2024

Report on Emergency Management and Humanitarian Aid

User Needs and Requirements

#EUSpace

EUSPA European Union Agency for the Space Programme

Executive Summary

The Emergency Management and Humanitarian Aid (EMAid) 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.

The tools provided by the EU Space Program, particularly Galileo and Copernicus, are being used by all EMAid stakeholders for a variety of use cases and applications. However, the key user needs vary with the clusters. In particular, there is one key characteristic for clusters 3, 4 and 6: the need for near real time data to support field operations. For the other clusters, the focus will be more on historical and accurate data to produce analysis of events.

In 2024, the focus of the User Needs and Requirements was put on three applications with a deeper analysis on Earth Observation:

- Flood prevention mainly used by municipalities and local authorities that are following the EU Floods Directive, implementing risks map and management plans
- Fire detection and spreading, used by firefighters to detect a fire start as quickly as possible and follow its evolution
- Human Rights Protection where satellite EO is more and more used to document human rights violation by NGOs or the press and when a trial occurs, as a proof to the court

Secure SATCOM has been introduced as well in 2024: the EMAid segment already makes a heavy use of SATCOM both in crisis situations whenever terrestrial communication networks are not available anymore or for international interventions.

While GNSS is used permanently during field operations, both for navigation and geolocation purposes, the use of EO remains limited and will increase with the availability of new systems and tools. The same applies for secure SATCOM, as cost, complexity of use and low performance constitute major barriers to overcome.

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1 INTRODUCTION AND SCOPE OF THE REPORT

1.1 Scope

The User Consultation Platform (UCP) is a process developed at the European Union Agency for the Space Programme (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.

The objective of this report is to provide a reference for the EU Space Programme and for the Emergency Management and Humanitarian Aid (EMAid) segment community, reporting the most up-to-date user needs and requirements in the EMAid market segment for the use of Position, Navigation and Timing (PNT), Earth Observation (EO) and secure telecommunications (SATCOM) technologies. Its scope is to cover needs and requirements from the user perspective, considering the market conditions, regulations, and standards that influence them. The report serves as a reference for end users, service providers and the whole EO community in planning and decision-making activities for those concerned. The report is also 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, and in the future Space Situational Awareness, GOVSATCOM and IRIS2.

The UCP process contains a regular event, where users from different market segments meet to discuss their needs and application-level requirements relevant for PNT, EO and SATCOM and the conclusions are presented in this document. This report is a living and evolving document that is regularly updated by EUSPA. It served as a key input to the UCP, that is continuous process to reflect the evolution of the user needs, market and technology captured during the event. 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.

This report is organized as follows:

- Section 2.1 addresses the prospective use of EO/GNSS/SATCOM in the EMAid segment, with identified trends, and innovations
- Section 2.2 presents the market evolution and key trends in the EMAid segment, together with definitions of main user groups and actors in the value chain, followed by Section 2.3, that describes the market drivers (regulations, standards etc.)
- Section 2.4 describes applications and operational scenarios relevant for EO/GNSS/SATCOM, presenting main user needs and expectations towards services and data to serve operational scenarios, together with limitations and gaps identified by end users. Some applications are more detailed as they have been assessed specifically during the 2024 UCP.
- Section 2.5 summarizes the main User Requirements for the EMAid segment in the applications domains analyzed in this report.

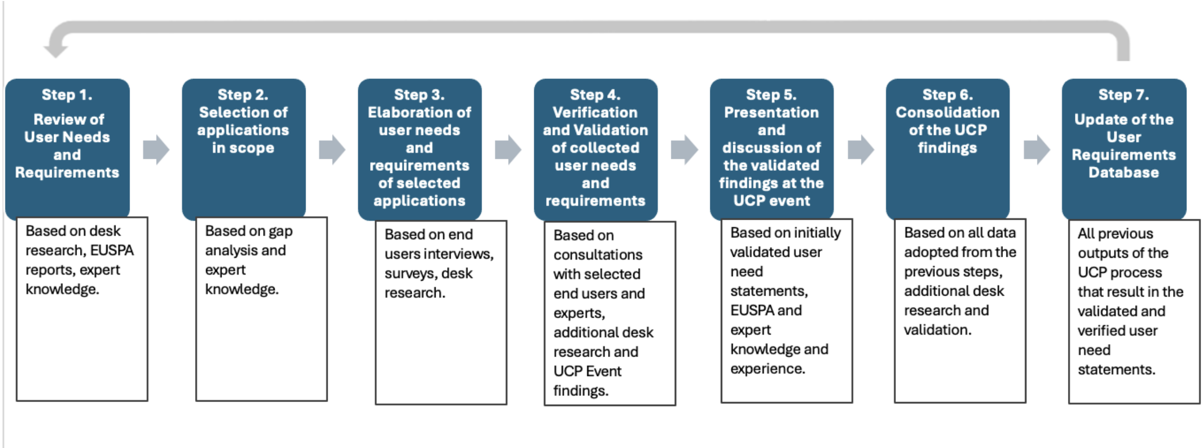
The 2024 edition of this Report on Emergency Management and Humanitarian Aid User Needs and Requirements brings two major updates:

- It introduces SATCOM with the list of EMAid applications and goes in detail into the Secured Communications for firefighting application
- It analyzes in detail 4 other EO applications: Floods Monitoring, Early-warning surveillance of forest fires, Operational wildfires modelling and Documenting Human Rights Violations.

1.2 Methodology

The UCP process follows systematic steps that are implemented in a continuous, repetitive manner. The logical steps allow transparency and continuous updates of the results, considering the new market developments and evolving user needs and requirements.

Figure 1: EMAid segment user requirements analysis methodology



Each Market Segment has its peculiar evolution due to the changes in legislation, standards, technological trends and so forth, therefore the update of the Report on User Need and Requirements can occur with a time distance of at least two years.

UCP user needs and requirements collection and analysis is based on one hand side on desk research and on the other, on stakeholders' consultations and experts' knowledge.

The UCP process starts with review and analysis of the most up-to-date sources related to the user needs and requirements in selected market segments. This step leverages on the previous UCP Reports on User Requirements, latest EUSPA EO and GNSS Market Report, Technology Reports and other expert publications and knowledge. The selection of relevant applications in each market segment is made based on the market analysis, the gap analysis from the earlier editions of the UCP and EUSPA, as well as external experts' know-how.

After the initial desk research, the stakeholders' consultations are carried out, both representing end users and intermediate users (service providers), in order to validate the findings and collect missing information (Step 3). Validation of user needs requires additional feedback from relevant users' representatives that review the draft version of the Report on User Needs and Requirements, prepared in advance of the UCP event.

The UCP event is organized by EUSPA on an annual basis and offers a forum to present and discuss the finding, being additional layer of updates and gaps filling in the process. All the information and data gathered during the previous steps are consolidated in the segment-specific, presented here Report on User Needs and Requirements (RUR) and later on in the EUSPA User Requirements Database (Step 7).

2 EMERGENCY MANAGEMENT AND HUMANITARIAN AID

2.1 The role of the European Space Programme to meet the evolving user needs

The European Space Programme, defined by the EU Space Programme Regulation implements space activities in the fields of Earth Observation, Satellite Navigation, Connectivity, Space Research and Innovation. The Programme is providing unique satellite-based data and services, strengthening both the upstream and downstream industrial ecosystem, boosting innovation and competitiveness.

EUSPA is the user-oriented operational agency of the European Union Space Programme. It adopts user-oriented strategies to stimulate uptake of the satellite-based services. In the execution of its mission, EUSPA counts on strong partnerships with the European Commission, European Parliament, Member States, European Space Agency, and private actors across the EU.

Key EUSPA competences are:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for GOVSATCOM and soon IRIS^2, and Front Desk services of the EU Space Surveillance Tracking whilst ensuring the systems' service continuity and robustness.
- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, GOVSATCOM and soon IRIS^2 across a broad range of domains.
- Fosters the development of a vibrant European space ecosystem by providing market intelligence, and technical know-how to innovators, academia, start-ups, and SMEs. The agency leverages Horizon Europe, other EU funding, and innovative procurement mechanisms.
- Implements and monitors the security of the EU Space Programme components in space and on the ground with the aim to enhance the security of the Union and its Member States. To do so, EUSPA operates the Galileo Security Monitoring Centre (GSMC).
- The EU Space Programme Security Accreditation Board is established within the Agency, representing the security accreditation authority for all of the EU Space Programme's components.

The Agency brings all space stakeholders together, allowing them to leverage the synergies between the Space Programme's individual components, and to have an impact on the evolution of the EU space programme. The end users can contribute to the flagship EUSPA activities to better understand the ever-evolving market, user requirements, as well as gaps and challenges, and that includes:

  - User Consultation Process and Platform
  - Market and Technology Monitoring and Forecasting Process
  - R&D Funding Needs Definition and Implementation
  - Piloting of innovative applications
  - Acceleration of innovative commercial ideas via CASSINI Programme
  - International cooperation, participation in working groups, and other.

Through participation in these initiatives, the end users have an impact on the evolution of the EU Space programme in line with user needs.

COPERNICUS

Copernicus is the Earth Observation component of the European Union's space programme, looking at our planet to support the management of the environment, mitigate the effects of climate change and ensure safety and civil security across Europe. Copernicus delivers its data and services with a free and open policy. It consists of three main components:

Space Component, which delivers data from a fleet of dedicated observation satellites (the 'Sentinels') and other Copernicus Contribution Missions (CCM). Six Sentinel satellites families are designed to serve a wide range of users and are provided with a free and open access globally. They ensure an independent and autonomous Earth Observation capacity for Europe with global coverage. The satellites provide observations which serve a wide range of users for a multitude of applications in the areas of climate, land and ocean services, emergency management, atmosphere and air quality, among others.

- Sentinel-1A provides all-weather, day and night radar imagery for land and ocean services. Sentinel 1-B was retired in December 2021.
- Sentinel-2A & -2B provide optical imagery for land and emergency services.
- Sentinel-3A & -3B provide optical, radar and altimetry data for marine and land services.
- Sentinel-5P provides atmospheric data, bridging the gap between ENVISAT and future Sentinel-5 data.
- Sentinel-4 & Sentinel-5 will fly aboard EUMETSAT MTG-S and Metop-SG satellites. They will monitor air quality, trace gases and aerosols over Europe at high spatial resolution and very high frequency.
- Sentinel-6 provides radar data to measure global sea surface height observations for climate monitoring and ocean and seasonal forecasts. It continues a time series of mean sea level rise measurements dating back to 1992.

CCMs complement the data portfolio in the Sentinel satellites missions with another layer of value to meet user needs, providing data from commercial data providers. There are around 30 existing or planned contributing missions, encompassing various technologies like Synthetic-aperture radar, optical sensors, spectrometers and altimetry systems.

In-Situ Component collects data acquired by a multitude of sensors at air-, sea- and ground-level, and includes geospatial reference data.

Service Component of Copernicus programme transforms the various data into timely and actionable information products. The Copernicus Services deliver value-added information products in six thematic areas:

Atmosphere	Climate	Emergency	Land	Marine	Security
Atmosphere Monitoring Service (CAMS)	Climate Change Service (C3S)	Emergency Management Service (CEMS)	Land Monitoring Service (CLMS)	Marine Environment Monitoring Service (CMEMS)	Security Service (CSS)[1]

The role of Copernicus has been key in the EMAid sector. Thanks to its historical data, it has been possible to consolidate prediction models for natural hazards such as floods, droughts which are key in prevention. The variety of sensors in EO and Synthetic-aperture radar are also important to provide a variety of datasets. In addition, Copernicus has made available its Emergency Management Service that is activated during major natural disasters and provides a quick assessment of the situation to all stakeholders. Copernicus EMS integrates also third-party data based on aerial data, in situ sensors or models to support disaster risk management for natural and man-made hazards.

Beyond providing information, Europe also supports more actively the EMAid sector via the Emergency Response Coordination Centre (ERCC) that mobilizes assistance or expertise during a crisis and more recently the rescEU mechanism that provides a reserve of European capacities in case member states ask for support from the EU. The EU space system is therefore an important part of the larger European Civil Protection and Humanitarian Aid Operations.

While Copernicus has paved the way for the use of satellite systems for EMAid, current requirements call for evolutions. To be more effective in situations of emergency, Copernicus should provide more near real time data when it is needed in the field. In addition, new sensors are required as well to provide new services: improved Synthetic-aperture radar as well as thermal sensors. Better accuracy has also been requested for all emergency and humanitarian applications, with better than 1m precision needed in most cases. Through its collaboration with private constellations, Copernicus will have access to more real time and accurate data for EMAid.

Beyond the technical improvements of the EO space assets, other gaps have been identified during the 2024 UCP process to facilitate the use of EO data:

- The need for a common **taxonomy** as different practitioners and users either use different wordings or apply different definitions to the same words. Such a taxonomy could also be part of a standard that could be applicable for specific applications.
- **Training** is another important topic that needs to be addressed to help users understand better the EO data and what can be expected
- As the **access to EO data** is often an issue**,** this should be facilitated in several ways. An easy-to-use hub with a search and display engine to find what data is available and, after selection, a simple system to download preprocessed data has been asked for.
- Means to guarantee the **integrity of EO data** have also been mentioned to make sure that the chain of custody has been maintained

European Global Navigation Satellite System (EGNSS)

EGNSS is the European satellite navigation program designed to provide highly accurate and reliable positioning, navigation, and timing services on a global scale and ensuring Europe's technological

[1] Copernicus Security Service is provided to registered public users only.

autonomy. EGNSS offers high-precision and multi-constellation capability. There is a free positioning service available to the public, as well as encrypted services for government and commercial use, like the Public Regulated Service (PRS) for government-authorized users. EGNSS includes two main systems:

- **Galileo** is the European satellite navigation system that provides highly accurate global positioning and timing information. It offers several unique features, including higher accuracy (especially in urban areas), improved availability, and an authentication service to prevent signal spoofing. Numerous EU economic sectors rely on Galileo, from transport and agriculture to border management and search and rescue. Its 20cm accuracy makes Galileo a game changer for autonomous driving and commercial drones. Already more than 3.5 billion smartphones are Galileo-enabled.

- **EGNOS** (European Geostationary Navigation Overlay Service) is a satellite-based augmentation system (SBAS) that improves the accuracy, integrity, and reliability of the navigation services to aviation, maritime and land-based users in over 30+ countries, and already operational in 426 airports and helipads.

Galileo has supported the EMAid segment with a range of innovative services. In the SAR (Search and Rescue) cluster, the Galileo Return Link Service (RLS), available since 2021, provides the user with an acknowledgement indication on the beacon that a distress signal from the beacon was received and its position located. This is a major morale booster for the people in life-threatening situations and has been endorsed by the Cospas-Sarsat system. The upcoming Galileo Early Warning Satellite Service (EWSS) will allow from 2025 onwards to broadcast alert messages directly to the population of areas threatened by a disaster. Users just need to have a Galileo enabled smartphone to receive Galileo information related to the hazard and instructions to follow. In view of the recent catastrophic flash floods in Southern Spain, EWSS has a key role to play to save lives. More general services of Galileo have been used systematically by emergency responders and humanitarian workers, for navigation application for onsite operations, to collect georeferenced data on disasters and for asset tracking applications. As such, Galileo remains an indispensable tool for the EMAid segment.

European Secure SATCOM

The EU Secure Satellite Communication System, known as **GOVSATCOM** is an investment made by the EU, which aims to provide secure and cost-efficient communication capabilities to security and safety-critical missions and operations. **IRIS²,** the new multi-orbital constellation of 290 satellites will provide secure connectivity services to the EU and its Member States as well as broadband connectivity for governmental authorities, private companies and European citizens, while ensuring high-speed internet broadband to cope with connectivity dead zones**.** The program is part of the EU's broader strategy to strengthen its autonomy, security, and defense capabilities, especially in response to increasing geopolitical challenges and cybersecurity threats.

In the EMAid segment, the need for reliable and secured communications is not currently met by existing systems. Other needed improvements are the **ease of set-up and use**, the smaller size of the field terminals and antennas, the **communication performance** (data rate, latency) as well as the need for SLAs as when in emergency situations, the access to an effective and reliable communication link is vital.

2.2 Market Overview & Trends

2.2.1 Market Evolution and Key Trends

EMAid is characterized by its variety of user communities managing emergencies:

- The largest community handles response to crisis situations, civil protection services for example
- Humanitarian aid is handled by a specific community of NGOs, international organizations and governmental responders
- SAR is provided by specialized services such as coast guards or civil protection
- Prevention and recovery is an activity in which regional government, municipalities and local institutions heavily contribute.

The key trends that drive the EMAid segment are external. The climate change is a major driver. European regions are now facing more frequent, severe, and longer lasting droughts. This increases the length and severity of the wildfire season, particularly in the Mediterranean region and expands the areas at risk from wildfires. Increased rainfall over extended periods leads to river flooding, while short, intense cloudbursts cause pluvial floods, where extreme rainfall causes flooding without any body of water overflowing. This directly impacts the activity of emergency responders and the EU civil security.

The climate change has an even stronger effect in countries in Africa (Chad, Sudan, DRC, Ethiopia…), Middle East (Yemen, Syria) and Asia (Afghanistan) with a larger direct impact on crisis and humanitarian aid needs.

The second major driver is due to the recent increase of human-made disasters (conflicts, epidemics, famine…) that increase the need of humanitarian aid. For example, international humanitarian assistance increased from $16B in 2013 to $38B in 2023[2].

These changes have a direct impact on civil protection and humanitarian aid, increasing the overall activity and the use of space technologies.

2.2.1.1 GNSS Key Market Trends

While GNSS is used whenever there are field operations by civil protection or humanitarian aid, SAR remains the largest cluster for the use of satellite navigation with an installed base of more than 2M units. While the evolution of this cluster has long been driven by the growth of the PLBs and personal communicators, this may change in the close future with the event of the 5G NTN. This technological evolution makes it possible to use standard smartphones to send emergency messages via satellite, outside of terrestrial cellular range. This will probably reduce the market for specialized emergency beacons, although in the aviation and maritime world, the need remains for dedicated devices. At the same time, the number of users of satellite enabled smartphones will increase and all use GNSS as a key feature to locate the emergencies.

2.2.1.2 EO Key Market Trends

Users in the civil protection and the humanitarian world have a need of ground data during response in an emergency situation. In all operations, information is collected by responders in the field or with the support of drones. But users have clearly identified the benefits of EO data: wide coverage, no need to be on the ground, large detection possibilities with many sensors available… However, the needs of

[2] https://devinit.org/resources/international-humanitarian-assistance-donors-channels-and-recipients/

responders in emergency situations are tactical to support immediate field operations. As such, real-time data and very accurate information is required which remains a challenge for satellite EO.

While improved accuracy has been continuously supported by private operators such as Airbus and Maxar, more real-time data with an improved revisit is brought by newspace operators with their larger constellations of small satellites that offer an improved time coverage.

As a matter of fact, the Copernicus program is supporting these specific user requirements with its contributing missions from newspace operators. The Iceye Synthetic-aperture radar constellation, with more than 30 satellites will provide high-resolution Synthetic-aperture radar images of any location on Earth, day or night, regardless of weather conditions. Iceye supports flood insights, wildfire assessments, volcanic activity monitoring and other surveillance activities. The Ororatech thermal constellation, with more than 80 satellites planned in 2027, will provide a scan every 30 minutes providing wildfire early detection, real-time monitoring and damage analysis.

2.2.1.3 SATCOM Key Market Trends

SATCOM is the largest commercial application of satellites, and it has supported the EMAid community for years as it fills essential gaps during emergency operations:

- After a natural disaster, traditional networks are often disrupted, and emergency aid and civil security must rely on satellite communications. For example, while firefighters, police and rescue workers have their own secure communication system, usually using the Tetra protocol, they also use satellite communications as a back-up.
- For international aid in foreign countries, NGOs and humanitarian organizations always rely on satellite communications as this will provide a quality of service they are used to. With an increase in the number of operations, use of SATCOM is on the rise as well.
- 5G NTN as part of SAR will drive the growth of SATCOM in Search and Rescue operations. The new phones that offer this feature already generated many search and rescue operations in the countries where the service is available.

A major trend in SATCOM is linked to the emergence of the new LEO broadband constellations that have disrupted the SATCOM market. Led by Starlink, these constellations bring a cost-effective service, high throughput, low latency and a very simple installation. As a matter of fact, most civil security organizations, NGOs and UN agencies are already using Starlink, although the system does not provide any security or guarantee of service.

2.2.2 Main User Communities

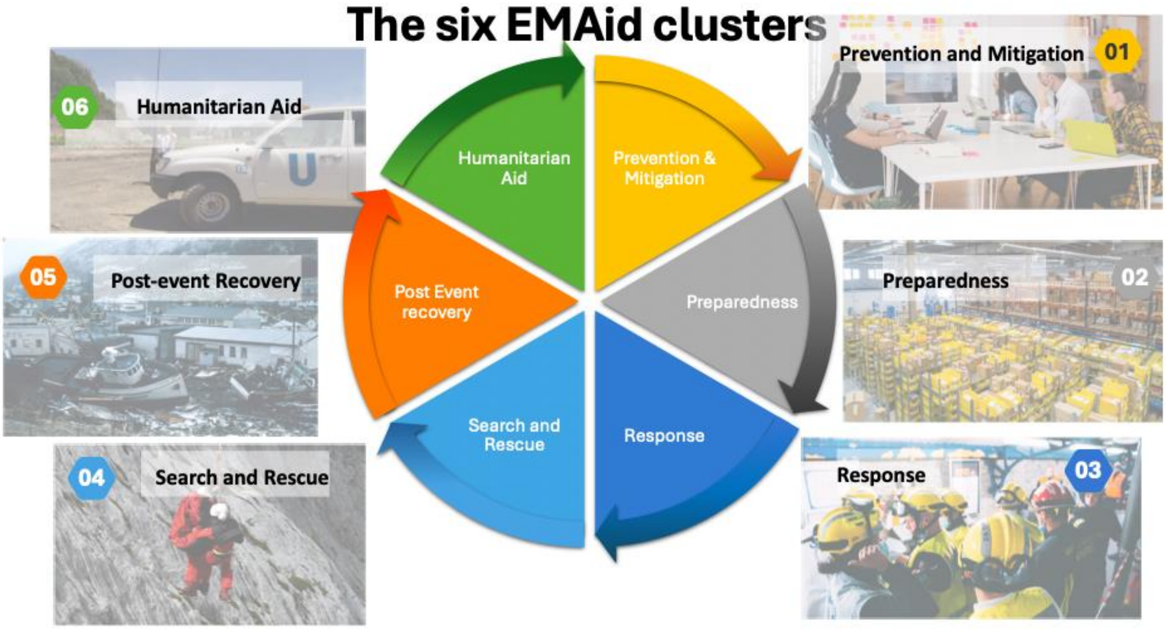
The main User Communities in the EMAid segment can be split by clusters in three groups:

• 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. For the applications analyzed in this report, key users are firefighters and local authorities that manage flood risks (city councils, departments, depending upon the countries). These organizations often have their own geomatic capability and thus access directly EO data and process it to their own needs.

• For cluster 4 (Search and Rescue), the end users can be split in two separate groups. First, the users of the GNSS beacon or device 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 services as well as private organizations providing rescue services. They receive the emergency signal from the beacons and use it to organize SAR operations and they can 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). For the Human Rights Protection application, users also include the judicial bodies like the ICC (International Criminal Court) and ICJ (International Court of Justice) as well as the press that is often active to relay such information.

Figure 2: The EMAid clusters



Beyond the end-user communities, it is worth mentioning the role played by the Civil Protection Mechanism of the Union that supports local civil security actions. Set-up in 2001, the EU Civil Protection Mechanism strengthens the cooperation of the member countries and thus improves the disaster prevention, preparedness and response. When a country, in Europe or elsewhere, is overtaken in its capacity to respond to the scale of a disaster, it can request assistance through the mechanism that brings together all Member States and 8 partner countries. For example, in 2023, the Mechanism was activated 66 times to respond to the war in Ukraine, wildfires in Europe and the earthquake in Syria and Türkiye.

2.3 Key market drivers – Policies, Regulations, Standards

The EMAid segment is not a heavily regulated segment, especially concerning the direct use of satellite systems. However, there are a number of EU regulations, international treaties and good practices and standards that are indirect drivers for the development of this segment and its use of satellite services.

This chapter gathers a non-exhaustive list of relevant organizations, regulations, standards and other guidelines that influence implementation of satellite-based services and define their requirements.

2.3.1 Selection of applicable regulations, treaties and conventions

General conventions and treaties for emergency management

The **International Charter Space and Major Disasters** has been established in 2000 as a worldwide collaboration of 17 space agencies, through which satellite data are made available for the benefit of disaster management. By combining Earth observation assets from its members, the Charter allows resources and expertise to be coordinated for rapid response to major disaster situations; thereby helping civil protection authorities and the international humanitarian community. The charter has been activated 900 times for events such as floods, landslides or wildfires.

The **Sendai Framework for Disaster Risk Reduction 2015- 2030** is a non-binding agreement adopted by the United Nations General Assembly in March 2015. It is the successor to the Hyogo Framework for Action 2005-2015 and provides a global framework for the reduction of disaster risk and loss of lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. While general in nature, it covers flood and wildfire risks as well.

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.

Regulations and EU strategies for floods

The **European Directive on Floods** (Directive 2007/60/EC), also known as the Floods Directive, was established by the European Parliament and the Council in 2007. Its primary aim is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage, and economic activities. The directive sets out a framework for the assessment and management of flood risks across the European Union (EU) which is imposed on local authorities.

Several European regional frameworks contribute on the flood risk reduction as well.

The **EU Strategy for the Danube Region (EUSDR)** is a policy framework that was adopted by the European Union (EU) in 2011 to promote cooperation and development in the Danube region, which encompasses 14 countries along the Danube River. The EUSDR promotes economic, social, and environmental sustainability in the region, and to address common challenges and opportunities through cooperation and coordination among the countries in the region. The EUSDR works on a range of issues, including infrastructure development, environmental protection, energy security, and cultural cooperation.

The **European Union Strategy for the Baltic Sea Region (EUSBSR)** was the first macro-regional strategy within the European Union. It aims at reinforcing cooperation within this large region to tackle several common challenges. The strategy also contributes to major EU policies and reinforces the integration within the area.

The **EU Strategy for the Adriatic and Ionian Region (EUSAIR)** is a macro-regional strategy adopted by the European Commission in 2014, that aims to promote economic and social prosperity and growth in the region by improving its attractiveness, competitiveness and connectivity. It covers ten countries: four EU Member States (Croatia, Greece, Italy, Slovenia) and six non-EU countries (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, San Marino, Serbia) and aims to contribute to the further integration.

Strategy for wildfires

Part of the European Green Deal, the **EU Forest Strategy** for 2030 sets the basis for increased fire prevention and climate resilience of forests. Also, the guidelines on land-based wildfire prevention call for managing vegetation and avoiding the accumulation of fuels on the ground to facilitate firefighting. Other EU policies apply as well to support wildfires prevention and fighting such as the EU Strategy on Adaptation to Climate Change (March 2021) and the proposal for a Nature Restoration Law.

Conventions and treaties for Human Rights

A number of international treaties are specific to the protection of Human Rights.

The **convention relative to the Protection of Civilian Persons in Time of War** also known as the Geneva Convention adopted in 1949 updated the previous conventions that dealt with combatants only, not with civilians. In this way, the new Convention 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.

The **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.

At EU level, the **Treaty of the European Union** (art. 2, 3.5) refers to the promotion of international law, human rights and international humanitarian law (IHL) worldwide. The Guidelines on the Compliance with IHL specifies this obligation.[3] Defending human rights and reporting on human rights violations and international humanitarian law is an important task for the European External Action Service (EEAS).[4]. Yearly reports stress the importance of collaboration with international tribunals and national courts[5]

The **International Covenant on Civil and Political Rights (ICCPR)** is a multilateral treaty that commits nations to respect the civil and political rights of individuals, including the right to life, freedom of religion, freedom of speech, freedom of assembly, electoral rights and rights to due process and a fair trial. It was adopted by United Nations General Assembly Resolution in 1966 and as of June 2024, the Covenant has 174 parties and six more signatories without ratification, most notably the People's Republic of China and Cuba.

The **United Nations Convention Against Torture (UNCAT)** is an international human rights treaty adopted in 1984 that aims to prevent torture and other acts of cruel, inhuman, or degrading treatment or

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[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009XG1215(01)

[4] https://www.eeas.europa.eu/eeas/2023-annual-report-human-rights-and-democracy-world-0_en

[5] https://www.consilium.europa.eu/media/ahzanxgy/7th-ihl-report.pdf

punishment around the world. The Convention requires member states to take effective measures to prevent torture in any territory under their jurisdiction and forbids member states to transport people to any country where there is reason to believe they will be tortured.

The **United Nations Convention on the Rights of the Child (UNCRC**) is an international human rights treaty which sets out the civil, political, economic, social, health and cultural rights of children. The convention defines a child as any human being under the age of eighteen, unless the age of majority is attained earlier or later under national legislation.

The **African Charter on Human and Peoples Rights** (also known as the Banjul Charter) is an international human rights instrument that is intended to promote and protect human rights and basic freedoms in the African continent and was adopted in 1979.

The **African Charter on the Rights and Welfare of the Child** (also called the ACRWC or Children's Charter) was adopted by the Organisation of African Unity (OAU) in 1990 and was entered into force in 1999. Like the United Nations Convention on the Rights of the Child (UNCRC), the Children's Charter is a comprehensive instrument that sets out rights and defines universal principles and norms for the status of children. The ACRWC and the UNCRC are the only international and regional human rights treaties that cover the whole spectrum of civil, political, economic, social and cultural rights.

The EU has its own human rights document, the **Charter of Fundamental Rights of the European Union** that was voted in 2000 and covers EU citizens and applies to all the bodies of the European Union. Similarly, the **European Convention on Human Rights** defines and guarantees since 1950 human rights and fundamental freedoms in Europe. All 47 member states of the Council of Europe have signed this convention and are therefore under the jurisdiction of the European Court of Human Rights in Strasbourg.

Other regulations

The Search and Rescue sector is the most regulated cluster, both for maritime and aviation. These regulations impact both requirements and performances for satellite systems used for Search and Rescue and are very explicit concerning the use of satellite systems.

- **ICAO GADSS** 6.0 Global Aeronautical Distress & Safety System (GADSS) 07 June 2017 implements aircraft tracking, mostly based on ADS-B.

- **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.

2.3.2 Other standards, practices and guidelines

The work of firefighters, especially the tactics used, varies with the countries. Many countries have developed their own doctrines. For example, the **French national strategy** calls for a quick attack of fires: in less than 10 minutes after its detection (or less than 1 burnt hectare), the firemen should be on site. This doctrine has been adopted in part in other EU countries such as Portugal, Spain or Italy. Such a method is not possible in larger countries like the US, Canada or Australia. One effect of this strategy is that whatever tools are used for detection of fire or to follow its spread require near real-time processing.

In the field of the humanitarian action, **the Code of Conduct for the International Red Cross and Red Crescent Movement and Non-Governmental Organizations** (NGOs) in Disaster Relief, a voluntary code seeking to “guard our [IFRC, ICRC and other NGOs] standards of behavior”. 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 **Leiden Guidelines on the Use of Digitally Derived Evidence** provide a framework for handling digital evidence to ensure its admissibility and reliability in judicial proceedings. These guidelines, formulated by international legal and technical experts, aim to standardize practices across jurisdictions to maintain the integrity and credibility of digital evidence. Key aspects include:

- **Admissibility**: Digital evidence must be collected, preserved, and analyzed in a manner that upholds its integrity and authenticity. Adherence to proper legal procedures ensures the evidence is admissible in court.

- **Chain of Custody**: A critical element in digital forensics, ensuring that the digital evidence is properly handled and tracked from the point of collection to presentation in court. The chain must be documented to prevent any claims of tampering.

- **Data Integrity**: Preservation of the original form of digital evidence is paramount. Forensic copies or mirrors of the data should be used for analysis, with tools that do not alter the data itself.

- **International Cooperation**: Given the cross-border nature of digital evidence, the guidelines emphasize the importance of collaboration between jurisdictions and the need to respect local legal frameworks, privacy laws, and data protection regulations.

- **Standardization of Procedures**: Best practices for collecting, analyzing, and presenting digital evidence are emphasized, with guidelines recommending the use of validated forensic tools and methodologies.

- **Ethical Considerations**: Legal practitioners and forensic experts must be aware of ethical responsibilities, particularly around issues of privacy and data protection when handling sensitive information.

These guidelines aim to harmonize the collection and use of digitally derived evidence internationally, ensuring fairness and consistency in legal proceedings involving digital information and as such apply to the use of EO data during judicial procedures.

2.3.3 Relevant Standards for EO

EO techniques present a lack of consistency between sensors and their calibration, in data formats and structures, in accuracies and terminology, and structures. Uptake of some EO techniques has been slow and there have been challenges in ensuring interpretability. International standards would help address these issues, and these guidelines aim to go some way towards improving the accessibility of EO data products and technologies.

There are currently very few standards or regulatory documents in EO, either in data quality or in processing or products. The internationally adopted standards in data formats and metadata associated with digital spatial data were provided by ISO, IEEE, OGC, GRSS and SEOAH:

- The International Organization for Standardization (ISO).
  - ISO/TR19121:2000 concerning Geographic information, imagery, and gridded data
  - ISO 19115:2014 Geographic Information - Metadata.
- The Open Geospatial Consortium (OGC) provides Standards and Schemas (XSD, JSON Schema, etc) for the geospatial information interoperability and implementation used by international organizations.
- EO product metadata: OGC's GML Application Schema for EO Products
- Collection and service discovery: OGC's Cataloguing of ISO Metadata using the ebRIM profile of CS-W.

- Catalogue Service : OGC's Catalogue Services Specification 2.0 Extension Package for ebRIM Application Profile: EO Products.
- Order: OGC's Ordering Services for EO Products
- Feasibility Analysis: OGC's Sensor Planning Service Application Profile for EO Sensors
- Online Data Access: OGC's WMS EO Extension
- Identity (User) Management: OGC's User Management Interfaces for EO Services.
- Geoscience and Remote Sensing Society (GRSS) created the Standards in Earth Observations (GSEO) Technical Committee to support the development and promotion of technical standards related to the generation, distribution, and utilization of interoperable data products from remote sensing systems.
- The Standards in Earth Observations Ad Hoc Committee (SEOAH) is the managing organizational unit within GRSS to handle standards development within the IEEE.

2.4 User Needs and Requirements

This chapter provides summary of user needs and requirements pertaining to EMAid applications introduced before, describing the different roles and needs covered by EO, GNSS and SATCOM and, ultimately, identifying the corresponding requirements from a user perspective.

The table below depicts the main applications making use of EO/GNSS/SATCOM technologies in SEGMENT, with indication whether this report covers it in the scope of the analysis or not. The list of applications is non-exhaustive and is expected to potentially grow and adapt according to the expected adoption of space technologies in the coming years and the innovations that should come with it. While each one of the applications addressed in this document can benefit or potentially benefit from satellite technologies, the current issue this report does not cover in detail the needs and requirements of all applications. Some applications are more mature than the others as it comes to uptake of EO/GNSS/SATCOM, therefore there is no equal level of details provided to all of them. The table below presents the scope of the analysis covered in the current version of user needs and requirements report.

Table 1: Applications analyzed in the report

Clusters	Applications	Covered in the Analysis	Updated in 2024
Prevention & Mitigation	Impact exposure analysis and proactive mitigation measures (EO)	YES	NO
Preparedness	**Early-warning surveillance of forest fires (EO, SATCOM)**	YES	YES
	Landslides and terrain deformation monitoring (EO, GNSS, SATCOM)	NO	YES
	Earthquakes monitoring (EO, GNSS, SATCOM)	NO	YES
	Tsunami monitoring (EO, GNSS, SATCOM)	NO	YES
	Volcanic activity monitoring (EO, GNSS, SATCOM)	NO	YES
	Floods monitoring (EO, GNSS, SATCOM)	YES	YES
	Storm surges monitoring (EO, SATCOM)	NO	YES
	Drought monitoring (EO, SATCOM)	NO	YES
	Mining monitoring (EO, GNSS, SATCOM)	NO	YES
	Fracking monitoring (EO, SATCOM)	NO	YES
	Monitoring of vector-borne diseases (EO, SATCOM)	NO	YES
	Monitoring of locust swarms (EO, GNSS, SATCOM)	NO	YES
	Space debris removal (GNSS)	NO	NO
Response	Crisis area assessment (EO, GNSS, SATCOM)	NO	YES
	Operational wildfires modelling (EO, SATCOM)	YES	YES
	Secured Communications for firefighting (SATCOM)	YES	YES
Search and Rescue	SAR operations: at sea (GNSS, SATCOM)	NO	YES

Clusters	Applications	Covered in the Analysis	Updated in 2024
	SAR operations: aviation (GNSS, SATCOM)	NO	YES
	SAR operations: land (GNSS, SATCOM)	NO	YES
	Situational awareness supporting SAR (EO)	NO	NO
Post-event Recovery	Post-crisis damage assessment and building inspection (EO, GNSS)	NO	NO
	Restoration of supply chain and infrastructure services (EO, GNSS, SATCOM)	NO	YES
Humanitarian Aid	**Documenting human rights violations (EO)**	YES	YES
	NGO's asset management (GNSS, SATCOM)	NO	YES
	Welcome applications to people in need of humanitarian aid (GNSS)	NO	NO
	Health and medicine response and coordination (EO, GNSS)	NO	NO
	Management of refugee camps (EO)	NO	NO
	Population Displacement monitoring (EO)	NO	NO

The following table lists additional secured SATCOM applications that have been identified beyond the application that will be analyzed this year.

Table 2: New applications for SATCOM

Clusters	Applications
Preparedness	Event detection. Vast networks of satellite IoT sensors can be established to detect events. This includes water level sensors (floods), gas sensors (wildfires), motion sensors (earthquakes), etc....
Response	Communications for firefighters, civil security with SATCOM (voice, data). In crisis situations, terrestrial networks often break down: SATCOM is then used to replace them for voice (key for response) and data to transmit status information such as maps.
	Fire spread following and reporting. Fire spread can be monitored in a variety of manners (on the ground or in the air) but this information is often transmitted via satellite.
	Vehicles and staff tracking. To optimize resources and protect firefighters, satellite enable trackers are used to improve situational awareness and locate staff in distress.
	Fire Hot spot identification and reporting by drone. Drones are used to identify zones where fires may restart. This information can be collected by satellite out of terrestrial coverage.
	Cellular backhaul. During an event, cellular bubbles can be established for first responders.
Search and Rescue	EPIRBs, Personal emergency trackers. Most Search And Rescue activities occur in areas that are outside of terrestrial networks and require the use of SATCOM.
Post-event Recovery	Cellular backhaul. After an event, it often takes a long time to re-establish cellular networks, SATCOM can be used to backhaul cellular service.

Clusters	Applications
Humanitarian Aid	Telemedicine. Remote diagnosis using equipment (portable or fixed) is performed using SATCOM to deliver data to medical staff without the need of a physical presence.
	Staff security. Personal trackers are used to send an emergency signal via satellite whenever staff is in danger.
	Rapid mapping. After a crisis, satellite maps are produced to give an assessment of the local situation. These maps along with other data is sent via satellite to local staff.
	Asset management. All valuable assets (vehicles, heavy equipment like generators, refrigeration equipment) are monitored via satellite for location and other relevant data.
	Cash transfer. SATCOM make it possible to transfer cash between remote locations such as refugee camps.
	Connectivity for refugees. This is considered now as a core relief item and when cellular networks are not available, may be provided via satellite communications

2.4.1 CLUSTER 1: Prevention & Mitigation

2.4.1.1 Impact exposure analysis and proactive mitigation measures (EO)

The prevention phase in emergency management focuses on activities that reduce the likelihood of disasters and ensure preparedness through measures and contingency plans, including humanitarian aid considerations. Impact exposure analysis is crucial for designing proactive measures like evacuation plans, taking into account factors such as road capacity, population density, and city population. Accurate data on risk, socio-economic factors, exposure, and vulnerability is essential for effective planning and response. This data should include land cover, building types, population estimates, and infrastructure details. However, maintaining up-to-date information is a significant challenge.

Stakeholders such as risk modeling organizations, civil security, first responders, and local authorities use EO (Earth Observation) data to enhance exposure analysis of assets and populations. Up-to-date vulnerability information combined with EO data enables impact-based forecasts, identifying areas and communities at higher risk. Copernicus EMS, for instance, provides products like impact assessment analysis on assets and population and flood exposure assessment.

2.4.2 CLUSTER 2: Preparedness

2.4.2.1 Early-warning surveillance of forest fires (EO, SATCOM)

Powered by the climate crisis, extreme wildfires are on the rise globally, hitting hard North America and Australia. The energy released by these fires more than doubled in the past 20 years adding to the release of carbon and vast smoke plumes comparable to volcanic eruptions. With around 400M Ha burnt every year, the devastated areas have been stable for the past ten years, with Africa representing 70% of the areas burnt. At any moment in time, there are 10000 active fires and 97% are suppressed before posing a major risk[6].

Europe has been relatively spared by wildfires with an average of 15M Ha burnt. However, since 2006, there is a general increasing trend in the number of fires and burnt areas, with recent critical years such as 2017, 2021, 2022 and 2023. The amount of burnt areas has increased in countries not commonly affected by wildfires in the past, especially in Northern and Eastern Europe. 2023 saw the largest fire episode in the EU, since 2000, with critical fires in Greece, Spain and Portugal with over 201,100 ha burnt within Natura 2000 protected areas. Future climatic projections indicate higher fire danger levels in Europe leading to more intense fires and larger burnt areas.[7]

As wildfires are becoming an increasing concern, with an average of more than 2.5B€ of annual damages in Europe, new measures and doctrines are being designed in Europe to fight these events. The French firefighters have designed a strategy to fight fires that has been adopted as such by Portugal or partially by Spain and Italy. This strategy calls for a rapid fight of new fires in periods of high risk: this means that a fire should have covered less than 1 hectare or that it should be attacked within 10 minutes of detection. This strategy is effective in Europe where there is a high density of people and housing to protect, and communication means to go to fire zones. This principle also implies that fighting means should be prepositioned in high-risk areas and that aerial fighting means are available as well. To support this strategy, daily risk assessments are needed as well as early detection tools, which are two use cases supported by satellites.

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[6] Data from https://ourworldindata.org/wildfires and https://www.xprize.org/prizes/wildfire

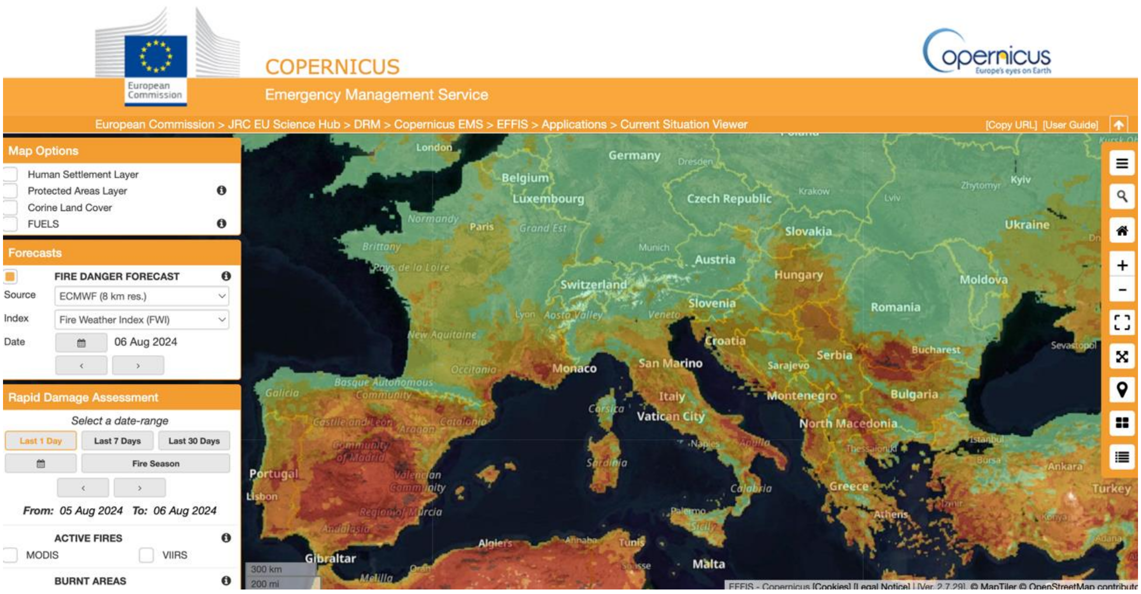
[7] Data from European Parliament, JRC, EFFIS

The first operational scenario is the advanced forecasting of wildfires. These forecasts are based on two main parameters: the weather and the fuel available and can provide a risk assessment of up to 10 days in the future.

The Copernicus Emergency Management Service proposes the European Fire Forecast Information System (EFFIS, http://effis.jrc.ec.europa.eu/) and the Global Wildfire Information System (GWIS, http://gwis.jrc.ec.europa.eu/). These systems rely on fire danger rating systems (the Canadian Fire Weather Index, CFWIS) to provide forecasts of fire danger based on numerical weather predictions at the European and global levels, provided by ECMWF. The probability of fire occurrence is assessed through the quantification of the meteorological fire danger, based on metrics obtained from empirical index systems, which evaluate the probability of ignition, and the fire spread rate, as well as infer the dryness level of the soil and the available fuels. The resolution is 8x8km, with a depth of 1 to 9 days and 6 scales, from Low to Very Extreme This fire danger rating system is more adequate to detect dangerous weather conditions favorable to uncontainable fires rather than modeling the probability of ignition and fire behavior. In France, the meteorological office provides daily risk indexes (Very high, high, moderate, low) of fire start for the whole country at the department level as a prevention tool for the general public. These indexes aggregate weather data (temperature, humidity, wind and precipitation) and soil dryness. In addition, Meteo France also provides more accurate risk indices (down to 1km) to the firefighters based on a CFWIS version adapted to France. Similarly, while only models of vegetation dryness are used, and R&D projects are under way to include satellite data for soil cover and moisture.

These risk maps are essential for the fire fighters as they allow to position fire suppression means (people, vehicles, water stock) in the high-risk areas and even to organize regular flights over these spots. This is the strategy used to attack the fires as quickly as they are detected.

Figure 3: The Copernicus EFFIS situation viewer displaying Fire Danger forecast on 6th of August 2024 (higher risks are in red)



Summary of needs for advanced forecasting of wildfires. For the preparation of firefighting, there are two different types of needs for risk forecasting. A first need is to have a forecast for 2-4 weeks covering large areas to prepare means and human resources. A second need is the daily forecast for the next day of risk with a resolution that is around 1km to prepare possible operations.

The second operational scenario is the early detection of wildfire. The doctrine, in most European countries, calls for a quick detection of a fire as a small fire is easier to extinguish. Today, various means are implemented for this purpose: crowdsourcing (passerby alert the fire services or social network data is used), human watch on towers or in aircrafts, cameras on poles with human surveillance, cameras with AI detection on poles, on drones or on balloons. The systems used depend on the size, relief and location of the area to monitor but the most commonly system today is cameras on towers. Detection takes generally a few minutes, but the main difficulty lies in the limited coverage as the range of a camera is in the order of magnitude of 10km. These cameras usually detect smoke (during the day) and light emissions (during the night). Similarly, IoT systems with sensors installed in forest are being implemented. These sensors usually detect gases that appear at fire start and relay this information via a network or via satellite. The necessity to install a large number of sensors and to maintain them makes such deployments a difficult task. Several projects are under way: Spanish satellite operator Hispasat supports the deployment of environment sensors and panoramic cameras in Portugal that report data via satellite and German Dryad has deployed its IoT network in Sicilian forests to provide early detection based on gas measurements and ground IoT.

In addition, Satellite EO can play an important role in early detection of fires as satellites cover large areas and thus do not necessitate important ground deployments. However, time is a key parameter for this use case. For example, the French firefighters specify a detection of a fire start over the French territory in less than 5 minutes with an accuracy of 50 meters and the tracking of the fire every 20 minutes[8]. In the USA, the Xprize challenge is even more difficult: one minute to accurately detect all fires across a landscape larger than entire states or countries, and 10 minutes to precisely characterize and report data with the least false positives to decision-makers on the ground[9].

Several satellite systems and projects support early fire detection where near real-time is a key feature:

- The American GOES-R is a geo satellite that uses both visible and ABI (Advanced Baseline Imager) infrared spectral bands to locate fires. Data is provided with a 2km resolution every 10 minutes over the Americas. This service is provided through the NASA Fire Information for Resource Management System (FIRMS) that also uses signals from Landsat, Meteosat 9 and 11, Sentinel 2A & 2B and JAXA's Himawari 8.
- The University of Southern Australia is working on a project of smallsat early fire and fire smoke detection[10]. Using AI algorithms onboard, the goal of this project is to detect small fires in less than an hour.
- German company Ororatech, one of the Copernicus contributing missions, is providing an early fire detection service part of its Wildfire Service (WFS). The system aggregates data from 27 LEO and GEO satellites, including the European Sentinels. In addition, Ororatech will launch its own LEO smallsats to provide early detection at a 4x4m resolution with 50 satellite passes every day starting in 2027.
- Google is supporting FireSat, a new global satellite constellation designed specifically to detect and track wildfires the size of a classroom within 20 minutes. The project is led by the Earthfirealliance NGO and calls for 50 satellites with high resolution IR sensors. Google provides its expertise in AI to detect quickly small-scale fires.

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[8] Appel à Manifestation d'Intérêt National (AMIN) Projet Panoptès – Entente Valabre -2023

[9] https://www.xprize.org/prizes/wildfire - 2023

[10] https://unisa.edu.au/media-centre/Releases/2024/fighting-fires-from-space-in-record-time-how-ai-could-prevent-a-repeat-of-australias-devastating-wildfires/

Figure 4: Wildfires ravaging northern and central Portugal (Sep 2024, Copernicus Sentienl-3 imagery)

On the R&D side, the following EU funded R&D projects address early fire detection:

- The SYLVANUS project (https://silvanus-project.eu/) proposes several technologies for early fire detection: social sensing (mainly from X, formerly Twitter), ground IoT devices or drones.
- The FIREUrisk project (https://fireurisk.eu/) aims to set an integrated approach to wildfire risk assessment (when, where, what and how may the landscapes burn), new fire management approaches as well as resilient recovery. Satellite is used for danger and vulnerability assessment in the various pilot sites of the project.
- The FIRE-RES project (https://fire-res.eu) will develop an integrated fire management strategy to efficiently and effectively address extreme wildfire events in Europe. EO is used in living labs to check the evolution of key forestland metrics and phenological parameters as well as for a better assessment of weather parameters.

Summary of needs for early detection of wildfires. Early detection of wildfires requires real time detection (less than 10 minutes) of small starting fires (1 square meter of footprint) over a whole country.

Table 3: Description of EO data needs and requirements relevant for Early-warning surveillance of forest fires.

ID	EUSPA-EO-UR-EMH-0008	EUSPA-EO-UR-EMH-0009
Application	**Early-warning surveillance of forest fires**	
Users	Firefighters	Firefighters, general public, policy makers, local authorities
	End Users Application Needs	
Operational scenario	**Early detection of wildfires.** The user needs to be alerted when a forest fire starts (typical size: less than 1 square meter) in less than 10 minutes	**Advanced forecasting of wildfires** The user needs an assessment of the risk of fires to preposition the firefighting means
Size of area of interest	Size of a European country	Size of a European country
Frequency of information needed	The information is needed on a continuous basis	The information is needed on a daily basis
Type of service (continuous, forecasting, one-off?)	The service is permanent whenever weather conditions create a risk of fire; however the need is greater during the summer season	The service is permanent whenever weather conditions create a risk of fire; however the need is greater during the summer season
Other (if applicable)		
	Satellite EO Data Requirements	
Spatial resolution	Less than 1m	1km is sufficient
Temporal resolution	Less than 10 minutes	Daily
Type of EO data needed	Multispectral (e.g. TIR bands) and Synthetic-aperture radar can be used	Synthetic-aperture radar and optical data are used for soil moisture
Other requirements (if applicable)	EO data needs to be processed quickly to provide the alarm service as well as the exact location: the latency is a key parameter. When real-time is needed, AI is a relevant tool for detection.	Weather data (wind, temperature) is added to EO data to provide a risk assessment Historical data on actual fires is needed to improve risk maps.

2.4.2.2 Landslides and terrain deformation monitoring (EO, GNSS)

This application was addressed during the 2022 UCP and is detailed in the 2022 EMAid User Needs and Requirements Report[11].

Landslides are the movement of rock, earth, debris, or mud down a slope, primarily caused by soil erosion and gravity but can also be triggered by natural events like rainfall, earthquakes, volcanic activity, or human activities such as deforestation, construction, and cultivation. Climate change increases the risk of landslides. They pose a serious threat, causing property damage, infrastructure loss, and environmental degradation.

[11] https://www.euspa.europa.eu/publications-multimedia/publications/ucp-user-needs-requirements-2022#:~:text=Report%20on%20Emergency%20Management%20%26%20Humanitarian%20Aid

There are two operational scenarios for landslide monitoring: the general large-scale inventory of landslides using change detection and monitoring specific landslide-prone areas using a variety of technologies.

This activity involves multiple actors such as civil protection agencies, private companies, national surveying institutes, NGOs, and GIS/mapping experts. These stakeholders use the data to prepare communities for emergencies and make risk assessments, particularly in regions lacking local monitoring capabilities.

Figure 5: After a landslide (Timo Volz on Unsplash)

Various technologies are used including in-situ sensors like piezometers and inclinometers to measure terrain deformation, advanced technologies like UAVs (drones) or laser scans. Satellite systems like GNSS and EO are critical for this task. GNSS solutions (differential, PPP, RTK) can provide point-based monitoring with millimetric accuracy but has limitations in covering large areas and in complex terrains. EO is effective for broad monitoring using radar images with high resolution and multi-temporal interferometric analysis (InSAR). However, limitations include challenges in real-time measurements, vegetated areas, and fast-moving landslides. The combination of GNSS and EO can be effective as GNSS helps calibrate interferometric radar data from EO to improve monitoring accuracy.

Several research and development projects, such as the Safeland Project (https://safeland-project.eu/) and the GIMS Project (https://www.gims-project.eu/), have advanced the use of satellite technologies and in-situ sensors for landslide risk assessment. The Copernicus Emergency Management Services (EMS) provides landslide risk assessments and aids in identifying vulnerable areas and the European Ground Motion Service (EGMS) under the Copernicus Land Monitoring Service offers ground motion data on a continental scale and provides valuable insights into slow-moving landslides using InSAR data.

However, EO technologies face limitations in fast-moving landslides, snow-covered areas, and vegetated or mountainous terrain. These situations hinder the effectiveness of satellite-based monitoring. And while very accurate, GNSS is limited to specific monitoring points. Dual-frequency receivers, with enhanced accuracy and removal of ionospheric interference, make landslide monitoring more efficient.

2.4.2.3 Earthquakes monitoring (EO, 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 Synthetic-aperture radar 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

2.4.2.4 Tsunami monitoring (EO, GNSS, SATCOM)

Tsunamis are caused by underwater earthquakes, landslides or volcanic eruptions, displacing large volumes of water on long distances.

Many countries with coastlines exposed to the impact of tsunamis possess a tsunami warning system. It is usually based on a network of seismometers and other sensors used to detect the phenomena. When a potentially destructive tsunami is detected, the national authorities then decide whether to issue a public tsunami warning and an evacuation order.

The prediction/alert of tsunamis is mainly based on networks of seismometers, sea bottom pressure transducers and sea level measurement stations that all make use of GNSS and SATCOM to report data,

In addition, 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 monitoring. 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.

2.4.2.5 Volcanic activity monitoring (EO, GNSS, SATCOM)

Before a volcanic eruption actually occurs, 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.

While seismometers are the main tool to monitor volcanoes, GNSS also plays a role. Thanks to cm-level accuracy GNSS stations installed around volcanoes, scientists conduct GNSS land deformation monitoring. The data collected on site is then transmitted to a relevant centre - in some cases using SATCOM - where measurements can be evaluated by experts. In areas lacking terrestrial communications, SATCOM may be used to collect the information.

Satellite-based EO also provides large-area observations. For example, the MOUNTS Monitoring System[12] (Monitoring Unrest from Space) uses Sentinel-1, 2 and 5P data along with Artificial Intelligence

[12] http://www.mounts-project.com/home

(AI) to assist volcano monitoring tasks. It provides near-real-time access to surface deformation, heat anomalies, SO2 gas emissions, and local seismicity at a number of volcanoes around the globe, providing support to both scientific and operational communities for volcanic risk assessment

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.

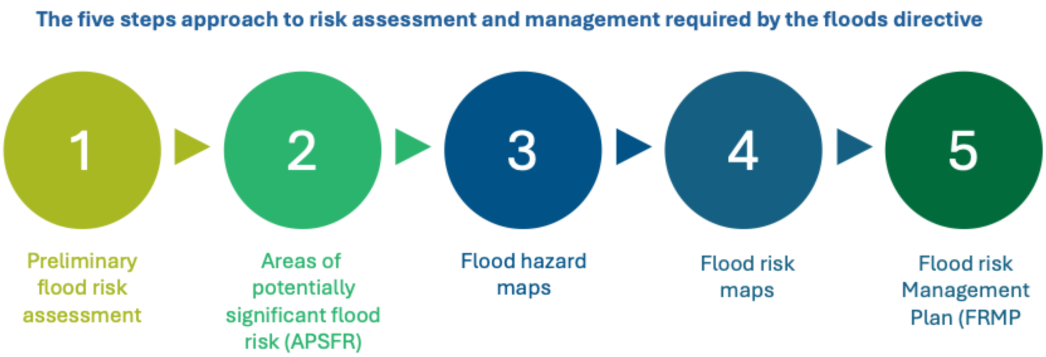
2.4.2.6 Floods monitoring (EO, GNSS, SATCOM)

Flood risk in Europe has changed over the last 50 years: climate change, urbanization and migrations towards coastlines make the flood risk landscape dynamic. For example, one in eight Europeans lives in an area at risk of flooding and critical infrastructures also lie in at-risk areas. Around 15% of industrial facilities in Europe may be located on flood plains. 11% of hospitals are also located in high-risk areas. (Source: EEA).

As a matter of fact, floods constitute the most expensive natural hazard in Europe. Between 1980 and 2022, climate-related extremes damages amounted to an estimated EUR 650 billion, 29% of which were due to floods followed by 20% due to heat waves[13]. Among the top 5 most expensive events, 3 were floods: the 2021 flooding in Germany and Belgium (EUR 44 billion), the 2002 flood in central Europe (EUR 34 billion) and the 2000 flood in France and Italy (EUR 14 billion). Recent studies[14] have shown that flood risk is projected to increase in the British Isles and Central Europe and that urban centers and their surrounding regions are hotspots of flood risk over Europe.

To address this increasing risk, the EU adopted in 2007 its Floods Directive to reduce the risk of flooding to people and property in the EU. The Floods Directive establishes a common approach to flood risk assessment and management across the EU and requires member states to identify flood risk areas and to develop flood risk management plans to address these risks. The EU has also developed the Floods Alert System (EFAS), which is a web-based platform that provides real-time information about flood events in the EU. The system is designed to help authorities and emergency services respond more quickly and effectively to flooding, and to provide information to the public about flood risks and how to stay safe.

Figure 6: The 5 steps approach in the Floods Directive (source: ECA)



In addition to these specific frameworks and strategies, the EU also has several broader policies and initiatives that address flood protection and risk management, including the Water Framework Directive, the EU Biodiversity Strategy, and the EU Adaptation Strategy. These initiatives aim to promote

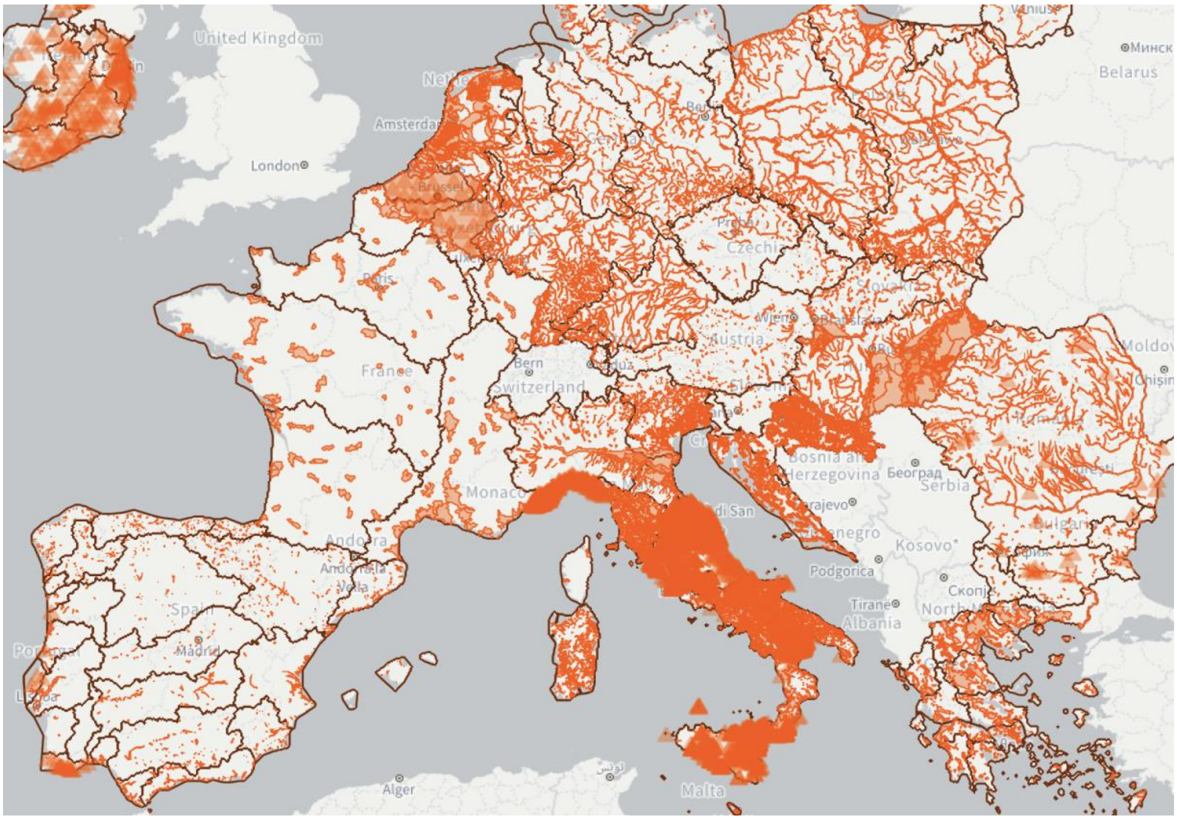
[13] https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related

[14] https://www.sciencedirect.com/science/article/abs/pii/S0959378022000978

sustainable water management and increase the resilience of communities and ecosystems to the impacts of flooding and other environmental hazards

Thanks to the Floods Directive, it is now possible to assess risks at the European level as shown on the following map that aggregates data made available by European countries.

Figure 7: The Flood Risk area viewer (https://discomap.eea.europa.eu/floodsviewer/)



The outcome of the second cycle of preliminary flood risk assessments (PFRAs, 2021) shows that half of the Member States have improved data collection and methodologies. Twelve Member States have updated criteria for identifying significant future floods. While urban flooding and sea level rise are gaining attention, river floods remain the most common in the EU. Most Member States now consider the impact of future floods on human health, the environment, cultural heritage, and economic activity, with increased focus on the environment and cultural heritage. However, 60% of EU river basins lack data on flood damage costs, highlighting the need for better data collection to prioritize measures. Long-term developments and climate change are being considered by all Member States, showing improvement from the first cycle.

The directive asks member states to map areas with a significant risk to inhabitants, housing, economic activity and to evaluate flood risks at the global level. These maps are constructed using historical flood data, using three types of events:

- the frequent event, corresponding to a return period of between 10 and 30 years.
- the average event, generally the reference flood of the Risk Prevention Plan (at least one hundred years).
- the exceptional event, on the order of the thousand-year flood

The evaluation of global flood risks is based on the risks of river floods or marine floods. This uses the topography of watersheds and coastal areas, geological data, a flow model and average (centennial) sea water level data. Land cover maps are also used to assess the risks to housing or economic activity.

The Floods Directive applies in each country to the government for the general risk assessment and usually to local authorities for high-risk areas and risk management plans. In some cases, international cooperation is required: this is the case for example for the Rhine River where 8 countries cooperated on this topic.

There are different types of floods:

- the most common is due to a river overflow following heavy rainfall or snowmelt. Two types of floods can be distinguished: slow floods, which occur mainly in the plains and take several days to evacuate; flash floods or torrential floods, which mainly affect areas with high levels and generally last only a few hours.
- Water runoff when rainwater flows over the ground until it reaches a river or a rainwater network. In some cases, runoff from this water can lead to flooding.
- The rise of a water table to the surface of the ground that causes flooding, often of long duration
- Marine submersion when poor weather and ocean conditions lead to a rise in sea level causing temporary flooding of the coastal area.

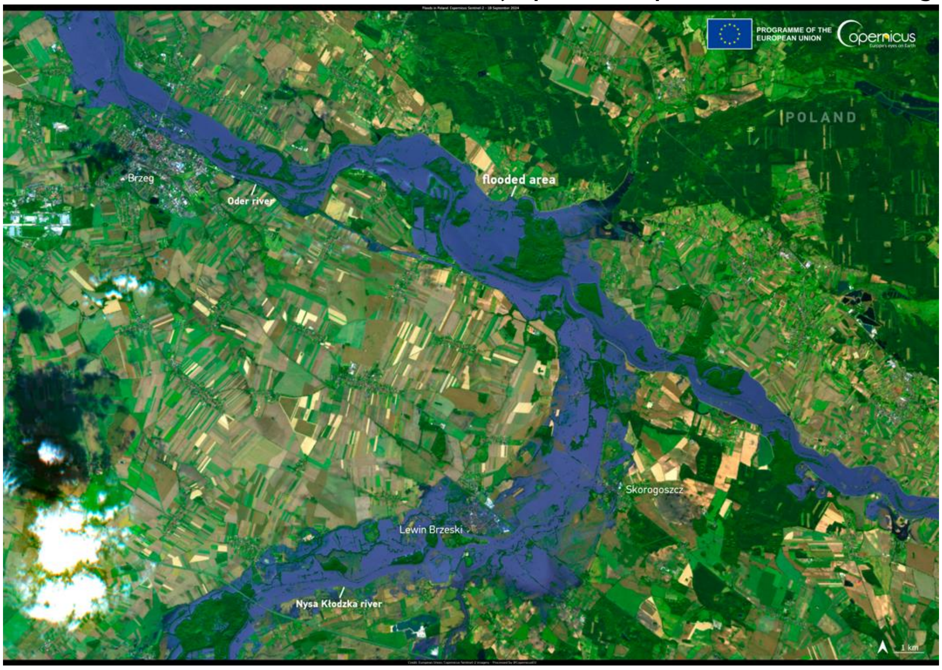
Preparedness to floods usually include two aspects: assessing the risks and warning of floods. The risk assessment is covered by the EU Floods Directive where risk maps and risk management plans were produced and are updated. Satellite EO may be used to assess the topography as well as for land cover for use in the risk maps.

Copernicus DEM covers Europe with a 10m resolution and the rest of the world with a 30m resolution. While it may not be accurate enough for flood risk assessment in Europe where other models are available, it is used elsewhere when there is not better data.

For floods warning, local authorities usually rely on large networks of water level stations and accurate weather forecasts. For example, in France there are more than 3000 stations using radars and cameras with AI on rivers that report water level every 5 minutes. In some areas, outside of terrestrial network coverage, satellite is needed to collect the data. This data is used with weather forecasts to produce flood warning. Weather data the most important parameter to produce a good forecast and existing products are not accurate enough (on average 1km resolution) as they cannot predict the amount of water that will fall on a small zone hour by hour.

To support preparedness of flood events, risk maps are an essential tool. These maps are using hydrological and hydraulic flood models. Actual flood extent data is key to validate and calibrate these models and improve risk maps. During such events, observers are sent on the ground or aerial means are used to accurately measure the flood extent using GNSS. Satellite EO is also a convenient mean but there are often clouds during floods that prevent optical imagery, and the satellite needs to pass at the right time (some flash floods are very short events, less than an hour). Thus Synthetic-aperture radar is also used as it can map floods day-night independently of atmospheric conditions.

Figure 8: Overflow of the Oder River in Poland (Sep 2024, Copernicus Sentinel-2 imagery)



There are also needs for improvements of other types of data. For example, the DTM should be cleared of vegetation with a horizontal accuracy of 1m and vertical of 10cm. The land cover data should also have an accuracy in the meter range. Also, data on ground humidity could be useful to assess the risk of floods as soaked ground is more prone to floods. When using Copernicus data such as ERA5, access should be simplified and made more operational with APIs instead of manual downloads.

Beyond the Floods Directive, the European Union supports flood prevention thanks to the Copernicus EMS and the various R&D projects that it endorses.

The Copernicus Global Flood Awareness System (GloFAS) combines information from satellites, models and in-situ measurements to produce Medium-range flood forecasts, Seasonal forecasts and Rapid Risk Assessment. These products are a combination of meteorological forecasts (mostly from ECMWF), hydrological modelling, and a catalogue of flood inundation maps.

GLOFAS also includes the Global Flood Monitoring (GFM) product available after a flood event. Based on Sentinel-1 radar, several flood detection algorithms are used to compute an ensemble flood map. This map produces several products of interest: the Observed Flood Extent, the Observed Water Extent, the Reference Water Mask, the Affected Population and other metadata.

While Sentinel-1 with its C-band Synthetic-aperture radar instrument offering a 5x5m resolution is widely used to map slow floods, it provides a revisit every 6 days only. A contributing Copernicus mission, Iceye will improve flood monitoring thanks to its Synthetic-aperture radar satellites capable of providing a new real-time assessment of flood extents, making satellite data more operational for emergency situations.

Several R&D projects have been set to improve floods prevention:

- The H2020 ECFAS, a Proof-Of-Concept for the Implementation of a European Copernicus Coastal Flood Awareness System (https://www.ecfas.eu/)
- The Horizon Europe FLOOD-SERV that aims to involve citizens in flood prevention and mitigation using modern ICT tools (https://www.floodserv-project.eu/)
- The ESA COSPARIN project that proposes global satellite services to support flood prevention and mitigation (https://business.esa.int/projects/cosparin)

Summary of needs for floods monitoring. The production of flood risk maps requires hydraulic and hydrological models as well as an accurate DTM and land cover data where EO can be used. In addition, the validation of the risk maps is based on actual data of the maximum extent of a flood with an accuracy better than 1m.

Table 4: Description of EO data needs and requirements relevant for Flood Preparedness and Response

ID	EUSPA-EO-UR-EMH-0007
Application	**Floods Monitoring**
Users	Local authorities in charge of floods prevention, specialized
End Users Application Needs	
Operational scenario	**Flood risk maps production** The user needs an assessment of the maximum extent of a flood to validate models used for risk maps.
Size of area of interest	The area of flood can be along a coastline or a watershed, typically from 10km2 to 1000km2 depending on the floods
Frequency of information needed	Information is needed several times a day when a flood happens to assess its maximum extent
Type of service (continuous, forecasting, one-off?)	The service is a one off, in case of an event
Other (if applicable)	
Satellite EO Data Requirements	
Spatial resolution	Resolution is generally better than 1m
Temporal resolution	Revisit should be several times a day
Type of EO data needed	Data can be optical or Synthetic-aperture radar
Other requirements (if applicable)	Other data such as DTM (Digital Terrain Model) and land cover is useful for the risk maps. Weather data is needed for floods forecasts.

2.4.2.7 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.

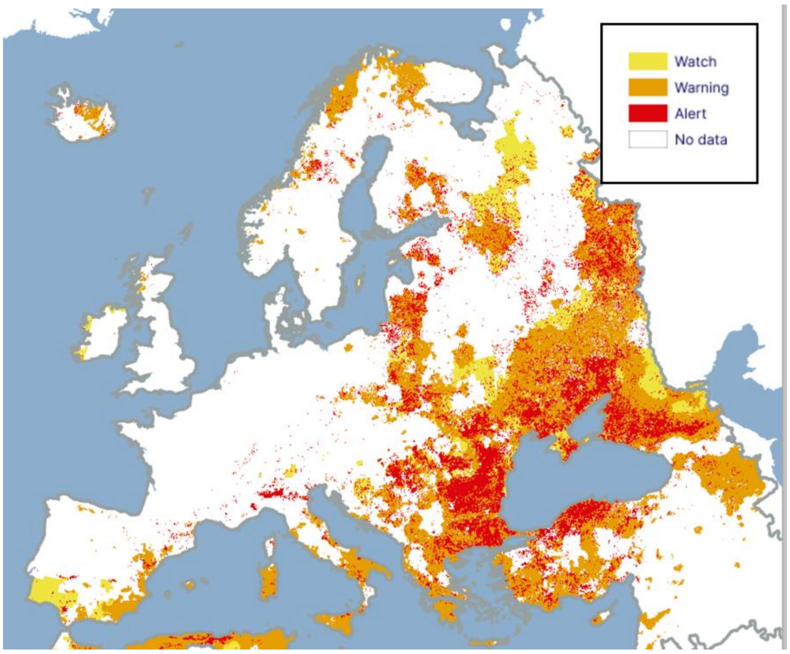
Spaced-based EO altimeter measurements can be used to validate storm surge models as well as provide near-real-time information that can be incorporated into predictions.

The Copernicus C3S 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.

2.4.2.8 Drought monitoring (EO)

Droughts are 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.

Figure 9: Map from the Copernicus drought observatory



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 organisations26. In this 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 and globally. Its drought reports give an overview of the situation in case of imminent droughts.

2.4.2.9 Mining monitoring (EO, GNSS)

Monitoring of mines allows operators to assess 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, for example, provides data that describes the state, the dynamism and the disturbances of the terrestrial vegetation. On the other hand, InSAR allows addressing mine stability concerns by using Synthetic-aperture radar products (e.g. land subsidence). Such stability studies can range from large-scale to specific movements at the pit scale. Sentinel-1 provides Synthetic-aperture radar 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, allowing to monitor terrain with centime level accuracy and in near real-time. While GNSS techniques alone do not meet the mm-level accuracy requirements that are needed for landslides located in mining areas, the combination of GNSS and EO observations, together with in-situ collected data, is the best option.

2.4.2.10 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). 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, Synthetic-aperture radar data is used to improve the security of fracking operations as it allows to reduce the land subsidence related risks of collapse.

2.4.2.11 Monitoring of vector-borne diseases (EO, GNSS)

Diseases are 'vector-borne' when the infectious agent is transmitted by a living organism, 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.

Satellite EO data is being included by scientists in predictive outbreak models for some vector-borne diseases like cholera, malaria and dengue. Both optical and radar instruments are used to map land-use and land-cover, detect humid zones thus providing information about human activities that affect mosquito habitats and exposure to mosquito bites.

The World Health Organization also uses GNSS when assessing epidemics: observers in the field collect local epidemiology data and include the GNSS position of the people infected.

2.4.2.12 Monitoring of locust swarms (EO, GNSS, SATCOM)

Locust plagues pose a threat to agricultural production as they cause widespread crop damage and, subsequently, livelihoods and food security. Favorable 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 project uses field reporting in combination with GNSS and SATCOM 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.

2.4.2.13 Space debris removal (GNSS)

The EU SST estimates that there are some 1 million objects over one centimeter 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 emergence 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.

2.4.3 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.

2.4.3.1 Crisis area assessment (EO, GNSS, SATCOM)

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.
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.

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 monitoring 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.

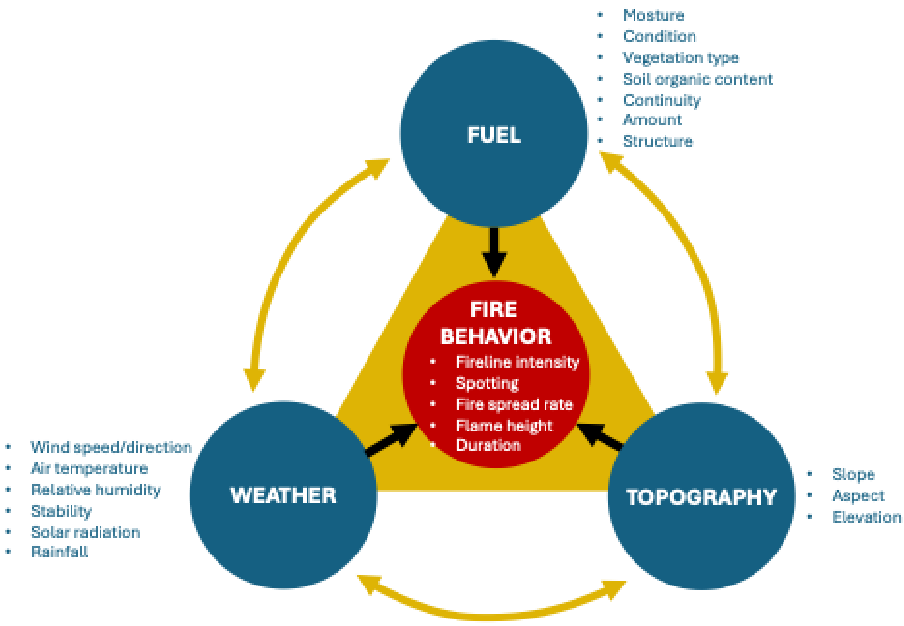
In the field, rescue teams need guidance to use the routes that are still available to reach the affected areas. The detailed maps generated and the highly accurate navigation and positioning capabilities from GNSS will permit so.

Responders also heavily rely on satellite communications to complement or replace existing terrestrial networks both for voice communications and transmission of data (such as GNSS and EO products).

2.4.3.2 Operational wildfires modelling (EO)

After detection of a fire start and if the fire is not rapidly extinguished, one of the key pieces of information for firefighters is the fire spread, or the knowledge of where the fire is heading to, at which rate and intensity. This is summarized in the following image, the fire behavior triangle, that illustrates the key variables that affect how a wildfire behaves. Spread models have been developed, mainly in North America and Australia, using terrain data, cover information and weather forecasts but they require to be adjusted to the European landscape.

Figure 10: The fire behavior triangle (Countryman, 1966)



Today, although tactical information on the fire spread is key for effective fire combatting, methods used are still very manual. For example, in France, most of the data comes from firefighters on the ground who report via radio a tactical situation to a command centre. In some cases, aircrafts are used to track the progression of the fire and if aircrafts are not flying, drones may be used. As a matter of fact, the use of drones is becoming more common among firefighters given its flexibility and ease of use. Other methods are being investigated including HAPS and balloons to monitor fire spread.

Satellite solutions offer the benefit of a wide coverage without the need for ground infrastructure. However, there is still a need for quick assessment added to a good resolution which makes the use of GEO satellites impractical. One of the Copernicus contributing missions, Ororatech, features ultra-fast wildfire propagation predictions. This service is based on a mix of real observations based on multiple optical and Synthetic-aperture radar satellites (Sentinels, Meteosat, GOES as well as the Ororatech satellites) and their weather and fuel model that delivers spread predictions. This allows to propose regular updates of the fire spread to the firefighters.

In the United States, Google supports fire spread tracking using geostationary satellites with IR instruments, especially in the 3–4 μm wavelength range. This allows to get information on the fire position with relatively minor distortions through smoke and other particulates in the atmosphere. However, this data is still difficult to use as both sensors are limited in accuracy (2km range) and fires have variable emissions and there are many IR perturbations during wildfires.

2018 Hechingen fire
On August 4, 2018, the Hechingen (Germany) firemen were called for a field fire that already spread over 5000m2 and was threatening adjacent woods and houses favored by high temperatures above seasonal average. No water was available on site so with limited resources, an efficient combat tactic was essential. They used a drone with an HR visible camera and an IR camera: the data collected allowed them to assess the situation and optimize their operations using effectively the vehicles, staff and water available. Thanks to the immediate assessment of the fire situation, it could be extinguished in less than two hours

Summary of needs for fire spread monitoring. The requirements for fire spread monitoring have been set by the French firemen in a call for tender where the need of fire front monitoring with 20 minutes updates was set (the fire front is the leading edge of a wildfire). The US XPrize challenge has set similar goals with 10 minutes updates of perimeter, direction and rate of spread and intensity of the fire with a better than 10m resolution.

Table 5: Description of EO data needs and requirements relevant for Fire Spread Monitoring

ID	EUSPA-EO-UR-EMH-0010
Application	**Operational wildfires modelling**
Users	Firefighters
End Users Application Needs	
Operational scenario	**Fire spread monitoring** The user needs to be informed about the position of the front fire
Size of area of interest	Size of a fire: regional
Frequency of information needed	The information is needed every 20 minutes
Type of service (continuous, forecasting, one-off?)	The service is continuous
Other (if applicable)	
Satellite EO Data Requirements	
Spatial resolution	Typically, less than 10m
Temporal resolution	Typically, less than 20 minutes
Type of EO data needed	Multispectral (e.g. TIR) can be used
Other requirements (if applicable)	The latency should be less than a few minutes. Other means are currently being used such as ground staff, aircrafts and drones to assess fire progression.

2.4.3.3 Secure Communications for firefighting (SATCOM)

Communications is a key tool for firefighters as in most operations a command centre is set-up that coordinates all field activities and receives and dispatches information. Today, firefighters and the civil protection at large use dedicated communication networks, generally based on Tetra or Tetrapol technologies, which date back from the 1990s. These networks will be replaced in the future by more modern technologies.

Requirements for communications means as set by firefighters include the following:

- Secure voice communication with access to the PSTN or in closed networks (PTT operations)
- High Speed two-way data communication for private networks or to the internet, with guaranteed data rates
- Resilient communications in crisis situation
- Coverage of a whole country with border extensions
- Priority communications
- 5G integration
- New requirements have been set for native features such as geolocation, video streaming or medical data transmission

However, in some operations, these requirements cannot be met as some wildfires occur in remote areas without terrestrial communications coverage or in crisis situations networks are saturated or just crash. This is why in such events firefighters use satellite communications to complement their terrestrial networks. In such a case, the same requirements apply.

Usually, broadband satellite communications require a heavy equipment like a large dish antenna, a high-power terminal and additional equipment such as routers, switches or cellular gateways. Data speed is limited to a few Mbps in KU band to tens of Mbps in Ka band. The service is provided over GEO satellites, typically Eutelsat, Intelsat or Inmarsat, usually as a managed service. The equipment can be installed on a fixed site but in many cases, it is in a vehicle that will be used to provide the telecommunication services on the operations site. Ideally, the satellite communication equipment will be used as a cellular tower and provide also WiFi access to that users can use their regular equipment.

Table 6: Description of SATCOM needs and requirements relevant for firefighters

SATCOM User Requirements for Firefighters	
Link Type	Bi-directional voice and data
Availability	High (used when traditional networks are not available)
Latency:	Normal
Bandwidth	High to accommodate simultaneous voice calls and data streams
Coverage	Local on an intervention zone but this zone could be anywhere
Symmetry Up/Down	50/50 as voice is key
Distribution	Multi-User
Setup	Immediate, in a few minutes
Speed	Low ≤40 Km/h
Security protection	Communications should.be protected and secured (available)

2.4.4 CLUSTER 4: Search And Rescue

Search And Rescue is a specific part of the Emergency Response phase, as it is an activity that is triggered by a distress signal received by specialized services. 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. This cluster is the largest user of GNSS in the segment as all emergencies need to be located; SATCOM is also an important tool to transmit the emergency signals.

The SAR cluster is evolving rapidly with the emergence of 5G NTN services. While GNSS will remain a key component of this application, 5G NTN will make it possible to use regular 5G devices to communicate with satellite networks. Emergency messaging is one of the key applications of 5G NTN. Key smartphone manufacturer such as Apple and Google are offering this service on their latest phone models. The key benefit is that anyone who has a smartphone will have access to emergency services. This evolution will transform this cluster as it will give access to emergency services to anyone, extending the reach of E112 even outside traditional terrestrial network coverage.

2.4.4.1 SAR operations: at sea (GNSS, SATCOM)

EPIRBs are mandatory safety equipment for many types of vessels, including commercial ships, fishing boats, and recreational boats that venture into open water. EPIRBs transmit a radio signal over two frequencies: 406MHz that is received by COSPAS-SARSAT satellites and 121.5MHz received by other ships or aircrafts. Since 2020, new EPIRBs include the SAR/Galileo Return Link Service (RLS) that provides an automatic acknowledgement message back to the user informing them that their request for help has been received with latencies lower than 15 minutes.

Many EPIRBs also include AIS transmission that can be received by nearby ships or satellites with AIS receiving capability.

2.4.4.2 SAR operations: aviation (GNSS, SATCOM)

ICAOs Annex 6 dictates that all airplanes 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. In many situations like trans-oceanic flights, the most suitable technology is ADS-B over satellite networks.

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).

2.4.4.3 SAR operations: land (GNSS, SATCOM)

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 has emerged in the past years that incorporates GNSS receivers but relies on private emergency services such as Focuspoint International or Garmin's International Emergency Response Coordination Centre (IERCC), using private satellite communications means such as Iridium or Globalstar. In addition to sending SOS messages, these beacons allow to send positions and check-in messages on a regular basis. This market is now challenged by 5G-NTN that allows to incorporate emergency satellite messaging features in standard smartphones that rely on modern Apple, Qualcomm or Samsung chips. Standardized by the 3GPP, 5G-NTN has the ability to disrupt the whole SATCOM industry, starting with Search And Rescue as it will make specialized device less relevant and make emergency satellite messaging a standard feature available on all smartphones, like GNSS.

2.4.4.4 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 ships to drift with respect to their reported position, 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, 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 specialties, 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.

2.4.5 CLUSTER 5: Post-event Recovery

2.4.5.1 Post-crisis damage assessment and building inspection (EO, GNSS)

This application was addressed during the 2022 UCP and is detailed in the 2022 EMAid User Needs and Requirements Report[15].

After a disaster, when the recovery phase starts, there are systematic damage assessments of buildings and infrastructure. These assessments serve two main purposes: identifying which structures are safe to inhabit and determining the extent and impact of the disaster. This information is vital for both humanitarian responses, such as restoring shelters and critical infrastructure, and long-term recovery planning.

Satellite EO and GNSS technologies play crucial roles in assessing disaster-affected regions. EO data, allows for large-scale assessments of affected areas and provides an accessible way to evaluate damage, even in inaccessible regions. High-resolution satellite images from EO, like those used during the 2010 Haiti earthquake, help to map damaged areas and classify buildings based on damage severity.

EO is highly effective in offering a preliminary view of the disaster's impact, especially in situations where communication networks have been disrupted, and first responders are yet to arrive on site. Copernicus Emergency Management Service (EMS), for instance, produces grading maps with damage categories, though EO is limited to assessing severe damage.

On the other hand, detailed inspections require in-situ technologies. Physical inspections by civil protection agencies complement satellite data by providing more granular details about building conditions. Ambient vibration (AV) surveys using accelerometers and velocimeters help assess structural integrity by measuring dynamic properties of buildings before and after disasters. GNSS solutions, which can provide positioning accuracy of a few millimeters, are employed to monitor deformations in critical infrastructure over long periods.

Drones are increasingly employed to gather horizontal and vertical damage assessments, including 3D mapping. Ground Control Points (GCPs) enhance accuracy in 3D models, though this may not always be feasible in emergency situations. Smartphones equipped with GNSS allow for crowd-sourced, geo-tagged images and text, aiding NGOs and humanitarian agencies in documenting damage and organizing responses. Applications like UN-ASIGN enable rapid sharing of geo-tagged information to disaster management systems.

2.4.5.2 Restoration of supply chain and infrastructure services (EO, GNSS, SATCOM)

Reconstructing supply chain networks is vital for post-disaster recovery. While fuel, power, food, water, communications and medical supplies are crucial in the immediate aftermath, other goods like building materials become essential during the recovery phase. Understanding transportation logistics, including the resources needed to move these goods, is critical. Earth Observation (EO) data aids in remotely assessing transportation routes, identifying bottlenecks, and planning alternative routes. It also supports the repair and creation of transport infrastructure, ensuring the functionality of critical supply chain components like power plants and gas stations. Additionally, GNSS integration enhances supply chain resilience by providing real-time visibility for logistics, helping to manage delays more effectively. And satellite communications are essential to provide communications means (voice and internet access) in places that lost terrestrial connectivity.

[15] https://www.euspa.europa.eu/publications-multimedia/publications/ucp-user-needs-requirements-2022#:~:text=Report%20on%20Emergency%20Management%20%26%20Humanitarian%20Aid

2.4.6 CLUSTER 6: Humanitarian Aid

Humanitarian aid offers critical, short-term assistance to victims of natural disasters, wars, and famines, focusing on saving lives, alleviating suffering, and preserving human dignity. Earth Observation (EO), Global Navigation Satellite Systems (GNSS) and SATCOM are essential tools in this effort.

Key stakeholders include UN agencies (WFP, UNHCR, WHO, UNICEF), NGOs (ICRC, MSF, Oxfam, Save the Children), national agencies (ECHO, USAid), and private companies (IEC Telecom, CLS, Airbus) specializing in EO, SATCOM and GNSS data. These technologies enable "geohumanitarian action," integrating geoinformatics to enhance aid planning and deployment and supporting emergency action. EO data aids in risk assessments, refugee camp analysis, and monitoring human rights violations. GNSS supports field personnel tracking and coordination. And SATCOM is key to keep communications possibles in disaster areas.

2.4.6.1 Documenting Human Rights violations (EO)

Human rights are universal (they concern all human beings), inalienable (they cannot be taken away), are indivisible and interdependent (between civil, political, economic, social and cultural rights). The Universal Declaration of Human Rights (UDHR), adopted by the UN General Assembly in 1948, was the first legal document to set out the fundamental human rights to be universally protected. The UDHR continues to be the foundation of all international human rights law. Its 30 articles provide the principles and building blocks of current and future human rights conventions, treaties and other legal instruments.

Thanks to the UDHR, the IHL and Conventions, the protection of human rights improved massively in the second half of the 20th century. With the establishment of the International Criminal Court (ICC) and the different tribunals in the period between 1990-2015, the perpetrators of international crimes can be brought to trial. However, this progress has not been linear: there have been setbacks in the 1970s and recent years, after 2010[16]. This data is coherent with the steep increase in death in armed conflicts (mostly intrastate) noticed since 2012 with a further increase in 2022 with war in Ukraine[17]. More than 110 conflicts in the world are currently reported by the Geneva Academy of Humanitarian Law[18], including 7 in Europe.

The notion of human rights has also been recently extended in 2022 to the right of a clean, healthy, and sustainable environment. While this is a non-binding resolution, it will probably pave the way to new environment and climate related actions on deforestation or pollution.

While protection of human rights is guaranteed by the UDHR and specific treaties that most countries have signed, in reality violations are numerous all around the world. This requires constant monitoring of how human rights are protected and violations need to be brought to light. This is the task of a number of organizations:

- UN bodies such as the United Nations Security Council, the United Nations Human Rights Council and the UN High Commissioner for Human Rights (UNHCHR) supported by 10 other committees. Via Commissions of Inquiry and other activities of the Human Rights Council, the violations can be reported to the General Assembly and to the Security Council.
- In Europe, the Council of Europe is responsible for both the European Convention on Human Rights and the European Court of Human Rights

[16] https://ourworldindata.org/human-rights

[17] https://ourworldindata.org/grapher/deaths-in-armed-conflicts-by-type

[18] https://geneva-academy.ch/galleries/today-s-armed-conflicts

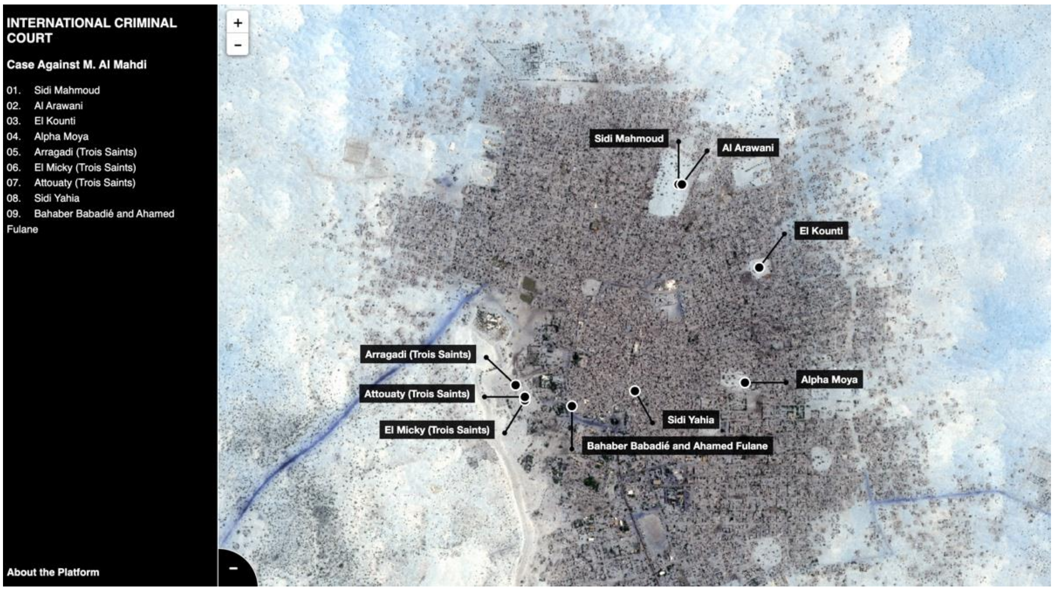
- Numerous NGOs are active in this field, such as Amnesty International, Human Rights Watch, World Organisation Against Torture, Freedom House, International Freedom of Expression Exchange and Anti-Slavery International. These organizations collect evidence and documentation of human rights abuses and apply pressure to promote human rights. Educating people on the concept of human rights has been argued as a strategy to prevent human rights abuses.
- The press has an important role as well as it serves as a relay of information to the general public and can also conduct its own investigations.

These organizations mainly identify, detect, report and document human rights violations. The next step is to take legal action and several courts specialize in human rights:

- The European Court of Human Rights (ECtHR) is the court of the Council of Europe which interprets the European Convention on Human Rights (ECHR). The court hears applications (states, individuals and organizations) alleging that a contracting state has breached one or more of the human rights enumerated in the convention. The court is based in Strasbourg (France) and can process cases in any of the 47 European countries members of the council.
- The Court of Justice of the European Union (CJEU) is the legal institution of the European Union (EU). Seated in Luxembourg, this EU institution is competent for all legal action concerning violations of EU law in one of the EU countries, including violation of human rights.
- The International Court of Justice (ICJ) is the United Nations' primary judiciary body and it has worldwide jurisdiction to settle disputes between nations. Most UN countries have recognized the jurisdiction of the Court.
- The International Criminal Court (ICC) is the body responsible for investigating and punishing individual perpetrators of war crimes, and crimes against humanity when such occur within its jurisdiction. Currently, 124 countries are party to the Statute of the Court. The ICC conducted dozens of investigations that led to the indictment of more than 50 people, for war crimes, crimes against humanity or crimes of aggression.
- The Tribunals established to bring perpetrators of violations of human rights and humanitarian law to trial. Examples are the International Tribunal for the former Yugoslavia (ICTY), the International Criminal Tribunal for Rwanda (ICTR) and the Special Court for Sierra Leone.
- The national courts who can, under the framework of (partly) universal jurisdiction, prosecute individuals on their territory who are suspect of grave violations of HR and IHL.

The statutes of the Courts and Tribunals specify the admissibility and the role that sources of evidence can play in the different stages of a trial. The weight attributed to pieces of evidence in a trial is depends on aspects such as reliability, credibility and authenticity. A transparent chain of custody for this form of digital evidence is an important condition.

Figure 11: Screenshot of the SITU visual platform used by the ICC to access visual and spatial information in the courtroom (http://icc-mali.situplatform.com/)



The major difficulty in documenting human rights violations in conflict areas is that they are often impossible to access, either in war zones or closed to the press, UN observers, NGO's and others who are monitoring the obeyance of human rights and humanitarian law and are collecting evidence in case of violations. This makes EO a perfect tool to identify and report human rights and humanitarian law violations as it does not require physical presence and allows to cover large and inaccessible areas. In addition, EO allows to investigate past violations as images are stored. There are however specific challenges[19] connected to this use of satellite data and information[20] including ethics, court admissibility and authenticity issues.

As access to satellite imagery remains a long task and as many high resolution images are still expensive, satellite EO is used for human rights protection on a case-by-case basis and usually after an event has been detected to provide evidence. In such a case, EO providers are solicited to check if images are available at the time and for the area of interest. These images are then analyzed to identify any data that could serve as a proof. Examples of detections include building destructions, displaced people (camps), prison facilities, modern war equipment, mass graves, cemetery extensions, village destructions or fires or even body counts. This requires high resolution imagery that could be used as evidence in court. Lesser resolution images can be used to prove the movement of troops to be related to perpetrators and large-scale damage such as crops and flooded areas.

The use of satellite data in courts present its own specific challenges such as the admissibility criteria for the ICC[21], the current absence of standards for this type of evidence, the lack of knowledge on either side in a trial and the need for expert advice in the presentation of the evidence. A transparent 'chain of custody' and access to the original source are also important conditions. In general, images should be understandable by non-experts to have a high impact and therefore not processed, and a second source is preferred (from another EO supplier or on the ground) to prove authenticity.

[19]https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/initial-paper-july-2022.pdf

[20] https://www.universiteitleiden.nl/en/news/2023/06/the-optimization-of-the-use-of-satellite-information-in-the-humanitarian-domain---legal-and-space-related-developments

[21] https://spaceforhr.com/wp-content/uploads/2023/12/1-SEHR-Publication-No-3-1-pdf.pdf

The use of satellite EO to assess human rights violation is on the increase as more and more data is available, with more accurate images and with AI that makes it possible to process this data with less human intervention And probably, the satellite EO will be more and more used as proof for other illegal activities, such as assessing that international aid has been actually spent as it should be, for construction or road work for example.

GNSS is another satellite tool that is used to assess human rights violations. For example, EO data is often complemented by ground truth: this information is collected via social networks or using smartphone applications and geotagged pictures. In these examples, the use of GNSS to get both correct location and timing data is essential.

Users in this application fall under the categories mentioned previously:

- International organizations such as the United nation and NGOs to document violations during wars. NGOs active in this field are global NGOs such as Amnesty, Humans Right Watch or NGOs specialized in specific actions or areas like Truth Hounds (Ukraine).
- The press to inform the general public. Several media have set-up internal experts to analyze satellite imagery: the New York Times Visual Investigations team, the "Révélateurs" from France Télévisions and Reuters also have established such teams.
- Court prosecutors and councils to use images as evidence during trials. To be used as evidence, images must be simple to understand by a non-expert. This includes mainly international courts and tribunals like the ICC that are competent for international human rights violations, but any other competent court could make use of such images

Summary of needs for floods Documenting Human Rights Violations. The need is to provide satellite data as an evidence in court: the data integrity should be guaranteed, information should be understandable without an expert and accuracy depends on the kind of evidence to provide but submeter is desirable.

Case study: the Bucha massacre revealed by satellite imagery
In April 2022, the Ukrainian army recovered the town of Bucha (Ukraine) from the Russian forces and discovered dozens of killed civilians. Moscow denied any responsibility and claimed that the events occurred after their troops left the town. However, several satellite images provided by Maxar showed human bodies in the streets for several weeks before the departure of Russian soldiers. A new mass grave was also identified next to the city church.
These images have been used by the press and several human rights organizations to document Russian exactions.

https://www.nytimes.com/2022/04/04/world/europe/bucha-ukraine-bodies.html

The following table summarizes the needs and requirements for Human Rights Protection using satellite EO.

Table 7: Description of EO data needs and requirements relevant for Documenting Human Rights Violations

ID	EUSPA-EO-UR-EMH-0011
Application	**Documenting Human Rights Violations**
Users	Courts of Justice, NGOs, press
End Users Application Needs	
Operational scenario	**EO as evidence of Human Rights Violation** The user needs to have an easy to understand, reliable and credible satellite image that can serve as a proof in a court of justice.
Size of area of interest	From local (a quarter, a city) to a country
Frequency of information needed	The information is needed usually once, but it requires access to historical data
Type of service (continuous, forecasting, one-off?)	The service is on demand, when evidence is needed
Other (if applicable)	
Satellite EO Data Requirements	
Spatial resolution	Typically, less than 50cm for local evidence; 10m for national
Temporal resolution	Typically, daily updates are sufficient
Type of EO data needed	Visible imagery is needed as it is simple and understandable
Other requirements (if applicable)	Access to the imagery should be simple. Cost of high resolution images is a concern. Barriers to data-access should be lowered, knowledge (training) should be improved, standards need to be developed and authenticity of the images should be guaranteed. Other OSINT sources are often used such as social media feeds.

2.4.6.2 NGO's asset management (GNSS, SATCOM)

This application was addressed during the 2022 UCP and is detailed in the 2022 EMAid User Needs and Requirements Report[22].

In crisis zones, delivering humanitarian aid is often difficult due to the remote locations of vulnerable populations or the difficulties in accessing the areas. Truck convoys, a common method for distributing supplies, face threats such as attacks, both while traveling and unloading. To improve convoy safety, real-time GNSS-based tracking systems are used to monitor convoy locations, alert control centers, and deploy help if needed. These tracking systems provide real-time positioning, fleet optimization, and enhanced security features like remote engine shutdown and panic buttons. Humanitarian organizations, such as UN agencies and NGOs, benefit from telematics, improving both security and efficiency. Key requirements are availability of the signal and security.

GNSS-enabled solutions not only track vehicle positions but also help monitor conditions of perishable supplies (temperature, humidity), and improve fleet management by sharing vehicles among different agencies. These systems integrate seamlessly into legacy frameworks and allow for better operational planning. In the future, historical tracking data will be leveraged to improve logistics, identify constraints, and map road networks, though issues related to security and data confidentiality remain.

[22] https://www.euspa.europa.eu/publications-multimedia/publications/ucp-user-needs-requirements-2022#:~:text=Report%20on%20Emergency%20Management%20%26%20Humanitarian%20Aid

SATCOM is also an essential part of this application as position and other vehicle and driver data needs to be transmitted to a central facility and terrestrial networks are often unavailable in crisis zones.

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

Welcome applications include applications to give support to people in need of humanitarian help. For example, the Spanish Red Cross provides the LoPe (People Location) 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. It allows for automatic entry/exit alarms configuration and consequently improves any kind of assistance that could be required during an emergency.

Another example is the Integreat[23] app, aimed at quickly and easily providing newcomers (in a city or region) with local information in several languages. This includes geo-spatial information about local services, which the users can quickly access and navigate to using the smartphone embedded GNSS capability.

2.4.6.4 Health and medicine response and coordination (EO, GNSS)

This application was addressed during the 2022 UCP and is detailed in the 2022 EMAid User Needs and Requirements Report[24].

In crisis situations, understanding the needs of affected populations is crucial for humanitarian aid planning. Accurate estimates of impacted zones and population counts are essential for organizing the distribution of supplies like food, water, and medicine. Aid distribution follows standards like SPHERE, and coordination between stakeholders is key, often facilitated by tools like the 3W analysis (who does what and where).

Civil protection bodies, humanitarian organizations like the ICRC, and UN agencies rely on accurate data for disaster-related goods distribution planning. There are two main types of consumers of 3W (Who, What, Where) information: in-country responders and global or headquarter-based humanitarians.

In developed countries, estimating the number of people affected by disasters is relatively straightforward due to the availability of geospatial data from local councils or national agencies. However, in regions with inaccurate census data or unplanned refugee camps, technologies are needed to estimate populations. National governments, regional authorities, NGOs, and other stakeholders use these technologies to monitor refugee displacement and manage camps effectively.

GNSS and EO are vital tools for population counting and mapping in disaster areas. EO combined with population density statistics and local knowledge, helps estimate populations in underdeveloped or unmapped areas. Tools like the "Missing Maps" initiative involve volunteers mapping areas from satellite imagery. Accurate, up-to-date maps that show post-disaster effects (e.g., affected roads, medical centers) are essential for effective response.

GNSS and handheld devices help humanitarians collect geo-referenced data such as village centers and water wells. Although GNSS tools have limitations like battery life in smartphones, they offer practical solutions for field data collection. EO imagery needs to be high-resolution and current, but visibility conditions like clouds or night can limit its utility, requiring complementary data like from Synthetic Aperture Radar.

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

[24] https://www.euspa.europa.eu/publications-multimedia/publications/ucp-user-needs-requirements-2022#:~:text=Report%20on%20Emergency%20Management%20%26%20Humanitarian%20Aid

Drones are increasingly used in disaster response, delivering medical supplies and assessing damage. The integration of GNSS and EO technologies aims to simplify and accelerate humanitarian work, ensuring responders can act efficiently and effectively in crisis zones.

2.4.6.5 Management of refugee camps (EO)

EO data is crucial for planning refugee camp layouts and resource distribution, such as wells and medicine, by mapping settlement concentrations and estimating populations. During disaster response, this data helps actively manage camps, including relocation if necessary, especially in conflict zones where access is restricted.

For example, Copernicus EMS product P18[25] uses high-resolution imagery to analyze human settlement structures, including informal areas. As it typically takes 5 to 10 days for delivery, NGOs often turn to UAV imagery to obtain faster and more precise data.

In Dadaab, Kenya, the world's largest refugee camp, EO data was vital in 2011 when a surge of 160,000 refugees overwhelmed on-the-ground management. Image analysis provided detailed insights into dwelling types and their distribution, aiding NGOs in efficient resource planning.

2.4.6.6 Population Displacement monitoring (EO)

Monitoring population displacement due to conflict or disaster greatly enhances humanitarian response planning. EO data plays a key role in tracking migration routes and identifying temporary dwellings.

The Internal Displacement Monitoring Centre (IDMC) uses EO data to provide global analysis of internal displacement, offering quick and accurate insights into population distributions, even in inaccessible areas. This approach ensures assessments without raising privacy concerns. Additionally, combining social media data, such as Twitter, with machine learning further supports internal displacement monitoring.

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

2.5 User Requirements Specification

The chapter provides a detailed synthesis of the requirements described in previous sections. The content of this section will be updated, completed, and expanded by EUSPA in the next releases of this report based on the results of further investigations discussed and validated in the frame of the UCP.

2.5.1 Synthesis of Requirements Relevant to GNSS

2.5.1.1 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)	[RD5]
EUSPA-GN-UR- EMH-2202	The availability should be better than 95%	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-2203	The size and weight should be minimized	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-2204	The autonomy in the field should be up to several years	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-2205	The antenna should be as small as possible	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-2206	The time to first accurate fix should be a few minutes	Performance (timeliness)	[RD5]
EUSPA-GN-UR- EMH-2207	The coverage needed is regional or local	Performance (coverage)	[RD5]

2.5.1.2 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)	[RD5]
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)	[RD5]
EUSPA-GN-UR- EMH-6103	The horizontal accuracy should be 2mm detailed building assessment	Performance (accuracy)	[RD5]
EUSPA-GN-UR- EMH-6104	The vertical accuracy should be 3-4mm detailed building assessment	Performance (accuracy)	[RD5]
EUSPA-GN-UR- EMH-6105	The vertical accuracy should be 3-4mm detailed building assessment for critical buildings	Performance (accuracy)	[RD5]
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)	[RD5]
EUSPA-GN-UR- EMH-6107	The system should be available in urban canyons	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-6108	The size and weight should be minimized	Feature (equipment)	[RD5]

Id	Description	Type	Source
EUSPA-GN-UR- EMH-6109	The autonomy in the field for geotagging should be more than five hours	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-6110	The time to first accurate fix should be a few seconds	Performance (timeliness)	[RD5]
EUSPA-GN-UR- EMH-6111	The coverage needed is regional or local	Performance (coverage)	[RD5]

2.5.1.3 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)	[RD5]
EUSPA-GN-UR- EMH-7102	The system should be available in urban canyons	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-7103	The system should be available in natural canyons	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-7104	The system should be available under canopies	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-7105	The system should be available indoors	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-7106	The availability should be better than 95%	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-7107	The system should be robust	Performance (robustness)	[RD5]
EUSPA-GN-UR- EMH-7108	The size and weight should be minimized	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-7109	The autonomy of a device should be more than 5 hours	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-7110	The antenna should be as small as possible	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-7111	The time to first accurate fix should be a less than a minute	Performance (timeliness)	[RD5]
EUSPA-GN-UR- EMH-7112	The coverage needed is national/regional	Performance (coverage)	[RD5]

2.5.1.4 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)	[RD5]
EUSPA-GN-UR- EMH-7302	The system should be available in urban canyons	Performance (availability)	[RD5]
EUSPA-GN-UR- EMH-7303	The size and weight should be minimized	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-7304	The autonomy of a device should be more than 5 hours	Feature (equipment)	[RD5]
EUSPA-GN-UR- EMH-7305	The time to first accurate fix should be a less than a few seconds in hot start	Performance (timeliness)	[RD5]
EUSPA-GN-UR- EMH-7306	The time to first accurate fix should be a less than a minute in cold start	Performance (timeliness)	[RD5]
EUSPA-GN-UR- EMH-7307	The coverage needed is regional	Performance (coverage)	[RD5]

2.5.2 Synthesis of Requirements Relevant to EO

2.5.2.1 EO User Requirements for Floods monitoring

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	Spatial resolution	Temporal resolution	Data type/spectral range	Other (if applicable)	Satellite data sources	Other data sources
EUSPA-EO-UR-EMH-0007	Floods Monitoring	Local authorities in charge of floods prevention, specialized	**Flood risk maps production** The user needs an assessment of the maximum extent of a flood to validate models used for risk maps.	The area of flood can be along a coastline or a watershed, typically from 10km2 to 1000km2 depending on the floods		Information is needed several times a day when a flood happens to assess its maximum extent	The service is a one off, in case of an event	Resolution is generally better than 1m	Revisit should be several times a day	Data can be optical or SAR	Other data such as DTM (Digital Terrain Model) and land cover is useful for the risk maps. Weather data is needed for floods forecasts.		

2.5.2.2 EO User Requirements for Early warning surveillance of forest fires

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	Spatial resolution	Temporal resolution	Data type/spectral range	Other (if applicable)	Satellite data sources	Other data sources
EUSPA-EO-UR-EMH-0008	Early-warning surveillance of forest fires	Firefighters	**Early detection of wildfires.** The user needs to be alerted when a forest fire starts (typical size: less than 1 square meter) in less than 10 minutes	Size of a European country		The information is needed on a continuous basis	The service is permanent whenever weather conditions create a risk of fire; however the need is greater during the summer season	Less than 1m	Less than 10 minutes	Multispectral (e.g. TIR bands) and SAR can be used	EO data needs to be processed quickly to provide the alarm service as well as the exact location: the latency is a key parameter. When real-time is needed, AI is a relevant tool for detection.		
EUSPA-EO-UR-EMH-	Early-warning surveillance of forest fires	Firefighters, general public, policy makers, local authorities	**Advanced forecasting of wildfires.** The user needs an assessment of the risk of fires to preposition the firefighting means	Size of a European country		The information is needed on a daily basis	The service is permanent whenever weather conditions create a risk of fire; however the need is greater during the summer season	1km is sufficient	Daily	SAR and optical data are used for soil moisture	Weather data (wind, temperature) is added to EO data to provide a risk assessment Historical data on actual fires is needed to improve risk maps.		

Note: during the 2024 UCP session, a need for a new EO application emerged, called "Defendability Maps". The expressed need is to establish, on a regular basis, so called "defendability maps" of areas at risk. These maps could make use of various data collected from EO, such as land cover, buildings, roads, etc... to assess the difficulty and effectiveness to fight wildfires in some areas, given the population, accessibility and assets to protect. This is a quite new concept that will be addressed in future UCPs.

2.5.2.3 EO User Requirements for Operational wildfires monitoring

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	Spatial resolution	Temporal resolution	Data type/spectral range	Other (if applicable)	Satellite data sources	Other data sources
EUSPA-EO-UR-	Operational wildfires modelling	Firefighters	**Fire spread monitoring** The user needs to be informed about the position of the front fire	Size of a fire: regional		The information is needed every 20 minutes	The service is continuous	Typically, less than 10m	Typically, less than 20 minutes	Multispectral (e.g. TIR) can be used	The latency should be less than a few minutes. Other means are currently being used such as ground staff, aircrafts and drones to assess fire progression.		

2.5.2.4 EO User Requirements for Documenting human rights violations

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	Spatial resolution	Temporal resolution	Data type/spectral range	Other (if applicable)	Satellite data sources	Other data sources
EUSPA-EO-UR-EMH-0011	Documenting Human Rights Violations	Courts of Justice, NGOs, press	**EO as evidence of Human Rights Violation** The user needs to have an easy to understand, reliable and credible satellite image that can serve as a proof in a court of justice.	From local (a quarter, a city) to a country		The information is needed usually once, but it requires access to historical data	The service is on demand, when evidence is needed	Typically, less than 50cm for local evidence; 10m for national	Typically, daily updates are sufficient	Visible imagery is needed as it is simple and understandable	Access to the imagery should be simple. Cost of high resolution images is a concern. Barriers to data-access should be lowered, knowledge (training) should be improved, standards need to be developed and authenticity of the images should be guaranteed. Other OSINT sources are often used such as social media feeds.		

2.5.2.5 EO User Requirements for Landslides and terrain deformation monitoring

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	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.		SAR: mm level Optical: submeter level	5 days	Optical SAR: C-band, L-band and Xband.	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)		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

2.5.2.6 EO User Requirements for Post-crisis damage assessment and building inspection

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	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.	Local and Regional	large	Very much depending on the type of event. At most, earthquakes or volcanic events may require daily updates.		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 rehousing purposes or less urgent for insurance or reconstruction.	Regional	Building Level	Single acquisition.		<1x1 meters	N/A	Optical (either as primary or as backdrop): RGB and infrared. SAR (processed products): C-band, Lband 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

2.5.2.7 EO User Requirements for Health and medicine response and coordination

ID	Application	Users	User Needs					Service Provider Satellite EO Requirements				Service Inputs	
			Operational scenario	Size of area of interest	Scale	Frequency of information	Type of service	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 analyze, visualize 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).		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 analyze, visualize and coordinate humanitarian responses.	Second phase response Areas of interest become local.	A few meters to identify features	Weekly or even monthly		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)

2.5.3 Synthesis of Requirements Relevant to SATCOM

2.5.3.1 Requirements for SATCOM for firefighters

ID	Application	Operational Scenario	Link type	Availability	Coverage	Setup	Security protection	Speed	Latency	Bandwidth (bit rate)	Symmetry up/down	Distribution
EUSPA-SAT-UR-EMH-0001	SATCOM for firefighters	Providing communication capabilities during firefighting operations	Bi-directional voice and data	High (used when traditional networks are not available)	Local on an intervention zone but this zone could be anywhere	Immediate, in a few minutes	Communications should.be protected and secured (available)	Low ≤40 Km/h	Normal	High to accommodate simultaneous voice calls and data streams	50/50 as voice is key	Multi-User

2.5.4 Sources for the requirements

This document is based on desk research and interviews. The sources of the requirements come from the feedback from experts and various UCP participants listed in the following table for the three applications addressed in 2024.

Application	Source of requirement
Early-warning surveillance of forest fires Operational wildfires modelling Secured Communications for firefighting	Panoptes call for tender, Xprize wildfire competition, Guide des techniques opérationnelles (French Ministry of the interior) Interviews with Entente Valabre, SDIS13, SDIS83, Forest Lab University of Thessaloniki,
Floods monitoring	Interviews with SCHAPI, Cerema, City of Montpellier, city of Nimes
Documenting human rights violations	Information from Human Rights Watch, Amnesty International Interviews with UNOSAT, TruthHounds, ICRC, Leiden University

3 ANNEXES

A.1 Definition of key EO performance parameters

This annex provides a definition of the most used EO performance parameters and includes additional details which are relevant for Road and Automotive community.

Spatial resolution refers to the level of detail and clarity in the images, specifically the size of the smallest discernible ground features. It is determined by the pixel size, which is the smallest unit in the image that represents a spatial area on the Earth's surface. Spatial resolution is usually measured in terms of meters per pixel. Thus, a spatial resolution of 1 meter means that each pixel represents 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 characterized 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).

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

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

A.2 Additional EO definitions

Ground deformation monitoring is the process which consists in tracking the vertical and horizontal movements of the land surface and their dynamics, whatever these movements are caused by natural phenomena (e.g. volcanic activity) or by human activities (e.g. aquifer exploitation).

Change detection is the process which aims at identifying difference in the state of "objects" (e.g. bridges, constructions, urban areas) or of a phenomenon (e.g. deforestation, soil sealing) by comparing snapshots of the situation at different times. In Earth Observation, change detection is extensively based on satellite imagery obtained through a wide variety of sensors (e.g. optical, radar, infrared, microwave, etc.

Geodesy (see [RD3]) is the earth science of accurately measuring and understanding three of Earth's fundamental properties: its geometric shape, orientation in space, and gravitational field. The field also studies of how these properties change over time. Today, geodesy goes beyond that, being the geoscience that deals among other with the monitoring the solid Earth (which includes the monitoring of displacement, subsidence or deformation of the ground and structures due to tectonic, volcanic, and other natural phenomena as well as human activity.

Interferometric Synthetic Aperture Radar (InSAR) is a technique enabling to generate surface deformation maps based on the processing of SAR images captured at different moments in time. The processing uses the fact that if the ground has moved between the times of two SAR images of the same area, a slightly different portion of the wavelength is reflected to the satellite resulting in a measurable phase shift that is proportional to displacement. The processing therefore consists in obtaining information about the vertical movements of the ground surface by calculating the phase difference between the emitted radar signal and the signal backscattered by the surface for successive images. InSAR can potentially measure deformations of millimeter-scale during periods ranging from days to years.

Near-Real-Time (NRT) refers, when used in the context of EO applications, to applications/services/products for which the time delay between the occurrence of a given event and the availability of the outcomes of the processing of the Earth observation data corresponding to that event is considered as being not significant from a user perspective. The notion of "near real-time" is therefore depending on user requirements. For Earth observation, the corresponding time delays may range from a few hours to a few days depending on the application/service/product.

A.3 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 Road and Automotive community.

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

- System availability: the percentage of time the system allows the user to compute a position - this is what GNSS Interface Control Documents (ICDs) refer to.
- Overall availability: considers the receiver performance and the user's environment. Values vary greatly according to the specific use cases and services used.

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

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

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

Integrity is a term used to express the ability of the system to provide warnings to users when it should not be used. It is the probability of a user being exposed to an error larger than the alert limits without timely warning. The way integrity is ensured and assessed, and the means of delivering integrity-related information to users are highly application dependent. Throughout this report, the "integrity concept" is to be understood at large, i.e. not restricted to safety-critical or civil aviation definitions but also encompassing concepts of quality assurance/quality control as used in other applications and sectors.

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

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

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

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

Probability of false alarm refers to the likelihood of the receiver to indicate the presence of a signal when no signal is present.

Probability of detection refers to the likelihood of a receiver to detect the presence of a GNSS signal when a signal is indeed present.

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.

A.4 Other performance parameters

EO

Agility corresponds to the ability of a satellite to modify its attitude and to point rapidly in any direction 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).

GNSS

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 timestamp.

A.5 List of Acronyms

Acronym	Definition
ACRWC	African Charter on the Rights and Welfare of the Child
C3S	Copernicus Climate Change Service
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EC	European Commission
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
ELT	Emergency Locator Transmitter
EMAid	Emergency Management and Humanitarian Aid
EO	Earth Observation
EPIRB	Emergency Position Indicating Radio Beacon
ESA	European Space Agency
EUSDR	European Union Strategy for the Danube Region
EUSBSR	European Union Strategy for the Baltic Sea Region
EUSAIR	European Union Strategy for the Adriatic and Ionian Region
EUSPA	European Agency for the Space Programme
GOVSATCOM	GOVernmental SATellite COMmunication
GNSS	Global Navigation Satellite System
HAS	High Accuracy Service
HR	Human Rights
ICC	International Criminal Court
ICJ	International Court of Justice
ICCPR	International Covenant on Civil and Political Rights
IHL	International Humanitarian Law
LEO	Low-Earth Orbit
LiDAR	Light Detection and Ranging
MEP	Member of European Parliament
MR	Market Report
NGO	Non-Governmental Organization

Acronym	*Definition*
OEM	Original Equipment Manufacturer
OHCHR	Office of the High Commissioner for Human Rights
OSINT	Open-Source Intelligence
OSNMA	Open Service Navigation Message Authentication
PLB	Personal Location Beacon
PND	Personal Navigation Device
PNT	Positioning, Navigation and Timing
PPP	Precise Point Positioning
R&D	Research and development
R&I	Research and Innovation
RTK	Real-Time Kinematic
RUR	Report on User needs and Requirements
SAR	Search and Rescue
SAR	Synthetic Aperture Radar (for a better understanding, SAR in this definition is only used in the summary tables in chapter 7)
SATCOM	Satellite communications
SLA	Service Level Agreement
SoL	Safety of Life Service
SSA	Space Situational Awareness
SST	Space Surveillance and Tracking
TTFF	Time to First Fix
UCP	User Consultation Platform
UNCAT	United Nations Convention Against Torture
UNCRC	United Nations Convention on the Rights of the Child
UNECE	United Nations Economic Commission for Europe

A.6 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]	SAR and Optical Satellite Images for Advanced Asset Monitoring	https://spottitt.com/industry-news/sar-and-optical-satellite-images-for-advanced-asset-monitoring/	
[RD4]	Expression of User Needs for the Copernicus Programme	Commission Staff Working Document Expression of User Needs for the Copernicus Programme	Nov 2019
[RD5]	UCP 2022 MoM	UCP 2022 Minutes of Meeting of the Emergency Management and Humanitarian Aid Market	2022

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The EU Agency for the Space Programme:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for GOVSATCOM and soon IRIS², and Front Desk services of the EU Space Surveillance Tracking whilst ensuring the systems' service continuity and robustness;
- Promotes and maximises the use of data and services offered by Galileo, EGNOS, Copernicus, GOVSATCOM and soon IRIS² across a broad range of domains;
- Fosters the development of a vibrant European space ecosystem by providing market intelligence, and technical know-how to innovators, academia, start-ups, and SMEs. The agency leverages Horizon Europe, other EU funding, and innovative procurement mechanisms;
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