ground. The higher the temporal resolution, the shorter the time between the acquisitions of two consecutive observations of the same area. In absolute terms, the temporal resolution of a remote sensing system corresponds to the time elapsed between two consecutive passes of the satellite over the exact same point on the ground (generally referred to as "revisit time" or "orbit cycle"). However, several parameters like the overlap between the swaths of adjacent passes, the agility of the satellites and in case of a constellation, the number of satellites mean that some areas of the Earth can be reimaged more frequently. For a given system, the temporal resolution can therefore be better than the revisit time of the satellite(s).

Spectral range refers to the wavelength range of a particular channel or band over in which remote sensing data must be collected.

Latency is the difference between the reference time of the satellite measurement and the time the final product is made available to the user (here the service provider).

Radiometric resolution expresses the sensitivity of the sensor, that is to say its ability to differentiate between different magnitudes of the electromagnetic energy. The finer the radiometric resolution, the more sensitive it is to small differences in the energy emitted or reflected by an object. The radiometric resolution is generally expressed in bit, a resolution of 8 bit meaning that the "brightness" of the image is measured with a scale of 28=256 nuances.

Temporal resolution relates to the time elapsed between two consecutive observations of the same area on the ground. The higher the temporal resolution, the shorter the time between the acquisitions of two consecutive observations of the same area. In absolute terms, the temporal resolution of a remote sensing system corresponds to the time elapsed between two consecutive passes of the satellite over the exact same point on the ground (generally referred to as "revisit time" or "orbit cycle"). However, several parameters like the overlap between the swaths of adjacent passes, the agility of the satellites and in case of a constellation, the number of satellites mean that some areas of the Earth can be reimaged more frequently. For a given system, the temporal resolution can therefore be better than the revisit time of the satellite(s).

Geolocation accuracy refers to the ability of an EO remote sensing platform to assign an accurate geographic position on the ground to the features captured in a scene. An accurate geolocation makes easier the combination of several images (e.g. combination of a Synthetic Aperture Radar image with a cadastral map and a map on fishing grounds or aquafarming).

Other performance parameters

Agility corresponds to the ability of a satellite to modify its attitude and to point rapidly in any direction in order to observe areas of interest outside its ground trace. High agility can improve the temporal resolution compared with the revisit time of the satellite.

Swath corresponds to width of the portion of the ground that the satellite "sees" at each pass. The larger the swath, the bigger the observed area at each pass.

Off-nadir angle corresponds to the angle at which images are acquired compared with the “nadir”, i.e. looking straight down at the target. In practice, objects located directly below the sensor only have their tops visible, thus making it impossible to represent the three-dimensional surface of the Earth. High resolution images are therefore generally not collected at nadir but at an angle. A large off-nadir angle enables a wider ground coverage at each pass and the identification of features not visible at nadir, but it reduces the spatial resolution. For optical imagery, typical off-nadir angles are in the range of 25-30 degrees.

Sun-elevation angle corresponds to the angle of the sun above the horizon at the time an image is collected. High elevation angles can lead to bright spots on the imagery while low elevation angles lead to darker images and longer shadows. The most appropriate angle depends on the type of application: a high sun elevation is appropriate for spectral analysis since the objects to be observed are well illuminated while a lower elevation angle is better suited to interpretation of surface morphology (e.g. the projected shadows can enable a better image interpretation)

A1.3 List of Acronyms

Acronym	Definition
3GPP	3rd Generation Partnership Project
A-GNSS	Assisted GNSS
A-GPS	Assisted GPS
B2B	Business to Business
B2C	Business to Consumers
B2G	Business to Government
BLE	Bluetooth Low Energy
CSO	Consumer Solutions, Tourism and Health market segment
EC	European Commission
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EM	Electronic Monitoring
EO	Earth Observation
ESA	European Space Agency
ETS	European Telecommunications Standards Institute
EU	European Union
EUSPA	European Agency for the Space Programme
G2G	Galileo Second Generation
GAGAN	GPS and GEO Augmented Navigation
GCF	Global Certification Forum GDP
GeoRSS	Geo Rich Site Summary
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System (Russian)
GNSS	Global Navigation Satellite System
GSA	European GNSS Agency
HAS	High Accuracy Service
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)

Acronym	Definition
M2M	Machine to Machine
MEMS	Microelectromechanical Systems
MKD	Market Development
MLBG	Mobile Location Based Gaming
MR	Market Report
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
R&D	Research and development
RUR	Report on User needs and Requirements
R&I	Research and Innovation
SATCOM	Satellite communications
SME	Small and Medium-sized Enterprise
SUPL	Secure User Plane Location
SoL	Safety of Life Service
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

A1.4 Reference Documents

Id.	Reference	Title	Date
[RD1]	GNSS Market Report 5	GSA GNSS Market Report Issue 5, URL: https://www.gsa.europa.eu/2017-gnss-market-report	January 2017
[RD2]	Mobile Location-Aware Services: 2002 Market Perspective	Bellocci, V., Genovese, S., Inuaggiato, D., and Tucci, M. - Mobile Location-Aware Services: 2002 Market Perspective	July 2002
[RD3]	GNSS and the Use of Medical Things	GSA - GNSS and the Internet of Medical Things, URL: https://www.gsa.europa.eu/newsroom/news/gnss-and-internet-medical-things	August 2016
[RD4]	Analysis of the Social LBS Market	GSA - Analysis of the Social LBS Market: Current needs and actual solutions available in the market	March 2016
[RD5]	GNSS Relevance in IoT and M2M Solutions	GSA - Report on the GNSS relevance in Internet-of-Things and Machine-to-Machine solutions – Internal GSA document	January 2015
[RD6]	Challenges of LBS Market Analysis	The Nottingham Geospatial Institute - Challenges of LBS Market Analysis: Current Market Description	January 2015
[RD7]	Location Data Increasingly Used to Stop Fraud and Cyber Crooks	Inside GNSS - Location Data Increasingly Used to Stop Fraud and Cyber Crooks, URL: http://www.insidegnss.com/node/3679	August 2013
[RD8]	LBS: An End-to-End Perspective	TeleCommunication Systems - Location-Based Services: An End-to-End Perspective	January 2010
[RD9]	Context Aware Services - Market Forecasts	Juniper – Mobile Context & Location Services - 2014-2019 Market Forecasts	August 2014
[RD10]	Context Aware Services - Market Trends	Juniper – Mobile Context & Location Services - 2014-2019 Market Trends	August 2014
[RD11]	15 Apps for Navigating with your Apple or Android Device	McLennan - 15 Apps for Navigating with your Apple or Android Device, URL: http://www.sailmagazine.com/diy/electronics/navigating-the-app-world/	June 2014
[RD12]	Best GPS Devices For Cycling	Delaney - Best GPS Devices for Cycling, URL: http://www.bikeradar.com/road/gear/article/best-gps-devices-for-cycling-43224/	May 2016
[RD13]	GNSS-Enabled Sports Tracker Moves Into Final Testing Phase	GSA - GNSS-Enabled Sports Tracker Moves Into Final Testing Phase, URL: https://www.gsa.europa.eu/news/gnss-enabled-sports-tracker-moves-final-testing-phase	August 2015
[RD14]	Location Authentication, Enabling New Smartphones Apps	Inside GNSS - Location Authentication, Enabling New Smartphone Apps, URL: http://www.insidegnss.com/node/3995	July 2014

Id.	Reference	Title	Date
[RD15]	Geolocated News is Going to Change the News Business	Geolocated News is Going to Change the News Business, URL: https://www.fastcompany.com/3032075/geolocated-news-is-going-to-change-the-news-business	June 2014
[RD16]	Smart Parking	Smart Parking, URL: https://www.smartparking.com/technologies/smartapp	Not specified
[RD17]	ETSI TR 103 183 V1.1.1 (2012-10)	ETSI - Satellite Earth Stations and Systems (SES) - Global Navigation Satellite Systems (GNSS) based applications and standardisation needs	January 2012
[RD18]	Pet trackers	GPS Trackers, URL: https://www.podtrackers.com/	Not specified
[RD19]	Engineering a Device to Locate Golf Balls	Massachusetts Academy of Math and Science - Engineering a Device to Locate Golf Balls	December 2012
[RD20]	Fish Hunter	Fish Hunter, URL: http://www.fishhunter.com/about-fishhunter-app/	Not specified
[RD21]	People Monitoring and Safety Solutions	Berg Insights - People Monitoring and Safety Solutions, Berg Insights (Executive Summary)	Not specified
[RD22]	Fall Detection and GPS Tracking	Fall Detection and GPS Tracking, URL: http://medicalalertsystemreviews.net/fall-detection-and-gps-tracking/	February 2016
[RD23]	Want to Track you Luggage?	GPS World - Want to Track you Luggage? Open Garden Offers Network for IOT Devices, URL: http://gpsworld.com/want-to-track-your-luggage-open-garden-offers-network-for-iot-devices/	September 2014
[RD24]	Dating App	Google Play – URL: https://play.google.com/store/apps/details?id=com.singlesaroundme.android (latest update)	August 2016
[RD25]	Tracking Ring Helps Keep Tabs on Significant Other	LiveViewGPS - Tracking Ring Helps Keep Tabs on Significant Other, URL: https://www.liveviewgps.com/blog/tracking-ring-helps-tabs-significant/	July 2015
[RD26]	TomTom to Add TripAdvisor App to Car GPS Navigation Units	TomTom to Add TripAdvisor App to Car GPS Navigation Units, URL: https://www.tnooz.com/article/tomtom-to-add-tripadvisor-app-to-car-gps-navigation-units/	August 2011
[RD27]	Dating Applications	Digital Trends - Paying for Tinder? So are 1 Million Other People, URL: http://www.digitaltrends.com/mobile/tinder-million-paid-users/#:N8jPEBEnsysM_A	May 2016

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EUSPA Mission Statement

The mission of the European Union Agency for the Space Programme (EUSPA) is defined by the EU Space Programme Regulation. EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the European Union.

Its goal is to:

- Provide long-term, state-of-the-art safe and secure Galileo and EGNOS positioning, navigation and timing services and cost-effective satellite communications services for GOVSATCOM, whilst ensuring service continuity and robustness;
- Communicate, promote, and develop the market for data, information and services offered by Galileo, EGNOS, Copernicus and GOVSATCOM;
- Provide space-based tools and services to enhance the safety of the Union and its Member States. In particular, to support PRS usage across the EU;
- Implement and monitor the security of the EU Space Programme and to assist in and be the reference for the use of the secured services, enhancing the security of the Union and its Member States;
- Contribute to fostering a competitive European industry for Galileo, EGNOS, and GOVSATCOM, reinforcing the autonomy, including technological autonomy, of the Union and its Member States;
- Contribute to maximising the socio-economic benefits of the EU Space Programme by fostering the development of a competitive and innovative downstream industry for Galileo, EGNOS, and Copernicus, leveraging also Horizon Europe, other EU funding mechanisms and innovative procurement mechanisms;
- Contribute to fostering the development of a wider European space ecosystem, with a particular focus on innovation, entrepreneurship and start-ups, and reinforcing know-how in Member States and Union regions.
- As of July 2023, EUSPA will take the responsibility for the Programme's Space Surveillance Tracking Front Desk operations service.

The European Union Agency for the Space Programme: linking space to user needs.

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