2023

Report on Emergency Management & Humanitarian Aid

User Needs and Requirements

#EUSpace

EUSPA European Union Agency for the Space Programme

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1 INTRODUCTION AND CONTEXT OF THE REPORT

The Emergency Management and Humanitarian Aid (EMHA) is one of the 17 market segments currently identified by the European Union Agency for the Space Programme (EUSPA) within its EO and GNSS Market Report [RD1].

The EMHA segment is very much synergetic by nature (i.e. balanced use of both EO and GNSS) and is composed of two sub-segments:

- Emergency (or disaster) management1, dealing with the organization, planning and application of measures preparing for, responding to and recovering from disasters. This management focusses on creating preparedness to decrease the impact of disasters and the disruption of the functioning of a community or society.
- Humanitarian Aid2, consisting on delivering life-saving assistance to those in need, without any adverse distinction: alleviating the suffering of victims, guaranteeing their subsistence, protecting their fundamental rights and defending their dignity, as well as, sometimes, fighting the community's socioeconomic destructuring and preparing it to face natural disasters. The humanitarian action of the EU is based on the following humanitarian principles3:
    - Humanity: human suffering must be addressed wherever it is found, with particular attention to the most vulnerable.
    - Neutrality: humanitarian aid must not favour any side in an armed conflict or other dispute.
    - Impartiality: humanitarian aid must be provided solely on the basis of need, without discrimination.
    - Independence: the autonomy of humanitarian objectives from political, economic, military or other objectives.

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 European Global Navigation Satellite System (EGNSS), encompassing 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

[1] For the purposes of this document the terms are used interchangeably. See https://www.undrr.org/terminology/disaster-management

[2] https://civil-protection-humanitarian-aid.ec.europa.eu/who/humanitarian-principles_en

[3] The International Red Cross and Red Crescent Movement adds three additional principles on top of the EUs' ones: Voluntary Service, Unity and Universality. These additional principles add the foundations on which the Red Cross and Red Crescent organizations are built and which enable them to uphold the other principles. https://www.ifrc.org/fundamental-principles

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 EU Space Programme.

In this context, the objective of this document is to provide a reference for the EU Space Programme and for the Emergency Management and Humanitarian Aid (EMHA) community, reporting periodically the most up-to-date user needs and requirements in the EMHA market segment. This report 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.

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 EU 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 organized 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 EU 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.

1.1 Methodology

The following figure details the methodology adopted for the analysis of the EMHA user requirements at application level.

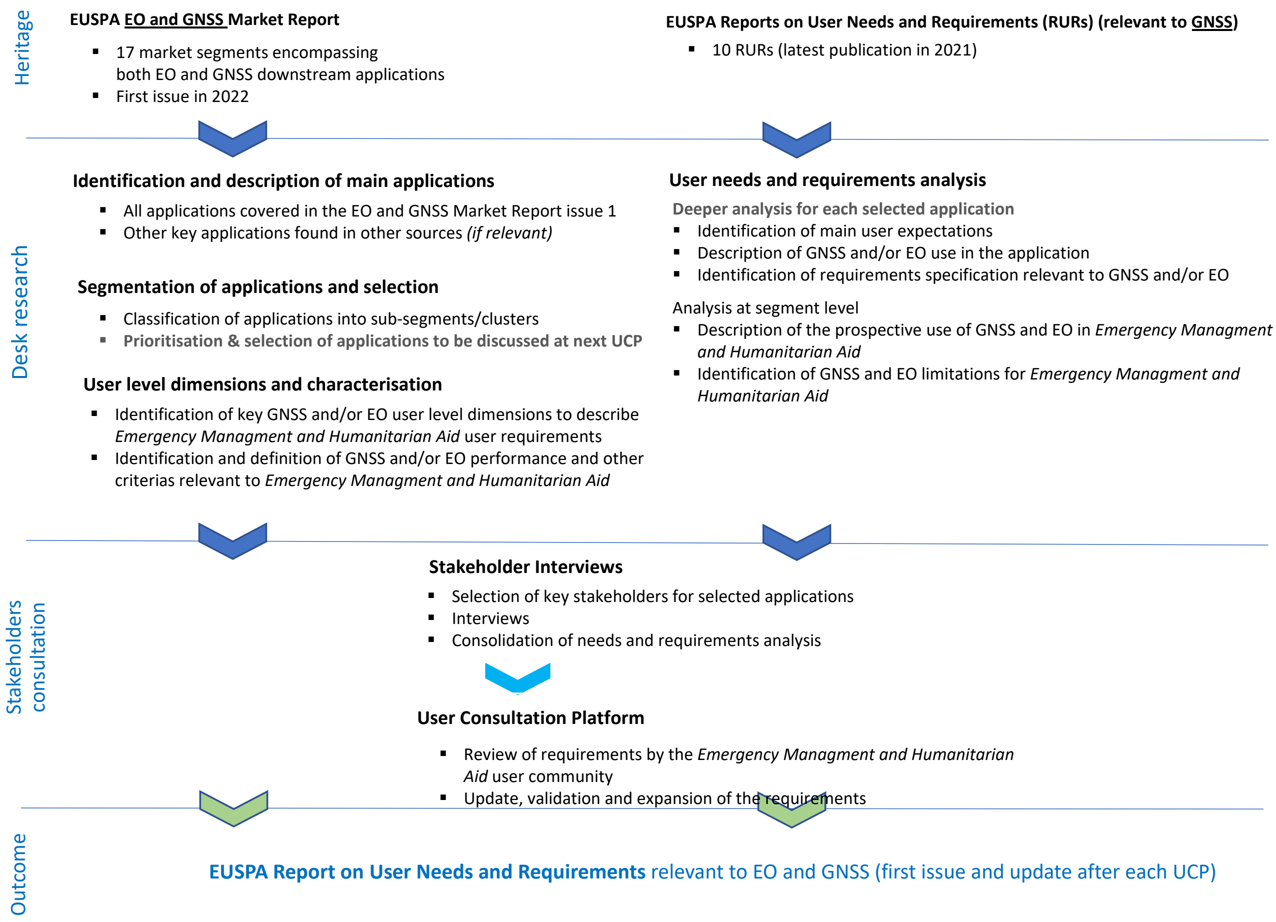

Figure 1 - EMHA user requirements analysis methodology

As presented in Figure 1, the work leverages on the latest EUSPA EO and GNSS Market Report, 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 a "**desk research**", aiming at refining and extending the heritage inputs and at gathering main insights, and a "**stakeholders' consultation**" to validate main outcomes.

More in detail, the "desk research" was carried out to consolidate the list of applications, classify them, and identify the key parameters driving their performances or other relevant requirements in addition to the main requirements specified. 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 EMHA user community. The outcomes of the EMHA 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 Programs 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 document starts with a market overview for Emergency Management and Humanitarian Aid (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.

Following its introduction, section 5 is organised as follows:

- Section 5.1 aims to present current GNSS and/or EO use and requirements per application, starting with a description of the application, presenting main user expectations and describing the current use of GNSS and/or EO space services and data for the application and providing a detailed overview of the related requirements at application level.
- Section 5.2 addresses in depth four specific applications: landslides and terrain deformation monitoring, post-crisis damage assessment and building inspection, NGOs' asset management and health and medicine response and coordination. These applications are assessed in more detail and take into account the specific feedback from the experts.
- Section 5.3 describes the main limitations of GNSS and EO to fulfil user needs in the market segment.
- Prospective use of GNSS and EO in EMHA is addressed in section 5.4.
- Section 5.5 concludes the section with a synthesis of the main drivers for the user requirements in EMHA.

Finally, section 6 summarises the main User Requirements for EMHA in the applications domains analysed in this report.

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

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.

2 EXECUTIVE SUMMARY

Key trends and market evolution

With increased availability, simple access policy and new advanced features, GNSS and EO use are on the rise all around the world. As a matter of fact, we could not live without these technologies and they are so pervasive that we do not notice them anymore.

One of the main drivers of this uptake has been the availability of the EU Space Program that has made available both a best-in-class GNSS system and free EO data. And as the EU Space System keeps improving, its use is foreseen to increase in the future.

For the GNSS systems currently at use, the main technological improvements are a better accuracy (less than 1m), availability of high accuracy (HAS), data authentication with the Open Service Navigation Message Authentication (OSNMA) and better Search and Rescue via the Galileo return link (RLS). Thanks to these evolutions, a significant increase in annual shipments of GNSS receivers is foreseen with more than 10 billion GNSS devices that will be operational by 2031. Growth in the number of devices brings also rising market revenues, estimated to reach €492 billion by 2031[4].

The EO market is growing even faster as more and more value-added services are benefiting from satellite remote sensing and advances in IT technologies such as AI and cloud computing. The ubiquitous availability of data from a variety of satellite systems, in near real-time, in various resolutions and in different bands makes it possible to develop and propose new applications to match innovative use-cases. The revenues in the EO sector are expected to reach €5.5 billion globally in 2031[5].

Another tendency is that EO and GNSS are increasingly combined in different downstream applications. This is especially true in the emergency management sector to provide the full picture needed for context-aware actions during the whole emergency management lifecycle.

While the services covered under this segment are public services mainly used by first responders, NGOs and governmental agencies, commercial businesses are often the ones implementing these emergency services, through governmental contracts and the provision of on-site support.

Current and prospective use of GNSS and EO in Emergency Management and Humanitarian Aid

With 432 disasters recorded in 2021, this figure represents a 25% increase of the yearly 347 events recorded on average from 2001 to 2020[6]. Most of these events have hit hard in Asia and America, relatively sparing Europe. More than half of the recorded disasters were floods (223), followed by storms (121) and earthquakes (28). Wildfires, droughts and landslides were also major disasters and are on the rise. For all these events, the EU Space Systems have demonstrated their effectiveness and cover the entire emergency management cycle: prevention and mitigation, preparedness, response and recovery.

Earth Observation and GNSS provide key information for emergency management at each of the following stages:

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[4] From [RD1]

[5] From [RD1]

[6] Emergency Events Database, 2021. www.emdat.be

- For **prevention and mitigation**, EO and GNSS provide risk assessment and simulation models. For example, long term observations of terrain with SAR and high accuracy GNSS help assess the risks of landslides.
- For **preparedness**, EO provides continuous observations and forecasts for many types of disasters such as flooding (e.g. hydrological modelling), earthquakes (e.g. surface deformation), landslides (e.g. terrain deformation), volcanic eruptions (e.g. atmospheric composition), tsunamis (e.g. wave height), wild fires (e.g. moisture conditions) and others. GNSS receivers also help to detect earthquakes and landslides. This could bring an additional warning time to a city of an imminent quake or landslide, which could result in enormous social benefits.
- During a disaster, for the **response** phase, EO and GNSS are used to provide rapid mapping (e.g. field-based mapping updates) allowing emergency responses to be coordinated as efficiently as possible.
- Finally, during **post-event** analysis, the comparison of recent and archival EO data assists relevant actors with an accurate damage assessment. GNSS is also used locally in disaster zones to map the affected area and assess accurately the damages, in order to assist the planification of the post-event actions.

The components of Copernicus Emergency Management Service (CEMS) provide various ways to access or download the data through individual data access points. On top of this, open data sources such as GEOSS, OGC, Terralook, Google Earth and other commercial services (e.g. 24/7 Emergency Service by Airbus) provide information to cover all kinds of natural and human-made disasters.

The Humanitarian Organizations such as NGOs or UN agencies have been using EO and GNSS for a long time in order to offer better response to crisis and emergency situations. Organizations such as UNOSAT (part of UNITAR) provide updated maps to all UN organizations and NGOs dealing with disasters.

Furthermore, GNSS also plays a crucial role in search and rescue operations by providing locations of disasters and distressed persons through beacons used in maritime, aeronautical or land transport. This market includes EPIRBs for maritime emergencies, ELTs for aviation use and PLBs for general emergencies. The PLBs dominate the market and this market will double to more than 2.5M units by 2029.

The EMHA user community

The EMHA user community can be divided in three large categories:

- The first community is dealing with Emergency Management. It includes public institutions that deal with emergency situations such as civil protection, decision makers or international organization. In addition, it includes industry players that offer products and/or services to the public institutions described above. Lastly, it also comprises of research institutions, laboratories and other public organizations, which develop new knowledge and study natural events in order to support prevention and early warning.
- The second community deals with search and rescue and comprises of end users sending alarm signals (e.g. hikers, vessel crews etc.) and the responders that will organize the SAR activities.
- The third community is the Humanitarian Aid community that acts in response to a humanitarian crisis situation. It includes NGOs, UN agencies and other governmental organization delivering aid in the field.

Drivers for users' requirements

This market segment is driven by three main drivers: new applications and use cases, technological improvement and regulations.

On the user side, there are several global challenges, which need to be responded to - amongst others climate change, pandemics and digital revolution. The number of global crises keeps increasing, both man generated or resulting from natural hazards. GNSS and EO will continue to contribute positively to these new challenges, helping prevent disasters, better respond to crisis and save human lives.

On the technology side, continuous improvement in the quality of data (EO span, resolution and real-time, GNSS accuracy and availability) along with new features support the development of new applications in the field of emergency management and humanitarian aid. In addition, the development of new technologies such as drones, artificial intelligence or pervasive connectivity will also contribute to the development of this segment.

The third driver is linked to regulations and best practices. While the Search and Rescue sector is really depending on applicable regulations, especially in the maritime and aviation field, this is not the case for other emergency applications. This field is more relying on best practices that have demonstrated their effectiveness over the years and which are evidence of the usefulness of EO and GNSS for EMHA.

3 MARKET OVERVIEW & TRENDS

3.1 Market Evolution and Key Trends

Introduction to the Clusters

The EMHA market segment is divided in 6 clusters that replicate the phases of the **emergency management cycle**, with the addition of *Search and Rescue* and *Humanitarian Aid*, which can be considered a very specific kind of Response operations, with distinct characteristics, needs, and community:

CLUSTER 1: Prevention and Mitigation. This cluster relates to studies and risk evaluation to prevent events and reduce their effect. It incorporates a variety of applications such as hazard forecasting and mitigation (forest fires, floods, earthquakes).

CLUSTER 2: Preparedness. The second cluster deals with the following step and covers applications such as forest fires early-warning surveillance, monitoring of hazards (geological, hydrometeorological, anthropogenic, etc..) or tsunami alerting.

CLUSTER 3: Response. The third cluster covers applications that use EGNSS and Copernicus for response to emergency situations. This is typically rapid mapping or crisis area assessment.

CLUSTER 4: Search and Rescue. This cluster is a major user of EGNSS and includes EGNSS applications using emergency beacons on land, sea or air as well as situational awareness supporting search and rescue with Copernicus.

CLUSTER 5: Post-event Recovery. The fifth cluster covers applications like post-crisis damage assessment and building inspection as well as restoration of supply chain and infrastructure services.

CLUSTER 6: Humanitarian Aid. This last cluster supports all applications that are implemented by NGOs and other humanitarian aid organizations such as asset management (e.g. vehicle, cargo, personnel etc.), welcome applications to people in need of humanitarian aid, health and medicine response and coordination, management of refugee camps and population counting and displacement monitoring. Humanitarian Aid actions are transversal to the emergency management cycle and tend to cover the whole cycle. They also have a distinct set of stakeholders and for this reason, in this document they are treated as an independent cluster.

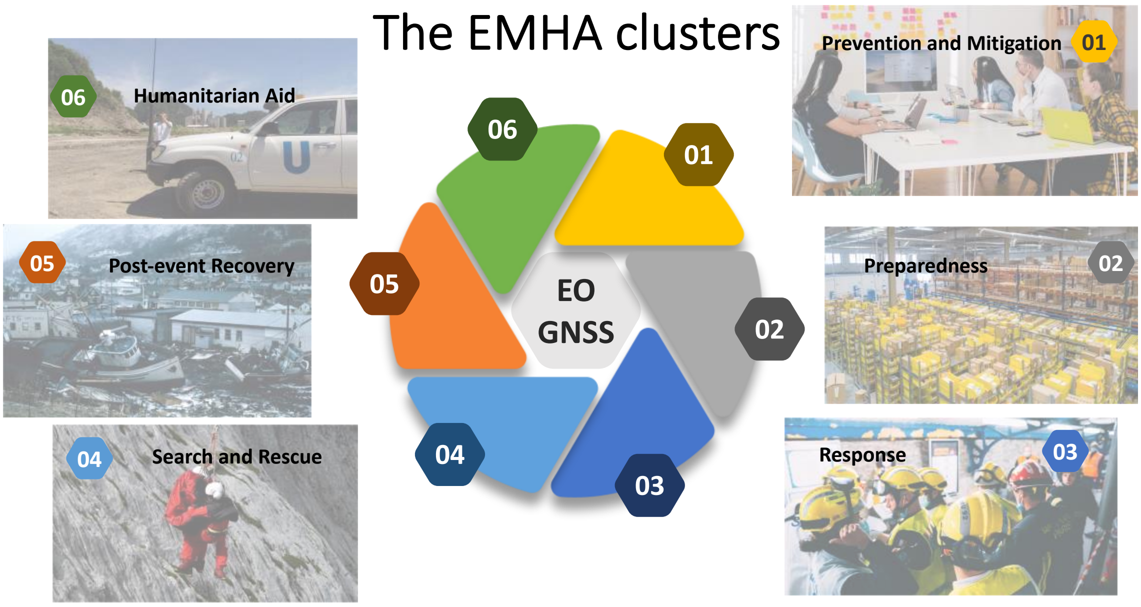

Figure 2 – The EMHA clusters

Key Market Trends

The EMHA segment presents a large diversity of applications and users. However, some clear trends appear in this segment:

- The use of EGNSS and Copernicus shows a steady increase as the tools are better performing and more easily accessible. The end-user community is more aware of the benefits of the systems and the advantages they can bring. In addition, new technologies such as AI and drones are drivers to use more Copernicus images and EGNSS.
- EO and GNSS are increasingly combined to provide the full picture needed for context-aware emergency response. These so-called “hybrid applications” leverage the benefits of both space assets.
- While emergency services and humanitarian response covered under this segment are public services mainly used by first responders and governmental agencies, commercial businesses or NGOs are often the ones implementing these emergency services, through contracts and providing on-site support.
- MEOSAR and the Galileo Return Link Service are in full operational capability and bring additional and much awaited-for features to the SAR operations. This allows better and faster response, to ultimately save more lives.

GNSS Market Evolution

In the EMHA market segment, Search and Rescue represents the largest cluster with more than 200.000 units shipped in 2020.

Within the Search and Rescue cluster, Personal Locator Beacons (PLBs) represents the largest group with an installed base of 750.000 units (2019). This is followed by Emergency Position Indicating Radio Beacons (EPIRBs) with 500.000 units in the field and Emergency Locator Transmitters (ELTs) with 100,000 units. AIS-MOB (Man Overboard) has been quite popular among boaters and represents now around 14% of the installed based. The last sub segments are ELT with a 6% share and AIS-SART

(Automatic Identification System Search and Rescue Transmitters) with a 1% share. The ELT sub-segment has been quite stable as it follows the growth of the aviation sector[7].

Overall, this cluster is expected to more than double in the coming decade, exceeding 4.2M units in 2031. This fast growth is explained by a variety of new products available that support a general societal trend for outdoor activities.

The Humanitarian Aid cluster is already relying heavily on GNSS for its field operations. Both UN agencies and their implementing partners (mostly NGOs) increasingly use GNSS both for tracking and tracing vehicles, field personnel or other assets such as supplies or generators and also for navigation in their operational fields. This cluster is expected to more than double over the next 10 years.

The other clusters currently represent a small use of GNSS. However, this will probably increase in the future with a number of new applications that are being deployed or under development. For example, drones are more and more used in emergency situations. And new applications of early warning for forest fire prevention will require extensive use of GNSS powered IoT sensors. Thus an increase in the other clusters is expected as well.

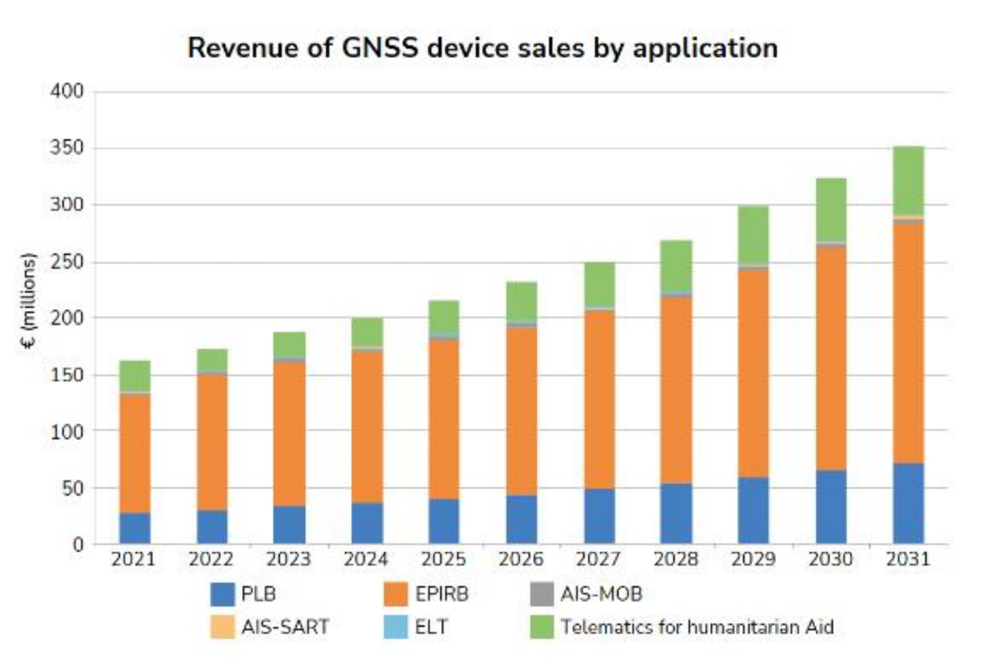

Figure 3 - Revenue of GNSS device sales by application (adapted from EUSPA EO and GNSS Market Report 2022 Issue 1)

[7] All figures extracted from [RD1]

The GNSS devices in Figure 3 fall in the following clusters:

- PLB (beacons for land), EPIRB, AIS-MOB, AIS-SART (beacons for maritime) and ELT (beacons for aviation) are in **CLUSTER 4 (search and rescue)**
- Telematics for humanitarian Aid fall in **CLUSTER 6 (humanitarian aid)**

In the EMHA market segment, the CLUSTER 4 remains the largest sub-segment for GNSS devices. While the number of EPIRBs and PLBs shipped is almost identical, EPIRBs are on average more than 3 times more expensive than PLBs, which explains the difference in revenues.

The most dynamic markets are foreseen to be North America and Asia Pacific in the next 10 years, with a market almost doubling.

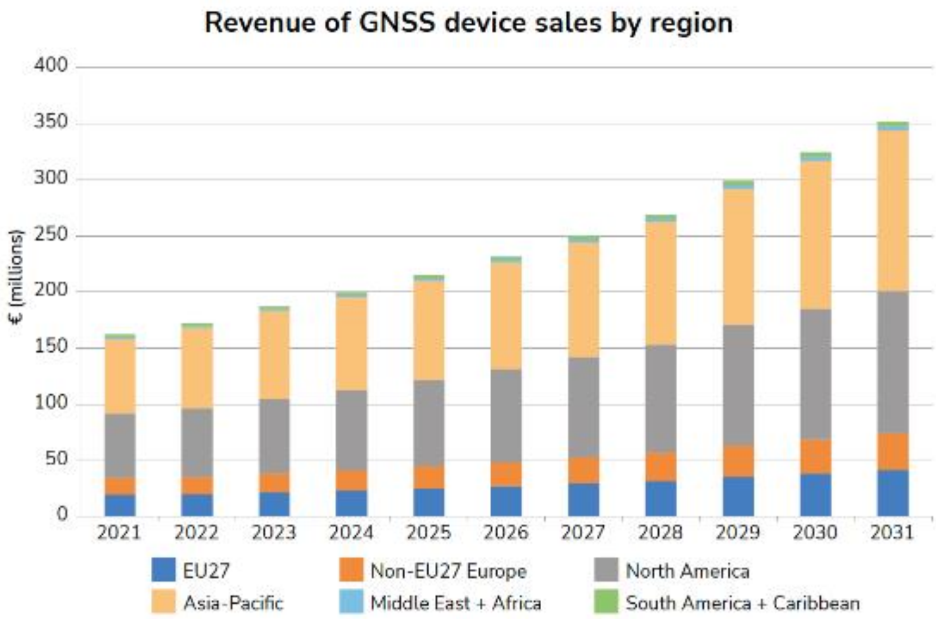

Figure 4 - Revenue of GNSS device sales by region (adapted from EUSPA EO and GNSS Market Report 2022 Issue 1)

EO Market Evolution

Sales of EO data and services are foreseen to continue growing, reaching almost €340 m by 2031 and almost doubling revenues from 2021. In the long run, all services will grow progressively at a similar pace, with a CAGR between 6% and 7% (Search and Rescue is the exception, at 4%).

Following the clustering presented at the beginning of this section, EO data and services for the Preparedness cluster will grow from almost €77 m in 2021 to almost €141 m in 2031, corresponding to over 40% of the total revenues. It is by far the largest cluster and is expected to stay at the same level of use. The market for EO data and services for the Response cluster is the second cluster, totalling almost €45 m or 25% of the total revenues in 2021. This cluster is expected be the fastest growing and to more than double by 2031, reaching 27% of the total market. The Post-event recovery cluster ranks 4th with 16% of total revenues.

The smallest market share is attributed to EO services for the Search and Rescue cluster with a 6% market share. This market is also expected to show the slowest grow with a 50% increase by 2031 while the average growth of the segment is around 90%.

The Humanitarian Aid cluster represents around 10% of the service and will display an average growth in the future, staying at 10% of the whole market in 2031. While this cluster makes heavy use of EO data and services, a large part of this may not come from the commercial markets.

The Prevention and Mitigation cluster is not shown on this chart as the data was not available at the time this document was produced.

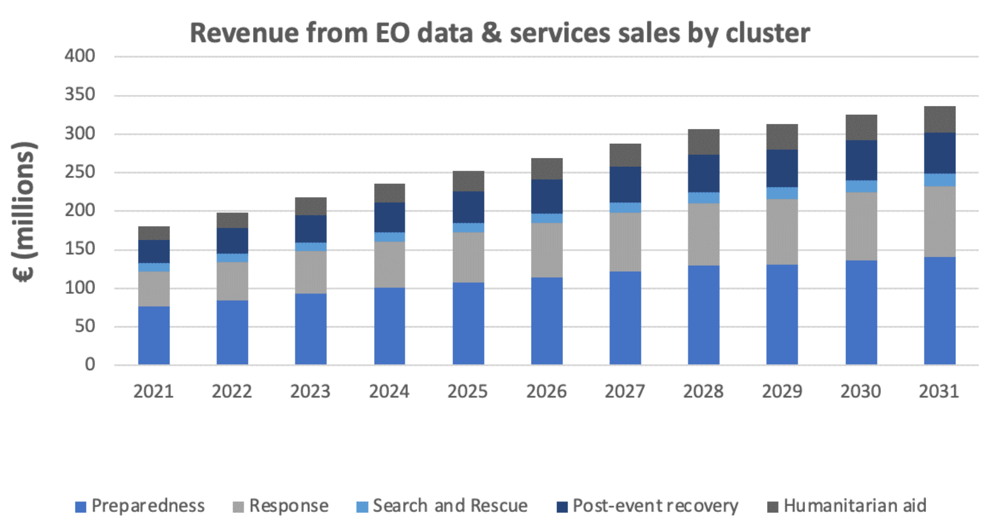

Figure 5 - Revenue from EO data and service sales by cluster (adapted from EUSPA EO and GNSS Market Report 2022 Issue 1)

The following charts show the sale of EO data and EO services by region. There is a sixfold factor difference between sales of EO data and EO services in 2021 that increases until 2031. The main markets in 2021 are North America and Europe. In the future, the projections show that North America remains a leading market while Asia Pacific will catch up upon Europe.

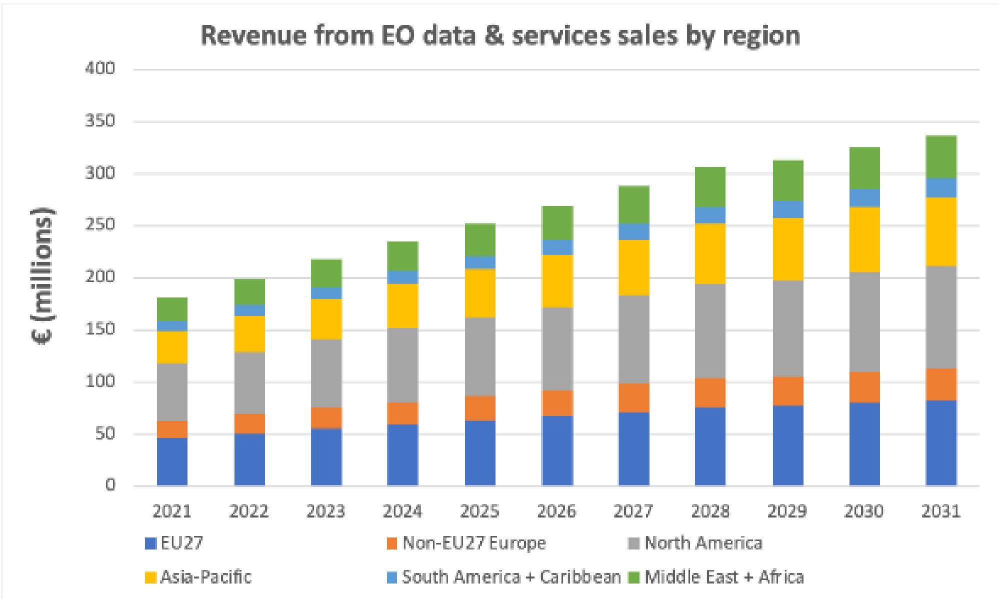

Figure 6 - Revenue from EO data and services sales by region (adapted from EUSPA EO and GNSS Market Report 2022 Issue1)

3.2 Main User Communities

The main User Communities in this market segment can be split by clusters in the following way:

- Clusters 1, 2, 3 and 5 (**Prevention and Mitigation, Preparedness, Response, Post-event Recovery**) incorporate the largest end-user community around the same general subject of emergency situations. This community is mostly comprising institutions and includes civil protection agencies, international organizations, specialized research organization and government bodies. As the use of EO can be quite complex, the user community also includes service providers that access the EO data to turn it into usable information. Although not strictly users, they are key to translate end user needs into technical requirements. EO is the most used satellite tool but the use of GNSS increases in specific applications.
- For cluster 4 (**Search and Rescue**), the end users can be split in two separate groups. First, the users of the GNSS beacon that include hikers, aircraft pilots, ship operators, boaters or offshore operators. This group uses the beacons to send distress alarms in life-threatening situations. The other group is made of the users of the positioning information and includes coast guards, civil security as well as private distress organizations. They receive the emergency signal from the beacons and use it to organize SAR operations and use as well EO data for situational awareness.
- Cluster 6 (**Humanitarian Aid**) deals essentially with the support of populations in distress after an emergency of any type (natural or man-made). The characteristic of this cluster is its operational nature with a requirement for speed and the importance of logistics. It includes NGOs, charities and international bodies (UN, European or regional). This cluster uses on a large scale both EO and GNSS technologies to support its operations in the field. As in clusters 1, 2, 3 and 5, application and service providers play an important role to turn the raw data into actionable information and thus can be considered as users of the data.

Figure 7 - Response teams during an emergency (picture for illustration)

3.3 Main Market Players

The Emergency Management and Humanitarian Aid segment is characterized by a large variety of applications and many different stakeholders although in many cases the end-users are institutional organizations.

EO Value chain

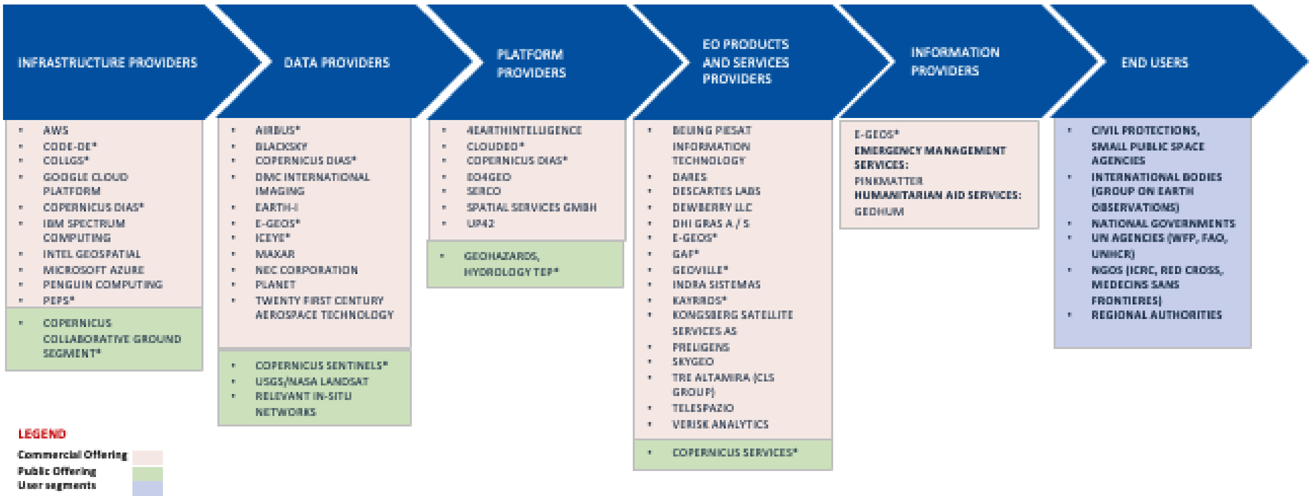

Figure 8 - The EO value chain in the EMHA segment

Most EO applications rely heavily on IT for infrastructure, processing, archiving which explains the organization of the value chain and the presence of many stakeholders adding their value at different steps. The various stakeholders in the value chain are not cluster specific: they provide data or services in all the clusters for emergency management and humanitarian aid.

Infrastructure providers offer various types of computing infrastructure upon which EO data can be accessed, stored, distributed or manipulated, such as cloud infrastructure, servers, databases, and storage systems. They make up the backbone by providing data centres and computing resources. This part is dominated by large US players although some EU companies start offering similar services. With regards to the EU Space Program, the Sentinel collaborative ground segment is intended to allow complementary access to Sentinel data and/or to specific data products or distribution channels. It is composed of elements funded by third parties (i.e. from outside the ESA/EU Copernicus programme) and provides the framework for international cooperation.

Data providers are the organizations that produce EO data. This can be raw or processed data. It includes many different types of information: visible imagery in different bands, IR imagery, radar scenes, lidar, altimetry, atmospheric chemistry, GNSS reflectometry... The data providers deploy and operate their own space infrastructure. It can be private companies such as Airbus, BlackSky, Planet Labs or public entities such as the EU with the Sentinel satellites. A key trend is a specialization and verticalization, for example, Germany based Ororatech plans to deploy a satellite constellation to detect forest fires.

As the access to EO data maybe difficult or complex, **Platform providers** propose online platforms and/or digital services to facilitate that. This starts with a simplified access to a repository of pre-processed EO data, specific tools and capabilities to analyse EO data, develop algorithms and build applications. A special mention should be made to the five Copernicus DIAS (Data and Information Access Services) developed by different EU consortia that have considerably eased the access to Sentinel data.

The **Service Providers** are a key link in the value chain as they transform raw data or products into services or usable information. In Europe, this is a fast growing market with many small companies taking advantage of AI and cloud computing to propose advanced analytics. At the same time, organizations like UNOSAT have been producing detailed maps of crisis areas for many years, freely available to all the emergency community. The EU is also active in the field with the Copernicus emergency management services that include a Mapping Component and an Early Warning Component. The Mapping Component supports all phases of the emergency management cycle from preparedness to recovery. On the other hand, the early warning component consists of three different systems: the European Flood Awareness System (EFAS), the European Forest Fire Information System (EFFIS), and the European Drought Observatory (EDO). The availability of the Copernicus emergency management services makes the use of service providers less relevant for many institutions that have access to the Copernicus services and is a service welcomed by many users.

Information Providers offer sector-specific information that incorporates EO data along with non-EO data, such as aerial imagery, IoT or other sensors, tailored to sector specific clients. While this part of the value chain is not very developed for Emergency Applications, companies start to propose new services.

End users are the final users of the applications and services offered by the various providers. These users, mostly public entities active in the field of emergency management and humanitarian aid. These end-users are specific to each of the clusters:

> **Prevention and Mitigation**. The end-users are frequently research organizations and laboratories that use EO data to assess risks on behalf of authorities.
>
> **Preparedness**. The end-users are, on the one hand, specialized organizations that provide early-warning surveillance, monitoring of hazards (geological, hydrometeorological, anthropogenic, etc..) or tsunami alerting. On the other hand, the role of local organisations (be it NGOs or public administrations) should be mentioned, as in the end they will be the ones able to apply preparatory measures and related mitigations.
>
> **Response**. This third cluster comprises all entities that deal operationally with crisis in the field and those that organize operations. This includes of course civil protection, firefighters and various NGOs and UN organizations.
>
> **Search and Rescue**. This cluster is different from the others as it deals with very specific and strongly regulated applications. It uses mostly GNSS and the limited EO applications (situational awareness) is used by authorities and search and rescue response (coast guards, local emergency management).
>
> **Post-event Recovery**. The users in the fifth cluster are local authorities that deal with restoration and reconstruction activities. They may be supported by universities and laboratories to produce information and recommendation based on EO data.
>
> **Humanitarian Aid**. The users in this last cluster are all stakeholders in the humanitarian field, including people in need. This includes national or European authorities (DG ECHO), UN organizations (WFP, FAO, UNHCR, UNICEF, WHO) and NGOs (ICRC and its local branches, MSF, Aktion Deutschland Hilft, Care, Telecoms sans Frontières). Usually, UN organizations either process directly EO data or subcontract this and then use the resulting information or provide it to their partner NGOs.

GNSS Value chain

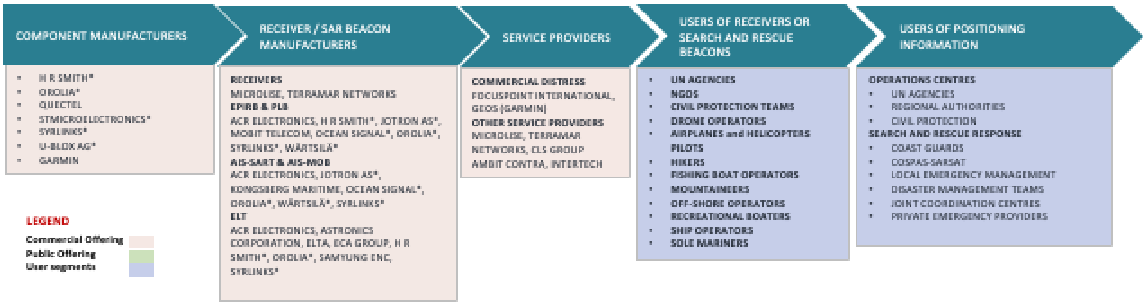

Figure 9 - The GNSS value chain in the EMHA segment

The GNSS value chain is simpler than the EO value chain as the use of GNSS requires less processing and is not as complex. However, with new applications in emergency management coming in line, service providers are more and more needed to bring more complete solutions to the end-users

Component Manufacturers include manufacturers of generic GNSS components (chipsets, modules or antennae) that will be transformed into end-user devices. This is a highly consolidated industry, with companies such as ST Micro, Garmin or U-Blox.

Receiver and SAR Beacon Manufacturers are the companies that will integrate the components into end products dedicated to their specific markets. The Search and Rescue market includes large European players such as Orolia, Syrlinks, Konsberg or ECA Group. For other applications such as asset tracking in the humanitarian sector, telematics companies such as Terramar Networks, Microlise or CLS provide their devices to the end users. Also, for specific high accuracy applications like landslides monitoring, special equipment is needed and manufactured accordingly.

Service providers are responsible for integrating GNSS capability into specific applications, such as asset tracking or distress signal processing and GNSS represents only a small part of the value in the product offering. This is also a fragmented market depending on the applications: for asset management, companies such as CLS and Terramar networks provide solutions to UN agencies while for commercial distress, companies such as GEOS (a subsidiary of Garmin) or Focuspoint International are key players to process alarm signals.

Users of receivers or SAR beacons are the persons in the field that use the devices. For SAR beacons, the end-user will only use the beacon to trigger an alarm in case of emergency (or the beacon may generate it automatically). These are people on ships (professional mariners or leisure boaters) and hikers or outdoors enthusiasts. In general, ELTs for aviation are automatically activated after an accident and as such do not require a “user". Similarly, most other devices used for asset tracking do not include a user interface and are just used to monitor the assets they are attached to, thus there are no specific users. In some cases, an SOS button is available to send an alarm message. This is the case for vehicle operators for the UN agencies.

Users of positioning information generated by GNSS receivers or SAR beacons are separated in two groups. The first group is in charge of processing SAR alarms and responding to calls for help. This includes coast guards, civil protection, response teams and commercial distress companies. On the other hand, users of GNSS data for asset management are UN organizations and NGOs with operations centres implemented for that purpose. For other monitoring applications requiring high accuracy, end-users are generally research or specialized teams that process data on their own.

4 POLICY, REGULATION AND STANDARDS

This chapter describes the various regulations and policies that apply to the segment and may influence the uptake of the EU Space Programme. It also covers best practices that have been implemented by various stakeholders in the field that imply the use either of EO or GNSS. Finally, an overview is given of the EU activities in this area as this often uses EU Space Systems.

4.1 Applicable regulations

The following regulations and rules apply for in the field of Emergency Management and Humanitarian Aid. Some specific regulations cover Search and Rescue and are much more technical, including the use of GNSS techniques.

- **Convention (IV) relative to the Protection of Civilian Persons in Time of War. Geneva, 12 August 1949.** The Geneva Conventions which were adopted before 1949 were concerned with combatants only, not with civilians. In this way, the Convention adopted in 1949 spells out the obligations of the Occupying Power vis-à-vis the civilian population and contains detailed provisions on humanitarian relief for populations in occupied territory. All EU countries have ratified the 4 Geneva Conventions and their Additional Protocols.
- **International Humanitarian Law.** IHL is based on the 1949 Fourth Geneva Convention on protecting civilians in conflict and the 1977 and 2005 Additional Protocols. The principles that guide and safeguard humanitarian action in armed conflicts are also based on IHL.
- **Council Regulation (EC) No 1257/96 on humanitarian aid.** This regulation sets out the main goals, principles and procedures for implementing EU humanitarian aid operations outside the EU.
- **Decision (EU) 2019/420 of the European Parliament and of the Council**. This decision amends Decision No 1313/2013/EU on a Union Civil Protection Mechanism. In this way, the EU Civil Protection Mechanism was upgraded in 2019 and the rescEU was created to reinforce and strengthen components of the EU's disaster risk management, and in particular the last resort capacity to respond, upon overwhelming situations, where existing capacities at national level and those pre-committed by Member States to the European Civil Protection Pool are not able to ensure an effective response. Nowadays, the 'rescEU reserve' establishes a European reserve of resources which includes a fleet of firefighting planes and helicopters, medical evacuation planes, as well as a stockpile of medical items and field hospitals that can respond to health emergencies.

Figure 10 - Firefighting aircraft (picture for illustration)

The Search and Rescue sector is heavily regulated, both for maritime and aviation. These regulations impact both requirements and performances for satellite systems used for Search and Rescue. The following paragraphs list the main regulatory references, although more information can be found in the RURs that deal with the maritime and aviation market segments.

- ICAO GADSS 6.0 Global Aeronautical Distress & Safety System (GADSS) 07 June 2017
- IMO Global Maritime Distress and Safety System (GMDSS). GMDSS is an integrated communications system which should ensure that no ship in distress can disappear without trace, and that more lives can be saved at sea. The regulations governing the GMDSS are contained in Chapter IV of the International Convention for the Safety of Life at Sea (SOLAS), 1974.
- IAMSAR Manual. Jointly published by IMO and ICAO, this manual provides guidelines for a common aviation and maritime approach to organizing and providing search and rescue (SAR) services.

4.2 Non-regulatory sources

The following are examples of guidelines which affect the work of humanitarian aid workers:

- The Code of Conduct for the International Red Cross and Red Crescent Movement and Non-Governmental Organisations (NGOs) in Disaster Relief, a voluntary code seeking to *"guard our [IFRC, ICRC and other NGOs] standards of behaviour"*. it does not contain operational details, but rather the principles necessary to maintain high standards of independence, effectiveness and impact to which disaster response NGOs and the International Red Cross and Red Crescent Movement aspire to.
- The Sphere Handbook (https://handbook.spherestandards.org/fr/sphere/) describes the charter and minimum standards applicable to humanitarian response. It focuses primarily on human wellbeing. Although it does not include specific requirement applicable to GNSS or EO

technologies, it suggests provisioning satellite images in case of emergency situations. These standards are used by many NGOs and humanitarian agencies.

- **Field Guide to Humanitarian Mapping**, published by MapAction to help humanitarian organizations to make use of mapping methods using Geographic Information Systems (GIS) and related technologies, such as GNSS.
- **EU policy guidelines on EU civil protection and humanitarian aid**, help field partners, who implement EU-funded programs, understand how policies should be applied.
- **Digital mapping and inclusion in humanitarian response**, a working paper published by the Humanitarian Policy Group (HPG) at ODI, which considers how technologies such as mapping have significant implications, both positive and negative, for inclusion in humanitarian responses.
- The 2009 UNDP MOSS (Minimum Operating Security Standard) calls for a "GPS vehicle tracking system" for all field vehicles. These standards apply to all UN organizations and their implementing partners that operate in the field which represents more than 100.000 vehicles in crisis areas.
- The **Fleet Forum** is a non-profit organization created by ICRC, the WFP and World Vision International to establish a collaborative organization dedicated to developing practical solutions to address complex aid and development sector challenges. The Fleet Forum sets standards and provides guideline for better use of vehicles within NGO, UN and other aid organizations, dealing with safety, fuel economy and better environmental practice.
- For Tsunami warning, UNESCO has established a set of guidelines that cover Assessment, Preparedness and Response to Tsunami. The 2022 version is available as **Standard Guidelines for the Tsunami Ready Recognition Programme** and is used by all stakeholders under the global tsunami program.

4.3 EU civil protection and humanitarian aid operations

EU is very active in the field of emergency management and humanitarian aid via several tools and mechanisms implemented at EU level by DG ECHO:

- The EU Civil Protection Mechanism aims to strengthen cooperation between the EU countries and 6 Participating States on civil protection to improve prevention, preparedness, and response to disasters.
- The Emergency Response Coordination Centre (ERCC) is the heart of the EU Civil Protection Mechanism and coordinates the delivery of assistance to disaster-stricken countries, such as relief items, expertise, civil protection teams and specialized equipment.
- The European Humanitarian Response Capacity (EHRC) is a set of operational tools designed to fill gaps in the humanitarian response to sudden-onset natural hazards and human-induced disasters. It provides common logistics services to EU humanitarian partners, prepositioned stockpiles of emergency items in critical areas worldwide and expertise, mainly in the health sector.

Figure 11 - Civil protection volunteers (picture for illustration)

5 USER REQUIREMENTS ANALYSIS

This chapter provides a detailed analysis of user needs and requirements pertaining to the EMHA applications identified along the 6 Clusters, describing the different roles and needs covered by GNSS and EO and, ultimately, identifying the corresponding requirements from a user perspective.

In this segment, and from a high-level perspective, **EO accomplishes two functions**.

- On the one hand, EO provides answers, or products, to specific application needs. The number of sensors and instruments carried on-board EO satellites is such that it is 'the enabler' of a significant number of applications.
- But, in the context of emergency management, EO provides valuable, full-picture, information of the overall context and situational awareness before, during and after emergencies, that when used in combination with other technologies (e.g. GNSS), allows for an even larger number of applications, ranging from prevention and mitigation to rapid mapping and post-event recovery.

Something similar happens with **GNSS. By itself, it is already an enabler of some applications**. But in the field, **GNSS is also a valuable tool to complement and/or complete the general picture provided by EO**, helping coordinate emergency response and humanitarian aid actions.

On the other hand, the new MEOSAR system of the **GNSS-based COSPAS-SARSAT programme** is estimated to save 2,000 lives a year, bringing critical improvements to the existing LEOSAR and GEOSAR systems. A number of SAR applications have been included as part of Cluster 4.

Table 1 below depicts a list of applications that make use of GNSS and/or EO technologies. The list of applications is non-exhaustive and is expected to grow with the 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 Emergency Management and Humanitarian Aid 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 Market Report [RD1], 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.

While each one of the applications addressed in this document can benefit from GNSS and/or EO, the current issue of the RUR does not cover in detail the user 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 EMHA 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. In some cases, requirements focus on only 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 below maps EMHA-related applications to the three above-mentioned types. **The following list of applications and their categorisation is 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)

Cluster	Application	Type of application / Analysis Level	
Prevention & Mitigation	Impact exposure analysis and proactive mitigation measures (EO)	C	○
Preparedness	Early-warning surveillance of forest fires (EO)	C	○
	Landslides and terrain deformation monitoring (EO and GNSS)	**A**	●
	Earthquakes monitoring (EO and GNSS)	B	◐
	Tsunami monitoring (EO and GNSS)	B	◐
	Volcanic activity monitoring (EO and GNSS)	B	◐
	Floods monitoring (EO and GNSS)	C	○
	Storm surges monitoring (EO)	C	○
	Drought monitoring (EO)	C	○
	Mining monitoring (EO and GNSS)	B	◐
	Fracking monitoring (EO)	C	○
	Monitoring of vector-borne diseases (EO)	C	○
	Monitoring of locust swarms (EO & GNSS)	C	○
	Space debris removal (GNSS)	C	○

Response	Crisis area assessment (EO and GNSS)	C	○
	Operational wildfires modelling (EO)	C	○
Search and Rescue	SAR operations: at sea (GNSS)	B	◐
	SAR operations: aviation (GNSS)	B	◐
	SAR operations: land (GNSS)	B	◐
	Situational awareness supporting SAR (EO)	C	○
Post-event Recovery	**Post-crisis damage assessment and building inspection (EO and GNSS)**	**A**	●
	Restoration of supply chain and infrastructure services (EO and GNSS)	C	○
Humanitarian Aid	**NGO's asset management (GNSS)**	**A**	●
	Welcome applications to people in need of humanitarian aid (GNSS)	C	○
	Health and medicine response and coordination (EO and GNSS)	**A**	●
	Management of refugee camps (EO)	C	○
	Population Displacement monitoring (EO)	C	○

Table 1 - Applications and level of investigation

Next section 5.1 addresses "type B" and "type C" applications, with a short description, a presentation of stakeholders and how they use EO and GNSS.

Section 5.2, on the other hand, addresses "type A" applications, with much more detailed information.

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 2 and explains the various inputs.

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 (e.g. an emergency responder is interested in a region impacted by an earthquake).
Scale	Describes the scale of interest (e.g. an emergency responder is interested to see at 10-meter level the areas impacted by a flood).
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 realize 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	
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.

Table 2 - Description of User Requirements Table[8]

5.1 Current GNSS/EO use and requirements per cluster

5.1.1 Applications in cluster 1: Prevention-Mitigation

The prevention phase is essential to emergency management activities. It includes all activities that reduce the likelihood of events with measures and contingency plans (considerations to Humanitarian Aid must therefore be accounted for) to prevent and cope with them in case events are unavoidable.

Impact exposure analysis and proactive mitigation measures (EO)

Impact exposure analyses enable the design and planning of proactive measures in order to mitigate the effects of the disaster; this could be the case of evacuation plans supported by network analysis (routing) accounting for Road capacity, Population Density & City Population.

In other words, should an unfortunate but predicted/modelled event occur, it is essential to count with valuable data about how much people and which assets would be affected. This will allow authorities and public emergency services to plan and respond in a more effective way.

Data related to risk, socio economics or exposure and vulnerability must be available, which together with information such as land cover, type of buildings and roof types present in an area, population estimations and infrastructures, are combined to increase the accuracy of the analysis.

This data, unfortunately, sometimes tends to be quite static and therefore one of the main issues during the prevention phase is to have up-to-date information.

Figure 12 - Planning of routes (picture for illustration)

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

Stakeholders include organizations that will model the risk with EO data (laboratories, specialized institutions), civil security and first responders and of course local authorities in the concerned areas.

EO can provide added value data when it comes to exposure analysis on assets and population. Hence, up-to-date vulnerability-related information in combination with EO enables impact-based forecasts which help identify where the impact of a disaster would be higher and which communities would be impacted the most.

In the case of Copernicus, today its EMS is providing product P14[9]. By requesting it, Civil Protection authorities and relevant bodies are provided with general statistical information about assets and population exposed during or affected by an event.

For example, should the exposure of population and assets to potential flood events wanted to be assessed, then product P5 (Modelled flood extent for major events)[10] would provide delineation of a hypothetical flood event over a certain area. Population exposure, P14, would be obtained by analysing the abovementioned flood extent with information on population density and assets provided by product P2[11] (Reference Datasets).

5.1.2 Applications in cluster 2: Preparedness

In this phase, the objective is to analyse the information on the different aspects (e.g. change in precipitation, water level, earth movements, etc.) to detect patterns and their changes and to issue early warning and other information relevant for the communities to be prepared for an emergency ahead of the event.

Early-warning surveillance of forest fires (EO)

Typically, man-made disasters such as fires cannot be precisely foreseen or avoided, but preparedness helps to minimise the eventual risks and initiate emergency actions by response teams. This allows pre-positioning emergency equipment and solutions: for example, positioning fire-fighting aircraft in bases/aerodromes closer to areas where the fire danger indices require so.

[9] https://emergency.copernicus.eu/mapping/ems/p14-impact-assessmentexposure-analysis-assets-and-population

[10] https://emergency.copernicus.eu/mapping/ems/p05-modelled-flood-extent-major-events

[11] https://emergency.copernicus.eu/mapping/ems/p02-reference-dataset

Figure 13 - Firefighting vehicles positioned (picture for illustration)

Stakeholders include organizations that will measure the risk with EO data (laboratories, specialized institutions, firemen), civil security, first responders and local authorities in the concerned areas. In addition, local communities may also be able to act on the subject and bring valuable knowledge to complement EO information (e.g. Community Forest Committees (CFC) established in some countries[12]).

The Fire Weather Index (FWI) system is the method to assess the fire danger level in a harmonized way throughout Europe. This index is calculated considering, amongst others, temperature, wind speed, relative humidity and precipitation. The danger also considers the so-called 'fuel type', which is the type of material available to burn (types of forests, grasslands, vegetations…) and the topography: for example, steep slopes facilitate fire spread, while southern facing slopes are likely hotter and drier.

Determination of fuel type and of most of these parameters can be done with EO. For example, Surface Soil Moisture (the relative water content of the top few centimetres soil) is provided by the Copernicus Land Monitoring Service[13]; while its Digital Elevation Model (DEM)[14] can also be used to evaluate local and broader topographic conditions.

[12] See for example https://www.recoftc.org/

[13] https://land.copernicus.eu/

[14] https://land.copernicus.eu/imagery-in-situ/eu-dem/

Earthquakes monitoring (EO and GNSS)

The monitoring of earthquakes effects is conducted by detecting deformation of the Earth's surface.

Scientists working at national bodies (National Geographic Institutes for example) are in charge of this task and make use of a variety of technologies to measure this deformation. This information is then used by civil security and local institutions.

EO and GNSS are also used as follow:

- EO provides continuous observations of ground deformations thanks to SAR data, for example;
- On ground, GNSS measurements help calculating the magnitude of these changes. Indeed, GNSS and accelerometer arrays are being explored as part of fully operational early warning systems (examples in California[15] and Japan[16]).

In the meantime, the prediction of earthquakes thanks to its pre-disaster affection to the ionosphere (ionospheric TEC variability induced by seismicity) remains a subject of scientifical investigations.

Tsunamis monitoring (GNSS & EO)

Tsunamis are typically generated by phenomena that have a capacity to displace large volumes of water. Therefore, most tsunamis are caused by underwater earthquakes, landslides and volcanic eruptions[17].

All countries with coastlines exposed to the impact of tsunamis should possess a tsunami warning system or be integrated into regional systems[18].

In some countries, stakeholders in charge of such systems and tsunamis alerting consists on a combination of Civil Protection bodies with those national organisations (e.g. Geographic Institutes) who operate the networks of seismometers and other sensors used to detect the above-mentioned phenomena. Others have incorporated this into existing bodies (be it the case of the US with the NOAA) or set-up organisations exclusively dedicated to this, such as France with its CENALT (Tsunami Alerts Centre).

When a potentially destructive tsunami is detected, the national authorities of each country have to decide whether to issue a public tsunami warning and an evacuation order.

The prediction/alert of tsunamis is mainly based on networks of seismometers and sea level measurement stations that send data in real time to national and regional warning centres. When an earthquake is detected, it is firstly located and then a magnitude value that characterizes the size of the earthquake is assigned. Then, the level of alert existing in the different stretches of the coast is obtained using decision matrices, and numerical simulation databases are used to estimate the maximum wave height and the arrival time of the first wave at the established forecast points.

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[15] https://www.shakealert.org/

[16] https://www.jma.go.jp/jma/en/Activities/eew.html

[17] According to NOAAs Global Historical Tsunami Database (https://www.ngdc.noaa.gov/hazard/tsu_db.shtml), 74% of worldwide registered tsunamis have been caused by earthquakes.

[18] For example, the ICG/NEAMTWS (Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas)

Buoy-based systems that make use of pressure sensors to detect changes in the sea level have been implemented more recently. These are dual systems composed of a seabed tsunameter and a floating buoy for external communication. This is the case of NOAAs DART (Deep-ocean Assessment and Reporting of Tsunamis (DART)) system[19].

However, DART's second-generation buoys also incorporate a GNSS receiver to maintain the buoy's computer clock's accuracy to ~1 sec. And the GNSS position of the buoy is also reported once a day.

Nevertheless, GNSS-enabled monitoring buoys, deployed at sea and in oceans, can provide early warning for tsunami events following seismic activities (e.g. undersea earthquakes). Such a system is in operation in Japan[20].

After alerts are issued from deep sea pressure-monitoring buoys, changes in sea level in coastal areas are monitored by coastal buoys (located less than 20 km from the coast) using real time kinematic (RTK) technique with a land-based station. The widespread adoption of GNSS for such purpose is, however, yet to happen.

Figure 14 - NOAA's DART buoy (picture for illustration)

In parallel and as in the case of earthquakes, research continues on how ionosphere total electron content (TEC) information provided by GNSS is affected after a tsunami occurrence and what applications may consequently be developed.

On the other hand, EO satellites that can measure water levels may also detect tsunamis, provided they are passing above a tsunami at the right time. Hence, the capability of satellites to provide up-to-date information (time to process satellite data and frequency of data gathering) is today's main limitation to use EO for tsunamis detection and monitorisation. Still, given the concerns that could exist with respect to the sustainability of buoy-based monitoring systems, it is worth continuing the exploration of EO for tsunamis monitoring.

[19] https://www.ndbc.noaa.gov/dart/dart.shtml

[20] https://www.data.jma.go.jp/eqev/data/en/tsunami/tsunamiwarning-leaflet.pdf

Volcanic activity monitoring (EO and GNSS)

Before a volcanic eruption may actually occur, scientists determine if the ground surface has locally deformed. The sensitivity of the technology used to measure this deformation, i.e. its ability to distinguish land deformation from monumentation deformation (i.e. movement of the station due to other reasons such as temperature excursion, wind, etc.), is critical.

Stakeholders include public entities that will monitor the risk with InSAR[21], GNSS and other means (USGS in the USA[22], the future European Volcano Early warning system[23]), civil security and first responders and of course local authorities in the concerned areas.

Thanks to GNSS stations installed around volcanoes, scientists conduct the so-called GNSS land deformation monitoring. This is significantly improved when a network of monitoring stations is installed in the area. The data collected by each of the network's stations are transmitted via GSM or radio modems to a relevant centre, where measurements can be evaluated by experts.

For example, during the La Palma eruption in Spain in 2021, vertical deformations of up to 24 centimetres were measured at the closest GNSS station before the first eruptions. Stations located away from the eruption location registered lower deformations.

On the other hand, satellite-based EO provides large-area observations and proves particularly useful when making use of InSAR technique. Indeed, this technique is particularly suited for remote and hard-to-reach volcanoes, as well as for locations where hazardous conditions prevent or limit ground-based volcano monitoring. In addition, and before the eruption eventually occurs, InSAR allows calculating uplift deformations of the terrain, which indicate spots where the magma may finally come out from.

By combining EO and GNSS with other data, scientists can know when a volcano is behaving out of "context" and showing signs of eruption, allowing them to provide warnings.

Floods monitoring (EO & GNSS)

Floods are becoming more and more common and flood warning systems have been put in place using various technologies to monitor a rise in water levels, helping alert local populations.

Locations prone to flooding are typically low-lying areas adjacent to rivers, lagoons or lakes. Most times, the rise in water levels is caused by heavy rains. However, in coastal areas and shorelines floods can also be caused by seawater when tsunamis or storm surges occur.

Usually, public bodies and often weather services or hydrological services are the organizations that deal with flood monitoring. Data is used by civil protection and public authorities to alert and support local populations.

Ground-based flood monitoring systems comprise sensors that are deployed in cities or any area of interest. Depending on their location, these will be connected to the electricity network or be solar-

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[21] InSAR is a s a radar technique used in geodesy and remote sensing that makes use of Synthetic Aperture Radar (SAR) microwave data. It allows the generation of digital elevation models and measurement of centimetric surface deformations of the terrain.

[22] https://www.usgs.gov/programs/VHP

[23] http://www.evevolcanoearlywarning.eu/

powered. Radio transmission is typically the standard telemetry option, yet satellite and cellular options may be more beneficial case-by-case.

The gauges will typically be able to measure precipitation levels and be equipped with some sensor able to monitor the water level (lidar, radar water sensor or submersible pressure transducers).

In rivers or channels, stream stage (or water level) and streamflow[24] (or discharge) are measured at locations called streamflow gaging stations. Then, hydrologists familiar with the history of a particular drainage basin can accurately predict discharge by measuring stream height (stage).

Satellite-based EO data are also of great help and are already in use. As already explained, satellites support the prevention phase by providing data to be used in simulations aimed at assessing the risk of flooding. At the same time, this allows discarding areas for camps or warehouse settlement purposes. But in the next phase, when the flooding has already happened, satellites collect pictures (typically SAR-imagery) and provide wide-area products that help identifying the extent of the event.

For example, Copernicus EMS delivers on-demand geospatial information for emergency situations and provides early warning information for floods, amongst other. It can provide "delineation products", showing the extent of the flooded area, the main access roads, and the settlements.

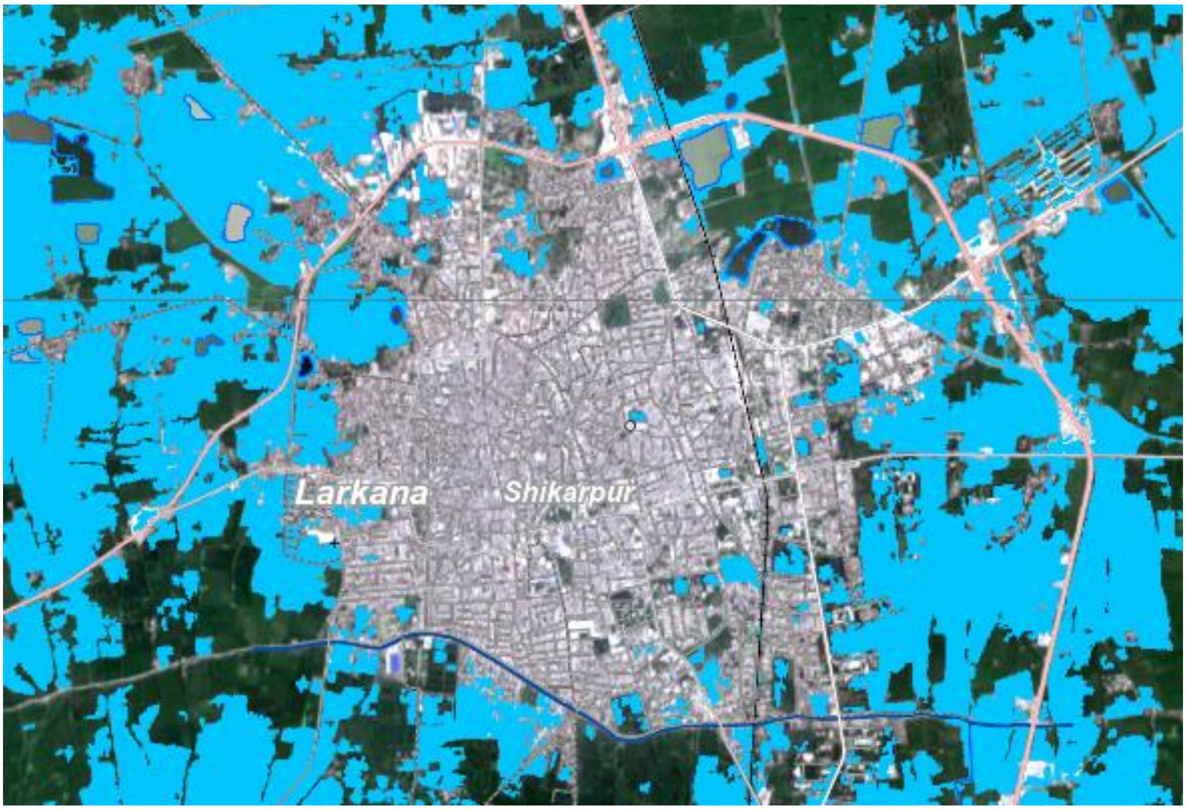

Figure 15 - 2022 Floods in Shikarpur (Pakistan): detail of Copernicus' flood delineation (adapted from Copernicus EMS) (picture for illustration)

[24] The amount of water flowing through the river over a fixed period of time (can be measured in m^3/sec).

On the other hand, there is a lot of on-going research work related to the use of social media data (especially Twitter), in combination with Machine Learning, to assess the impact of meteorology events like these.

When it comes to GNSS, the so-called GNSS-R (GNSS reflectometry) has already been tested as new kind of remote sensing technique. In GNSS-R, GNSS signals reflected from, for example, the surface of the Earth's oceans are received and measured by low Earth orbit satellites to determine wave motion and windspeed. The same principle can be used to assess flood extent over land.

Storm surges monitoring (EO)

Storms surges are abnormal risings in seawater levels associated with low-pressure weather phenomena such as intense storms, typhoons, and hurricanes. Storm surges, when coincident with normal high tides, can cause floodings in coastal areas.

Spaced-based EO altimeter measurements can be used to validate storm surge models as well as provide near-real-time information that can be incorporated into predictions.

The Copernicus C3S[25] provides high quality climate data on the storminess in European coastal seas: a consistent dataset of storm surge, tide and wave conditions, including the effect of sea level rise, for all of Europe's coastal waters.

Figure 16 - The surge is caused primarily by a storm's winds pushing water onshore (picture for illustration)

Drought monitoring (EO)

The term drought refers to temporary situations where there is a lack of water availability. This can be caused by different factors: shortfalls in precipitation over extended periods of time, inadequate timing of rains compared to the needs of vegetation cover or a negative water balance due excessive water evaporations caused by high temperatures.

Drought monitoring is based on the analysis of a series of drought indicators, representing different components of the hydrological cycle (e.g. precipitation, soil moisture, reservoir levels, river flow, groundwater levels) or impacts (e.g. vegetation water stress).

The monitoring of droughts is usually the responsibility of institutions or governmental agencies. It can support early actions taken by local communities with the help of humanitarian organisations[26]. In this

[25] https://climate.copernicus.eu/

[26] Severe droughts can lead to the loss of crops, but also of livelihoods of local communities (e.g. a shepherd losing all or part of his/her livestock). When possible, humanitarians try to support the restoration of likelihood during the early recovery phase.

way, the effectiveness and impact of such early action can be measured and its applicability in other regions considered.

For example, the status of drought resistance crops planted before the dry season can be monitored by means of EO. The Copernicus EMS Drought Observatory (DO) provides drought-relevant information and early-warnings for Europe (EDO)[27] and globally (GDO)[28]. Its drought reports give an overview of the situation in case of imminent droughts.

Mining monitoring (EO & GNSS)

Monitoring of mines allows mine operators to know which is the stability of mine openings, and more in general to know which are the effects of the activity over the environment, allowing to implement preventive measures and mitigations before a disaster could happen.

To name a few examples: installation of additional support where needed or the removal of personnel and equipment from potentially hazardous situations; monitoring of vegetation status, water bodies and abandoned sites, enabling near real-time planning to prevent emergencies; location of dangerous encroachments onto vulnerable lands; and surface restoration upon mine closure matching original environmental and ecological conditions.

The Copernicus Global Land service[29], for example, "*provides, in a timely manner, a set of biophysical variables describing the state, the dynamism and the disturbances of the terrestrial vegetation*".

On the other hand, InSAR allows addressing mine stability concerns by using SAR products (e.g. land subsidence). Such stability studies can range from large-scale to specific movements at the pit scale. Sentinel-1 provides SAR data that can be used by service providers for these purposes.

In addition to EO, GNSS also contributes to monitor potential hazards derived from mining activity. What's more, when used simultaneously with EO, GNSS supports the study and monitoring of the stability of slopes (i.e. landslides).

GNSS techniques, alone, do not meet the mm-level accuracy requirements that are needed for landslides located in mining areas. In addition, the visibility of GNSS satellites in deep-pit mines can also be compromised. For this reason, the combination of GNSS and EO observations, together with in-situ collected data, is the best option.

Fracking monitoring (EO)

Hydraulic fracturing, or fracking, is a drilling technology mainly used for extracting oil and natural gas from deep underground: a high-pressure mixture of water, sand and chemicals is injected at a rock layer to obtain the fossil fuels.

However, concerns about the environmental impact of this technique have slowed or stopped its use due to environmental concerns (gas emissions, induced seismicity or groundwater contamination).

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[27] https://edo.jrc.ec.europa.eu/

[28]rhttps://edo.jrc.ec.europa.eu/gdo

[29] https://land.copernicus.eu/global/themes/vegetation

Stakeholders include public entities that need to monitor the impact of fracking, private EO providers that market the service and fracking companies to improve the safety of their operations.

EO can support monitoring of this activity. For example, observations from the Sentinel-5P spectrometer can help monitoring and tracing methane emissions in case of accidents at extraction plants. In addition, SAR data is used to improve the security of fracking operations as it allows to reduce the land subsidence related risks of collapse.

Monitoring of vector-borne diseases (EO)

A disease is called 'vector-borne' when the infectious agent is transmitted by a living organism (i.e. by the vector), from an animal to a human or another animal. Malaria is perhaps the most widely known vector-borne disease, where mosquitoes act as the vector in spreading the pathogen with every bite.

Stakeholders include research organizations and laboratories that develop predictive outbreak models and public health organizations (ministries, WHO, UNICEF) and policy and decision makers.

EO data provided by satellites is being included by scientists in predictive outbreak models for some vector-borne diseases like cholera, malaria and dengue.

EO can be leveraged to estimate environmental variables (temperature, soil moisture, water bodies or vegetation conditions) that influence the transmission cycle of the pathogens that lead to mosquito-borne diseases.

In other words, it is possible to determine and anticipate when disease-favouring conditions exist.

Figure 17 - Vectors are frequently arthropods, such as mosquitoes, ticks, flies, fleas and lice (picture for illustration)

This will improve the management of mitigation actions.

Monitoring of locust swarms (EO & GNSS)

Locust plagues pose a threat to agricultural production as they cause widespread crop damage and, subsequently, livelihoods and food security. Favourable conditions for desert locusts to swarm happen when a period of drought (extremely low soil moisture) is followed by good rains (high soil moisture) and rapid vegetation growth (green vegetation). It is then possible to identify the areas locusts go to breed, and then immediately eradicate the eggs or newly hatched hoppers with pesticides. EO assists during all the process, as these indicators (soil moisture and green vegetation) can be observed over large areas.

Locust monitoring is an activity that has been led for a long time by the FAO with various supporting organizations (ESA, EUMETSAT, Regional Climate Centres) to provide data to local governmental bodies in charge of locust, usually ministries of agriculture.

In addition, GNSS is widely used to assess the locust threat in the field and to take adequate measures when an outburst is detected. For example, the FAO elocust[30] project uses field reporting in combination with GNSS to monitor local situation, insect type and age and report potential locust outburst and development. Combined with 10-15 day weather forecasts, that provide useful data about wind direction and expected rainfalls, this is used to predict the path of locusts in flight and take preventive actions. And this information is also used to take adequate measures in the field once a locust infestation has been detected.

Space debris removal (GNSS)

The EU SST estimates that there are some 1 million objects over one centimetre in size that have no use orbiting the Earth. And as outer space becomes increasingly crowded, the risk of collision between space objects statistically increases with every new launch.

In this context, active debris removal is seen particularly valuable. Even more considering the imminent age of mega-constellations: thousands of satellites will soon be formation-flying in low orbits to offer low-latency telecommunications or global high-repeat Earth observation coverage.

The Astroscale ELSA-M spacecraft aims, for example, to remove multiple retired satellites from LEO in a single mission. This spacecraft will use the off-the-shelf 'Constellation On Board Computer' (cOBC) GPS and a Galileo-enabled RUAG GNSS receiver.

5.1.3 Applications in cluster 3: Response

This phase is initiated once the event occurs. Then, the users (such as civil protection personnel, paramedics, fire brigades or search-and-rescue staff) need quick access to the latest information (including EO imagery) to understand the extension of the damage from the event, identify the hot spots, flag the dangerous locations, etc to optimize the action in field.

[30] https://www.fao.org/ag/locusts/en/activ/DLIS/eL3/index.html

Crisis area assessment (EO & GNSS)

Information Management (IM) in the context of emergencies is vital, as it ensures that everyone working on the emergency gets the precise information that they need.

Figure 18 - Professionals in different control rooms will centralise information (picture for illustration)

During the response phase, EO data proves as an extremely useful contributor to generate a general picture of the area, while location-referenced GNSS information can be processed and incorporated into the general picture: GNSS geo-tagged information collected in the field (pictures, videos, text reports, routes and itineraries) about the positioning of assets (e.g. hospitals, warehouses) or most affected areas, or information obtained from social media, are examples of these.

Stakeholders are specialized organizations to produce the data and the civil protection as the users.

For Crisis Area Management, Copernicus EMS Rapid Mapping provides on-demand and fast provision (hours-days) geospatial information products in support of emergency management activities immediately following a disaster.

The so-called reference products allow responders to quickly acquire knowledge about the territory and assets prior to the emergency; this would typically be based on the latest images captured prior to the event.

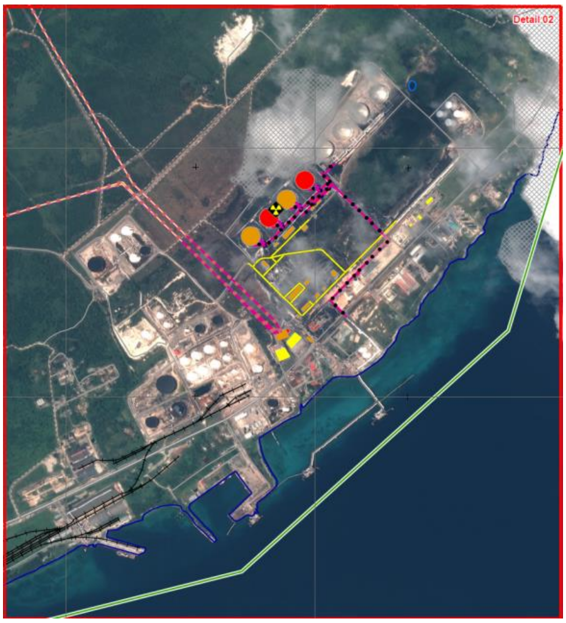

Figure 19 – Industrial accident in Matanzas, CUBA. Example of rapid mapping from Copernicus EMS. (picture for illustration)

Then, First Estimate products are used to assess the most affected locations within the area of study; they provide early information, with different levels of resolution and sensor types depending on the earliest suitable available post-event image. Delineation products (such as flood delineation maps) provide a better delineation of the event impact and its extent, allowing subsequent monitorisation as updated information is delivered.

Finally, grading products permit qualifying the damage caused by the event, considering the extent provided by the applicable delineation product.

In the field, rescue teams need guidance to use the routes that are still available to reach the affected areas. The detailed maps generated and the highly accurate navigation and positioning capabilities from GNSS will permit so.

Operational wildfires modelling (EO)

Fire-management agencies involved in decision-making have, over the last years, adopted the use of fire spread models/tools. These SW tools aim at accurately predicting fire progression, both spatially and temporally.

And what's more, the same models can be used to plan the application of suppression fires[31] during an emergency.

To improve the effectiveness of these tools, the scientific community is dedicating significant efforts to improve input data quality. For such purpose and context, remotely sensed observations from satellites, aircraft and UAVs have become fundamental.

Satellite-based active fire products have been used to generate fire spread maps, validate fire spread models and adjust simulations. Yet, they are subject to inherent limitations such as spatial resolution, return rates and atmospheric obstructions.

The DISARM project[32], for example, made use satellite data for the detection of fires and the estimation of biomass, amongst others, in order to deliver an innovative, integrated observatory platform and an early warning system for protecting the environment, thus promoting sustainable development in Greece, Bulgaria and Cyprus (the three participating countries).

[31] Intentional application of fire to speed up or strengthen fire suppression action on wildfire.

[32] http://disarmfire.eu/

In parallel, improvements in remote sensing methods bring accurate and updated spatiotemporal data of wildland fuels, canopy characteristics and their distribution, consequently improving the models.

The modelled behaviour of wildfires becomes then an input to plan the dispersion of firefighting means on the ground, and so firefighting brigades will use GNSS positioning to locate themselves in the assigned spots.

5.1.4 Applications in cluster 4: Search And Rescue

Figure 20 – Helicopter rescue operation (picture for illustration)

As part of an Emergency's Response phase, Search And Rescue activities might be one of the first activities with which to commence, while of course fulfilling the basic needs of the affected population on a humanitarian basis.

SAR crews need to act swiftly and efficiently to rescue the maximum number of persons while minimising the risk for the rescuers themselves. GNSS and Near Real Time information (including EO) is needed to identify the hot spots and plan safest routes in and out of the emergency area.

In this cluster, stakeholders are divided in two categories: the users who send an alert signal using a device specific to the sector (aeronautical, maritime, or land) and the authorities in charge of SAR operations that will use the signals to assist people in distress.

The Aviation, Maritime and Consumer Reports on User Needs and Requirements contain SAR-related descriptions and/or requirements for each specific segment.

Nevertheless, the following paragraphs provide an overview about how GNSS and EO contribute to SAR operations in the maritime, aviation and land domains.

SAR operations: at sea (GNSS)

On January 21 2020, the SAR/Galileo Return Link Service (RLS) was declared operational. Since then, Galileo not only locates people in distress and makes their position known to the relevant authorities (this capability was already operational back in December 2016), but also provides an automatic acknowledgement message back to the user informing them that their request for help has been received.

The SAR/Galileo service is the biggest contributor to the Cospas-Sarsat[33] MEOSAR programme in terms of ground segment and space segment assets, and is providing superb performances in, for example, ensuring RLS delivery latencies within 15 min. At user level, alerting systems include emergency position indication radio beacons (EPIRBs) and personal locator beacons (PLB).

On the other hand, GNSS allows aerial SAR means to follow precise search patterns over oceanic areas, where no visual references are available, thus optimising the operational constraints (fuel consumption, range, autonomy) and maximising its effectiveness.

SAR operations: aviation (GNSS)

ICAOs Annex 6 dictates that all aeroplanes should be equipped with Emergency Locator Transmitters (ELTs). These devices are an integral part of the COSPAS-SARSAT programme and help Search and Rescue operations in the event of an incident.

But aviation tragedies such as the losses of Air France 447 and Malaysia Airlines 370 made ICAO to newly develop the Global Aeronautical Distress and Safety System (GADSS) concept, with three main associated functions:

- Aircraft Tracking;
- Autonomous Distress Tracking; and
- Post Flight Localization and Recovery.

Aircraft Tracking is enabled by GNSS-derived positioning, which must be automatically provided (using available technologies as deemed effective) every 15 minutes or less.

Autonomous Distress Tracking ensures that the aircraft position information is transmitted at least once every minute, and includes the capability to deliver the distress tracking information to SAR Agencies. Again, there is no mandate about the type of technology to rely on. However, GNSS-enabled ELTs would cope with the need.

In the event of an accident, the Post Flight Localization and Recovery phase function relies on ELTs and ULDs (Underwater Locating Devices).

SAR operations: land (GNSS)

Climbers, hikers, bikers and, in general, any user accessing remote or difficult to reach locations, are advised to equip themselves with a Personal Location Beacon (PLB) in case they find themselves in distress. While many PLBs are based on COSPAS-SARSAT service, a market is quickly emerging that incorporates GNSS receivers but relies on private emergency services such as Focuspoint International or

[33] https://www.cospas-sarsat.int/en/

Garmin's International Emergency Response Coordination Centre (IERCC). In addition to sending SOS messages, these beacons allow to send positions and check-in messages on a regular basis.

In addition, when rescue teams perform the search of potential victims in disaster areas (be it under water, under snow or under collapsed buildings) with the help of thermal sensors and specially trained dogs, they can also can make use of GNSS to record the position of areas already covered.

Situational awareness supporting SAR (EO)

Search and Rescue is an overarching field, with specificities in each type of terrain the operation is to be conducted in. These subfields include air-sea rescue of aircrafts/sea vessels in distress, or mountainous and urban areas.

EO allows to map the risk, provide pre- and post-event imagery, as well as Near Real Time mapping to support the situational awareness of the crews, leading to a safer and more efficient SAR operation. The before and immediately after event mapping is crucial to improve the safety and efficient of SAR operations.

EO services can assist Maritime and Joint Rescue Coordination Centre's (RCC) during Search and Rescue (SAR) operations and exercises. EO information, combined with maritime data and external sources, can provide a better understanding and improved monitoring of activities at sea (incl. detection of ships in distress, SAR response support, etc.).

The Copernicus Marine Environment Monitoring Service, for example, provides oceanic dynamics data including real-time and forecast information on currents and winds. These effects cause drifts in the ship's position with respect to the reported, so the corresponding information becomes extremely helpful for SAR operations over the sea. This contributes to increasing marine safety.

Another example comes from the Atmosphere Monitoring Service[34], which provides products that help improve the situational awareness of SAR means. This service can identify and monitor ash plumes from volcanic eruptions, which can have dramatic consequences on aircraft engines. In this way, the service can support the operation of aerial SAR means near disaster volcanic areas.

But the term SAR in not limited to air-sea rescue over water. It also encompasses other specialities, according to the terrain the activity is conducted over, as can be urban SAR in cities or mountains. These other SAR operations can also be greatly improved by relying on EO-enabled situational awareness. Thanks to its mapping capabilities and together with in-situ data, Copernicus EMS provides thematic map layers with terrain features that can greatly improve the information available for SAR units over land.

[34] https://atmosphere.copernicus.eu/

5.1.5 Applications in cluster 5: Post-Event Recovery

The aim of the recovery phase is to restore the affected area to its previous state, with a significant focus on actions that involve rebuilding destroyed property, re-employment, and the repair of other essential infrastructure.

In urban environments, EO imagery can be used to estimate damages to infrastructure and insurance companies can use the post-event analysis data to analyse the damage to the areas, infrastructure and other objects with the view to define payments, etc.

On the field, GNSS is the perfect complement to EO, since it facilitates coordination of deployed means and increases the quality of mapping activities.

Restoration of supply chain and infrastructure services (EO and GNSS)

The reconstruction of supply chain networks plays a crucial role in post-disaster residential recovery programs. Supply chains of fuel, power, food, water and medical supplies are critical in the response phase. But during the recovery phase, other goods take relevance too, as could be building materials for housing reconstruction (e.g. clay, cement, bricks).

Analysis and understanding of the transportation footprint, to understand the resources required to move the goods, becomes of utmost importance. EO data can provide valuable data so support remote evaluation of transportation routes (e.g. highways, secondary roads, bridges) to help identify bottlenecks and define mitigation actions, such as alternate routing. Satellite EO data also supports the removal, re-building or creation of transport facilities, while giving insight to conduct analyses on accessibility, proximity or traffic activity. It can help monitoring the status of the so-called 'critical infrastructure' but also of essential parts of supply chains, as could be power plants, manufacturing facilities, or, simply, recovered access to gas stations that will ensure fuel distribution for cargo trucks.

GNSS also supports supply chain resilience. For real-time visibility platforms for shippers, logistics service providers and carriers, integration of GNSS becomes a powerful tool for logistics companies and supply-chains to better manage delays along their routes.

5.1.6 Applications in cluster 6: Humanitarian Aid

Humanitarian Aid is assistance to people who need it, usually short term and to victims of natural disasters, wars or famines. This segment focuses on material and logistical help to save lives, alleviate suffering, and maintain human dignity. EO and GNSS are widely used for a variety of applications.

Stakeholders include all organizations delivering aid: UN agencies (WFP, UNHCR, WHO, UNICEF), NGOs (ICRC, all Red Cross and Red Crescent, MSF, Oxfam, Save the Children, CARE, World Visio, etc.) and national agencies (ECHO, USAid, Crisis Response Centre of the German Federal Foreign Office, the French Centre of Crisis and Support of the Foreign Office, etc). In addition, there is a number of private companies (CLS, Airbus, Telespazio, SES, Marlink, etc.) or public organizations (UNOSAT, the EU Copernicus services, Rapid Mapping CH, Sertit in France, etc.) that specialize in processing EO or GNSS data to deliver actionable information for humanitarian aid. For some applications, especially when GNSS is used, stakeholders may include people in the field: either NGO and UN personnel or the refugees or people that are assisted.

Thanks to EO, the so called "geohumanitarian action" is made possible: the integration of EO and GI (geoinformatics) supports the planning and deployment of humanitarian aid. Organisations delivering humanitarian aid can gather data in conditions that, for example, could be dangerous on the ground, to conduct risk assessments in the preparedness phase or to analyse humanitarian aspects of natural and man-made disasters, including the displacement and settlements of persons, flows of refugees, availability of food, cases of violation of human rights (mass graves, destruction of buildings), etc. The characteristics and evolution of refugee camps, the number of refugees and even some of the conditions in which people live can be extracted from EO data, also to plan aid efforts and supplies accordingly.

In this context, GNSS can assist organisations by providing a means for in the field personnel tracking and local coordination.

Welcome applications to people in need of humanitarian aid (GNSS)

This includes applications ready to give support to people in need of humanitarian help. The Spanish Red Cross, for example, provides the LoPe (People Location)[35] service since 2008, with around 20.000 active users in 2022. This telematics service is based on an application installed in a smartwatch which reports its GNSS position every 10 minutes, allows for automatic entry&exit alarms configuration and consequently improves any kind of assistance that could be required during an emergency.

This service was initially aimed at assisting people who suffer from some type of cognitive impairment (dementia, Alzheimer's, memory loss, etc.) and who may become disoriented or lost, even when conducting simple activities such as the daily shopping. In these cases, the Spanish Red Cross operator will give a phone call and provide instructions, based on real-time GNSS tracking, to route the user back home.

Another example is the Integreat[36] app, aimed at quickly and easily providing newcomers (in a city or region) with local information in several languages.

Local information as made available by city councils, for example, can be provided to refugees. This includes geo-spatial information about local services, which the users can quickly access and navigate to using the smartphone embedded GNSS capability.

Figure 21 – Elders can also need humanitarian aid (picture for illustration)

ComuApp[37] is another application where help in one's local area can be requested and given. Originally conceived in the context of the COVID19 pandemic, the application is expected to also facilitate the provision of help to refugee in the context of the war in Ukraine. Information about needs is provided over a GIS, so the helper and the person in need of help can locate each other and meet.

[35] https://www2.cruzroja.es/web/teleasistencia/localizador-de-personas-lope

[36] https://integreat-app.de/

[37] http://commuapp.fi/en/

Management of refugee camps (EO)

Figure 22 - Settlement concentration (picture for illustration)

In this application, EO data is used for planning of camp layouts (be it as a preparatory step during the prevention phase, or as a mitigation one during the response), and for the distribution of resources e.g., wells and medicine, by displaying settlement concentrations and estimating population in different areas of a camp.

The management of refugee camps during the response phase is therefore active, up to the point where sometimes the camp may have to be re-allocated according to the evolution of the disaster.

EO is especially useful for camps that are not accessible because in a conflict area. Copernicus EMS product P18[38] uses very high-resolution imagery to provide information about human settlements structures, and particularly the informal settlements areas. However, their delivery time is stated to be 5 to 10 days.

For faster delivery and more accurate counting, users (such as NGOs not formally authorised to activate the service) sometimes prefer to make use of UAV imagery.

In the world's largest refugee camp located in Dadaab, Kenya (with more than 200000 refugees), EO data was used to monitor the camp evolution when back in 2011, the camp was overwhelmed by an influx of more than 160000 new refugees that made management from the ground impossible. EO was used to provide in-depth information for supporting efficient resource planning. Information on the amount and type of different dwelling structures and their spatial distribution were extracted through image analysis to support NGOs in the field.

Population Displacement monitoring (EO)

When monitoring of population displacement patterns is possible, due to conflict or disaster for example, then it is easier to plan humanitarian responses.

EO data can be used to monitor migration routes, as well as for the identification of temporary dwelling structures.

The Internal Displacement Monitoring Centre (IDMC) is providing data and analysis on internal displacement at a global scale. It has been using EO data to draw a fast and accurate picture of population distributions, especially for specific local contexts such as individual villages or refugee camps. It brings the benefit to make assessment even when the field is not accessible because of the local situation and it does not raise any privacy concern. The use of social media (e.g. Twitter) can be data source for Internal Displacement Monitoring when combined with machine learning.

[38] https://emergency.copernicus.eu/mapping/ems/p18-human-settlements-mapping

So in summary, research is still on-going to increase the applicability of such data sources to IDMC's monitoring work.

5.2 Focus on four key applications

5.2.1 Landslides and terrain deformation monitoring (cluster 2)

Description of the application

A landslide is a massive movement of rock, debris, earth, or mud down a slope.

While most landslides result of soil erosion and are caused by gravity, they can also be the consequence of rainfall, earthquakes, volcanic eruptions, groundwater pressure and erosion, but also by destabilization of slopes as a result of deforestation, cultivation, construction or snow or melting glaciers. Fast-moving landslides, such as mud flows, are especially dangerous because of their speed and volume. The current climate change increases significantly the risk of landslides in the future.

Given the losses that landslides can cause in terms of property and infrastructure damage, along with environmental degradation, it is of utmost importance to be able to prevent them from occurring, or at least to reduce their impact to a minimum in case of occurrence.

Two major applications have been identified for landslides monitoring:

- General inventory of landslides, mostly using change detection
- Monitoring landslides in predefined areas, using a variety of technologies.

Figure 23 – Example of a dwelling threaten by a landslide (picture for illustration)

In general, users need to analyse information collected from various sensors and technologies to **detect patterns and their changes and to issue early warning and other information relevant for the communities** to be prepared for an emergency ahead of the event.

Actors and stakeholders

The monitoring of ground motion including landslides is conducted in the context of many activities such as civil protection, mining, constructions works or tunnelling. Private companies and national surveying institutes are amongst the main actors in producing landslide maps. However, in the EMHA segment, main beneficiaries of this application include **civil protection bodies** . In countries or regions without such capability, **GIS and mapping experts from NGOs** present in the area become both users beneficiaries. Indeed, in the context of international development projects, landslides maps are sometimes used by NGOs to identify areas prone to landslides. This allows evaluating the risk faced by their own personnel if/when deployed in the field.

Technologies and role of GNSS and EO

There is a need for tools that allow locating, monitoring and conducting risk assessment of landslides. Today, different technologies can monitor landslides (in terms of terrain deformation) to help make territories more secure. Each technology has its advantages and drawbacks. Thus, the choice of the best monitoring solution depends on several factors, like landslides' typology and velocity or available budget.

Sensors commonly used in-situ include **piezometers and inclinometers**, whereas other technologies, such as **laser scans or UAVs** (which can carry different types of sensors) are also used when their relevant capabilities in terms of resolution, coverage or continuity of measurements, amongst other indicators, are deemed appropriate.

The use of **EO** and of **GNSS** is also a reality since several years ago. And as landslides are a major threat to human life, property and constructed facilities, infrastructure and natural environment especially in Europe, there have been several R&D projects addressing this problem.

In 2010, the Safeland project[39] supported by FP7 started identifying satellite techniques as technologies for monitoring risk areas and tools for early warning.

A few years later, the GIMS project worked on the integration of various monitoring technologies, including EGNSS, Copernicus SAR and in-situ sensors, to monitor landslides' ground deformations. **EGNSS provided point-wise continuous monitoring; SAR provided area-wise monitoring at each satellite pass** (for Sentinel-1, every 6 days). With this baseline, the GIMS consortium was able to identify up to which level the current capabilities of these EU technologies can support landslide monitoring tasks, to finally define recommendations (in the form of EU Space programs user requirements). See project's deliverable *D3.1 – User Requirements Document* [40].

Satellite-based generated maps (i.e. EO) allow **overall monitoring of landslide displacement** by processing radar images. By means of interferometric analysis, these images (with spatial resolution of several meters) allow measuring ground motion of large areas with millimetre accuracy.

[39] https://www.ngi.no/eng/Projects/SafeLand

[40] https://www.gims-project.eu/work-packages/

The effectiveness of satellite EO for this purpose, however, is hampered in the following situations:

- if the landslide moves quickly or if it is covered by snow;
- if real-time measurements are needed;
- in vegetated and forested areas;
- in hilly and mountainous terrain, where signals may be shadowed or suffer from foreshortening or layover.

Satellite EO, imagery in the visible spectrum, is also used to perform **an inventory of landslides**. This inventory is done annually on a particular area or after heavy rain. It requires to have regularly images on the same zone and is based on change detection. This information is used in modelling.

When it comes to Copernicus, the following remarks must be made:

- At product level:
  - The Copernicus Emergency Management Service Product 17 aims to provide **landslide risk assessment**, supporting decision makers in localizing areas prone to landslides, helping them defining anti-landslides measures.

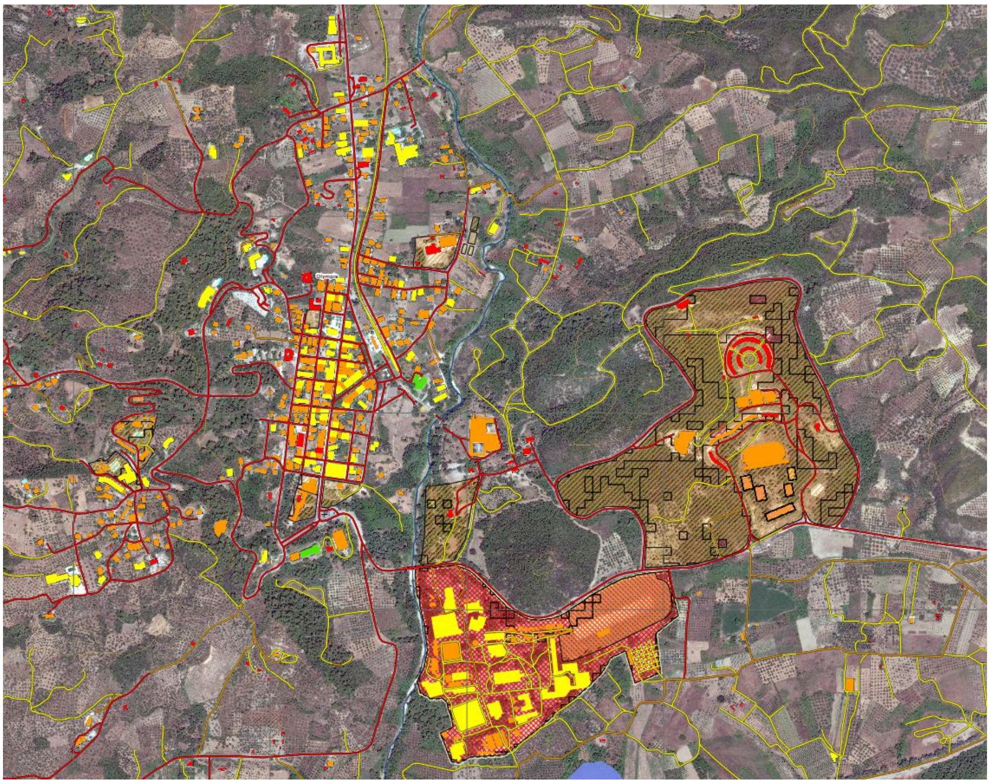

Figure 24 – Detail of Copernicus Landslide Risk Assessment (earthquake induced) for Olympia archaeological site (2022) (picture for illustration)

  - The European Ground Motion Service (EGMS)[41] from the Copernicus Land Monitoring Service represents a baseline for ground motion applications at continental, national and local level. Indeed, the service is a direct response to the request of users for ground motion data at continental scale.

[41] https://land.copernicus.eu/pan-european/european-ground-motion-service

In the case of **slow-moving landslides**, EGMS provides an opportunity to study them. The EGMS does multi-temporal interferometric analysis (InSAR) of Sentinel-1 radar images at full resolution. This technique allows identifying reliable measurement points for which ground motion velocity values and time series of deformation are extracted. The relative motion between points on the ground is measured with very high (millimetric) accuracy; however InSAR cannot directly measure an absolute motion. This implies that external data is needed in order to reference the ground motion estimates to an absolute frame of reference. Typically, **GNSS networks are exploited for resolving this issue**. In other words, GNSS data is used as calibration of the interferometric measurements. In the case of the EGMS, almost 4.000 GNSS stations located over the European continent were used.

- At data level, Copernicus possesses several features related to landslides monitoring. Thus, service providers making use of the data to apply their own InSAR algorithms enjoy from:
    - Global coverage: under nominal operations allows to have Sentinel-1 data every 6 days;
    - Both the ascending and descending modes of the imagery. This is an advantage since it allows for better results.

GNSS, on the other hand, can monitor movements down to millimetric level (through the use of PPP or RTK techniques), and systems able to collect data at a frequency of 1Hz with Near Real Time processing are **especially useful to monitor fast-moving landslides**.

However, this performance is achieved for single points i.e. locations where the GNSS station is installed. For this reason, it cannot give an overall idea of a landslide's movement. Positioning of antennas is also time-consuming, unless these are permanently installed, and in some situations the availability of continuous power supply to the GNSS stations may be complex.

Achievement of millimetric accuracies is favoured by the increasing availability of dual-frequency (L1 + L5) receivers, as these permit removing measurement errors caused by ionospheric effects. But since the monitoring of terrain deformation and of landslides through GNSS is usually conducted by means of several ground stations, the use of single-frequency receivers is also possible. When the distance between the monitoring stations and the base station is short enough, the ionospheric delays can be removed rather easily without having to use dual-frequency receivers, which tend to be more expensive. Today low-cost mono (L1) frequency receivers exist, and full operational systems (including battery, digitizer, solar panel and real time telemetry) are available for ca. 700€ per station.

Dual-frequency is thus mostly desirable when the baselines are longer, over 10km; that is when the ionosphere starts to decouple from stations.

In any case, sometimes both methods (GNSS and EO) are combined in order to improve the overall result. Worth to note is the case when GNSS in-situ measurements are used by service providers to validate Interferometric Synthetic Aperture Radar (InSAR) images, as presented above for the Copernicus EGMS.

The following table presents the main GNSS user requirements for *Landslides and terrain deformation monitoring*. The definition of the key GNSS performance parameters can be found in Annex A1.1.

GNSS user requirements for Landslides and terrain deformation monitoring		
Accuracy	Horizontal	cm / mm-level
	Vertical	cm / mm-level
Availability	Canopy	No
	Better than 95%	High
	Better than 99%	High
Robustness		Low
Integrity and reliability		Low
Spectrum	L1	Always needed
	L1 + L2	Sometimes needed
Size, weight, autonomy	Relevance	Yes
	Time a device can run in the field	Up to several years
	Antenna size	The smaller the better.
Cost	Price of full monitoring station	<1.000€/station
TTFaF		A few minutes
Sampling	Frequency of recordings	1 Hz
Service area	Geographical coverage	Regional / Local

The following table introduces the practical EO user needs for *Landslides and terrain deformation monitoring*, linking it to the service providers services offering.

ID	EUSPA-EO-UR-EMH-001	EUSPA-EO-UR-EMH-002
Application	**Landslides and terrain deformation monitoring**	
Users	Civil Protection bodies, National Institutions, NGOs, Mapping Companies	Civil Protection bodies, National Institutions, NGOs, Mapping Companies
User Needs		
Operational scenario	**Monitoring of landslide displacement.** Surveillance of a specific area for landslides and ground motion with great accuracy	**Inventory of landslides** Maintaining a database of landslides though a regular inventory of events.
Size of area of interest	Local and Regional	Regional
Scale	Millimetric	Metric
Frequency of information	Less than every 5 days, 3 days if possible.	Once a year or upon request (after an event)
Other (if applicable)	Availability under cloud cover or a lack of illumination.	Availability under cloud cover or a lack of illumination.
Service Provider Offer		
What the service does	Provides downloadable files to the user, preferably georeferenced raw data with quality index and metadata AI can be used for accelerating the processing of data and to automatically detect new landslides.	
How does the service work	For scheduled acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider.	
Service Provider Satellite EO Requirements		
Spatial resolution	SAR: mm level Optical: submeter level	Optical: meter level
Temporal resolution	3 days	1-2 per year
Data type / Spectral range	Optical SAR: C-band, L-band and X-band.	Optical
Other (if applicable)	Better collocation (revisit at the same spot)	
Service Inputs		
Satellite data sources	Synthetic aperture radar (SAR) instrument operating in one or more bands (X, C and L): Sentinel-1, Cosmo Skymed, Saocom, Radarsat, IceEye, Capella Space. Optical: Sentinel-2, Pléiades, Landsat, Maxar Worldview, Planet	Optical: Sentinel-2, Pléiades, Landsat, Maxar Worldview, Planet
Other data sources	Not satellite-based	Field checking with visual inspection and local data collection

5.2.2 Post-crisis damage assessment and building inspection (cluster 5)

Description of the application

During the recovery phase of the disaster management cycle, it is necessary to assess the damages caused by the event to assets, typically buildings and infrastructure. These assessments have a double purpose. On one hand, they allow to identify which structures are sound and can be inhabited again and which ones are no longer habitable. On the other hand, the identification of the overall damages is used to identify the general impact zone of the event and to assess the direction and strength of the event in the case of an earthquake.

Figure 25 – Example of damages on a building (picture for illustration)

As shelter is one of the critical needs of communities affected by a disaster, this remains a central part of a humanitarian response in any given crisis (no matter if due to man-made or natural disaster event). Shelter provides security and personal safety, protection from the elements and resistance to disease. Therefore, those who have lost their homes altogether want to rebuild them as soon as possible; and those who saw that schools and/or medical facilities, close to their homes, have been destroyed will also want them back into service.

Actors and stakeholders

Before re-building activities may restart, it becomes necessary to know the status of populated/city areas.

In this way and to plan the recovery, **decision-makers (civil protection bodies and rescue teams)** work with maps where the after-event situation is depicted, and the location of buildings and infrastructure are shown together with information about its status/damage grade (e.g. not damaged, damaged, destroyed) and other available field data. **NGOs** also benefit from these assessments so as to know where their support may be more urgent.

Technologies and role of GNSS and EO

Satellite EO data has proven, and is, extremely useful for these assessments; satellites are very well suited for **large-scale assessments** and provide a fast and cheap way to conduct preliminary assessments, including evaluation of the affected region's accessibility. The comparison of recent and archival EO data assists relevant actors to picture accurate damage assessment. Maps generated with EO can help identify the zone impacted by an event such a fire, earthquake or flood. SAR data, for example, is used to produce impact maps of flooded areas, with the benefit of being available regardless of weather conditions.

The strength of EO is its capability to provide a rapid picture of the situation when communication is difficult (loss of networks) and before first responders have arrived onsite.

It is worth noting on the other hand that methodologies to use EO in this kind of applications are being consolidated. In this context, scientists aim for solutions providing higher revisit times and higher spatial resolutions.

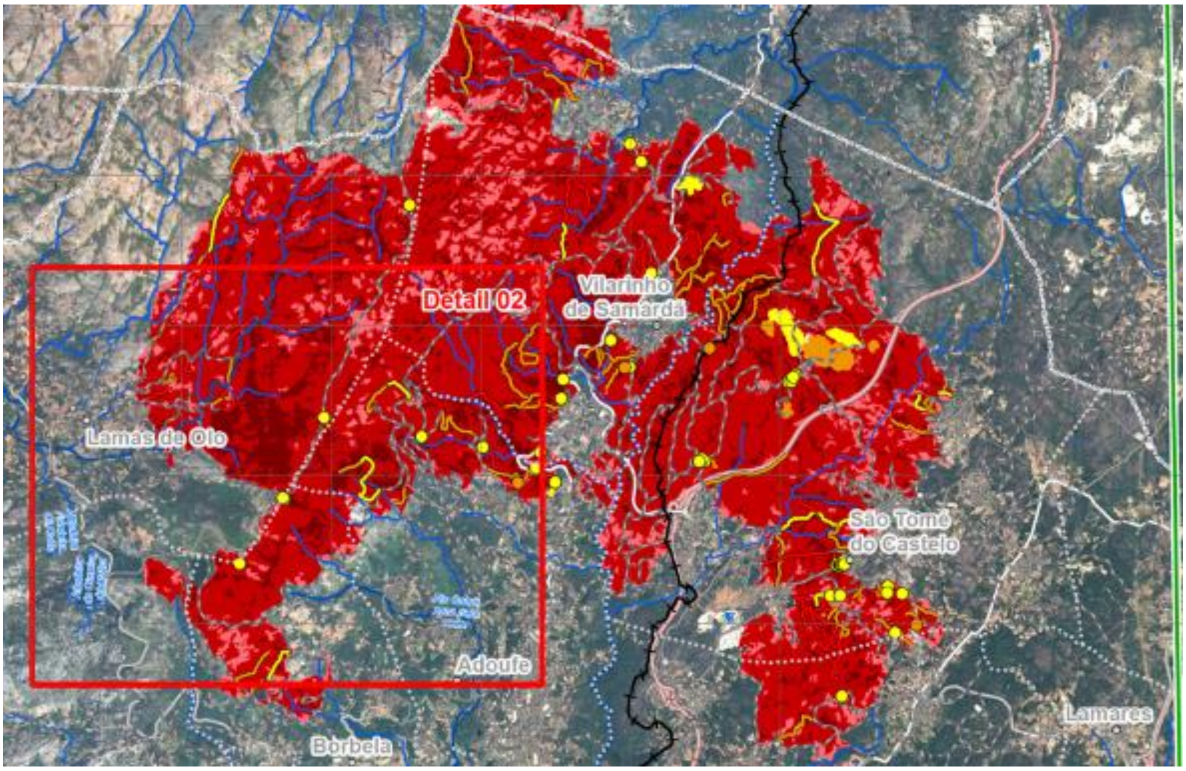

Figure 26 – 2022 Portugal wildfire: detail of Copernicus' damage assessment (from Copernicus EMS, data from Spot6) – Destroyed areas in red.

In addition, satellite EO data has the capability to provide pre-event images. For example, during the 2010 Haiti earthquake, the only pre-event images that were available were satellite images. This information was crucial in helping to discern damage patterns from the earthquake. In the first days, the "counting" of number of severely-damaged buildings was based on very high-resolution orthographic satellite imagery (better than 1m and up to 30 cm resolution)[42].

[42] https://www.gfdrr.org/en/publication/2010-haiti-earthquake-post-disaster-building-damage-assessment-using-satellite-and

Another example is Copernicus EMS Product 08[43], which provides a comprehensive assessment of the event's impact on the infrastructure in the affected areas with so-called grading maps. These maps identify the damages locally on a 5 categories scale (no damage, negligible to slight damage, moderately damaged, highly damaged and destroyed). **EO is used to provide a rapid assessment of the situation**, the limit being the precision of the information (EO is limited to the two last categories), the weather constraints, the fact that only vertical damage can be assessed and the lack of information on the building itself (age, nature of construction, etc..).

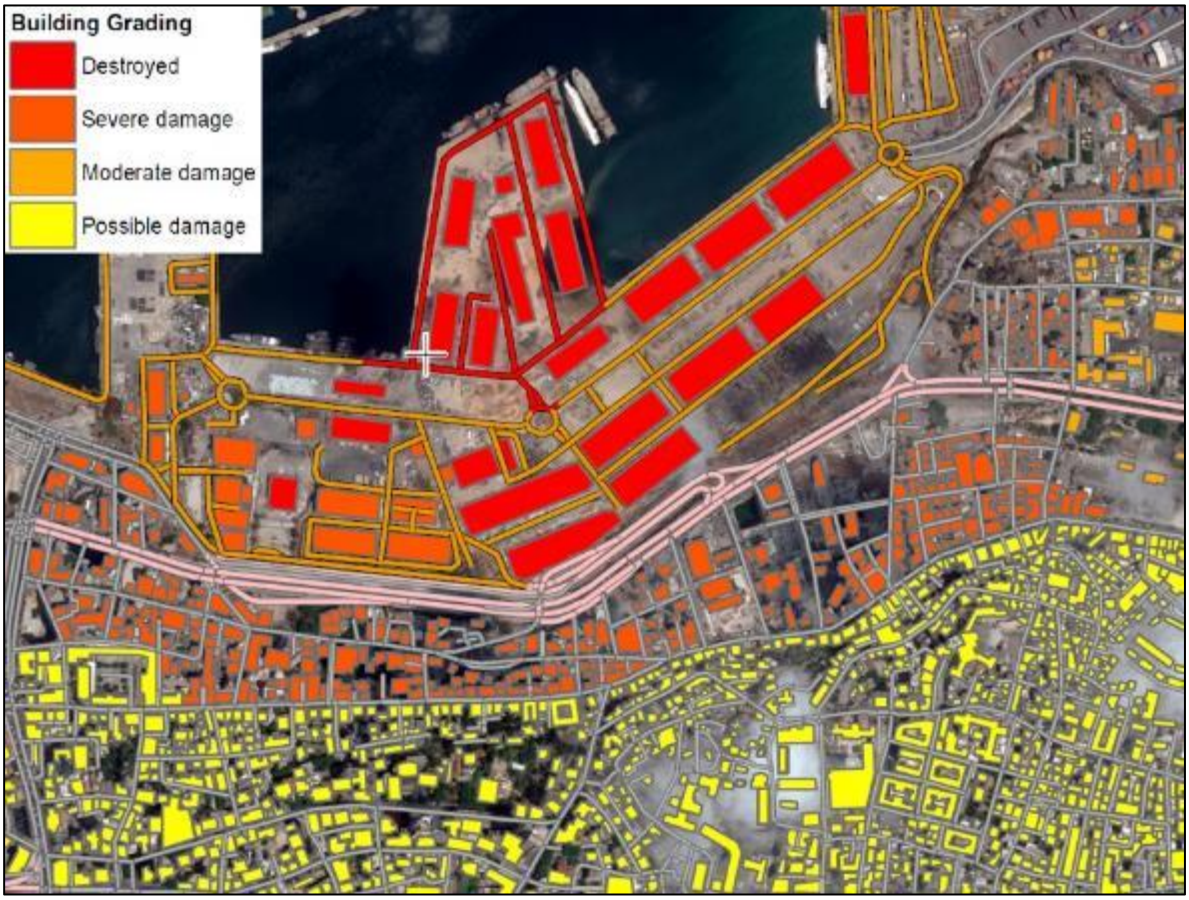

Figure 27 – 2020 Beirut's explosion: detail of Copernicus' damage assessment (adapted from Copernicus EMS) (picture for illustration)

Thus, an onsite **detailed building inspection** is necessary to complement the use of EO observation. Specialised personnel from civil protection bodies will conduct physical inspections of every building, as risk allows, to collect detailed information about its status and number of households. The preliminary estimation in the number of damaged buildings permits calculating the number of technicians necessary to be sent in-situ for detailed inspection of buildings.

Different types of ambient vibration measurement equipment, such as accelerometers or velocimeters, will be used in-situ too to conduct ambient vibration (AV) surveys[44]. These devices are installed on the floors of buildings and allow obtaining information about the dynamic properties of the structure,

[43] https://emergency.copernicus.eu/mapping/copernicus-emergency-management-service#zoom=2&lat=40.12004&lon=30.60926&layers=0BT00

[44] A step forward could be COTS services consisting on continuous building monitoring systems that provide instant notification when a building threshold is exceeded.

including the fundamental frequencies mode shapes and damping ratio. In areas prone to earthquakes, for example, comparison of pre-event and post-event measurements allow identifying if and how much the building was affected.

GNSS antennas and receivers are installed too (indeed not always only during the recovery phase). By making use of precise positioning techniques, GNSS equipment may be installed for years on the roof of large buildings or in open-sky areas of infrastructures (bridges and viaducts, dams...) and measure potential movements with an accuracy in the range of 2-4 millimetres. Such high accuracy is needed to monitor the displacements/deformations of very rigid buildings, a type to which critical buildings most times belong to.

The case of cultural heritage protection, finally, is worth to mention as a matter particularly relevant for Europe. An ever-increasing interest on this subject is being observed and several countries and even, the Copernicus EMS, are working on it to set-up specific services and/or products.

The use of drones is also increasing in the field as they are well suited for quick micro assessments. They allow to provide a damage assessment both vertically and horizontally. All data is georeferenced to provide an accurate mapping of the damages, and state-of-the-art techniques now allow a 3D reconstruction of the scene thanks to photogrammetry with a cm accuracy. Ground Control Points (GCPs) will be used when absolute accuracy is needed, however their use may not be straight-forward during an emergency situation. Therefore, the accuracy of 3D reconstruction models may vary depending on the operational scenario.

Geo-tagged (i.e. GNSS) text, pictures and/or videos, helping assess the impact of the damages both from the humanitarian and financial (i.e. documentation for cost claims such as insurances) perspectives will be of great importance too. Indeed, it is worth noting the increasing reliance in smartphones, which enable users to become map creators as a result of the democratisation of digital mapping. In this way, in some regions in the field NGOs will use smartphones (and handhelds) to 'map' such data: for example logging of waypoints at the start and end of damaged road sections or logging of tracklogs around the perimeter of damages (e.g. around the perimeter of remaining flooded and/or collapsed areas).

For example, as part of a European FP7 Funded Project called GEO-PICTURES[45], the UN-ASIGN application was developed and made available for Android and iOS devices. The app allows the crowd-sourcing of geo-tagged photos and text from areas affected by larger humanitarian disasters. Seconds after the geo-tagged image is sent by the smartphone, it becomes available in a map at the receiver side. This app requires the availability of communication networks to be effective.

This in-situ visual information helps UNOSAT, affected countries, UN, EC, ICRC and NGOs to make better and faster decisions in disaster management, but also to assess damages both during the response and post-event recovery phases.

The geo-tagging and timestamping of photos is made through device-embedded GNSS chipsets, supported by cellular (3G) and Wi-Fi networks positioning when indoor. In addition, due to potential communications bandwidth limitations, photos are compressed significantly to save time and cost.

A step forward was conducted in the H2020 GEO-VISION[46] project. A mission-critical visual communications software solution was implemented to guarantee that critical visual information would

[45] https://cordis.europa.eu/project/id/242390/en

[46] https://cordis.europa.eu/project/id/641451

get through to emergency services, potentially in areas were communication networks may have low and unknown capacity.

On the one hand, the project innovated on how GNSS is used for providing trust and confidentiality into data provided by UAVs deployed in the field, mainly through Galileo signal authentication (OSNMA), spoofing and jamming countermeasures.

To sum up, **the work of end users relies on a thorough and long-terms analysis of the evolution of the area post-event and also comparison with the pre-event situation where necessary. The field users must be capable of collecting and sharing geo-referenced photos, text and videos**.

The following table presents the main GNSS user requirements for *Post-crisis damage assessment and building inspection*.

GNSS user requirements for Post-crisis damage assessment and building inspection			
Accuracy	Large-scale assessment	Horizontal	m-level for geotagging dm-level for UAV 3D reconstruction
		Vertical	m-level for geotagging dm-level for UAV 3D reconstruction
	Detailed building assessment	Horizontal	2 mm cm-level for UAV 3D reconstruction
		Vertical	3-4 mm / 2mm for critical buildings cm-level for UAV 3D reconstruction
Availability	Urban canyon		Yes
	Better than 95%		Medium
	Better than 99%		Medium
Robustness			Low
Integrity and reliability			Low
Size, weight, autonomy (when smartphone based)	Relevance		Yes
	Time a device can run for geotagging		>5h
TTFaF	In hot start		A few seconds
Service area	Geographical coverage		Regional / Local

The following table introduces the practical EO user needs for *Post-crisis damage assessment and building inspection*:

ID	EUSPA-EO-UR-EMH-003	EUSPA-EO-UR-EMH-004
Application	**Post-crisis damage assessment and building inspection**	
Users	Civil Protection bodies, National Institutions (Geological Institutes, Research Centres), NGOs	Civil Protection bodies, National Institutions (Geological Institutes, Research Centres)
User Needs		
Operational scenario	**Large scale damage assessment** The user needs a fast overall assessment of the zone and structures impacted.	**Detailed building damage assessment** The user needs an accurate, reliable assessment of the damages to structures. It can be urgent for re-housing purposes or less urgent for insurance or reconstruction.
Size of area of interest	Regional or local	Local
Scale	Large	Building level
Frequency of information	Very much depending on the type of event. At most, earthquakes or volcanic events may require daily updates.	Single acquisition.
Other (if applicable)	Timeliness of data delivery: 1 day	Timeliness of data delivery: 5-10 days
Service Provider Offer		
What the service does	**General mapping of impacted zones and structures.** Provides downloadable files to the user, in the form of products already calibrated and geo-referenced. In addition, AI is applied for accelerating the processing of data incl. automatic detection.	**Detailed characterization of buildings or other infrastructures** Provides downloadable files to the user, in the form of products already calibrated and geo-referenced.
How does the service work	For scheduled/archived acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider.	
Service Provider Satellite EO Requirements		
Spatial resolution	Optical: 10x10 meters. SAR: <10x10m already available.	<1x1 meters
Temporal resolution	Daily in the immediate aftermath of a disaster	N/A
Data type / Spectral range	Optical (either as primary or as backdrop): RGB and infrared. SAR: C-band, L-band and X-band. Must integrate data from different sensors and technologies (satellite, UAV and in-situ).	Optical (either as primary or as backdrop): RGB and infrared. SAR (processed products): C-band, L-band and X-band.

		Must integrate data from different sensors and technologies (satellite, UAV and in-situ).
ID	EUSPA-EO-UR-EMH-003	EUSPA-EO-UR-EMH-004
Application	**Post-crisis damage assessment and building inspection**	
Service Provider Satellite EO Requirements *(continued)*		
Other (if applicable)	Pre-processed data must be provided to technical final users. Metadata must be provided to final users, together with historical data before the event. Decision makers require actionable information.	Pre-processed data must be provided to technical final users. Metadata must be provided to final users, together with historical data before the event. Decision makers require actionable information.
Service Inputs		
Satellite data sources	Sentinel-1 and 2 data. Data from commercial providers (Airbus, Maxar…)	Data sources such as Pleiades, GeoEye or WorldView are used. In some instances, the satellite data is made available through the Copernicus Emergency Service.
Other data sources		Data collected by aircraft, drones and observers on the ground provide additional and more accurate information

5.2.3 NGOs’ assets management (cluster 6)

Description of the application

In crisis zones, humanitarian aid has to reach the most vulnerable populations, often located in remote places. The ability of humanitarian actors to reach those most in need, or the affected people’s access to assistance and services is often restricted. Truck convoys are a common method to distribute any sort of goods and supplies, depending on the needs of the receptors and the nature of the disaster. The same convoy might be used, in the return trip, to evacuate people from affected areas.

Unfortunately, attacks on humanitarian aid convoys may occur: the convoys are either attacked whilst travelling (in transit) or whilst docking and unloading at the warehouse/distribution centres. Such a thing may happen both in conflict[47] and in non-conflict zones.

One way to increase the security of convoys is that these report their position on a regular basis, so alerts can be raised and help be deployed in case of need.

Figure 28 - Humanitarian convoy (picture for illustration)

[47] IHL violations continue to be among the most critical challenges for protecting civilians and humanitarian and medical workers. Buildings belonging to relief organisations are attacked, vehicles and convoys hijacked, and personnel murdered or kidnapped. Such violence affects civilians and prevents millions of people from receiving life-saving assistance.

Actors and stakeholders

UN agencies and NGOs are the main promoters of this application. But given the nature of their activities, justified concerns hence exist when it comes to the safety and the security of those involved.

In this way, the Inter-Agency Standing Committee (IASC) of the UN has developed non-binding guidelines under the overriding principle that armed escorts for humanitarian convoys should be used only as a last resort. With this in mind, it is considered that space programs can provide solutions that help increase the safety and security levels of humanitarian operations.

Technologies and role of GNSS

Traditionally, periodic reporting of a vehicle or convoy's position could be done via voice radio.

However, nowadays such reporting has significantly improved thanks to the availability of **GNSS-based real-time tracking solutions**, aimed at providing real-time localisation capabilities of staff who are on a mission, allowing the control centre to monitor their location and maintain situation awareness.

In this way, **GNSS-enabled telematics allows humanitarian organizations working in crisis zones to track assets and personnel**. This improves the safety and security of both the personnel and the delivery vehicles working in emergency response. For most operations the UNDP MOSS (Minimum Operational Security Standard) apply and they call for a GNSS based tracking system for all field vehicles. Thus, most UN agencies have fitted all their vehicles (SUVs and trucks) with telematics devices. In security-critical places, there is even more redundancy, since the GNSS tracking device is complemented by voice radio that can be also used for reporting. In addition, vehicles include a panic button that end-users can push in case of an attack or carjacking to alert the local office. Since the use of "UN markings" on vechicles has significant implications (NGOs often act as implementing partners of UN agencies, using the same fleets of vehicles), it is usually possible to shut the engine down remotely and thus immobilise the vehicle.

In the case of medical goods or other perishable supplies, GNSS-based positioning is complemented with other information such as the cargo's temperature and humidity, to allow continuous monitoring of its status.

GNSS telematics also improves fleet performance, leading to vehicle fleet optimisation up to 15%. This is happening thanks to a new concept implemented by UN agencies (such as UNHCR) and NGOs based on vehicle leasing instead of buying. Fleets of vehicles are now centrally managed from Dubai and vehicles are allocated on a country-by-country basis depending on operational requirements. Once operations are over, vehicles are returned to the central facility and maybe reallocated to other countries. This organization requires a permanent knowledge of vehicles whereabouts and usage to manage efficiently the fleet and its usage.

Other applications of GNSS are also deployed by the Humanitarian Aid actors such as **fleet sharing** (among different agencies), vehicle trip reservation and sharing (a mix of BlaBlaCar and Uber-like service dedicated to UN fleets) or smart routing. This reduces the environmental footprint and the operational costs linked to fuel and maintenance.

This type of applications must be designed, not only with accuracy in mind, but also with safety and security objectives in mind, and considering the operational environment in which is to be used. In addition, integration of services or data in legacy systems must be considered too (a generic requirement overall the humanitarian aid sector): new technologies and services will be embraced if they seamlessly integrate in legacy systems in support for a better decision-making process.

Better planning of humanitarian operations will be possible as more and more information from different organisations can be placed together in one place; this will allow developing new tools and services.

Therefore, the GNSS-enabled telematics positioning and tracking solution should be such that allows for:

- Continuous and automatic recording of track and position;
- Automatic sending of real-time and archived tracks and positions to the control room, when under network coverage;
- Depiction of the user's location on a map;
- Metric-accuracy geolocation;
- Anonymity of individuals in case of device or messages interception;
- Two-way communication between user and control room, allowing the user to report threats, current location, or for the control room to send notifications/alerts;
- Resilience to attacks or interferences like jamming or spoofing;
- Security and confidentiality of the data;
- Integration into legacy systems.

The following table presents the main GNSS user requirements for *NGO's Asset Monitoring*.

GNSS user requirements for NGO's Asset Monitoring		
Accuracy	Horizontal	m-level
	Vertical	m-level
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	Yes
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		Low
Size, weight, autonomy (when smartphone or handheld based)	Relevance	Yes
	Time a device can run	>5h
TTFaF	In hot start	Less than a minute
Service area	Geographical coverage	National/Regional

Finally, it is worth mentioning that in the future, and once the use of tracking data is more and more normalised, the humanitarian community will **start exploiting archive tracking data for other uses and applications** such as the identification of goods delivery points, accessibility constraints (e.g. road closures, "access constraints" maps), impossible crossings, or even the mapping of road networks. **The potential for getting the most out of such data is big (even more if combined with EO) and represents a field for exploration**[48] which still needs to resolve a number of issues, like for example the security and confidentiality implications derived from sharing data between humanitarian organisations.

[48] The creation of applications that can detect infrastructure changes, such as dynamic access constraint maps, could be one of those benefitting from combined use of GNSS and EO.

5.2.4 Health and medicine response and coordination (cluster 6)

Description of the application

Understanding the needs of the people affected by a crisis is one of the most important tasks of humanitarian responders. When disasters occur, it is essential to know, as precisely as possible, the zone impacted and the number of people affected.

The counting, or estimation, of populations is of particular relevance, as it constitutes one of the main elements used to plan aid efforts and supplies. Estimations might be used to plan the distribution of essential products, such as food, blankets, medicines or water, be it in urban areas, in underserved areas or in refugee camps. Usually, aid is provided according to the SPHERE standard (see chapter 4.2). The use of this and other standards from OCHA and IFRC allows the Red Cross and Red Crescent societies, for example, to work under the same principles and apply the equivalent procedures for each of the capabilities needed in a response.

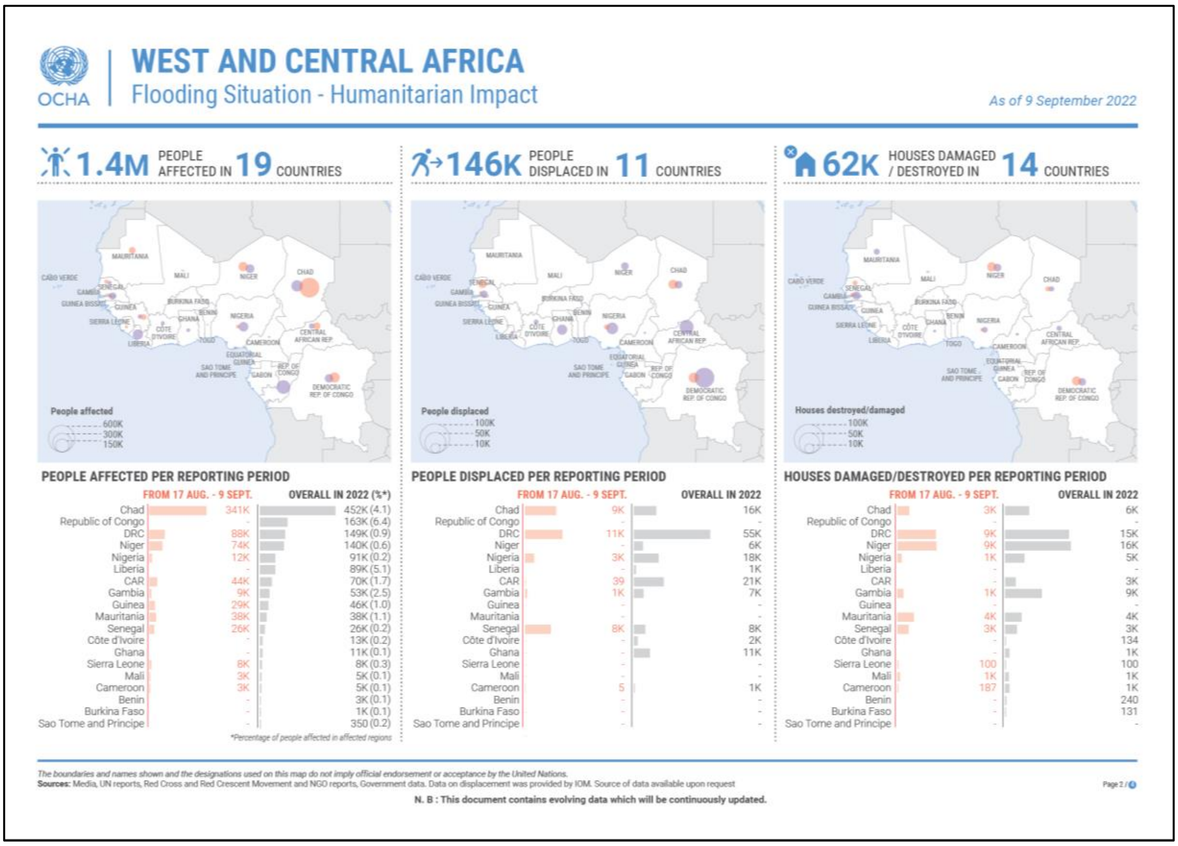

Figure 29 – Humanitarian impact of floods in West and Central Africa (source: UNOCHA) (picture for illustration)

On the other hand, the response must always be coordinated by the different stakeholders that are deployed in the field. For example, it is common across Red Cross and Red Crescent organisations that the leadership is held by local societies, providing others whenever possible the kind of help the local society is requesting.

One of the tools that is used for this coordination is the 3W (who does what and where)[49] analysis. Its main purpose is to show the operational presence by sector and location within an emergency.

A needs assessment can then be drawn up. This will help to define potential response options, evaluate the priority needs of affected communities and plan the different activities to be carried out in an efficient way.

It is important to remember that the impacts of disasters or crises vary from one to another, but affected people typically need the following types of support in the immediate aftermath: food, safe drinking water, shelter, essential items (such as blankets, heaters and water containers), medical care, sanitation and waste disposal, psychosocial support and protection.

At the same time, the needs will vary significantly according to the phase of the disaster.

The situation tends to change rapidly during the first two or three weeks immediately following the disaster. In the majority of occasions Search And Rescue missions tends to be concentrated in this period. In this phase, it is highly desirable to operate with information updated on a daily basis. In addition, because all organisations and responders need to become familiar with the, it is highly probable that the extent of the areas under evaluation are relatively large.

As the situation is better known and stabilizes, it eventually enters into Early Recovery. It is then acceptable to relax the recency of the information managed and focus into selected areas of a more local scale.

Actors and stakeholders

Civil protection bodies and humanitarian organisations (such as the ICRC), or UN agencies acting in disaster areas, need to count with this information for the above-mentioned goods distribution planning. In the humanitarian sector, in particular, there are two types main types of 3W product consumers: in-country responders and global/headquarter based humanitarians.

In first world countries, estimation of people affected by a disaster (e.g. number of evacuated people due to a wildfire) may be somehow straight forward as geospatial data might available from various sources, such as **local councils or national institutes**.

However, in countries and regions where census data may not be accurate, or where refugee camps have been established without apparent planning, it becomes necessary to make use of technologies that permit such estimations. **National Governments, Regional Authorities, NGOs and other 'end users'** need to monitor displacement of refugees and internally displaced persons (IDPs), as well as to manage refugee camps.

[49] As 3W maps contain a large amount of information, please see UNOCHA's 3W dashboard for an example https://3w.unocha.org/

Technologies and role of GNSS and EO

Satellite imagery and EO are very powerful tools for population counting.

Lack of baseline data is in some places a big limitation. Indeed, many of the most vulnerable places to disasters are also the less mapped places on the planet. That was the main motivation for the creation, several years ago, of the Missing Maps initiative. Under this initiative, volunteers make use of **visible satellite imagery** to identify dwelling structures, which then must also be inspected on-site by more volunteers.

Hence, in combination with population density statistics, local knowledge or other sources of information, EO allows estimating population based on (semi-) automated dwelling counting from very high-resolution optical satellite imagery. In some occasions, however, the resolution of available imagery is too poor or the images are too old to be used. Indeed, for most NGOs automation has not been incorporated in their data processes.

Therefore, the response of NGOs and other organisations will be improved if detailed maps of the affected areas are available:

- Base maps might be of different natures although, fortunately, in the last years and thanks to **satellite EO**, they are becoming increasingly accurate. However, the response can only be guaranteed if these are complemented by showing post-event effects: specific hazards, affected roads, key landmarks and work areas, location of logistics resources, and medical treatment areas, to name a few. Tthe use of EO data is for the time being mostly limited to satellite optical imagery or drones. Neither SAR images nor Artificial Intelligence algorithms are used.
- To improve these maps and make them even more useful both during the response and post-event phases, personnel working 'in the field' will collect a significant amount of data. This precious data will have to be **geo-referenced**, to the best possible extent, to permit its subsequent 'mapping'. This georeferencing is usually achieved thanks to GNSS. **Deployed personnel will use GNSS devices (handhelds and smartphones typically) to 'map' relevant data**, exactly in the same way as it is done for post damage assessment and building inspection activities, where relevant information consists on geo-tagged (i.e. GNSS) text, pictures and/or videos.
- With the final objective to improve the response, information must be collected, for example, on the location of village centres, water wells, clinics or even individual disease cases, logging of tracklogs along the main roads/streets of settlements, etc.

As for **GNSS-related requirements**, the kind of tools used by humanitarians have to be taken into account. In particular, it should be noted how:

- Smartphones provide friendly data-entry capabilities and today, most people, including local communities, use or own one. Together with tablets, they are perfect when gathering data using offline applications, becoming so useful to collect primary data via surveys that are tailored with relevant questions and can include photos or audio if necessary. However, they tend to suffer from battery life duration when the 'GPS function' is constantly being used and options for battery charging are scarce. In crisis areas, the user must plan for that and for having some sort of locally-stored base map that can be displayed (even if with very crude and certain amount of detail) and which will at least provide a broad overview of the user's location.
- Handheld devices typically solve these two issues (bigger battery and incorporated base map) and tend to be more tolerant against external agents like dust and humidity. However, they normally are less friendly, local communities are not used to them, and require more effort to

input attributes data. This might be partially solved by complementing its GNSS data with paper notes, with its pros and cons as well.

Therefore, given the kind of geo-referenced information that humanitarians could collect (described a few paragraphs above), and the tools available to do it, the expected GNSS performance requirements for such a non-critical application seem rather low-demanding when compared to other applications or market segments. If only, requirements on power consumption present some additional criticality.

On the other hand, although applications in conflict zones can require some additional degree of robustness, such operational scenario seems not to be representative of this application.

The following table presents the main GNSS user requirements for *Health and medicine response and coordination*.

GNSS user requirements for Health and medicine response and coordination		
Accuracy	Horizontal	m-level
	Vertical	m-level
Availability	Urban canyon	Yes
	Better than 95%	Medium
	Better than 99%	Medium
Robustness		Low
Integrity and reliability		Low
Size, weight, autonomy (when smartphone based)	Relevance	Yes
	Time a device can run	>5h
TTFaF	In hot start	A few seconds
	In cold start	<1 minute
Service area	Geographical coverage	Regional

When it comes to **EO requirements**, these might be divided into technical and practical (or logistical) ones.

- Technical:
  - NGOs very much work with 'visible spectrum' (or optical) imagery as it facilitates the identification of relevant features when deployed. Their needs concentrate on having imagery which is up-to-date and with a higher resolution. However, this kind of data has noticeable limitations: it is affected by visibility conditions, as could be clouds, fog, heavy rain or, simply, night time. Filling the gaps from optical imagery by means of other data is necessary. For example, some terrain features or man-made structures (e.g. dwelling) might be identified thanks to SAR;
  - When it comes to spatial resolution, the need is to have imagery in the range of High Resolution i.e. around 5 meters or a bit less. With that resolution, it should be possible to identify dwelling structures.
  - Resolutions around 1 meter or less are usually not needed, however some NGOs and UN organizations have arrangements to have free access to VHR data from private providers. This is also available via the Copernicus Emergency Management Service (EMS) and allows to get access to best-in-class data when needed.
  - Digital Terrain Models (DTMs) are sometimes used to understand the topography of the disaster affected area. A resolution <30 meters is considered enough.

- Practical/logistical:
    - The area of interest is sometimes not exactly the one of the emergency; the settlement areas are located at a certain distance (in the range of kms) from the disaster/conflict zone. When a service/product (such as the Copernicus EMS) is "activated" and requested, it is usually linked with the event, but the area of interest may differ. Therefore, rapid mapping services should include a regional view, at least at the onset of a crisis.
    - The product should be digestible in quick time i.e. the data must be downloadable in standard formats and be split, if necessary, in smaller files). Given the working conditions humanitarians may face in the field, with limited means available, the EO data should not be provided in a 'raw' form that needs a lot of computer processing. Instead, its use should be at least easily interoperable and integrable with other data and used systems.

The following table introduces the practical EO user needs for *Health and medicine response and coordination*:

ID	EUSPA-EO-UR-EMH-005	EUSPA-EO-UR-EMH-006
Application	**Health and medicine response and coordination**	
Users	NGOs (e.g. IFRC, MSF, Save the Children) including local actors, UN Agencies (WFP, UNICEF, WHO)	
User Needs		
Operational scenario	Creation and use of maps and of geospatial information (including population estimations counting) to analyse, visualise and coordinate humanitarian responses.	
Size of area of interest	**First response** Variable, from local to regional, depending on the zone affected by the disaster (a coarse grain overview of all affected areas is necessary)	**Second phase response** Areas of interest become local.
Scale	A few meters to identify features	
Frequency of information	Daily or bi-daily updates for rapid changing scenarios (e.g. flooding or active military campaigns).	Weekly or even monthly
Other (if applicable)	The product has to be usable by legacy systems, not needing significant processing resources. It must be accessible globally. The data must be treated confidentially. Metadata must be available.	
Service Provider Offer		
What the service does	Provides downloadable files to the user, as small as possible and in a standard format (shape file, KML or Geotiff). Files can be printed or used	

ID	EUSPA-EO-UR-EMH-005	EUSPA-EO-UR-EMH-006
Application	**Health and medicine response and coordination**	
	on other supports like tablets or smartphones in the field. If possible it must also provide information on displacement of affected population.	
How does the service work	For scheduled/archived acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider. In the case of optical imagery, the user has access to a low-resolution preview to check if no clouds are obscuring the area of interest before purchasing it.	
Service Provider Satellite EO Requirements		
Spatial resolution	Optical imagery: <5 meters	Digital Surface and/or Elevation Models: <30 meters (and application specific[50]).
Temporal resolution	Daily or weekly (including the preparedness phase).	5 years for reference datasets no matter the phase of the emergency. Weekly in case new image is necessary post-disaster.
Data type / Spectral range	Optical, complemented by others (SAR, NIR or IR) when necessary.	-
Other (if applicable)	Area of interest relatively close (maximum 5 kms) to the disaster zone. Global coverage.	
Service Inputs		
Satellite data sources	Visible spectrum imagery (Sentinel-2 or private providers)	Optical, radar or combination of both.
Other data sources	UAVs are also used to collect images	DEM from various sources (SRTM, Copernicus)

[50] E.g. for the planning of water pumps better resolutions may be needed.

Figure 30 - Humanitarians have specific requirements (picture for illustration)

Finally, the use of drones is now a reality when it comes to the response. They are capable of transporting vital equipment to rescue services, as was seen in the 2015 European Satellite Navigation Competition (ESNC) winning entry that uses a drone system to deliver defibrillators.

More recently, during the Ukraine crisis in 2022, Draganfly drones were used to deliver blood, pharmaceuticals, insulin/medicines, vaccines and wound-care kits to hard-to-reach hospitals. Remote piloting of the drones, and specially its tracking, is usually supported by means of GNSS as well.

WFP has been an innovator in the use of drones for a variety of use cases, from cargo delivery, damage assessment and search and rescue to flood modelling. Drones are today prepositioned in 5 regions and cover more than 50 activities[51].

Thus, in all cases the introduction of new technology (including EO and GNSS) should not complicate but rather ease, or at least help speed-up, the work from humanitarians.

[51] https://drones.wfp.org/

5.3 Limitations of GNSS and EO

As presented in section 1.1, the methodology followed to produce this report has made use, amongst others, of interviews conducted with a number of selected stakeholders operating in the field of the selected applications. It is mainly from these interviews, and reference documentation consulted as suggested by stakeholders, that the following limitations on the use of GNSS and EO in the field of Emergency Management and Humanitarian Aid have been identified.

Some limitations, on the other hand, have also been identified during the Desk Research phase, which included review of projects' documentation, scientific papers or audio-visual resources.

5.3.1 GNSS power consumption

During the after-event phases of an emergency (i.e. Response and Recovery) and when providing humanitarian aid, personnel deployed in the field is often equipped with smartphones to conduct some of their tasks. Nowadays smartphones incorporate many capabilities (phone, internet connection, photo and video camera, GNSS capability, etc), making them 'the' enablers for many applications.

However, the permanent background running of GNSS in smartphones requires a considerable amount of energy that can lead to a battery life issue. Indeed, the incorporation of dual-frequency GNSS chipsets in the smartphones[52] world may further exaggerate this effect. The main benefit of these chipsets is the enhanced positioning accuracy that can be achieved by directly estimating the ionosphere delay. In addition, dual-frequency GNSS improves robustness against jamming and opens the door to the application of extremely accurate techniques such as PPP (Precise-Point Positioning) and RTK (Real Time Kinematics).

Figure 31 - GNSS increases power consumption in smartphones (picture for illustration)

Decimetre accuracy, though, is nowadays not a requirement in the EMHA segment. Therefore, mitigation to battery life issues includes the use of single-frequency smartphones and proper planning of the mission to optimize battery usage, supported by the use of power banks and replaceable batteries when possible.

5.3.2 Demanding data collection

When there is a need of collecting a vast number of data points per second, typically in order to obtain millimetric or centimetric ground measurements, the use of GNSS might become too time consuming.

In these situations, users could prefer using technologies that are easy to use and allow faster data collection, as could be laser scanner or LIDAR technologies. LIDAR is, indeed, one of the various technologies that has been used onboard drones for years in order to conduct ground surveys.

[52] https://www.usegalileo.eu/EN/inner.html#data=smartphone

5.3.3 Real-time status and position reporting

Applications requiring real-time connection (GNSS tracking) or constant data upload (in field geo tagged captured data including photos, videos and text) to a control centre might not perform at its best when outside the coverage of the telecommunications network (cellular for example). The disaster event might have caused damages to the supporting infrastructure, or the user might simply be operating in remote areas. The limitation to provide timely reports and tracking may pose a thread onto people's life.

The solution is to rely on satellite-based communications, which is more expensive by an order of magnitude than conventional terrestrial communications. This is why NGOs and UN organization rely on services provided by private firms (with specific contractual arrangements) or organizations such as Telecom Sans Frontières to establish critical communication infrastructure every time there is a crisis. However, this requires at least a few days, which means that in the immediate aftermath of a crisis, communication is usually difficult.

5.3.4 Time-to-First-Fix in remote areas

When responders, humanitarians and especially local actors need to geolocate information in remote areas (for example record the position of isolated shelter or of destroyed infrastructure), it can occur that the smartphones they rely on are not able to timely calculate a position. When geolocation is not achieved in less than a minute, the sensation is that the device is not working properly. This causes the data (e.g. the survey) to be collected without all the necessary information.

Today's smartphones make use of the so-called 'Assisted-GPS' (A-GPS) function, which allows the device to get orbital data (typically through a mobile-network internet access) and thus accelerate the calculation of a first fix. When such mobile-network coverage does not exist or is not available, however, the Time-to-First-Fix (TTFF) can be of minutes and thus spoil the response.

5.3.5 Jamming and spoofing of GNSS signals affecting safety and security

The impacts of intentional GNSS jamming and spoofing are numerous but of different consequences to different emergency responders and humanitarian aid users. Jamming results in service unavailability: reduced quality in the monitoring of hazards, no georeferencing and no mapping of data collected during post-disaster recovery phases, for example. Spoofing can have disastrous effects, some even affecting the security of users and putting their lives in (e.g. a humanitarian convoy following a wrong route, outside humanitarian corridors, may end up being the target of violent attacks).

The need is therefore to work towards the adoption of solutions/technologies helping increase the robustness of the PNT source (e.g. Galileo OSNMA and PRS).

5.3.6 Temporal resolution of EO

This is referred as to how often a satellite (or constellations of satellites) obtains imagery of a particular area. This resolution is directly dependent on the characteristics of its orbit around the Earth.[53]

Even if satellites offer a regular and frequent revisit, when the dynamics of the events is significantly faster than the rate at which new imagery can be made available, EO may not be the best option if used

[53] The definition of *Temporal Resolution* is included in A1.2.

alone. Examples of such events include tsunamis, fast-moving landslides or volcanic events. Indeed, during an eruption, daily updates allowing the measurement of terrain deformation are needed.

Users may decide then to combine information from various sources or service providers in order to fill their needs in terms of data update. For example, during La Palma (Canary Islands) volcanic eruption in 2021, various sources of information (including Copernicus and UAVs) were used and the Copernicus EMS service was activated[54].

In the case of humanitarian organisations relying on optical data, the activity in applications such as MapSwipe can spike when a catastrophe hits, thanks to the effort from the global community, who helps mapping the areas affected, via the validation of optical imagery and the identification of dwelling structures, for example.

Finally, the premature end of Sentinel-1B mission is impacting InSAR analyses for applications such as the monitoring of landslides, as there is no availability of combining ascending/descending modes. In this context, the launch of Sentinel-1C mission is pre-anticipated. In the longer term, the launch of the Harmony mission (which will accompany, by 2030 the new series of Sentinel 1 satellites) will increase the revisit time by a factor 2. Thus it will be a very relevant and structuring mission.

5.3.7 Timeliness of EO data delivery and cut-off times

Quick and flexible access to EO data is sometimes pointed out by users as an area with room for further improvements.

Particularly applicable to data already acquired by the satellites, timeliness refers to the time lapse from the moment a user orders data until this data is provided by the service provider, since the latter may need some time to access and process the product according to the specific needs of the user. For certain applications, 1 or 2 days of lapse is just too much and in such case the user will approach a different provider.

On the other hand, and applicable to non-scheduled acquisitions, cut-off time is also important. This refers to the last date on which it is possible to request imagery. In other words, the deadline by which the image request must be sent by the user to the service provider before an acquisition (e.g. an image) takes place by the satellite.

5.3.8 Accuracy and spatial resolution of EO

Higher spatial resolution and increased accuracy in EO products provide added value in some applications.

In the particular case of landslides monitoring:

- SAR data is well-suited for this application. Indeed, in the particular case of Copernicus / Sentinel-1, which is equipped with a C-band SAR:
    - It is useful for open or rural areas

[54] https://emergency.copernicus.eu/mapping/list-of-components/EMSN112

    - It is not that useful for urban areas (the affection to buildings and infrastructures is studied), where resolution requirements are higher. In this case the data from other service providers[55] is used.
    - Having L-band instrumentation would allow more penetration of the signal in forested areas[56].
- Sentinel-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m[57], six bands at 20 m and three bands at 60 m spatial resolution. Such medium resolution is in general hardly used for landslides monitoring. However, research[58] has been conducted in the case of Sentinel-2 due to its greater revisit time versus Sentinel-1's one (5 days and 6 days respectively), which can provide added value in case of landslides where relevant changes happen over a very short period of time (days).

Copernicus EMS generates Digital Surface Models (DSM) as part of product P01. Other products, such as flood modelling (P05) make use of this DSM to simulate flood extents based on estimated discharges and water levels. With even more detailed DSMs, however, the accuracy of this simulations would increase. This is particularly important for relatively flat areas, with low slopes even imperceptible for the human eye.

LIDAR technology has been around for decades and has been massively employed for this demanding flood modelling. When mounted on an aircraft, it can provide absolute accuracies of about 20cm horizontal and 10cm vertical. With photogrammetry, these values might even be improved.

The drawback of LIDAR is the limited area an aircraft or a drone can cover compared to a satellite.

5.3.9 User experience of EO data

When considering the **Humanitarian Aid sector**, there is yet a bridge between the technical capabilities of EO and its industry, and how it is approached by practitioners on the ground.

These persons work in post-disaster situations, which by their nature are chaotic, distressed and difficult to operate within – in short, confusing. Therefore, any tool or data which exists to help within that system should be targeted at alleviating the confusion and ensuring that the affected communities and individuals are at the heart of any solution:

- Remotely sensed data do not and will not solve humanitarian information management problems by themselves. Their added value comes from combining these data effectively with other digital maps, surveys and ground-based information;
- Although EO must meet the 'technical' requirements – suitable resolution and accuracy, for example –, practical and logistical requirements have to be also considered. For example: working with limited bandwidth, digestible in quick time, interoperable with commonly used systems;

[55] For example COSMO-Skymed providing 1x1 meters resolution.

[56] Radio waves of C- or X-band radars (wavelengths of ~6 and ~3 cm respectively) are reflected by leaves at the upper part of trees and cannot reach the ground. L-band radar instead, which has a wavelength of about 24 cm, can penetrate the vegetation.

[57] Sentinel-2 offers 10 m resolution for blue (B2), green (B3), red (B4) and infra-red (B8) bands.

[58] Pascal Lacroix, Grégory Bièvre, Erwan Pathier, Ulrich Kniess, Denis Jongman. Use of Sentinel-2 images for the detection of precursory motions before landslide failures. Remote Sensing of Environment, Volume 215, 2018.

- The presentation of information must be 'easy-to-understand', by means of use cases or pilot projects, so users can have a clear understanding of the service and get in contact with persons capable of explaining how the service will fit their need.

For example, users in developing countries see InSAR too complex. Products need to be adjusted to the final users, who need the end result. The final result would be the 'risk' map.

In summary, **connections between both worlds need to improve to make sure that the information is available and prepared to support the action of practitioners**. Simplifying and tailoring the data and information to the user needs, will increase the adoption of EO data use in the EMHA segment.

5.3.10 Accessibility to EO data

Easy access to EO data is reported as a recurrent problem by both Emergency Management and Humanitarian Aid users.

Access to EO Products from commercial providers is limited to larger organizations that have the competencies to process them. There are usually very competitive commercial agreements in place as the providers consider these organizations as key customers and know that their resources are limited.

In the case of the Copernicus:

- The download of datasets has room for improvement, as reported by both types of users. Indeed, the Alaska Site Facility website (https://asf.alaska.edu/) is widely used because of its simplicity to download data. Users report advantages when large volumes of data have to be obtained, while best appreciating the capabilities of this browser to define areas of interest by means of ShapeFiles, KML files or coordinates.
- Despite the awareness efforts that are being carried out at programmatic level, the humanitarian community is not always sure about who can actually activate the EMS service, or how to get in touch with the right organizations that can activate it. Indeed, this problem seems to be most important in the preparedness phase (see 5.1.1), when the actual disaster and derived emergency has not occurred, and the attention paid by organizations authorized to activate the EMS is rather low. To conduct population counting, for example, the lack of up-to-date imagery is evident in non-emergency times. But for planning purposes, up-to-date information would be highly beneficial.
- Copernicus delivers a large portfolio of data, products and services, which makes the program very capable. The counterpart of it is that for some humanitarian users it may at some point become difficult to identify which of those products are best-suited for their needs. This is particularly relevant when organisations are actively facing and emergency, as no time is available to look into the Copernicus EMS website looking for what product could be useful.
- Users in the field often rely on Google maps or Google earth products, even if outdated, as they are much more user friendly than Copernicus, which is used from the central office.

The adoption of EO by the humanitarian community is highly impacted by a different economic factor: in times of no-emergency humanitarian organizations suffer a significant lack of resources. This can prevent the incorporation of new technologies, data and products in their working streams.

All these factors can discourage NGOs from adopting new technologies and new sources of available information, and **keep relying on something they were already using**. For example, still today, DEM data from the Shuttle Radar Topography Mission (SRTM)[59] [60] is widely used, despite more up-to-date data is available (e.g. such as the DEM generated by Copernicus[61]) and that this dataset was collected in February 2000 (i.e. more than 22 years ago). Amongst the reason for that, GIS technicians working in the humanitarian aid perceive the **SRTM DEM as easily accessible and easily downloadable to laptops** before a deployment starts. In addition, **where other elevation data are not available, the SRTM's DEM forms a useful backdrop to so many maps**, helping responders get a feel for the topography of the disaster affected area and, in some cases, assists in logistics planning, market analysis and winterisation predictions.

Therefore, an increased adoption of EO data use in the EMHA segment should be expected as soon as the access to data is best suited to not only the user requirements but also to their working environment.

5.3.11 Complexity of "EO language"

"Complexity of use" is pointed as one of the main barriers preventing the uptake of space-based applications amongst the Emergency and Humanitarian communities.

In contrast to other sectors such as the insurance one, the range of EO expertise within humanitarian organizations is very heterogenous. Some humanitarian organizations (mostly larger ones) may have personnel capable of understanding both the EO and the humanitarian worlds, thus being able to fill the gap between both worlds (see 5.3.9).

Instead, other organizations might not count with in-house expertise on EO. Today, most people know about platforms such as Google Earth and hence are aware about optical satellite imagery, but there are other data and use cases that are not so obvious and this prevents a massive adoption of EO in this segment.

InSAR products are a clear example. Training/capacity building is needed. Nowadays, some on-line platforms are available to ease the InSAR and the optical satellite imagery processing for geohazards (e.g. Comet in the UK, GEP operated by ESA, EPOS-ERIC for Europe, of Data-Terra/ForM@Ter in France). This should help democratize the use of InSAR/optical correlation in the future for new applications and non-experts.

As an example, the management of displaced people camps can be considered. Very often, analysts working with/in NGOs try to estimate the population of these camps by making use of satellite imagery in the visible spectrum. This could be considered inefficient due to two reasons:

- As already explained in 5.1.6, the Copernicus EMS offers already one specific product for this application (the suitability of the product in terms of accuracy or identifiable size of dwelling structures being a separate requirement). If NGOs were aware of this and could activate the EMS service, they could save precious time in the analysis;
- Optical imagery is acquired during daylight, and in emergencies in cloud-covered areas might not be always useful due to the presence of clouds. An alternative solution is to use UAVs, which if allowed by local regulations, will fly only daylight below the cloud layers and take images of the camp. Other alternative solutions, such as the use of SAR imagery, is often discarded or not considered, due to lack of expertise or inability to buy SAR data.

[59] https://www2.jpl.nasa.gov/srtm/

[61] https://land.copernicus.eu/imagery-in-situ/eu-dem/

In this example (but relevant to other applications too), it is suggested to **the EO industry to dedicate more efforts in communicating to NGOs that many types of EO products are available** and could perhaps respond to their needs, offering:

1. Higher resolution, when the application requires it;
2. Acquisition of imagery under any degraded visibility conditions, including cloud layers;
3. Acquisition of imagery also during night time periods, if applicable.

Landslides monitoring, on the other side, are very often something which does not attract a lot of attention and, in some countries, users need information related to landslide risks (landslides derived from heavy rains for example) in the preparedness phase. People may think that anything that UN proposes could be too complex and too expensive for them, thus demonstrating an issue with respect to how communication of available products is conducted.

The trustability element then needs to be overcome as well, as decision makers should be hesitant to take decisions based on some products otherwise. For this reason, the delivered products should be described with relevant metadata and the processing lineage should be described (to be able to be reproduced); the products should also be delivered with "errors bars" and quality indicators.

Assuming that the suggested communication was achieved, humanitarians who then decide to dig into the EO world might find themselves reading websites and documents making use of the "scientific" language, the jargon, that helps define the systems, services and capabilities.

This becomes another barrier that can prevent novel users from making use of EO data and products simply because they cannot understand whether a product will fit their needs or not. For this reason, it is necessary to dedicate more effort in **making EO products easier to comprehend, aligning them with the "humanitarian language"**.

The humanitarian community is calling for a short and concise catalogue of products tailored to their activity, focusing on the products that could be useful for them when an emergency occurs, together with some quick training adapted to humanitarians.

5.3.12 Uptake of imagery other than visible spectrum

As already introduced, visible spectrum satellite imagery has a very important limitation: it is not appropriate for post disaster scenarios, when clouds or smoke cover the area of interest. In some applications, satellite-based SAR can help overcome these problems, as its signals can penetrate clouds and smoke, and imagery can be acquired also at night.

The problem is the **lack of familiarity of the humanitarian community with types of products other than the visible spectrum imagery**. A direct consequence is that imagery may only be acquired well after it was needed and the relief effort has already moved on to a new phase.

Indeed, those organizations counting with more know-how on EO and geospatial information can restrict the use of optical imagery to small areas of interest, as simple background for other data (such as in refugee camps) or to compare and highlight conditions before and after events.

5.4 Prospective use of GNSS and EO

5.4.1 The use of UAV/drones in disaster relief

The number of uses/applications and of UAV technologies that has emerged in the last years is also applicable to the EMHA segments. Mentions to some of them have been made in previous sections of this document: image acquisition, photogrammetric surveys, inspection of remote areas or delivery of medicines, for example.

The reality is twofold:

- **The usefulness of drones has already been proven for some applications and during some emergency management phases.**
  For example, the acquisition of VHR imagery using drones to monitor a landslide during the preparedness phase is, from a logistics perspective, quite straight-forward. The operational context is very different to the one of the response phase.
  Instead, delivering an interpreted and compact set of data (e.g. damage assessment) within 72 hours of the disaster occurring, in an area where normality has broken down, can become very complex;
- **The adoption of this technology is only starting.**
  We should observe, in next years, that as projects and emergency situations occur, technologists and relief personnel will learn ones from others to find new uses and develop operational concepts acceptable for all. GNSS services allowing better geo-localisation should be adopted which, together with better resolutions and improved data acquisition and processing tools, will contribute to maximise the use of these platforms all along the Emergency management cycle.

5.4.2 Use of pre-processed datasets

Persons working in post-disaster situations, and especially those deployed in affected areas during the response or recovery phases, will more and more **make use of relatively-small pre-processed geospatial datasets derived from imagery and reference data products, rather than heavy raw imagery itself**. The use of **Artificial Intelligence** could support this and alleviate the data processing needs 'on-site' in a number of use cases, such as automatic quick damage assessments, detection of fires or population counting.

It should be taken into account that, in such places, normal communications and electric power supplies may be at challenge, and hence it is not practical having to download large volumes of data and process it to obtain meaningful information, when on top of that the disaster situation may be evolving rapidly and time constraints take much relevance.

5.4.3 Data integration

For some use cases, communities are calling for the integration of EO data coming from different sensors, including satellites, UAVs and in-situ via sensors. On the other hand, there is a consensus on the need to integrate EO and GNSS information into legacy systems.

Therefore, integration of information is key to increase the added-value of services and products and advancements and development of new technologies able to do so are expected in the coming years.

5.5 Summary of drivers for user requirements

5.5.1 Drivers for GNSS-related user requirements

The analysis of the many applications found in this segment and the significant number of exchanges held with end users indicates that the main drivers for the use of GNSS very much depend on the communities using it and the phase of the emergency.

In the pre-event phases (Prevention and Mitigation, and Preparedness), monitoring tasks take much relevance and so does the work of 'scientists', which makes that, in many occasions, accuracy becomes a relevant parameter, down to centimetric levels.

In the response and post-event recovery phases, very high accuracy is relevant for specific tasks such as the monitoring of critically affected buildings and infrastructures, reaching millimetric level requirements.

The use of GNSS by humanitarians typically spikes when having to deliver some sort of aid after an emergency occurs, although some usage could also be expected in the Preparedness phase. This community usually bases its activity on the use of the GNSS embedded into smartphones, although GNSS is also used for assets management and tracking. Therefore, they do not call for very high accuracy, but rather to other aspects related to security and usability in the environments they operate: robustness, ease of use, availability and TtFF.

In all cases, availability of solutions combining GNSS with other technologies and sensors are central to the greater uptake of GNSS solutions in this segment.

5.5.2 Drivers for EO-related user requirements

Most EMHA-related EO-based applications require optical (visible) and/or SAR imagery. The main drivers are:

- Spatial resolution (the most demanding applications require Very High Resolution SAR imagery, with submeter-level resolution);
- Temporal resolution (daily updates of EO data are needed when disasters hit);
- The availability of historical data (to enable change detection or to identify trends) and of baseline data (in under-mapped areas where humanitarian organizations operate).

In addition to the above-mentioned performance-related drivers, other aspects are central to the greater uptake of EO solutions in the EMHA sector:

- The interoperability and compatibility of EO data and products with legacy systems;
- The availability of EO data in the preparedness phase, which sometimes does not receive that much attention from the public, media and/or institutions;
- An easy and simple access to data and products suited to the needs of the humanitarian community in terms of product and language complexity and size.

6 USER REQUIREMENTS SPECIFICATION

The chapter provides a synthesis of the requirements described in section 5.1 and 5.2 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 Requirements relevant to GNSS

6.1.1 GNSS user requirements for Landslides and terrain deformation monitoring

ID	Description	Type	Source
EUSPA-GN-UR-EMH-2201	The horizontal and vertical accuracy should be in the cm/mm level	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-2202	The availability should be better than 95%	Performance (availability)	[RD11]
EUSPA-GN-UR-EMH-2203	The size and weight should be minimized	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-2204	The autonomy in the field should be up to several years	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-2205	The antenna should be as small as possible	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-2206	The time to first accurate fix should be a few minutes	Performance (timeliness)	[RD11]
EUSPA-GN-UR-EMH-2207	The coverage needed is regional or local	Performance (coverage)	[RD11]

6.1.2 GNSS user requirements for Post-crisis damage assessment and building inspection

ID	Description	Type	Source
EUSPA-GN-UR-EMH-6101	The horizontal and vertical accuracy should be in the m level for geotagging (large-scale assessment)	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-6102	The horizontal and vertical accuracy should be in the dm level for UAV 3D reconstruction (large-scale assessment)	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-6103	The horizontal accuracy should be 2mm detailed building assessment	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-6104	The vertical accuracy should be 3-4mm detailed building assessment	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-6105	The vertical accuracy should be 3-4mm detailed building assessment for critical buildings	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-6106	The horizontal and vertical accuracy should be in the cm level for UAV 3D reconstruction (detailed building assessment)	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-6107	The system should be available in urban canyons	Performance (availability)	[RD11]

EUSPA-GN-UR-EMH-6108	The size and weight should be minimized	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-6109	The autonomy in the field for geotagging should be more than five hours	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-6110	The time to first accurate fix should be a few seconds	Performance (timeliness)	[RD11]
EUSPA-GN-UR-EMH-6111	The coverage needed is regional or local	Performance (coverage)	[RD11]

6.1.3 GNSS user requirements for NGO's Asset Monitoring

ID	Description	Type	Source
EUSPA-GN-UR-EMH-7101	The horizontal and vertical accuracy should be in the m level	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-7102	The system should be available in urban canyons	Performance (availability)	[RD11]
EUSPA-GN-UR-EMH-7103	The system should be available in natural canyons	Performance (availability)	[RD11]
EUSPA-GN-UR-EMH-7104	The system should be available under canopies	Performance (availability)	[RD11]
EUSPA-GN-UR-EMH-7105	The system should be available indoors	Performance (availability)	[RD11]
EUSPA-GNUR-EMH-7106	The availability should be better than 95%	Performance (availability)	[RD11]
EUSPA-GN-UR-EMH-7107	The system should be robust	Performance (robustness)	[RD11]
EUSPA-GN-UR-EMH-7108	The size and weight should be minimized	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-7109	The autonomy of a device should be more than 5 hours	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-7110	The antenna should be as small as possible	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-7111	The time to first accurate fix should be a less than a minute	Performance (timeliness)	[RD11]
EUSPA-GN-UR-EMH-7112	The coverage needed is national/regional	Performance (coverage)	[RD11]

6.1.4 GNSS user requirements for Health and medicine response and coordination

ID	Description	Type	Source
EUSPA-GN-UR-EMH-7301	The horizontal and vertical accuracy should be in the m level	Performance (accuracy)	[RD11]
EUSPA-GN-UR-EMH-7302	The system should be available in urban canyons	Performance (availability)	[RD11]
EUSPA-GN-UR-EMH-7303	The size and weight should be minimized	Feature (equipment)	[RD11]
EUSPA-GN-UR-EMH-7304	The autonomy of a device should be more than 5 hours	Feature (equipment)	[RD11]

EUSPA-GN-UR-EMH-7305	The time to first accurate fix should be a less than a few seconds in hot start	Performance (timeliness)	[RD11]
EUSPA-GN-UR-EMH-7306	The time to first accurate fix should be a less than a minute in cold start	Performance (timeliness)	[RD11]
EUSPA-GN-UR-EMH-7307	The coverage needed is regional	Performance (coverage)	[RD11]

6.2 Synthesis of Requirements relevant to EO

6.2.1 EO user requirements for Landslides and terrain deformation monitoring

ID	Application	Users	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)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite Data Sources	Other Data Sources
EUSPA-EO-UR-EMH-001	Landslides and terrain deformation monitoring	Civil Protection bodies, National Institutions, NGOs, Mapping Companies	Monitoring of landslide displacement. Surveillance of a specific area for landslides and ground motion with great accuracy	Local and Regional	Millimetric	Less than every 5 days, 3 days if possible.	Availability under cloud cover or a lack of illumination.	Provides downloadable files to the user, preferably georeferenced raw data with quality index and metadata	For scheduled acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider.	SAR: mm level Optical: submeter level	5 days	Optical SAR: C-band, L-band and X-band.	Better collocation (revisit at the same spot)	Synthetic aperture radar (SAR) instrument operating in one or more bands (X, C and L): Sentinel-1, Cosmo Skymed, Saocom, Radarsat, IceEye, Capella Space. Optical: Sentinel-2, Pléiades, Landsat, Maxar Worldview, Planet	Not satellite-based
EUSPA-EO-UR-EMH-002	Landslides and terrain deformation monitoring	Civil Protection bodies, National Institutions, NGOs, Mapping Companies	Inventory of landslides. Maintaining a database of landslides though a regular inventory of events.	Regional	Metric	Once a year or upon request (after an event)		Provides downloadable files to the user, preferably georeferenced raw data with quality index and metadata	For scheduled acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider.	Optical: meter level	1-2 per year	Optical		Optical: Sentinel-2, Pléiades, Landsat, Maxar Worldview, Planet	Field checking with visual inspection and local data collection

6.2.2 EO user requirements for Post-crisis damage assessment and building inspection

ID	Application	Users	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)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite Data Sources	Other Data Sources
EUSPA-EO-UR-EMH-003	Post-crisis damage assessment and building inspection	Civil Protection bodies, National Institutions (Geological Institutes, Research Centres), NGOs	Large scale damage assessment The user needs a fast overall assessment of the zone and structures impacted.	Regional or local	Large	Very much depending on the type of event. At most, earthquakes or volcanic events may require daily updates.	Timeliness of data delivery: 1 day	General mapping of impacted zones and structures. Provides downloadable files to the user, in the form of products already calibrated and geo-referenced.	For scheduled/archived acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider.	Optical: 10x10 meters. SAR: <10x10m already available.	Daily in the immediate aftermath of a disaster	Optical (either as primary or as backdrop): RGB and infrared. SAR: C-band, L-band and X-band.	Pre-processed data must be provided to technical final users. Metadata must be provided to final users, together with historical data before the event. Decision makers require actionable information.	Sentinel-1 and 2 data. Data from commercial providers (Airbus, Maxar…)	
EUSPA-EO-UR-EMH-004	Post-crisis damage assessment and building inspection	Civil Protection bodies, National Institutions (Geological Institutes, Research Centres)	Detailed building damage assessment The user needs an accurate, reliable assessment of the damages to structures. It can be urgent for re-housing purposes or less urgent for insurance or reconstruction.	Local	Building level	Single acquisition.	Timeliness of data delivery: 5-10 days	Detailed characterization of buildings or other infrastructures Provides downloadable files to the user, in the form of products already calibrated and geo-referenced.		<1x1 meters	N/A	Optical (either as primary or as backdrop): RGB and infrared. SAR (processed products): C-band, L-band and X-band.	Pre-processed data must be provided to technical final users. Metadata must be provided to final users, together with historical data before the event. Decision makers require actionable information.	Data sources such as Pleiades, GeoEye or WorldView are used. In some instances, the satellite data is made available through the Copernicus Emergency Service.	Data collected by aircraft, drones and observers on the ground provide additional and more accurate information

6.2.3 EO user requirements for Health and medicine response and coordination

ID	Application	Users	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)	What the service does	How does the service work	Spatial Resolution	Temporal Resolution	Data Type / Spectral Range	Other (if applicable)	Satellite Data Sources	Other Data Sources
EUSPA-EO-UR-EMH-005	Humanitarian needs assessment	NGOs (e.g. IFRC, MSF, Save the Children) including local actors, UN Agencies (WFP, UNICEF, WHO)	Creation and use of maps and of geospatial information (including population estimations counting) to analyse, visualise and coordinate humanitarian responses.	First response Variable, from local to regional, depending on the zone affected by the disaster (a coarse grain overview of all affected areas is necessary)	A few meters to identify features	Daily or bi-daily updates for rapid changing scenarios (e.g. flooding or active military campaigns).	The product has to be usable by legacy systems, not needing significant processing resources. It must be accessible globally. The data must be treated confidentially. Metadata must be available.	Provides downloadable files to the user, as small as possible and in a standard format (shape file, KML or Geotiff). Files can be printed or used on other supports like tablets or smartphones in the field.	For scheduled/archived acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider. In the case of optical imagery, the user has access to a low-resolution preview to check if no clouds are obscuring the area of interest before purchasing it.	Optical imagery: <5 meters	Daily or weekly	Optical, complemented by others (SAR, NIR or IR) when necessary.	Area of interest relatively close (maximum 5 kms) to the disaster zone. Global coverage.	Visible spectrum imagery (Sentinel-2 or private providers)	UAVs are also used to collect images
EUSPA-EO-UR-EMH-006	Humanitarian needs assessment	NGOs (e.g. IFRC, MSF, Save the Children) including local actors, UN Agencies (WFP, UNICEF, WHO)	Creation and use of maps and of geospatial information (including population estimations counting) to analyse, visualise and coordinate humanitarian responses.	Second phase response Areas of interest become local.	A few meters to identify features	Weekly or even monthly	The product has to be usable by legacy systems, not needing significant processing resources. It must be accessible globally. The data must be treated confidentially. Metadata must be available.	Provides downloadable files to the user, as small as possible and in a standard format (shape file, KML or Geotiff). Files can be printed or used on other supports like tablets or smartphones in the field.	For scheduled/archived acquisitions, users can download data from a web portal, by defining their area of interest. For user-defined acquisitions, data is distributed directly to the user by the service provider. In the case of optical imagery, the user has access to a low-resolution preview to check if no clouds are obscuring the area of interest before purchasing it.	Digital Surface and/or Elevation Models: <30 meters (and application specific).	5 years for reference datasets no matter the phase of the emergency. Weekly in case new image is necessary post-disaster.		Area of interest relatively close (maximum 5 kms) to the disaster zone. Global coverage.	Optical, radar or combination of both.	DEM from various sources (SRTM, Copernicus)

6.3 Sources for the requirements

The requirements gathered in previous paragraphs have been obtained from the Emergency Management and Humanitarian Aid (EMHA) community, by means of a significant number of interviews, and later on validated in the frame of the EMHA User Consultation Platform (UCP).

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 [RD2] and includes additional details which are relevant for the Emergency Management and Humanitarian Aid 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: the percentage of time the system allows the user to compute a position – this is what GNSS Interface Control Documents (ICDs) refer to
- Overall: takes into account the receiver performance and the user's environment (for example if they are subject to shadowing).

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: 0-10cm; decimetre level: 10-100cm; 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.

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.

Robustness is a qualitative, rather than quantitative, parameter that depends on the type of attack or interference the receiver is capable of mitigating. It can include authentication information to ensure users that the signal comes from a valid source (enabling sensitive applications).

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

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).

Time To First accurate Fix (TTFaF) is a measure of a receiver's/solution's performance covering the time between activation and output of a position within the required accuracy bounds.

A1.2 Definition of key EO performance parameters

This Annex provides a definition of the most commonly used EO performance parameters and are not specifically focused on the Emergency Management and Humanitarian Aid 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.

Spectral resolution refers to the ability of a sensor to differentiate electromagnetic radiation of different wavelengths. In other words, it refers to the number and "size" of wavelength intervals that the sensor is able to measure. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. In remote sensing, features (e.g. water, vegetation) can be characterised by comparing their "response" in different spectral bands.

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, e.g. an 8-bit image has a scale of 2^8=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 vegetation map).

A1.3 Other performance parameters

Size, weight, autonomy and power consumption. Power consumption and size are not strictly GNSS performance parameters, however they are also considered in this analysis, especially for GIS and Mapping-related applications.

- **Autonomy**. Power consumption is the amount of power a device uses to provide a position. The power consumption of the positioning technology will vary depending on the available signals and data. For example, GNSS chips will use more power when scanning to identify signals (cold start) than when computing a position. Typical values are in the order of tens of mW (for smartphone chipsets). GNSS is considered one of the heaviest drains on smartphones batteries
- **Size, weight**. Most GIS devices used by NGOs are handheld or rugged tablets/phones, which implies that they must remain small and lightweight.

Resiliency is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions; including the ability to recover from deliberate attacks, accidents, or naturally occurring threats or incidents. A resilient system will change its way of operations while continuing to function under stress, while a robust (but non-resilient) system will reach a failure state at the end, without being able to recover.

Connectivity refers to the need for a communication and/or connectivity link of an application to be able to receive and communicate data to third parties. Connectivity relies on the integration with both satellite and terrestrial networks, such as 5G, LEO satellites, or LPWANs.

Interoperability refers to the characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, in either implementation or access, without any restrictions (e.g. ability of GNSS devices to be combined with other technologies and the possibility to merge the GNSS output with the output coming from different sources).

Traceability is the ability to relate a measurement to national or international standards using an unbroken chain of measurements, each of which has a stated uncertainty. For Finance applications, knowledge of the traceability of the time signal to UTC is essential to ensure regulatory compliance of the time-stamp.

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).

A1.4 List of Acronyms

Acronym	Definition
3W	Who, What, Where
CEMS	Copernicus Emergency Management Service
CENALT	CENtre d'ALerte aux Tsunamis
COSPAS	Cosmicheskaya Sistyema Poiska Avariynich Sudov
DART	Deep-ocean Assessment and Reporting of Tsunamis
DEM	Digital Elevation Model
DSM	Digital Surface Model
EC	European Commission
ECHO	European Community Humanitarian Aid Office,
EGMS	European Ground Motion Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
ELT	Emergency Locator Transmitters
EMS	Emergency Management Service
EO	Earth Observation
EPIRB	Emergency Position-Indicating Radio Beacon
ERCC	Emergency Response Coordination Centre
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUSPA	European Agency for the Space Programme
FAO	Food and Agriculture Organization
FWI	Fire Weather Index
GADSS	Global Aeronautical Distress & Safety System
GEORSS	Geographical Really Simple Syndication
GEOSAR	Geostationary Search And Rescue
GEOSS	Global Earth Observation System of Systems
GMDSS	Global Maritime Distress & Safety System
GNSS	Global Navigation Satellite System
GNSS-R	Global Navigation Satellite System Reflectometry
GSD	Ground Sampling Distance
HAS	High Accuracy Service
IDMC	Internal Displacement Monitoring Centre

Acronym	Definition
IAMSAR	International Aeronautical and Maritime Search and Rescue
ICAO	International Civil Aviation Organization
ICRC	International Committee of the Red Cross
IMO	International Maritime Organization
INSAR	Interferometric Synthetic Aperture Radar
LIDAR	Laser Imaging, Detection And Ranging
LEOSAR	Low Earth Orbit Search And Rescue
MEOSAR	Medium-altitude Earth Orbit Search And Rescue
MR	Market Report
MSF	Médecins Sans Frontières
NGO	Non Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
OGC	Open Geospatial Consortium
OSNMA	Open Service Navigation Message Authentication
PLB	Personal Locator Beacon
PNT	Positioning, Navigation and Timing
PPP	Precise Point Positioning
R&D	Research and Development
RGB	Red Green Blue
RTK	Real Time Kinematic Positioning
RUR	Report on User needs and Requirements
R&I	Research and Innovation
SAR	Search And Rescue Synthetic Aperture Radar
SARSAT	Search And Rescue Satellite-Aided Tracking
SATCOM	Satellite communications
SME	Small and Medium-sized Enterprise
SoL	Safety of Life
SRTM	Shuttle Radar Topography Mission
SST	Space Surveillance and Tracking
TTFaF	Time To First accurate Fix
UCP	User Consultation Platform
ULD	Underwater Locating Device
UN	United Nations
UNHCR	United Nations High Commissioner for Refugees

Acronym	Definition
UNICEF	United Nations International Children Emergency Fund
UNITAR	United Nations Institute for Training And Research
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOSAT	United Nations Satellite Centre
WFP	World Food Program
WHO	World Health Organization

A1.5 Reference Documents

Id.	Reference	Title	Date
[RD1]	EUSPA Market Report	EUSPA EO and GNSS Market Report (*Issue 1*)	Jan. 2022
[RD2]	GNSS Technology Report	GSA GNSS Technology Report (*Issue 3*)	Sept. 2020
[RD3]	AFPS Amatrice Report	AFPS_Rapport_mission_2016_Amatrice (Italie)	Oct 2016
[RD4]	Research paper (André Stumpf, Jean-Philippe Malet, Christophe Delacourt)	Correlation of satellite image time-series for the detection and monitoring of slow-moving landslides	Nov 2016
[RD5]	Sphere Handbook	The Sphere Handbook	2018
[RD6]	CRED-USAID report	*2021 Disasters in numbers*	2021
[RD7]	MSF catalogue	*GIS Products & Services on Offer*	2022
[RD8]	WFP - ESRI	WFP GIS Catalogue	2019
[RD9]	UNDP MOSS	Policy for United Nations Minimum Operating security standards	2009
[RD10]	UNESCO Manual	Standard Guidelines for the Tsunami Ready Recognition Programme	2022
[RD11]	UCP 2022 MoM	UCP 2022 Minutes of Meeting of the Emergency Management and Humanitarian Aid Market	2022

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.

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