2025

Report on EU Border & Internal Security

User Needs and Requirements

#EUSpace

EUSPA

EXECUTIVE SUMMARY

This document reports the findings of the User Consultation Platform (UCP) 2025, in terms of user needs and requirements with regard to the use of EO (Earth Observation) and GNSS (Global Navigation Satellite System) in the EU Border and Internal Security (EUBIS) segment.

Formerly labelled “Resilient Societies" in the frame of UCP 2023, the EUBIS market segment refers to non-military activities to protect people, the environment, the economy and the organisation of our societies by increasing situational awareness, preventing, deterring and, if necessary, mitigating activities undertaken by hostile actors and managing other threats, risks and hazards that could endanger EU assets and people’ life or properties.

The EUBIS market segment encompasses a very wide and varied applications, in several sectors for EU Border Security (namely Border Management, Customs Operations, Democracy and Human Rights) and for Internal Security (namely Law Enforcement and Justice Actions), as shown in the next figure.

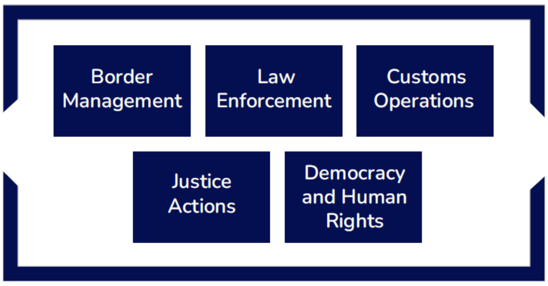

Figure 1: EUBIS market segment (EUSPA’s segmentation)

The EUBIS’s applications apply to *diverse complex scenarios and operating environments*, and are aimed to:

- Protect and safeguard the security of the EU borders, in the domains of Border Management, Customs Operations, Democracy and Human Rights
- Oversee and ensure the EU internal security and devoted to Law enforcement and Justice Actions.

The involved *typologies of users* encompass:

Governmental entities and Law Enforcement Agencies (LEASs), operating at local/national and EU/international level, in charge of monitoring, control, prevention and risk management, prosecution, law enforcement actions

- Non-Governmental Organisations (NGOs) and bodies
- Practitioners, such as scientists, researchers and archaeologists, supporting the governmental entities and LEAs.

EO and GNSS technologies and services are excellent tools to address the challenges of the EUBIS applications. In combination with other technologies and techniques, EO and GNSS offer advanced functionalities, supporting law enforcement actions and enabling to:

- Ensure resilience in diverse contexts and operating scenarios/environments (e.g., road, sea, rail, cities, rural areas).
- Improve the effectiveness and safety of policing by transforming the way in which LEAs respond to the threats and challenges they face.

Considering the breadth and the heterogeneity of the segment, for the purpose of UCP 2025, **20 priority applications, 10 for GNSS and 10 for EO,** were chosen. The selection of the applications was carried out based on several criteria, such as:

- They show use cases of interest, and advances with respect the previous UCP 2023.
- They present today's utilisation and available solutions/use cases, interesting key trends, evolutions of the segment and possible generated opportunities (along with gaps to be likely addressed with concrete actions).

For the selected 20 priority applications, UCP 2025 conducted an extensive survey and consultation targeting key stakeholders (including users) of the EUBIS market segment, with the purpose of collecting inputs to formulate:

- Application description, use cases, user needs and requirements for EO and GNSS
- A relevant Case Study/User Story (if any)
- Identified novelties, gaps, opportunities, recommendations.

Despite the diversity of the applications and the involved typologies of users, as explained above, many commonalities have been observed in relation to the use of satellite technologies. While differences and particular needs are mainly due to the specific applications and use cases. The EUBIS's users already today take advantages of solutions based on EO and GNSS (or EO/GNSS in integration) in their activities. EO data (including the Copernicus ones) is largely utilised by LEAs, NGOs and practitioners (e.g., scientists, researchers and archaeologists). GNSS is already adopted in operations (also in combination with satellite communication), by means of commercial solutions and products in some cases, and in the form of pilots/best practices in other cases.

The opportunities for a more synergetic wider use and exploitation of EU satellite technologies and services essentially rely on the combination with other technologies and techniques, depending on the specific application and use case's needs, such as IoT (Internet of Things), AI (Artificial Intelligence) and Machine Learning (ML) based tools, network and data, text, and speakers' analytics. The advantages generated by the combination with other technologies and techniques are to further enhance the safety and the efficiency of the present operations, and to develop new use cases. There is a broad and strong interest towards cutting-edge technology, more performant and advanced solutions/services, also including EO and GNSS.

Galileo OSNMA (Open Service Navigation Message Authentication) is perceived (but not yet widely adopted) as key enabler to increase integrity and resilient/reliable position and time information, across all applications. A possible value is envisaged for Galileo EWSS (Galileo Early Warning Satellite Service) in specific applications and operations, to transmit alert messages directly through navigation signals.

Concerning GNSS, the main recommendations are to further explore the possible role of EWSS and to support the development of ready-to-the market multi-GNSS/Galileo OSNMA based products customised for this market involving users in the products completion for the operational deployment.

Concerning EO, the main recommendations are:

- To exploit synergies among different application, in order to reduce costs, simplify personnel effort/training/operations and maintenance, while enhancing the resilience and reliability in high range of contexts and complexity.
- To incentivise the establishment and adoption of harmonised data and interoperable platforms, towards a greater interoperability among different systems/solutions/data formats.
- To reach a higher awareness by specialists, practitioners and LEAs, and to boost privileged and facilitated accessibility to EO data by them.

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1 SCOPE AND METHODOLOGY

1.1 Scope

The User Consultation

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 EU Border and Internal Security (EUBIS) segment community, reporting the most up-to-date user needs and requirements in the EUBIS market segment for the use of Positioning, Navigation and Timing (PNT), Earth Observation (EO) and (secure) Satellite Communications (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 satellite technologies and services 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, the Earth Observation system, Copernicus, the satellite communication, GOVSATCOM, and in the future Space Situational Awareness and IRIS2.

The UCP process contains a recurring event, where users from different market segments meet to discuss their needs and application-level requirements relevant for PNT, EO and SATCOM. This report is an evolving document that is regularly updated by EUSPA. It served as a key input to the UCP, to collect and 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 EUBIS segment, with identified trends, and innovations.
- Section 2.2 presents the market evolution and key trends in the EUBIS segment, together with definitions of main user groups and actors in the value chain.
- Section 2.3 describes the specific market drivers influencing the considered applications, in terms of policies, regulations and standardisations.
- 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 2025 UCP.
- Section 2.5 summarizes the main User Requirements for the EUBIS segment in the applications domains analysed in this report.

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.

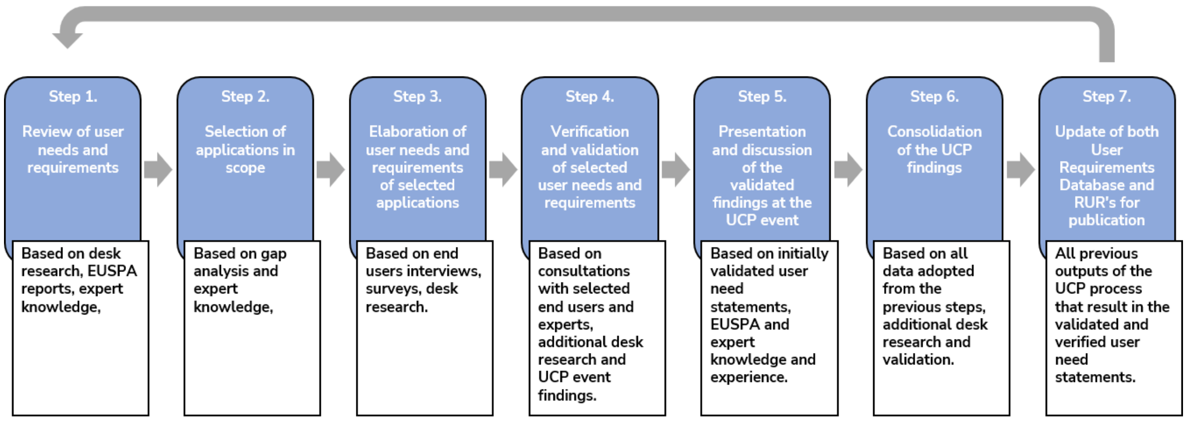

Figure 1: EUBIS segment user requirements analysis methodology

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, 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 EU BORDER AND INTERNAL SECURITY

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

The role of EUSPA

EUSPA plays a pivotal role in the context of the EU Space Programme, acting as a key operational agency that is user-oriented and focused on promoting and maximising the uptake of satellite-based services across various sectors, through the following activities and strategies:

1. User-Centric Approach

- EUSPA adopts strategies that prioritize the needs and requirements of users. It aims to enhance the accessibility and integration of satellite services, ensuring that a broad spectrum of users, including governmental bodies, businesses, and citizens, can benefit from services related to Earth Observation, Satellite Navigation, and Connectivity.

2. Service Provisioning

EUSPA is responsible for providing state-of-the-art services in areas such as:

- Positioning, Navigation, and Timing: Through the Galileo and EGNOS systems.
- Satellite Communications: It facilitates communication services for governmental applications through GOVSATCOM and is working on the new IRIS2 initiative.
- Space Surveillance: EUSPA manages Front Desk services for the EU Space Surveillance and Tracking program, ensuring safety and security in space operations.

3. Enhancing the European Space Ecosystem

EUSPA works to foster a robust European space ecosystem by:

- Providing market intelligence and technical expertise to innovators, SMEs[1], and academia.
- Leveraging EU funding programs such as Horizon Europe to stimulate innovation and research in space-related technologies.
- Supporting startups and developing partnerships that enhance technological advancements.

4. Ensuring Security

- EUSPA plays a critical role in the security of the EU Space Programme. By operating the Galileo Security Monitoring Centre (GSMC), it implements and monitors the security of satellite services, thereby bolstering the overall security framework for EU Member States[2].

5. Stakeholder Engagement

- EUSPA actively engages stakeholders from the entire space value chain, including industry leaders, academic institutions, and end-users. It facilitates feedback mechanisms where users can express their needs and satisfaction levels regarding EU satellite services. This engagement is crucial for the continuous evolution of the EU Space Programme.

[1] Small to Medium-sized Enterprise

[2] MS

EUSPA conducts various essential activities including:

- User Consultation Processes: These are designed to gather insights and perceptions from users to improve service delivery.
- Market and Technology Monitoring: EUSPA analyses trends and forecasts in the space industry to inform strategic decisions.
- Research and Development Funding: The agency identifies funding needs for R&D initiatives and ensures their implementation.
- Pilot Programs: EUSPA supports the testing and piloting of innovative applications to explore new possibilities in space services.
- Commercial Acceleration Programs: Through the CASSINI Programme, EUSPA promotes innovative commercial ideas and facilitates their growth in the marketplace.

In summary, EUSPA serves as a cornerstone of the EU Space Programme, bridging the gap between technological advancements and user needs. By providing innovative satellite services, fostering a collaborative space ecosystem, ensuring security, and engaging with a wide array of stakeholders, EUSPA is crucial in advancing the EU's strategic interests in space and enhancing the overall benefit of space technologies for society.

The role of 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. The Sentinel-1C satellite was launched on 5 December 2024 and Sentinel-1D launch is planned in 2025.
- 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 to contribute missions, encompassing various technologies like SAR, 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 Monitoring Service (CAMS)	Climate Change Service (C3S)	Emergency Management Service (CEMS)	Land Monitoring Service (CLMS)	Marine Environment Monitoring Service (CMEMS)	Security Service (CSS)[1]

Figure 2: Copernicus services

Copernicus Marine Service, ran by Mercator, provides a single access point to over 300 scientifically proven products, that are provided for free. Copernicus Marine Service provides multi-year datasets, as well as almost NRT datasets. The datasets are subdivided in three categories, Blue Ocean, White Ocean and Green Ocean. Their models are developed on satellite observation data, in-situ data and numerical models. The Mercator **product offering supports trade and marine navigation** for various stakeholders through information on ocean currents, sea level, waves, temperature, among others. The data assists in route optimisation and ocean condition modelling.

Copernicus is **increasingly important for maritime spatial planning**, detecting and linking pollution to ships at sea, and ensuring the sustainability of fisheries and aquaculture. While it primarily feeds into evidence-based policymaking rather than regulations or standards, its role is expected to grow.

First, in terms of **environmental and marine pollution monitoring**, high-resolution satellite imagery can be used to monitor marine ecosystems, detect pollution, and assess the impact of climate change. Copernicus is currently already being used in combination with commercial EO data to enable advanced modelling of species and polluted surfaces and is seen as a key tool.

For **marine disaster management**, EO data, including public data from Copernicus and NASA, are being used for monitoring oil spills and chemical spills. Advanced EO techniques are necessary to detect and monitor new types of oils, such as low sulphur oils, which behave differently on water. In 2023, the Copernicus Marine Environment Monitoring Service (CMEMS) expanded its capabilities by incorporating new high-resolution satellite data and advanced machine learning algorithms. This enhancement allows for more accurate and timely monitoring of marine environments, supporting better decision-making for maritime spatial planning and environmental protection. Copernicus services are seen as a more cost-effective solution than physical monitoring, planes, and drones; as well as a more robust and flexible tool to cover large and remote areas.

Secondly, in route optimisation and merchant navigation, EUMETSAT data is becoming central to solutions aimed at optimising fuel efficiency and reducing emissions. Accurate weather forecasting and ocean condition monitoring enable ship operators to plan optimal routes, minimising fuel consumption and emissions. Weather and Spotter Buoys complement satellite data by providing in-situ measurements of weather conditions and sea state.

EUMETSAT operates a fleet of Geostationary (GEO) and Low Earth Orbit (LEO) satellites that provide continuous weather monitoring and forecasting capabilities.

- METEOSAT 2nd and Upcoming 3rd Generation: Provide continuous weather monitoring and forecasting capabilities.
- METOP 1st and Upcoming 2nd Generation: Deliver high-resolution atmospheric data for weather prediction and climate monitoring.
- Jason-3 Satellites: Provide precise measurements of sea surface height, essential for oceanography.
- Sentinels 3, S-6, Upcoming S-4 and S-5: Enhance the capabilities of the Copernicus programme by providing additional data for environmental monitoring and climate change studies.

Key takeaways for EO from the 2025 UCP EUBIS
The following relevant takeaways for EO resulted from UCP 2025 in relation to the European Space Programme components for EUBIS: • EO data (including the Copernicus ones) is largely utilised by LEAs, NGOs and practitioners (e.g., scientists, researchers and archaeologists). • Synergies among different application can reduce costs, simplify personnel effort/training/operations and maintenance, and enhance the resilience and reliability in high range of contexts and complexity. • To this purpose, the establishment and adoption of harmonised data and interoperable platforms can lead to a greater interoperability among different systems/solutions/data formats. Moreover, exploiting a higher awareness by specialists, practitioners and LEAs, and boosting privileged and facilitated accessibility to EO data by them, can generated a wider utilisation of EO data and services.

Table 1: Takeaways for EO from the 2025 UCP in relation to EUBIS

The role of 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 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 20 cm accuracy makes Galileo High Accuracy Service (HAS) 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.

For the Maritime and IWW[3] segment, Galileo provides highly accurate PNT information, essential for safe and efficient Maritime operations, including navigation, collision avoidance, and search and rescue missions. Galileo's unique features, such as higher accuracy and improved availability, making it a valuable tool and asset.

[3] Inland Waterways

Key takeaways for EGNSS from the 2025 UCP EUBIS
The following relevant takeaways for GNSS resulted from UCP 2025 in relation to the European Space Programme components for EUBIS: • Galileo OSNMA is perceived (but not yet widely adopted) as key enabler to increase integrity and resilient/reliable position and time information, across all applications. • A possible value is envisaged for Galileo EWSS in specific applications and operations, to transmit alert messages directly through navigation signals. This possible role has to be further explored. • Broad and strong interest towards cutting-edge technology, more performant and advanced solutions/services, including GNSS ones. A wider introduction and adoption can be facilitated thanks to the development of ready-to-the market multi-GNSS/Galileo OSNMA based products customised for this market involving users in the products completion for the operational deployment.

Table 2: Takeaways for GNSS from the 2025 UCP in relation to EUBIS

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 defence capabilities, especially in response to increasing geopolitical challenges and cybersecurity threats.

Key takeaways for SATCOM from the 2025 UCP EUBIS
In EUBIS applications, SATCOM key role is generally two-fold: 1. To complement terrestrial communication in the case of rural environments, in areas with no existing communication infrastructure. Satellite networks fill connectivity gaps in the communication dead zones where terrestrial and cellular options are unreliable or altogether lacking. 2. In hybrid terrestrial/satellite networks, to ensure reliable and resilient connectivity, on top of continuous coverage. Commercial SATCOM are already used in several applications, especially those involving drones' operations, open sea and maritime environments. The advances in robotics and the growing introduction of robots, autonomous and unmanned vehicles will have a strong impact, empowering the value of SATCOM, especially in hybrid terrestrial/satellite configurations.

Table 3: Takeaways for SATCOM from the 2025 UCP

2.2 Market Overview and Trends

Next figure shows the EUBIS market segment sectors and related groups of applications, according to the EUSPA's segmentation.

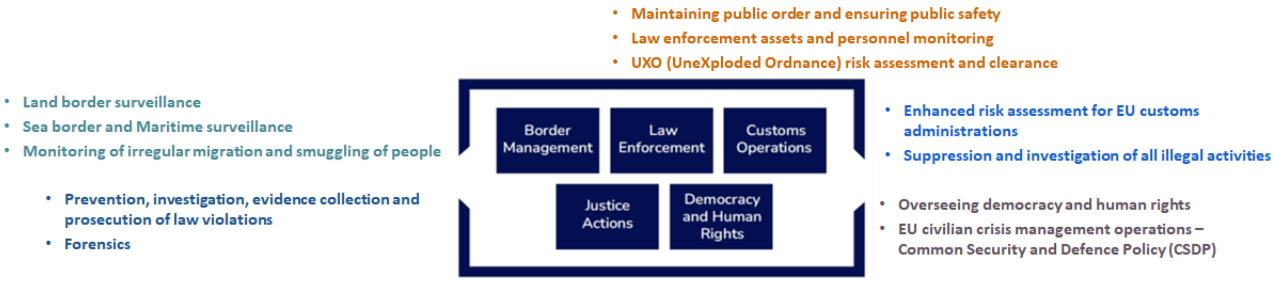

Figure 3: EUBIS market segment sectors and groups of applications (EUSPA's segmentation)

Considering the breadth and the heterogeneity of the segment, for the purpose of UCP 2025, **20 priority applications, 10 for GNSS and 10 for EO,** were chosen. The selection of the applications was carried out based on several criteria, such as:

- They show use case of interest, and advances with respect the previous UCP 2023.
- They present today's utilisation and available solutions/use cases, interesting key trends, evolutions of the segment, gaps, and possible opportunities.

The 10 priority applications for GNSS, focus of UCP 2025, are:

- "GNSS 1 - EU Border Security/Border Management/Land border surveillance - GNSS for safe and secure cross-border transport of dangerous goods also to support EU customs data hub"
- "GNSS 2 - EU Border Security /Border Management/Sea border and Maritime surveillance - Port security/"virtual security gates" & IoT also to support EU customs data hub"
- "GNSS 3 - EU Border Security /Border Management/Sea border and Maritime surveillance - Cargo security in ports/"virtual security gates" & IoT"
- "GNSS 4 - EU Border Security /Customs Operations/Prevention and suppression of illegal cross-borders trafficking and smuggling of cultural heritage - GNSS data for locating cultural heritage looting"
- "GNSS 5 - EU Border Security/Democracy and Human Rights/Multilateral humanitarian agreements monitoring - Crisis resource management and aid management monitoring"
- "GNSS 6 - Internal Security/Law Enforcement/Fight against environmental crime (e.g. illegal pollution, illegal logging, illegal mining, poaching) - Digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU"
- "GNSS 7 - Internal Security/Justice Actions/Forensics - GNSS to support environmental crime investigations"
- "GNSS 8 - Internal Security/Justice Actions/Forensics - Accident and crime scene reconstruction for forensics"
- "GNSS 9 - Internal Security/Law Enforcement/Maintaining public order and ensuring public safety - Counter-UAS[4]"
- "GNSS 10 - Internal Security/Law Enforcement/Fight against organised crime groups - GNSS for prevention and suppression of international drug trafficking trade"

[4] C-UAS

None of the GNSS applications listed above was analysed during UCP 2023.

The 10 priority applications for EO, focus of UCP 2025, are:

- "EO 1 - EU Border Security/Border Management/Land border surveillance - EO data for the safe and secure cross-border transport of dangerous goods"
- "EO 2 - EU Border Security/Border Management/Sea border and Maritime surveillance - EO data to support port and cargo security"
- "EO 3 – EU Border Security/Customs Operations/Prevention and suppression of illegal cross-borders trafficking and smuggling of cultural heritage - EO data for preventing and suppressing cultural heritage looting and illegal trafficking"
- "EO 4 - EU Border Security/Democracy and Human Rights/Multilateral humanitarian agreements monitoring - EO data in damage and conflict zone mapping"
- "EO 5 - EU Border Security/Border Management/Sea border and Maritime surveillance - EO data for monitoring illegal fishing"
- "EO 6 - Internal Security/Law Enforcement/Fight against environmental crime (e.g. illegal pollution, illegal logging, illegal mining, poaching) - EO data for surveillance of waste disposal implementation"
- "EO 7 - Internal Security/Law Enforcement/Fight against drug, firearms trafficking, and cybercrime - EO data for fighting against transnational firearms trafficking"
- "EO 8 - Internal Security/Justice Actions/Forensics - EO data in environmental crime investigations"
- "EO 9 - Internal Security/Law Enforcement/Fight against organised crime groups - EO data for the prevention and suppression of international drug trafficking"
- "EO 10 - Internal Security/Law Enforcement/Fight against environmental crime (e.g. illegal pollution, illegal logging, illegal mining, poaching) - EO data for monitoring illegal fishing and deforestation"

It is worth to notice that **only EO 3 was analysed during UCP 2023**. UCP 2025 confirmed the requirements formulated in 2023, however the reason for considering EO 3 also in UCP 2025 is linked to new needs raised for this application with respect to UCP 2023.

For each application, **based on the inputs and feedback gathered during the UCP's survey/remote consultation phase**, the following aspects are reported in this document:

- Application description, user needs and requirements
- A relevant Case Study/User Story (if any)
- Identified novelties, gaps, opportunities, recommendations

Due to the high heterogeneous nature of the EUBIS segment and because novelties are often linked to opportunities and recommendations, it is considered effective to address the novelty aspects application by application. When commonalities are found, these are mentioned and explained. This approach ensures a clearer and more immediate understanding of the identified novelties.

In the frame of UCP 2025, during the survey/remote consultation phase, **a total of 65 interviews** (**34 interviews on GNSS** applications and **31 interviews on EO** applications) were performed for EUBIS, involving the interviewed stakeholders listed in Table 4. Most of the interviewees were able to address several applications (considering the commonalities from the law enforcement and from the technologies/solutions perspectives).

The content of this document is based on information collected directly from the stakeholders consulted through a series of interviews, in preparation for the UCP 2025 event (as detailed in section 1.2 above). The gathered inputs and feedback were analysed in an aggregated manner, and the involved stakeholders had the opportunity to review and validate the outcomes of the analysis discussed during the UCP 2025 event and reported in this document. The table below lists the stakeholders who answered and participated in the consultation, interviews, and accepted to be mentioned in this document.

Organisation	Name	Surname
ARPA Lombardia	Dario	BELLINGERI
ARPA Lombardia	Nadia	FIBBIANI
Autorità di Sistema Portuale del Mare Adriatico Orientale - Port of Trieste	Valentina	BOSCHIAN
Bochon & Partners	Martin	BECKMANN
Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement (CEREMA)	Jean-Philippe	MECHIN
Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research (CENTRIC)	Fraser	SAMPSON
CEOBS (The Conflict and Environment Observatory)	Eoghan	DARBYSHIRE
MD Services Ltd	Michael	DOHERTY
Erathosthenes Centre of Excellence	Dante	ABATE
EUCAB	Martin	REUTER
OpenStreetMap Team	Jessie	PECHMANN
Leto Space	Patrick	PILS
MAPS International	Willem	MUDDE
PARCS Solutions	Axel	KEREP
Scidrones PC	Argyrios	MOUSTAKAS
The European Border and Coast Guard Agency (Frontex)	Marta	KRYWANIS
Trimble	Stefan	JUNKER
World Customs Organisation (WCO)	Christel	VAN ECK
WSense	Maria	ANGELUCCI
Zabala	Margherita	VOLPE

Table 4: Some of the stakeholders involved in the UCP 2025 survey and consultation

2.2.1 Market Evolution and Key Trends

Despite the breadth and the heterogeneity of the segment, and the diversity of the involved typologies of users, many commonalities in relation to the use of satellite technologies were identified. Differences and particular needs are mainly due to the specific applications and use cases, as detailed below in this document.

EO is often used in combination with GNSS, especially for geolocating objects (such as land and maritime sensors) and drones. In fact, there is an extensive use of drones in the considered applications. Then combined use of GNSS and EO in the majority of the applications mostly copes with the potential advantages derived from using the same technologies in different applications. Especially the combination of EO with GNSS) is generally a target for technology/solution/service providers in order to reduce development's costs and risks and driven by economy of scale (e.g. same satellite image used for different purposes) and for the users with the purpose of optimising personnel, training, operations and maintenance.

The **integration with other technologies and techniques** is essential also for a wider adoption of satellite technologies, in order to:

- Enhance resilience and reliability (often GNSS is used to complement EO and vice versa). In some cases, the integration is intentionally pursued to compensate for the limitations of one technology through the characteristics of another, especially when such limitations are temporary and expected to be overcome by future technological developments, or when data availability and budget constraints — particularly for SMEs — make integration a practical and ready-to-the-market solution.
- Fill the gaps (especially the temporal resolution of the EO images).
- Depending on the specific application and use case to cope with the specific needs.

EO data of the **EU's external land and sea borders** are often used in combination with GNSS, for geolocating objects (such as land and maritime sensors), to support situational awareness and operations in borders surveillance and maritime security. Moreover, EO data are fundamental instruments to monitor and fight against irregular migration and smuggling.

GNSS position and time information from the vessels Automatic Identification System (AIS) are coupled with satellite images by **customs administrations** to check the actual shipment with respect to the expected journey, as well as to implement enhanced risk assessment procedures and prevent and identify illicit activities related to drug trafficking, looting of cultural heritage, smuggling of sensitive and counterfeited goods, illegal mining and fishing.

Satellite images supported by drones are utilised by LEAs to plan in advance and gain tactical advantages in their actions aimed at public order and safety. GNSS-based solutions are adopted for the remote localisation and monitoring of assets and personnel during law enforcement operations. EO data play a crucial role in **investigations aimed to overseeing democracy and human rights**. Damage maps of conflict zones are elaborated through satellite imagery, to perform analyses and evaluations over time and across large areas. GNSS technology is used to geo-locate specific sites and to remotely assist staff in the field.

Images from satellites and drones are a key tool in the **deployment of non-military civilian crisis missions**, enabling an accurate assessment in the preparatory phase to effectively prevent or respond to the outbreak of crisis or conflict situations. GNSS real-time and precise location data significantly enhance the management of the deployed assets, and the safety of the involved personnel. The emerging trend of recent years is that satellite data can provide **acceptable proof in forensics to prosecute criminals in court**. The use of GNSS is already a common investigative practice, supporting the collection of evidence of misconduct. Combined EO and GNSS data help prosecute crimes in court, especially crimes to the environment, waste disposal, and pollution. In fact, EO has great potential for use in court proceedings, as contemporary forensic evidence systems have been considered admissible in legal settings. The potential to monitor cultural heritage looting has been explored.

2.2.1.1 GNSS Key Market Trends

Digitalisation of customs processes and **port security** are among key trends for GNSS in EUBIS market. The exploitation of satellite technologies is today a widespread practice in customs operations, in the activities devoted to the control and suppression of illegal trafficking, to the safeguard of citizens' health, and to the protection of society from transborder criminal activities. Satellite technologies, integrated with a variety of other technological tools and techniques, aid customs officials in the observation, analysis, investigation, inspection and supervision of the entry, exit, and circulation of ships and freights moving across the seas and in ports.

Across the seas, satellite technologies help detect the movements of suspicious vessels and monitor their activity in-real time. Satellite images also enable the supervision of maritime traffic. GNSS instruments such as AIS on-board of the vessels provide precise continuously updated positions. Drones equipped with advanced sensors and high-resolution cameras give a comprehensive real-time aerial view, and act as a proactive measure for discouraging illicit activities. **GNSS-based tracking systems** (often using satellite communication to overcome the lack of terrestrial network coverage in open sea) are installed on board vehicles, trucks and containers to trace their movements, and to identify any deviations from authorised routes. The combination with electronic seals allows to check the integrity of the shipments and to localise the occurrences of possible irregularities.

In ports, the data gathered from the GNSS-based tracking systems, coupled with information from others sources, such as Optical Character Recognition (OCR) and Radio-Frequency IDentification (RFID), allow customs authorities to monitor the traffic of freights, as well as detect the presence of suspicious objects and goods. The collected data across the sea and in the ports' areas allow the dynamic tracking of suspicious vehicles. Real-time intelligence functions are delivered to customs authorities, for heightened risk assessment and swift responses, in order to detect and prevent drug smuggling, import and export of prohibited or undeclared goods, cross-borders trafficking of counterfeited merchandises, poaching and tax evasion.

Every single touchpoint within customs operation (i.e. each shipment, inspection, and cross-border movement) generates valuable data. Advanced techniques based on AI, IoT principles, digital twin representations, ML and data analytics are drawn up to analyse traffic and trade patterns in specific areas, in order to identify anomalies and to take steps to analyse and investigate possible illicit activities.

Satellite technologies and services contribute to the digitalisation of customs processes as envisaged in the new Union Customs Code (**UCC**) presently under revision (as part of the customs reform package tabled by the European Commission[5]), and to the envisaged establishment of a EU Customs Data Hub serving as a central point where European customs authorities and other regulatory bodies can retrieve and add data[6].

GNSS plays an essential role in enhancing **port security** by supporting integrated and extended traceability solutions tailored to IoT ecosystems for port security applications; mainly, it helps with the implementation of 'virtual gates'. Goods and vehicles moving within the port can be checked at the entry-exit points by the port 'virtual security gates', ensuring a seamless entry and exit of designated logistics nodes without interrupting the logistical flow of goods and the port operations.

GNSS solutions combined with smart sensors of physical security systems, feed ports' situation awareness platforms with localisation information, and help port operators to reduce vulnerabilities, by implementing smart fencing and geofencing of port areas, and effectively anticipating threats and attacks. Physical security systems can include **IoUT (Internet of Underwater Things)** systems, envisaging the use of GNSS to provide the position of the underwater sensors and objects. IoUT systems represent an **emerging trend** of recent years for GNSS in the EUBIS market segment. They consist of networks of

[5] EC

[6] EU Communication C/2025/1035, establishing the Union Customs Code and the European Union Customs Authority, and repealing Regulation (EU) No 952/2013

underwater multi-sensor objects, designed to operate in waterways submerged environments, and enabling the collection, processing, and transmission of data to and from the underwater world.

The integration of GNSS positioning with the images provided by satellites and drones, and with AI, help port and customs authorities and law enforcement officials in surveillance and early warning in port environments. GNSS services joined with blockchain technology enhance antitheft measures for cargo security in ports and deliver advanced measures to detect anomalies in real-time. Recent developments in ports protection capabilities against threats and intrusions indicate a shift towards more automated surveillance tools, which are exploiting cutting-edge technologies such as robotics and unmanned systems, both of which are relying on GNSS for position, navigation and timing.

GNSS data are adopted in **criminal trials and investigations** by police forces, authorities and private professionals, to attribute evidence to specific suspects and to prove an intent. GNSS devices embedded in mobile phones/devices or vehicles enable to locate almost in real-time suspected individuals or reconstruct their movements. Based on a series of measurements, coordinates of position are stored in databases that can be recovered and analysed. Combination with 3D scanning technology allows investigators to reconstruct the dynamics of a crime, by generating a scanned 3D model and a digital twin of the crime/accident scene. Moreover, GNSS devices allow for **remote monitoring the behaviour of criminals under legal restrictions** (e.g., under house arrest or prison labour schemes).

GNSS technology has also allows several utilisations in the field of **Unexploded Ordnance (UXO)**. GNSS technology allows for the for the effective detection of using drones, as well as their precise removal through GNSS-controlled automated platforms and robotic systems.

Entities and organisations in charge of **overseeing democracy and human rights**, take advantage from satellite technologies and services: EO images allow damage and conflict zone mapping, GNSS position is used to geolocate objects, GNSS position and time enable to remotely locate, assist and coordinate humanitarian aid personnel and assets.

2.2.1.2 EO Key Market Trends

Specifically concerning use of EO in the EUBIS market segment, main drivers resulted from UCP 2025 concerned:

- The accessibility of high-quality satellite images, particularly the ones referred as very high spatial resolution imagery (i.e. VHR). The demand is for privileged and facilitated accessibility to EO data by specialists, practitioners and involved LEAs.
- The interoperability issues among legacy systems, and the costs associated with commercial data providers. There is a need for harmonized, interoperable data platforms, based on common standards.
- The lack of awareness and need for multidisciplinary working groups with complementary competences from both use case and technical side. The EUBIS market segment is impacted from limited understanding of the potential of EO data especially among the LEAs. In the Forensics application area, this challenge is more eminent, due to the limited number of existing use cases. In general, the suggested approach is to establish specific working groups (involving complementary competences) and facilitated by the research community, to enhance awareness, foster collaboration, and promote operational uptake.
- Specifically concerning the admissibility in legal disputes, there is a potential to be exploited. Contemporary forensic evidence systems have considered admissible in legal settings the produced proof of environmental crimes in several cases, while for cultural heritage crimes the potential remains still unexploited. The great potential of EO in court proceedings should be broadly considered and pursued, as an opportunity able to generate a wider adoption and a beneficial economy of scale. Pilot projects could be launched, according to the following key pillars:
  - Undertaken pilot activities should consider pre-deployment on solutions and closely linked with innovators for the technology demonstrations in the field with high Technology Readiness Level

(TRL) of 7+. It will enable to understand the user needs, verify strengths and weaknesses, and proceed with commercialisation if the technology fits the purpose.

- Close cooperation with decision makers, to be part of testing campaigns and involved in working groups, should be pursued.
- Leveraging cutting-edge technology and new advanced performances/functionalities and services are considered useful, as long they are integrated in trustfully solutions, and near-to-the market/ready-to-fruition products. New advanced performances/functionalities and services should be tested in operational scenarios through practical use cases involving users.
- Optimal utilisation of AI and ML techniques should be addressed, for automatic detection and processing, large data storage and processing required. The majority of the considered applications rely on huge amount of information collected, and multi-sensor data sets.
- Synergies among EO and GNSS should be exploited at the maximum extend, for each application, based on the relevant specificities, as drawn in the document.

2.2.1.3 SATCOM Key Market Trends

SATCOM has a crucial value in the EUBIS market segment. For EO applications in the context of **border surveillance**, the value of a robust network combining terrestrial and satellite communications is to provide a consolidated situational awareness for complex missions:

- Satellite connectivity is a prerequisite for operational readiness to seamlessly link patrol vessels, land and airborne assets zones that may lack adequate terrestrial communication infrastructure.
- Specifically in sea border and maritime surveillance, SATCOM ensures vessels to remain connected regardless of their location on the globe, enabling real-time communication, efficient navigation (especially in combination with GNSS), and enhanced data exchange between ships and onshore operations.
- SATCOM solutions allow for the real-time transmission of data from the sensors, providing coverage to remote and hard-to-access areas (e.g., in areas without reliable terrestrial connections). For example, a typical system includes a network of sensors and cameras installed in a remote stretch of border and connected via a satellite network. Thanks to SATCOM, the system can detect suspicious activity and transmit data in real time to control centres, without the need for terrestrial infrastructure, improving the responsiveness of law enforcement forces and reducing intervention times.
- SATCOM is the technology ideal for drones operating in remote regions, to transmit in real-time imagery and video captured, as well as other sensor data, that are integrated with satellite images.

SATCOM enabled drones are also employed in EO applications related to the detection of **eco-crimes and waste illegal shipment**, in remote or underserved locations when a continuous monitoring and a timely intervention are envisaged. In maritime missions devoted to the prevention and suppression of **illicit trafficking** (such as drug, firearms, hazardous goods and waste shipment) and **illegal, unreported, and unregulated (IUU) fishing**, SATCOM enables more efficient and secure operations, ensuring to maintain critical links.

In hybrid telecommunication, SATCOM networks guarantee secure and resilient communications thus involved LEAs can maintain secure, real-time communication links and coordination with their personnel and workforces, especially in safety critical conditions. The rise of hybrid threats, such as cyberattacks and transnational crime, has further expanded the need for resilient satellite communication systems to enhance situational awareness and facilitate rapid response to emerging threats.

In GNSS applications, data coverage may be extended by SATCOM to track and trace the patrol fleets, assets, and personnel involved in public safety activities. SATCOM offerings to LEAs may envisage:

- Different services, i.e., voice communication, data connectivity, internet

- Different configurations, i.e., fixed, on the move, on the post
- Integration of different terminals depending on the specific needs (e.g., vehicular, personal mobility).

SATCOM is also used in the controlled automated platforms, operating in remote regions. In **customs operations and port security**, the role of SATCOM is increasing. Technological advancements in communication, including SATCOM, are considered among the most significant developments, as they collectively contribute to more robust and effective maritime borders/ports surveillance and security, addressing:

- The evolving challenges posed by illicit activities at sea
- The growing specific needs

In the past SATCOM was relegated to a backup role in GNSS-based tracking systems installed on board of vehicles, trucks and containers to trace their movements, and to identify any deviations from authorised routes. Tracking and tracing through GNSS devices often integrating commercial SATCOM (such as Iridium, Globalstar, or Eutelsat communications) to overcome the lack of terrestrial network coverage in open seas. Tracking and tracing enabled by SATCOM is widely used in logistics and freight transport and supports the implementation of IoT principles. This is the case of solutions for the remote monitoring, tracking and tracing of dangerous goods, waste, and luxury goods. The solutions are also able to report the status of the key parameters of the transported material through the integration with sensors and generate alarms in the case of anomalous conditions and exceeded thresholds occurrence. The combination with electronic seals allows to check the integrity of the shipments and to localise the occurrences of possible irregularities. In ports, the data gathered from the GNSS-based tracking systems, coupled with information from other sources, such as OCR and RFID, as explained above.

In the recent years, private 5G networks are becoming a cornerstone in seamless integration with terrestrial systems. The integration of satellite networks with the 5G networks provides high-speed connectivity between terrestrial and non-terrestrial networks, suitable for an increased reliance on automation, and realising the potential of IoT especially in sectors requiring high reliability, low latency, and enhanced security. By leveraging dedicated spectrum and network infrastructure, private networks ensure that critical IoT applications, such those dedicated to port security, operate efficiently without interference from public network traffic. This dedicated environment is pivotal for applications demanding stringent control and real-time data analytics, in which advanced automation, operational efficiency, and security are critical (for example, the seamless operations of high definition of video surveillance). In the realm of IoT, port authorities are investing heavily in 5G becoming a backbone for the introduction of other (satellite) technologies, into hybrid terrestrial/SATCOM networks: these can bolster communication resilience, especially with modern 5G devices (e.g., handsets, mobile phones) already incorporating satellite capabilities. The on-going evolutions and progresses, driven by the introduction of robots (for example, dog robots) ROV, autonomous vessels and AUVs (Autonomous Underwater Vehicle) are expected to boost the use of a high resilient communication backbone including SATCOM.

2.2.2 Main User Communities

The EUBIS's market segment is characterised by a breadth of heterogenous applications, in diverse complex scenarios and operating environments. The involved typologies of users encompass:

- Governmental entities and LEAs, operating at local/national and EU/international level, in charge of monitoring, control, prevention and risk management, prosecution, and law enforcement actions
- NGOs and bodies
- Practitioners, such as scientists, researchers and archaeologists, supporting the governmental entities, and LEAs

The majority of the applications relies on the combined use of GNSS and EO, therefore the above typologies belong to both EO and GNSS user communities.

2.3 Key Market Drivers – Policies, Regulations, Standards

The following policies and regulations drive users' needs and requirements in the EUBIS market segment, specifically concerning the considered 20 applications. Concerning the applications dealing with **freight transport** (i.e., GNSS 1 and EO 1), the main applicable international regulations are those related to the inland shipment of dangerous material including waste:

- **ADR** - European Agreement concerning the International Carriage of Dangerous Goods by Road[7]
- **RID** - Regulations concerning the International Carriage of Dangerous Goods by Rail[8]
- **ADN** - European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways[9].

Transporting dangerous goods involves strict regulations to ensure safety and compliance to rules, established by the above listed international regulations for road, rail and river respectively. In the case of dangerous waste, GNSS tracking devices contribute to the traceability in waste management and digitalisation, as dictated in the **Waste Shipments Regulation EU Regulation 2024/1157 dealing with digitalisation for the transboundary shipments of waste.**

Another specific case is the transport of **nuclear and radioactive material**, that is a typology of dangerous goods. Transport comprises all operations and conditions associated with and involved in the movement of the nuclear and radioactive material. The transport of nuclear and radioactive material is an essential activity worldwide. Both safety and security during transport are matters of national and international importance. International Atomic Energy Agency (IAEA) safety standards and regulations (**IAEA Regulations and Safety Standards Series No. SSR-6 for the safe transport of radioactive material**) for the safe transport of nuclear and radioactive material apply to all modes on land, water or in the air, including transport that is incidental to the use of the nuclear and radioactive material. Though generally nuclear and radioactive material accounts for a very small proportion of all dangerous material shipped packages of nuclear and radioactive material are transported each year on public roads, railways, and ships potentially representing a threat.

Other important regulatory and policy pillars refer to the digital transformation of the transport and logistics sector, namely the **eFTI electronic Freight Transport Information Regulation** (EU) 2020/1056 aimed to digitalise freight transport across the EU, and the **European Common Data Spaces** proposed in the European data strategy[10]. As explained for GNSS 1, presently in 2026, the regulations still envisage the option of having paper form documents, for the purposes of transport operations, law enforcement and accidents (retrieved by police and emergency services), however guidelines for the use of the electronic transport document are in place approved by the competent authorities in the frame of the relevant UNECE (United Nations Economic Commission for Europe) Working Party[11]. The **UNECE's guidelines** also specify the data set to be contained in the electronic transport document (**eDGTI** – electronic Dangerous Goods Transport Information) in compliance with the regulations, and envisaging multi-GNSS (GPS, Galileo, GLONASS, BeiDou, EGNOS) and the authentication of Galileo Open Service via OSNMA for the position information. The reason is that the companies transporting hazardous materials by road and rail largely adopt telematics based on satellite navigation for monitoring, tracking and tracing, and hence gathering already most of the data required in eDGTI. The rationale for introducing multi-GNSS and authentication is linked to the ability to provide a more robust and reliable position.

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[7] https://unece.org/transport/standards/transport/dangerous-goods/adr-2023-agreement-concerning-international-carriage [RD12]

[8] https://www.era.europa.eu/era-railway-terminology-collection/rid/abbreviation_1/freight [RD13]

[9] https://unece.org/transport/dangerous-goods/adn-2025 [RD14]

[10] Data Act: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

[11] https://unece.org/transport/dangerous-goods

In fact, GNSS-based tracking devices (often integrating sensors and electronic seals) are widely used in the transport of dangerous goods for localisation and tracking. The use of these devices is not only a matter of efficient logistics, rather it is fundamental to predict and prevent, to manage in the case of accidents (for example properly organising recovery operations, rerouting the movements/traffic avoiding populated areas, and protecting the environment). Installed on-board of the assets, these devices send position and other information (such as temperature and/or pressure depending on the types of sensors and/or electronic seal). Transmitted data are collected and processed by a tracking platform and displayed for user monitoring accurate and timely information on the tracked items. The tracking platform uses software to display real-time or historical location data on a map and enables configuration of alerts based on parameters like speed, location boundaries, or specific actions.

The following functions are generally implemented:

- Localisation of moving objects or assets in real-time
- Timestamping of certain events like shipment, loading, and unloading operations
- Fleet Management
- Geo-fencing for granular real-time information
- Detection and alerting of incorrect and unauthorised paths
- Checks of the correct movements (or stops longer with respect to the planning)
- Driver behaviour monitoring, in the case of road trucks/shipments
- Additional real-time or periodic location data, including speed, direction, and other relevant parameters provided by the sensors, enabling to monitor the status of the transported material and to promptly be informed in the case of problems or losses
- Monitoring the integrity of the shipments and the occurrences of possible irregularities/tampering, as provided by electronic seals.

PVT data is transmitted mainly through terrestrial communications, but SATCOM is also used (as back-up or in alternative to terrestrial communications) to ensure coverage also in difficult scenarios, for example in rural unserved/unpopulated areas and open seas.

EO images are sometimes used for planning purposes and to assist recovery operations in the case of accidents leading to environmental damages. In fact, by integrating traffic information on dangerous goods with geospatial data (e.g., natural parks, schools, residential areas) and information on social events, and by using specific algorithms, it is possible to optimise traffic flows, suggest a path that minimises travel time and reduces the risks linked to the social events and to the environment. Additionally, in the case of accident, the exact knowledge of the transported dangerous goods position and load characteristics allows for a more rapid and efficient intervention, and disaster management.

Concerning the applications dealing with **customs operations**, the new UCC presently under revision marks an important step towards a more efficient and modern customs system. One of the most notable changes is the establishment of a central EU data hub, that is set to transform customs processes in the European Union. The aim of the EU Customs Data Hub is to adopt a more centralised and digitalised approach to customs, to ensure a more efficient, strengthened and fraud-proof EU-wide customs. The hub will serve as a centralised Information Technology (IT) environment that will streamline the submission of data by customs actors involved in the movement of goods into and out of the European Union. With the introduction of the central data hub, improved access to business records, the Trust and Check system, and the establishment of a new customs agency, compliance will be strengthened, and administrative burdens on businesses will be reduced. In this way, the hub will create greater coherence and efficiency in Customs procedures, reducing processing times and minimising errors. Furthermore, the future EU Customs Authority (EUCA) that will support the Member States' customs authorities in simplifying customs for businesses and contribute to enhancing the protection of the Single Market against unsafe or illicit products.

Concerning the applications related to **environmental crimes**, two elements offer a relevant framework to possibly exploit use satellite technologies and services. The first being the Directive (EU) 2024/1203 of the European Parliament and of the Council of 11 April 2024 on the protection of the environment through criminal law, which has to be transposed into national law by 21 May 2026, defines minimum standards on criminal and non-criminal penalties, clarifying key terms, and providing guidance on assessing environmental damage for the needs of criminal prosecution. The Directive aims to strengthen and better define the sanctioning system, encouraging the investigative system and criminal action both at national and international levels. The second important element is the "DRAFT POLICY ON ENVIRONMENTAL CRIMES UNDER THE ROME STATUTE" issued by the Office of the Prosecutor on 18 December 2024, setting the determination to investigate and prosecute crimes that have an environmental dimension.

2.4 User Needs and Requirements

As mentioned above, **20 priority applications, 10 for GNSS and 10 for EO**, were considered for the purpose of UCP 2025. For each application, based on the inputs and feedback gathered during the UCP's survey/remote consultation phase, the following aspects were analysed and assessed:

- Application description, user needs and requirements
- A relevant Case Study/User Story (if any)
- Identified novelties, gaps, opportunities, recommendations.

2.4.1 Application GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods

Application description, user needs and requirements

GNSS, combined with terrestrial and/or SATCOM is used to monitor in real-time location and movement of assets transporting dangerous goods (DG). Tracking and tracing devices (often integrating sensors and electronic seals) are installed on-board of the assets; they send positions and other information (such as temperature and/or pressure depending on the types of sensors and/or electronic seal). Transmitted data are collected and processed by a tracking platform and displayed for user monitoring. The tracking platform uses software to display real-time or historical location data on a map and enables configuration of alerts based on parameters like speed, location boundaries, or specific actions.

The following functions are generally implemented:

- Localisation of moving objects or assets in real-time
- Timestamping of certain events like shipment, loading, and unloading operations
- Fleet Management
- Geo-fencing for granular real-time information
- Detection and alerting of incorrect and unauthorised paths
- Checks of the correct movements (or stops longer with respect to the planning)
- Driver behaviour monitoring, in the case of road trucks/shipments
- Additional real-time or periodic location data, including speed, direction, and other relevant parameters provided by the sensors, enabling to monitor the status of the transported material and to promptly be informed in the case of problems or losses
- Monitoring the integrity of the shipments and the occurrences of possible irregularities/tampering, as provided by electronic seals.

GNSS (multi-GNSS/Galileo Open Service (OS)) is today adopted in open environments, rural and urban areas, for remote location, and tracking and tracing assets transporting DG. Galileo OSNMA is considered of interest, especially for specific transports (such as the transport of DG, nuclear and radioactive material), also considering the regulatory framework and the involvement of LEAs.

Transmitted data are collected and processed by a tracking platform and displayed for user monitoring, accurate and timely information on the tracked items. The tracking platform uses software to display real-time or historical location data on a map and enables configuration of alerts based on parameters like speed, location boundaries, or specific actions. Data is transmitted mainly through terrestrial communications, but SATCOM is also used (as back-up or in alternative to terrestrial communications) to ensure coverage also in difficult scenarios, for example in rural unserved/unpopulated areas and open seas.

Conceived for the logistics and transportation industry, to track vehicles, shipments, and cargo in real-time, the main purpose is for improving operational efficiency, ensuring timely deliveries, and reducing the risk of theft. The data collected from tracking and tracing devices are also used by customs authorities in customs operations and by port authorities in port security applications. Collected and processed data, also on top of EO images, enable the implementation IoT principles and digital twin representations, enabling high level risk assessment, situational awareness immediate responses to changes. Typologies of users are competent governmental entities (such as environmental and transport agencies) and LEAs, operating at local/national and EU/international level. In the case of maritime.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0101	
Application	GNSS for safe and secure cross-border transport of dangerous goods	
Accuracy	Horizontal	2 m (this is the required minimum distance to recognise which road/side of the road/direction)
	Vertical	3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No (tunnels use other technologies such as cameras)
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[12]	Relevance	Yes
	Time a device can run	>12 months for intermodal shipment ≤1 month for road-only shipment
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/European
Other		Multi-GNSS (including Galileo OS), SATCOM, terrestrial communications, tracking and tracing platforms, sensors and electronic seals, IoT and digital twin technologies; integration with SATCOM and IoT for

[12] The time that a device can run on its internal battery

		situational awareness and risk assessment

Table 5: Application GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods

Case Study/User Story

Case Study/User Story
The transport of DG can be organised on intermodal routes using special containers (tank containers) that can be easily shipped and adapted to the different transport modalities. This transport model uses different types of vehicles combined along the supply chain in order to optimise consumption and improve travel times. The inland shipment of dangerous material including waste, is regulated by the international regulations ADR[13]/RID[14]/ADN[15] for road, rail and river respectively. These regulations assign duties and define rules for the transport, workplace, storage and consumer, in order to prevent accidents to the public, property or the environment, to minimise the risks for workers and emergency services, and to assure an effective response in the case of problems. Presently in 2026, the regulations still envisage the option of having paper form documents, for the purposes of transport operations, law enforcement and accidents (retrieved by police and emergency services), however guidelines for the use of the electronic transport document are in place approved by the competent authorities through the relevant UNECE's guidelines and electronic transport document (eDGTI) in compliance with the regulations, and envisaging multi-GNSS (GPS, Galileo, GLONASS, BeiDou, EGNOS) and the authentication of Galileo OSNMA for a robust and reliable position information. When petrochemical companies ship explosive products in rail tank cars and tank containers, it is essential that they always know the location of these assets, especially so if they travel long distances on their way to distribution partners and customers. The complexity of moving assets and cargo over long distances is exponentially increased when what's being transported is highly explosive gases. Properly handling the shipment of these dangerous materials also involves safety and security aspects. Furthermore, when addressing security aspects, localisation and tracking are no longer a matter of efficient logistics, rather fundamental to predict and prevent, management in the case of accidents (for example properly organising recovery operations and rerouting the movements/traffic avoiding populated areas and protecting the environment). Advanced tracking technology solutions that harness IOT, with the latest IoT hardware and software, as well as space-based technology, ensure that potentially explosive materials can be monitored reliably even when the cargo travels beyond the reach of conventional telecom networks. In this respect, Galileo OSNMA is considered of interest for the transport of DG, also considering the regulatory framework and the involvement of LEAs. Precise and reliable localisation and tracking can come to aid especially in cross-border operations, by enabling: • The continuous reliable control and monitoring of DG traffic during transport • The collection of data to be further analysed for statistical reporting and incident prevention • Timely intervention in case of accident where knowing the exact location of the DG allows for more rapid and effective operations by rescue teams. By integrating traffic information on DG with geographical data (natural parks, schools, residential areas) and information on social events, and by using specific algorithms, it is possible to optimise traffic flows, suggest a path that minimises travel time and reduces the risks linked to the social events and to the environment. Additionally, in the case of accident, the exact knowledge of the transported

[13] European Agreement concerning the International Carriage of Dangerous Goods by Road

[14] Regulations concerning the International Carriage of Dangerous Goods by Rail

[15] European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways

DG position and load characteristics allows for a more rapid and efficient intervention, and disaster management.

Specifically for the transport of DG, there are synergies with the use of EO as described in the application EO 1 - EO data for the safe and secure cross-border transport of DG. Competent national authorities often adopt a multi-layered approach, envisaging GNSS tracking information on top of satellite images, allowing to monitor in real-time the traffic of DG across their territory. Concerning the GNSS tracking, there are also commonalities with the application GNSS 6 - Fight against environmental crime (e.g. illegal pollution, illegal logging, illegal mining, poaching) – GNSS to support digitalisation in transboundary shipments of waste.

Identified novelties, gaps, opportunities, recommendations

Regarding novelties, gaps, opportunities, and recommendations, there are similar elements with the applications listed above.

Novelties

Novelty 1 In the context of digitalisation of transport and customs procedures, the availability of OSNMA, enabling to increase the trustworthiness of GNSS devices, offers a very important added value. Particularly the features of multi-GNSS/Galileo OSNMA enabled devices (i.e., higher availability and integrity) can ensure more reliable position and timing information, that combined with data from other sensors can support the evolution of today's operation based on papers with advantages in terms of safety and security. For this reason, they are perceived as important differentiators for the involved entities (economic operators and customs authorities) to evaluate if they can trust the data delivered in digital format. This is a driver for the enhancement of present operations, and the establishment of new operations and processes.

Novelty 2 The new UCC (as part of the customs reform package tabled by the EC) presently under revision has envisaged enhanced digitalisation of customs processes and the establishment of a EU Customs Data Hub. The hub will be serving as a central point where European customs authorities and other regulatory bodies can retrieve and provide data. The EU Customs Data Hub is planned to be a digital platform intended to centralise and manage all EU customs data. It will gradually replace the existing fragmented national IT systems, enabling a unified, data-driven EU approach to risk management and customs processes across the Union. The value of GNSS and especially of Galileo OSNMA is to increase the reliability and trustability of location and time related data. Moreover, Galileo OSNMA based time information can enhance the check of accesses (for data entry and retrieval) to the Customs Data Hub.

Gaps

Gap 1 As written above, presently in 2026, the regulations still envisage paper form documents, for the purposes of transport operations, law enforcement and accidents (retrieved by police and emergency services). The digital freight transport documents adopted by transport operators for their own commercial purposes, are not considered valid in case of controls law enforcement. Therefore, the transport operators are still obliged to produce paper documents,

Gap 2 Though the Galileo OSNMA is operational, ready-to-the-market tracking device solutions are not available, moreover the cost is an important factor driving the introduction and adoption. Multi-GNSS/Galileo OSNMA capabilities should be a default configuration for this application; however, the availability of trustfully solutions and products is also extremely important.

Opportunities

Opportunity 1 In the frame of digitalisation, the data collected through these tracking technology solutions can be useful to complete the eDGTI, and to provide the necessary information in customs operations (such as clearances procedures) in the case of cross-border shipments. In this context, solutions based on GNSS technologies are already used, as best practices, to contribute to daily customs operations, usually to track and trace the freights and to monitor their movement/shipment and in combination with data from various sensors and geofencing techniques. GNSS and especially Galileo OSNMA can increase reliability and trustability, thus enhancing safety and security.

Opportunity 2 Trustable position data provided by multi-GNSS/OSNMA enabled devices can play a key role in the EU Customs Data Hub environment, linked with the eDGTI.

Recommendations

Recommendation 1 The development of ready-to-use tracking device solutions based on multi-GNSS/OSNMA is of high priority, allowing to prove experiment the new features in practice. Research projects should be put in place. Relevant extensive validations in real conditions are beneficial.

Recommendation 2 Proof-of-concept pilots should be launched, for the development and pilot projects of:

- eDGTI including multi-GNSS/OSNMA, in real-life operational conditions and involving cross-border operations among several EU MSs
- Customs clearance procedures and risk assessment based on the data and information coming from multi-GNSS/OSNMA, in the perspective of the future integration into the EU Customs Data Hub
- Multi-layered approach, combining GNSS tracking information on top of EO images.

These pilots should be associated with wide-scale demonstrations addressing transboundary shipments (across and outside EU).

Recommendation 3 Joint efforts and synergies shall be kept with the applications above mentioned, in relation to the combination with EO and in relation to the tracking capabilities for the cases of dangerous waste.

2.4.2 Application GNSS 2 - GNSS for cargo security in ports and customs operations

Application description, user needs and requirements

As explained in section GNSS Key Market Trends, satellite technologies is today a widespread practice in customs operations and for port security. GNSS position and time information are received from the vessels AIS and when possible (generally on the basis of specific agreements with logistics operators and freight forwarders), form the cargos. The collected data across the sea and in the ports' areas allows the dynamic tracking of suspicious vehicles, and offers the ports and customs authorities with real-time intelligence for heightened risk assessment in order to prevent and detect the possible transit of illegal and irregular cargos likely linked to organised crime activities such as drug smuggling, contraband, counterfeit goods, import and export of prohibited or undeclared goods, cross-borders trafficking of counterfeited merchandises, poaching, and tax evasion.

In ports areas and maritime environments, GNSS is combined with technologies like IoT, AI, OCR, RFID, ML and data analytics tools, for advanced risk management and facilitation of cargos operations. Moreover, the integration with satellite imagery contributes to an enhanced situation awareness concepts and resilience in ports' areas.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0201	
Application	GNSS for cargo security in ports and customs operations, related to freight traffic and support to EU Customs Data Hub	
Accuracy	Horizontal	2 m (this is the required minimum distance to

		recognise which road/side of the road/direction)
	Vertical	3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No (tunnels use other technologies such as cameras)
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[16]	Relevance	Yes
	Time a device can run	>12 months for intermodal shipment ≤1 month for road-only shipment
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/European
Other		GNSS tracking systems (multi-GNSS), SATCOM, drones, AI-based risk analysis, IoT-enabled sensors, OCR and RFID systems. EO imagery, AIS vessel tracking, drone surveillance, sensor data from vehicles and containers, physical inspections, EU Customs Data Hub integration, advanced analytics for risk assessment

Table 6: Application GNSS 2 - GNSS for cargo security in ports and customs operations

Case Study/User Story

Case Study/User Story
The new UCC presently under revision marks an important step towards a more efficient and modern customs system. One of the most notable changes is the establishment of a central EU data hub, that is set to transform customs processes in the EU. The aim of the EU Customs Data Hub is to adopt a more centralised and digitalised approach to customs, to ensure a more efficient, strengthened and fraud-proof EU-wide Customs. The hub will serve as a centralised IT environment that will streamline

[16] The time that a device can run on its internal battery

the submission of data by customs actors involved in the movement of goods into and out of the European Union. With the introduction of the central data hub, improved access to business records, the Trust and Check system, and the establishment of a new customs agency, compliance will be strengthened, and administrative burdens on businesses will be reduced. In this way, the hub will create greater coherence and efficiency in Customs procedures, reducing processing times and minimising errors. The modern Customs' key pillars (digitalisation and the central data hub) offer a framework for the exploitation of GNSS data and services, moreover also an opportunity for the Galileo OSNMA service.

GNSS-based tracking and tracing is widely used in logistics and freight transport, often with commercial SATCOM to overcome the lack of terrestrial network coverage in open seas. Integrated with (generally passive, for cost reasons) e-seals, provided GNSS position and time information plays a role in modern customs concepts and particularly in advanced risk management techniques.

During the trip the vessel is tracked through the AIS at the port of arrival the passive e-seals enable to identify the specific container and to make the necessary checks on the relevant status. Those containers continuously monitored thought the electronic seals and the AIS, that have not been tampered/damaged during the trip (i.e., anomalies have been detected from the relevant electronic seals) are not considered suspicious, and for them simplified customs' clearance procedures/less checks may be foreseen. Risk analysis determines the necessity for checks in the case of suspicious vessels (for example, in the event of a vessel making an unplanned stop).

The implementation of robust position information and time stamping, achievable thanks to the use of multi-GNSS/Galileo OSNMA enabled devices, at the level of authorities would strengthen the integrity of the data exchanged. Correct date and time data are fundamental for border crossing checks.

Strengthen the resilience of the supply chains, digitalisation contributes to the security of the EU borders. Ports and customs authorities play a pivotal role against broader threats, by monitoring for potential security risks, such as weapons smuggling or the entry of harmful substances. Ports and customs authorities collaborate with other agencies to address these challenges, ensuring the safety and security of the nations and of the EU. Moreover, they support law enforcement actions, towards the suppression of illegal cross-borders trafficking (such as of drugs or weapons), and smuggling of sensitive freights (e.g. money, luxury items/jewels, cigarettes, cultural objects, hazardous material, and waste) and counterfeited goods (e.g. animals, plants, or perishable/food), injecting threats linked to organised crimes.

For cargos' operations in ports and maritime, GNSS data are used in conjunction with EO images, and it contributes to the MDA concepts and overall picture, in combinations with other applications, namely:

- GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
- GNSS 3 - GNSS for ports security operations and virtual security gates
- GNSS 4 - GNSS data for locating cultural heritage looting
- GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
- GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
- EO 1 - EO data for the safe and secure cross-border transport of dangerous goods
- EO 2 - EO data to support port and cargo security
- EO 3 - EO data for preventing and suppressing cultural heritage looting and illegal trafficking
- EO 6 - EO data for surveillance of waste disposal
- EO 7 - EO data for fighting against transnational firearms trafficking
- EO 9 - EO data for the prevention and suppression of international drug trafficking trade

Identified novelties, gaps, opportunities, recommendations

The interviewees clearly state that they already use advanced technologies, as long as they are ready-to-use, cost effective and easy-to-integrate solutions. As long as a new technology comes available, users may decide to start using it, also envisaging new use cases today not possible with the existing solutions.

It has to be considered that the introduction of any new technology and solution leads to change of processes, and this usually has impacts in terms of operations and related costs.

Novelties

Novelty 1 The introduction of the EU Customs Data Hub, further detailed above in section 2.4.1.

Novelty 2 The digital transformation of the transport and logistics sector, whose main pillars are the eFTI electronic Freight Transport Information Regulation (EU) 2020/1056 set to digitalise freight transport across the EU, and the European Common Data Spaces proposed in the European data strategy[17].

Gaps

No important gaps of relevance were revealed from the inputs collected from the interviewees.

Opportunities

Opportunity 1 It is linked to The EU Customs Data Hub, as detailed above in section 2.4.1.

Opportunity 2 It is linked to the eFTI Regulation and the European Common Data Spaces. The use of GNSS can enhance the quality of data. Moreover, the differentiator of Galileo OSNMA is perceived by the interviewees as an enabler to effectively implement the need of reliability and trustability of data, as foreseen in the eFTI Regulation.

Opportunity 3 There is another important opportunity to remark, as explained in the section SATCOM Key Market Trends. Port authorities are heavily investing in 5G and building dedicated environments. Private 5G networks are becoming a cornerstone in realising the potential of IoT, especially in critical IoT applications requiring high reliability, low latency, and enhanced security. This dedicated environment is pivotal for applications demanding stringent control and real-time data analytics, and to advance automation and efficient operations, such as in smart and secure ports involving for example seamless operation of remotely controlled cranes, automated vehicles, and high-definition video surveillance. According to the interested interviewees, this should be seen as an opportunity for SATCOM, in particular to exploit its role and the added value in hybrid terrestrial/satellite networks for an enhanced communication resilience.

Recommendations

Recommendation 1 The main recommendation is to pursue the use of multi-GNSS/Galileo OSNMA by launching proof-of-concept developments in real conditions and life operations. The proof-of-concept developments should foresee satellite-based products and high TRL solutions (from TRL 7 onwards) into operational systems, to be combined with already adopted technologies, such as e-seals and RFID equipment, and leveraging cutting-edge techniques (including SATCOM).

The focus should be on how precise and reliable real-time data sharing would ensure that goods move seamlessly across borders with full traceability and minimised risk in line with the vision of the EU Customs Data Hub, and in coherence with the eFTI Regulation.

The proof-of-concept developments should look at the perspective a large-scale deployment, involving several Member States (for example with extension through corridors across the EU). This may also increase the production of the solutions and generate an economy of scale to limit the related costs.

Moreover, according to the collected inputs, key pillars common to other applications (such as EO 7 and EO 9) must be considered:

- Undertaken pilot activities should consider pre-deployment on solutions and closely linked with innovators for the technology demonstrations in the field (with high TRL 7+). It will enable to understand the user needs, verify strengths and weaknesses and proceed with commercialisation if

[17] Data Act: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

technology fits the purpose. This testing activities shall be funded in an efficient way to minimise the administrative burdens (e.g. tickets for pre-deployment that could be lump sum).

- Close cooperation with decision makers, to be part of testing campaigns and involved in working groups, should be pursued.
- Leveraging cutting-edge technology and new advanced performances/functionalities and services are considered useful, as long we they are integrated in trustfully solutions, and near-to-the market/ready-to-fruition products. New advanced performances/functionalities and services should be tested in operational scenarios through practical use cases involving users.

2.4.3 Application GNSS 3 - GNSS for ports security operations and virtual security gates

Application description, user needs and requirements

Port security is part of the nations and EU border security, and of the Maritime Domain Awareness (MDA) in more general terms. Ports are crucial for the transport of goods and persons across the EU. The strategic role of ports makes them vulnerable to criminal networks. The majority of illegal goods trafficking is over maritime routes (e.g., drug, firearms), and ports are strategic transportation where fraud is committed. Scalable multidimensional situation awareness platforms are generally being implemented across ports' areas to protect ports and reduce the relevant vulnerabilities. By integrating physical fencing and smart geofencing of port areas and terminals, these platforms are conceived to help port operators in port and cargo security operations.

GNSS technologies is widely adopted to enhance port security, by providing "virtual" gates through geofencing functionalities. Integrated into the ports' scalable multidimensional situation awareness platforms. GNSS contributes through extended "traceability" solutions tailored on IoT ecosystems, by implementing "virtual gates" instead of expensive and slow to deploy physical gates. Goods and vehicles moving within the port can be checked at the entry-exit from the port "virtual security gates", ensuring seamless entry and exit of designated logistics nodes without interrupting the logistical flow of goods and port operations.

In ports areas and maritime environments, GNSS solutions (providing position and time information) and intrusion sensors of physical security systems feed ports' situation awareness platforms and help port operators to reduce vulnerabilities by implementing smart fencing and geofencing of port areas and effectively anticipating threats and attacks.

The sensors, for example those adept at detecting door breaches and geofencing promptly alert authorised personnel and officials via email, text messages, or API (Application Programming Interface) notifications, facilitating swift responses to potential security breaches such as theft, stowaway intrusion, or the introduction of contra band during transit. Geofencing warnings can be position and time based, providing the time of a certain access event or a breach, both of which are important for port security. The integration with information from GNSS (position and time) and other sensors amplifies conventional physical security systems, establishing a more resilient security framework. GNSS positioning and timing are also combined with images provided by satellites and drones, to help port authorities and law enforcement officials in surveillance and early warning in port environments using AI.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0301	
Application	GNSS for ports security operations and virtual security gates	
Accuracy	Horizontal	2 m (this is the required minimum distance to recognise which road/side of the road/direction)

	Vertical	3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No (tunnels use other technologies such as cameras)
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[18]	Relevance	Yes
	Time a device can run	>12 months for intermodal shipment ≤1 month for road-only shipment
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/European
Other		GNSS-based positioning and timing at the core, supported by intrusion and geofencing sensors, IoT-connected devices, AI-driven situational-awareness platforms, physical perimeter systems, satellite and drone imagery, and multi-channel communication (email, API, SMS)

Table 7: Application GNSS 3 - GNSS for ports security operations and virtual security gates

Case Study/User Story

Case Study/User Story
This application contributes to the Case Study/User Story of the application GNSS 2 - GNSS for cargo security in ports and customs operations.

Identified novelties, gaps, opportunities, recommendations

The identified novelties, gaps, opportunities, recommendations are the same as for the application GNSS 2 - GNSS for cargo security in ports and customs operations (reported in section 2.4.2).

[18] The time that a device can run on its internal battery

2.4.4 Application GNSS 4 - GNSS data for locating cultural heritage looting

Application description, user needs and requirements

Satellite technologies in combination with several complementary technologies and techniques are extensively used to detection and evaluate looting in archaeological sites as well as assess damage to the heritage. Spatial and temporal resolutions of satellite data are critical factors to quickly identify and respond to looting, and to achieve accurate and granular quantification of damage.

The users are competent entities performing activities devoted to the cultural heritage protection and involved in fighting against illicit trafficking of movable cultural properties, including antiquities and artworks. Specifically, the users include national, EU, and international LEAs, as well as international organisations such as World Customs Organisation (WCO), United Nations Educational, Scientific and Cultural Organisation (UNESCO), customs authorities, Coast Guards in the case of cross-border maritime shipment, academics, and NGOs.

In open environments and seas, satellite images are extensively used to monitor archaeological sites to detect endangered areas and to capture changes, anomalies indicative of unauthorised excavation, and looting activities. However, the new trend is a multimodal/multi-technology approach, envisaging GNSS for the location in conjunction with different technologies, including drones and AI. The purpose is to digitise the entire site, for temporal comparison through time to detect any disturbances that could be potential indicative of looting activities.

By providing a precise location, GNSS is a crucial technology to enhance operations through the production of inventory maps of target archaeological sites. Integrated EO and GNSS data contribute to create an Inventory-Map, including:

- Location: precise geographic coordinates of target archaeological sites and any related objects
- Description: site type, age, and condition
- Imagery: EO images, photographs, maps, and visual documentation
- Threats: erosion, looting, etc.

In the case of international illicit trafficking of cultural heritages, inventory maps also address aspects related to cross border and border management. Inventory maps rely on a multi-technology integration, combining EO data, imagery from drones, satellite imagery, and advanced data analysis to safeguard cultural heritage and to enhance monitoring capabilities. AI has a pivotal value in automation, considering the huge amount of data to be processed. Inventory maps can be a suitable instrument to involved LEAs in combatting heritage trafficking during their field operations, particularly in identifying, implementing risk assessment procedures and protective measures for vulnerable heritage locations, tracking and intercepting illicit cultural property trade.

<table>
<tr><th colspan="3">GNSS Requirements</th></tr>
<tr><td>ID</td><td colspan="2">EUSPA-GN-UR-EUBIS-0401</td></tr>
<tr><td>Application</td><td colspan="2">GNSS data for locating cultural heritage looting</td></tr>
<tr><td rowspan="2">Accuracy</td><td>Horizontal</td><td>Sub-meter to meters preferred; ideally <30 cm for detailed site analysis</td></tr>
<tr><td>Vertical</td><td>Approx. 1–3 m (to distinguish underwater depth variations and coastal elevations)</td></tr>
<tr><td>Availability</td><td>Urban canyon</td><td>Not applicable/limited relevance</td></tr>
</table>

	Natural canyon	Yes (relevant for coastal cliffs and underwater terrain)
	Canopy	Partial (possible signal degradation in dense coastal vegetation or near structures)
	Indoor	No (underwater operations rely on acoustic/INS systems)
	Better than 95%	High
	Better than 99%	Medium
Robustness		High (required for harsh marine and coastal conditions)
Integrity and reliability		High (necessary for legal protection and enforcement activities)
Size, weight, autonomy[19]	Relevance	Yes
	Time a device can run	Typically, several months for coastal stations; several hours to days for underwater sensors or drones
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/European (European coastal and selected external waters)
Other		GNSS integrated with EO (Copernicus, Planet, Airbus Pleiades), drones, radar/multibeam bathymetry, magnetometry; interoperable with AIS, INS, and law-enforcement databases for real-time monitoring and rapid-response capability

Table 8: Application GNSS 4 - GNSS data for locating cultural heritage looting

Case Study/User Story

Case Study/User Story

Inventory Maps elaborated also with the help of GNSS are suitable in the field of underwater archaeology under threat. Underwater archaeological looting poses a significant threat to subaquatic cultural heritage. This illicit activity involves the unauthorised retrieval of artifacts from underwater sites, including shipwrecks and submerged cities. The looting often targets high-value artifacts such as ancient coins, ceramics, and precious metals, which are easily sold on the black market.

The high market value of these artifacts and advancements in technology have fuelled this phenomenon. The vast expanse of the oceans presents a major challenge in protecting these sites. Looting operations are often carried out by teams of skilled divers and organised groups. In some cases, looters use semi-submersible vessels and GNSS-guided underwater drones to locate and extract artifacts with minimal detection. The repercussions of such activities are severe, including the loss of cultural heritage, ecological damage, and the hindrance of archaeological research.

[19] The time that a device can run on its internal battery

Efforts to combat this issue encompass international conventions, national laws, and collaborations with NGOs. However, significant challenges remain, such as difficulties in law enforcement and the persistent demand for artifacts on the black market. Moreover, the coordination between different national authorities is often limited by fragmented regulations, language barriers, and data-sharing restrictions. Ultimately, safeguarding underwater heritage necessitates global cooperation, adequate resources, the development of new technological tools, centralised process and platforms, and increased awareness. Training programs for local authorities and public outreach campaigns are also critical to promote compliance and support for conservation efforts.

SEA-CLOP (Space and Radar Technology for Underwater Heritage Protection) is an initiative designed to leverage multi-sensor technologies and real-time monitoring capabilities, with the objective to address the challenges related to the protection of underwater archaeology and coastal heritage under threat. The underlying concept is protecting underwater archaeological sites using GNSS and emerging radar/EO technologies. The goal is to secure no-anchoring zones and combat looting by integrating multiple technologies:

- Multi-technology integration: GNSS, GNSS-based AIS, and image recognition. The system can also integrate Synthetic Aperture Radar (SAR) and LiDAR[20]-derived bathymetric data to detect changes in underwater topography.
- Intelligence gathering: to facilitate legal action against looters and link sites, artifacts, and crimes to strengthen evidence chains. This includes geotagged evidence management, temporal change detection, and cross-referencing vessel activity with historical site data.
- Interdisciplinary approach: to enhance investigations through collaboration between archaeologists, law enforcement, and tech experts. It also encourages cooperation with environmental scientists to assess ecological impact alongside heritage protection.

A poly-technology approach is proposed, encompassing:

1. Interconnect and aggregate data:
   - Centralise archaeological, scientific, and legal data.
   - Leverage emerging EO technologies.
2. Law enforcement integration:
   - Support investigations and legal actions via dedicated platforms. These platforms should provide dashboards with real-time alerts, automated reporting, and predictive analytics for resource allocation.
3. Coastal Site Mapping:
   - Inventory sites detected through scientific methods (geophysical remote sensing, multibeam bathymetry, acoustic mapping, magnetometry, etc.).
4. Maritime activity monitoring:
   - Detect abnormal ship stations in no-anchoring zones using GNSS and satellite AIS.
   - Combat spoofing and smuggling tactics.
   - Optimise operations: assist coast guards and law enforcement in surveillance and targeted interventions. Operational dashboards allow prioritisation of patrols and automated notification of violations.
5. Smuggling prevention, involving the illegal transport of archaeological goods across borders, by offering the following functions:
   - Risk Assessment: Identifying high-risk areas and routes for smuggling.
   - Intelligence Gathering: Collecting intelligence on smuggling operations.
   - Surveillance: Monitoring maritime activities to detect suspicious behaviour.
   - Interdiction: Intercepting and seizing vessels involved in smuggling.

[20] Light Detection and Ranging

The use of multi-GNSS/Galileo OSNMA is potential considered of interest especially for “non-cooperative” and “dark” vessels. Considering the stealth’s techniques of smugglers (such as jamming and spoofing). There are similarities with several other applications:

- EO 3 - EO data for preventing and suppressing cultural heritage looting and illegal trafficking
- EO 7 - EO data for the prevention and suppression of international drug trafficking
- GNSS 2 - GNSS for cargo security in ports and customs operations
- GNSS 10 - GNSS for prevention and suppression of international drug trafficking.

Additionally, SEA-CLOP’s framework could serve as a model for integrating AI-driven predictive analytics, real-time alerts, and cross-sector data sharing to enhance EU-wide operational effectiveness in heritage protection.

Identified novelties, gaps, opportunities, recommendations

Based on the inputs collected from the interviewees, the—outcomes in terms of novelties, gaps, opportunities, and recommendations are similar to those elaborated for other GNSS applications. Additional considerations specific to this application can be drawn.

Novelties

Novelty 1 The main novelty is the proposed integrated multi-technology approach, envisaging a key role for GNSS and a focus on multi-GNSS/Galileo OSNMA.

Gaps

Gap 1 Lack of a sufficient awareness among practitioners, LEAs, and decision-makers which have the key role of supporting the development of suitable policies and rules aimed to incentivise the introduction of the proposed integrated multi-technology approach, in addition to the today’s widespread adopted EO-based one)

Opportunities

Opportunity 1 Priority case studies, such as the underwater archaeology under threat described above, offer the possibility to raise the attention and trigger new ideas.

Recommendations

Recommendation 1 Launching pilot projects on case studies, involving complementary and multidisciplinary competences aimed to show the advantage of the multi-technology approach and to give a particular emphasis on the use of multi-GNSS/Galileo OSNMA (underlining the values in terms of security, reliability, and precision).

Recommendation 2 Developing targeted communication campaigns based on the results of the pilot projects, for promotion and for the definition of an optimal path towards a smooth/step-wise operational introduction.

2.4.5 Application GNSS 5 - GNSS in crisis resource management and aid management monitoring

Application description, user needs and requirements

The application aims to enhance crisis resource management and humanitarian aid monitoring. It serves emergency responders, humanitarian organisations, government agencies, local communities, and NGOs by providing a platform that integrates space-based and complementary non-space data for effective decision-making during humanitarian actions. This application is particularly useful in open environments for emergency response and disaster relief. It enables accurate positioning of assets in affected areas, real-time monitoring of aid distribution, and efficient resource allocation. By utilising GNSS data along with satellite imagery, in-situ observations, and other sensors, the application creates a comprehensive view of the crisis.

Key user needs include immediate access to accurate information, efficient resource allocation, and enhanced situational awareness. The application can support community engagement by allowing local members to participate in data collection and reporting, fostering collaboration. It also facilitates inter-agency communication and coordination, essential for effective crisis management.

The application features an intuitive interface to accommodate diverse users and provides training resources to maximize usability. Security measures can be implemented to protect sensitive data, ensuring compliance with privacy regulations. Data is continuously processed during emergencies, allowing for real-time updates and periodic analysis for reporting. GNSS data can be sourced from non-affiliated mobile phones, as well as from devices of NGO-affiliated stakeholders. This flexibility enhances the application's ability to gather comprehensive information.

Overall, the GNSS implementation in humanitarian monitoring offers a useful enhancement. By addressing user needs and drawing on multiple data sources, it supports stakeholders in responding to crises and facilitating timely aid delivery.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0501	
Application	GNSS in crisis resource management and aid management monitoring	
Accuracy	Horizontal	Metre-level
	Vertical	Metre-level
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	No
	Indoor	No
	Better than 95%	High
	Better than 99%	Medium
Robustness		Medium
Integrity and reliability		Medium
Size, weight, autonomy[21]	Relevance	Not applicable
	Time a device can run	Not applicable
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/Local
Other		Not applicable

Table 9: Application GNSS 5 - GNSS in crisis resource management and aid management monitoring

Case Study/User Story

Case Study/User Story
The deployment of ChatMap by the Humanitarian OpenStreetMap Team (HOTOSM) during disaster response operations is a relevant use case. ChatMap is a tool that leverages GNSS data and instant messaging platforms (such as WhatsApp and Telegram) to collect and map critical information from

[21] The time that a device can run on its internal battery

affected communities in real time. During recent crises, HOTOSM used ChatMap to gather geolocated reports of damage, resource needs, and urgent requests from local populations. This data was then integrated with satellite imagery and GIS tools to create detailed situational maps, enabling emergency responders and aid organisations to prioritize interventions, allocate resources efficiently, and monitor the impact of relief efforts.

Identified novelties, gaps, opportunities, recommendations

The following main elements can be retrieved from the interviewees, in terms of gaps, opportunities, and recommendations.

Novelties

No major novelties were found from the inputs collected from the interviewees.

Gaps

Gap 1 There are concerns about how location data from affected individuals—especially when sourced via messaging apps or mobile devices—is collected, stored, and shared. These issues limit data access and coordination among humanitarian actors. Clear anonymisation and consent mechanisms are often missing or inconsistently applied, creating legal, and ethical risks.

Gap 2 Many local responders, NGOs, and community organisations remain unaware of the advanced capabilities of GNSS, such as authentication (e.g., OSNMA), multi-constellation robustness, or integration with EO datasets. This limits uptake, especially where legacy systems (manual reporting, paper-based tracking, etc.) are still used.

Opportunities

Opportunity 1 GNSS-enabled tools can enhance live visibility over the movement and final destination of relief goods, vehicles, and personnel. This transparency strengthens accountability and donor confidence while improving fairness in allocation.

Opportunity 2 Integrating GNSS data with EO and socio-economic models allows near real-time decision support for logistics, evacuation planning, and needs forecasting. This can significantly reduce response times and optimise resource distribution.

Opportunity 3 synergies with other possible GNSS utilisation in the domain of crisis resource management and aid management, such as remote location and tracking of personnel and staff involved in real-field operations which are often hazardous to the health of the deployed units. In this respect multi-GNSS/OSNMA solution should be considered as a “default” configuration, considering the need to trustfully solutions.

Recommendations

Recommendation 1 Design and test integrated interfaces combining GNSS, EO, and in-situ data (from drones or mobile devices) to avoid data fragmentation. Interoperability standards (e.g., OGC, INSPIRE) should guide development.

Recommendation 2 Conduct targeted awareness campaigns, workshops, and training sessions to familiarise NGOs and local authorities with advanced GNSS functionalities (e.g., multi-constellation use, OSNMA authentication, high-availability receivers).

Recommendation 3 Synergies with other GNSS utilisation, as detailed above, should be pursued.

Recommendation 4 Development of ready-to-use tracking device solutions based on multi-GNSS/OSNMA is of high priority, allowing to prove experiment the new features in practice. Research projects should be put in place, the relevant extensive validation in real conditions are beneficial.

2.4.6 Application GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU

GNSS technologies contribute to the traceability in waste management and digitalisation, as dictated in the new Waste Shipments Regulation EU Regulation 2024/1157. In open environments, rural, and urban areas, GNSS technologies offer to governmental entities (such as environmental and transport agencies) and competent LEASs (operating at local/national and EU/international level) systems for tracking waste shipments.

The key elements of a system for tracking waste shipments are:

- GNSS tracking devices, which are crucial for real-time monitoring of waste shipments, especially for cross-border transport. It helps ensure compliance with regulations by providing data on the location and movement of waste, thus preventing illegal dumping and misrouting.
- IoT solutions, enabling to monitor waste collection containers and fleets. These systems can provide data on operational performance and ensure that waste is transported to the correct facilities.
- Traceability functions. Effective waste management requires comprehensive traceability systems that document the movement of waste from its origin to disposal. This includes data collection methods, unique identification of waste items, and centralised databases to track waste throughout its lifecycle.

Geospatial data are advantageous for industries like logistics, urban planning, and environmental monitoring to combine GNSS tracking with Geographic Information System (GIS) data since this enables real-time location monitoring, route planning, and spatial analysis. Traceability in waste management allows for tracking and documentation of the movement and disposal of waste materials. In order to ensure compliance with rules and encourage transparency, it requires tracking information about origin, transit, treatment, and final disposal. These sets of information support responsible waste management practises, identifies inefficiencies, and aids in monitoring environmental effect.

The EU has established strict regulations governing the shipment of waste, particularly to prevent illegal dumping and ensure environmentally sound management. The Waste Shipments Regulation, which was updated and effective from May 2024, introduces stricter controls on waste exports from the EU, aiming to enhance environmental protection and support the circular economy, by enhancing traceability and control over waste transport within and outside the EU. Key objectives include:

- Preventing illegal shipments. The regulation strengthens enforcement mechanisms to deter illegal waste transport.
- Increasing traceability. It requires detailed documentation and tracking of waste shipments to ensure they are handled properly throughout their lifecycle.

In this respect, the new Waste Shipments Regulation EU Regulation 2024/1157 envisages two key pillars:

- Real-time tracking. The new rules include provisions for real-time tracking of waste shipments, enhancing accountability and traceability throughout the transportation process.
- Digitalisation of procedures. The regulation aims to modernize waste management by moving towards electronic documentation and submission processes, reducing reliance on paper-based systems.

GNSS Requirements	
ID	EUSPA-GN-UR-EUBIS-0601
Application	GNSS to support digitalisation in transboundary shipments of waste

Accuracy	Horizontal	2 m (this is the required minimum distance to recognise which road/side of the road/direction)
	Vertical	3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No (tunnels use other technologies such as cameras)
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[22]	Relevance	Yes
	Time a device can run	>12 months for intermodal shipment ≤1 month for road-only shipment
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/European
Other		GNSS tracking devices, IoT sensors, GIS-based monitoring, centralised traceability systems Traceability systems documenting origin, transit, treatment, and disposal; digital documentation compliant with EU Regulation 2024/1157

Table 10: Application GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU

Case Study/User Story

Case Study/User Story
Officially entered into force in May 2024, the EU Regulation 2024/1157 fixes stricter controls on waste exports outside the EU by modernizing and digitalising procedures. A core aim is to move away from paper-based systems towards a fully electronic submission of information, increasing efficiency and data availability across the EU. Presently, the EC is working on the development of the central system for electronic submission and exchange of information and documents concerning shipments of waste. DIWASS will be used for the

[22] The time that a device can run on its internal battery

exchange of documents and information as of 21 May 2026. The system will be based on the existing Information Management System for Official Controls (IMSOC) digital platform.

The DIWASS should be interoperable with other systems and software that are used by some competent authorities or economic operators. Accurate and trustworthy data provided by GNSS tracking devices for freight shipments can contribute to DIWASS. Moreover, the use of multi-GNSS/Galileo OSNMA can support trustable and non-reputable information usable for law enforcement purposes. There are also commonalities with the application GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods.

Identified novelties, gaps, opportunities, recommendations

Based on the inputs gathered from the interviewees, the following elements in term of novelties, gaps, opportunities, and recommendations can be outlined.

Novelties

Novelty 1 The new Waste regulation (EU Regulation 2024/1157) establishing the updated legal framework that will govern all transboundary shipments of waste by modernising and digitalising procedures, envisages real-time tracking.

Gaps

Gap 1 Though the Galileo OSNMA is operational, specialised ready-to-the-market tracking device solutions are not available. Moreover, the cost is perceived as an important factor driving the introduction and adoption. Similarly, to the application devoted to GNSS tracking of dangerous goods, multi-GNSS/Galileo OSNMA capabilities should be a default configuration for this application, however the availability of trustfully solutions and products is extremely important.

Opportunities

Opportunity 1 EU Regulation 2024/1157, which entered into force in May 2024, represents a timely and significant opportunity for stakeholders to prepare for forthcoming obligations. While the regulation is already legally in effect, the general application date of 21 May 2026 marks the point at which most provisions will become mandatory for businesses. This defined transition period creates a valuable window for organisations to analyse the regulatory changes in detail and proactively adapt their processes, systems, and compliance strategies ahead of full enforcement.

Opportunity 2 Trustable position data provided by multi-GNSS/OSNMA enabled devices can play a key role in the process of digitalisation and in the DIWASS framework.

Recommendations

Recommendation 1 Joint efforts and synergies shall be kept with the application GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods, due to similarities and considering dangerous waste cases for which ADR[23]/RID[24]/ADN[25] rules apply in the inland shipments and International Maritime Dangerous Goods (IMDG) Code in the maritime shipments.

2.4.7 Application GNSS 7 - GNSS to support environmental crime investigations

Application description, user needs and requirements

GNSS data often contributes to larger datasets from satellite imagery, drone imagery, sensors, etc. They enable environmental agencies, competent LEAs and NGOs, forensic experts, and courts to:

[23] European Agreement concerning the International Carriage of Dangerous Goods by Road [RD12]

[24] Regulations concerning the International Carriage of Dangerous Goods by Rail [RD13]

[25] European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways [RD 14]

- Detect illegal dumping, habitat destruction, pollution monitoring, chain of custody for evidence, wildlife smuggling, etc.
- Generate accurate documentation of environmental crimes, legal evidence in compliance with regulations devoted to environmental monitoring and enforcement actions.

GNSS data are used in open environments, during investigations, and periodically for analysis and reporting. Based on a series of measurements, GNSS coordinates of position are stored in databases that can be recovered and analysed. Combination with 3D scanning technology allows investigators to reconstruct the dynamics of a crime, by generating a scanned 3D model and a digital twin of the crime/accident scene.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0701	
Application	GNSS to support environmental crime investigations	
Accuracy	Horizontal	Metre-level in most cases, cm-level for high precision ones
	Vertical	Metre-level
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	Yes
	Indoor	No
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[26]	Relevance	Not applicable
	Time a device can run	Not applicable
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	Regional/Local/Specific site
Other		Authentication through OSNMA is key

Table 11: Application GNSS 7 - GNSS to support environmental crime investigations

Case Study/User Story

Case Study/User Story
In Central Africa, investigators embedded GNSS tracking units inside two realistic counterfeit elephant tusks made of resin. Each unit included a GNSS receiver for geolocation and a satellite transmitter to send position data at regular intervals. Once the tusks entered the illicit trade network in Central Africa, the GNSS data pinpointed their exact coordinates every few hours, revealing the smugglers' transport routes, border crossings, and storage sites. The positional logs were later overlaid on maps to trace the full journey from the point of origin to ports used for export.[27]

Identified novelties, gaps, opportunities, recommendations

[26] The time that a device can run on its internal battery

[27] https://www.earthisland.org/journal/index.php/magazine/entry/tech-rescue-wildlife-trafficking-poaching

Key novelties, gaps, opportunities, and recommendations can be outlined, on the basis of feedback gathered from the interviewees.

Novelties

Novelty 1 As of July 2025, Galileo's OSNMA has become operational, marking a pivotal advancement for forensic applications. For the first time, forensic investigators can verify that GNSS data used in accident and crime scene reconstructions is authentic just using the Galileo signal. This authentication is essential in legal contexts, where the integrity of evidence is paramount. OSNMA enables courts and forensic experts to trust that the positioning and timing data presented as evidence genuinely originates from Galileo and has not been altered, significantly strengthening the reliability of digital forensic reconstructions in criminal and civil proceedings. Galileo OSNMA-enabled receivers were tested for evidentiary data collection by European Environmental Crime Units in illegal waste tracking and habitat monitoring contexts.

Gaps

Gap 1 Prosecutors and legal professionals are often unaware of how geospatial intelligence can be used as evidence in environmental crime cases.

Gap 2 No clear technical or legal standards for generating, validating, and presenting geospatial data in court.

Gap 3 Lack of awareness and training in relevant agencies.

Opportunities

Opportunity 1 Drones today provide higher spatial resolution mapping products than satellites, as well as additional thematic quantitative mapping products. The synergy between satellites' and drones' imagery can generate several new use cases.

Opportunity 2 Synergies in the cases of GNSS tracking for the transport of dangerous goods and waste, including possible added value of multi-GNSS/OSNMA.

Recommendations

Recommendation 1 Implementation of awareness and engagement is fundamental in order to:

- Raise awareness among judges and prosecutors about how geospatial intelligence can support investigations and evidence.
- Foster regular interaction between legal professionals and technical experts.

Recommendation 2 Stimulating technical and legal integration to:

- Define clear protocols for producing and presenting geospatial intelligence suitable for court use.
- Conduct requirements' analyses to identify what geospatial information is legally relevant and admissible.

Recommendation 3 Promoting capacity building is a key for:

- Strengthening the capabilities of environmental agencies and competent authorities to use geospatial technologies.
- Developing technical and analytical skills among staff to collect, process, and interpret geospatial data effectively.

Recommendation 4 Sustaining collaboration and cooperation between technical experts and legal practitioners ensures accurate, credible use of geospatial evidence.

Recommendation 5 Pursuing synergies and exploitation with the GNSS use in other applications linked can generate a snow-ball effect towards a wider introduction, with focus on multi-GNSS/OSNMA.

2.4.8 Application GNSS 8 - GNSS in accident and crime scene reconstruction for forensics

Application description, user needs and requirements

The application focuses on accident and crime scene reconstruction, utilising advanced technologies to support forensic investigations. This application is vital for police, forensic experts, accident investigators, courts, and insurance companies involved in documenting accidents and crime scenes in various environments, including indoor, open, and shadowed or difficult satellite conditions.

The application employs GNSS data for georeferencing and timing, integrating it with satellite and drone imagery, laser scanner data, sensors, total station data, mobile phone data, black box data, and communication network data. The anticipated implementation of Galileo's OSNMA will enhance data authenticity, ensuring that the information can be reliably used in legal proceedings. Additionally, RTK[28] positioning can be utilized to improve accuracy when feasible.

Data is processed through a series of measurements, with coordinates stored in databases for recovery and analysis. By combining GNSS data with 3D scanning technology, investigators can reconstruct the dynamics of accidents and crimes, generating scanned 3D models, and digital twins of the scenes. This capability is essential for accurate scene documentation and understanding the context of incidents. The application facilitates the transmission of relevant data to stakeholders, during scene documentation and for periodic analysis and reporting. The primary purposes of data processing include accurate scene reconstruction, providing legal evidence, supporting insurance claims, and ensuring compliance with regulations.

In summary, the use of GNSS is to become intrinsic to forensic science. By addressing the specific needs of its users and leveraging a variety of data sources, it enhances the ability of stakeholders to effectively document and analyse accidents and crime scenes, thereby supporting legal and insurance processes.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0801	
Application	GNSS in accident and crime scene reconstruction for forensics	
Accuracy	Horizontal	cm-level
	Vertical	cm-level
Availability	Urban canyon	Yes
	Natural canyon	Yes
	Canopy	No
	Indoor	No
	Better than 95%	High
	Better than 99%	Medium High
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[29]	Relevance	Not applicable
	Time a device can run	Not applicable
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	Local (crime scene)

[28] Real-Time Kinematic

[29] The time that a device can run on its internal battery

Other		

Table 12: GNSS 8 - GNSS in accident and crime scene reconstruction for forensics

Case Study/User Story

Case Study/User Story
The UK Police Collision Investigation Units and German Federal Police use RTK GNSS survey kits (e.g., Leica or Trimble) to capture centimetre-level 3D reconstructions of crash sites. Based on a series of measurements, coordinates of position are stored in databases that can be recovered and analysed. Combination with 3D scanning technology allows investigators to reconstruct the dynamics of a crime, by generating a scanned 3D model and a digital twin of the crime/accident scene. These reconstructions are then used in court as admissible evidence for determining impact speed, angle, and vehicle trajectory. Another relevant use case is related to the Czech Republic's Traffic Police, already using GNSS solutions, combined with EO images and integrated with different technologies and techniques depending on the specific circumstances and operational environments. Off-the-shelf, ready-to-market products are widely accepted, to gradually replace manual “traditional” methods for measurements. The collected data are generally post-processed, in conjunction with the data from several sources. There is a wide acceptance, for the law enforcement and legal perspectives: technology enables to collect high-quality more reliable, accurate and enriched information in a faster and more efficient way, to be processed according to the specific necessity such as representation, visualisation, filtering, statistics, etc.

Identified novelties, gaps, opportunities, recommendations

Key novelties, gaps, opportunities, and recommendations can be outlined, on the basis of feedback gathered from the interviewees.

Novelties

Novelty 1 According to the interviewees, generally LEAs are willing to leverage cutting-edge technologies and new features as long as they become available, provided that trustfully and proven solutions are ready for deployment or integration. Difficulties caused by challenging environments (such as low satellite visibility) and intentional interferences (jamming and spoofing) are overcome through the use of different complementary technologies. Most devices and solutions are multi-GNSS.

Gaps

Gap 1 Mainly regulation and legal barriers rather than a technological barrier to adoption

Gap 2 Restrictions due to privacy and concerns in data collection and use, when a specific person is concerned. Only in the case of aggregated information (as for traffic and incident situations and statistics), privacy and General Data Protection Regulation (GDPR) are not perceived as limitations.

Gap 3 In a legal context, evidence based on GNSS data could be challenged due to its inherent vulnerabilities. While GNSS accuracy is sufficient for navigation, it may not meet the higher standard of proof required in court, where a much greater level of reliability is essential.

Gap 4 The need of changes working procedures into digitally based ones and the lack of sufficient training from practitioners hinder the wider adoption.

Gap 5 Costs of the solutions may hinder a wider adoption.

Opportunities

Opportunity 1 GNSS data are adopted in criminal trials and investigations by police, authorities and professionals to attribute evidence to suspects and to prove an intent. GNSS devices embedded in mobile phones/devices or vehicles enable to locate almost in real-time suspected individuals or reconstruct their movements. Combination with 3D scanning technology allows investigators to reconstruct the dynamics of a crime, by generating a scanned 3D model and a digital twin of the crime/accident scene.

Opportunity 2 GNSS data retrieved from automotive black boxes is already adopted and considered admissible as proof in court for accident recontractions. GNSS information is integrated with the data collected from other sensors, such as gyroscopes and Inertial Measurement Unit (IMU). This can generate a general acceptance and thus lead to a wider utilisation.

Recommendations

Recommendation 1 Integrity of signal to be improved so that the technology is considered trustworthy enough by higher courts of law.

Recommendation 2 Supporting a stepwise and gradual introduction into operations of market-available solutions.

Recommendation 3 In this respect, EU research and development funds create the opportunities for cooperation among several stakeholders with complementary competences, such as industry and LEAs. The recommendation is to take advantage of research and development initiatives to foster collaboration, innovation, promotion, and awareness. The following drivers are suggested by the interviewees:

- Target large-scale implementation. A wide-scale deployment has the ability also to generate an economy-of-scale, with consequent reduction of solutions' costs
- Cross-border cooperation among LEAs from different MSs, for exchange of experiences
- Focus on high TRL and near to the market solutions in order to easy the acceptance
- Encouraging the participation of newcomers, especially among the users.

2.4.9 Application GNSS 9 - Counter-UAS

Application description, user needs and requirements

Unmanned Aircraft Systems (UAS) are instrumental for a variety of purposes in external border security and in law enforcement actions aimed to oversee and maintain the internal security. Given their versatility and mobility, LEAs have become increasingly reliant on UAS as effective tools in their operations.

In **border crossings and surveillance activities**, UAS combined with smart sensors and camera-based solutions, provide EU border security practitioners with significantly improved and timelier situational awareness and decision-making capacities.

In **customs operations**, drones provide additional vigilant eyes in the sky to authorities, pre-emptively identifying and disrupting smuggling attempts or making escape attempts more challenging.

In **law enforcement activities** for internal security, the drone's capabilities are exploited in tracking the movements of criminals, including smugglers and human traffickers, attempting illegal border crossings.

Drones are invaluable in supporting crowd monitoring during protests, gatherings, and events providing real-time video feeds for heightened situational awareness. In event security drones equipped with high-definition (HD) high-resolution cameras and thermal imaging technology provide aerial surveillance, crowd management, and safety protocols.

Satellite technologies are adopted in UAS operations, mainly GNSS for positioning and SATCOM to transmit data. Location, tracking, and communication are necessary to ensure the proper condition of flight. The value of SATCOM in drone's operations is more detailed in a dedicated section of this document.

Unauthorised UAS activities pose significant challenges, including hostile surveillance, smuggling, and other illicit operations, representing a potential threat. **C-UAS** (Counter UAS) refers to systems, technologies, and measures designed to detect, track, identify, and neutralise hostile, unauthorised, and 'non-cooperative' drones. C-UAS solutions are becoming essential to support LEAs in better protecting the integrity of the external borders, safeguarding the internal security and the public safety.

Effective C-UAS are essential for:

- Protecting the EU external borders, i.e., safeguarding the integrity of the EU external borders and of its infrastructure.
- Enhancing situational awareness, i.e., improving the ability of border authorities to detect, track, identify and eventually neutralise UAS-related threats promptly.
- Maintaining operational integrity, i.e., ensuring that border management operations are not compromised by unauthorised or hostile UAS activities.
- A comprehensive C-UAS system requires multiple integrated components that collectively establish a robust defence mechanism. These components function in unison to detect, track, identify, and mitigate threats posed by UAS.
- These solutions employ a variety of methods, including but not limited to electronic jamming, spoofing, directed energy, kinetic actions, and cyber-based neutralisation, to mitigate or neutralise threats posed by UAS. Under this initiative the focus is on neutralisation methods assessment relevant for EU border management authorities.

In this respect, C-UAS are being considered by Frontex to meet the requirements of command, control, communications, cryptography, intelligence, surveillance, targeting, target acquisition, and reconnaissance that enhance safety operations, enforcement and intelligence. In the frame of UCP 2025, Galileo EWSS was identified as a technology with potential added value for C-UAS operations, for early warning purposes, including support to deployed assets and the dissemination of information to the population in relevant operational scenarios. Warranting further technical and operational assessment, the recommendation resulting from UCP 2025 is to explore and to conduct a specific investigation.

During the UCP 2025's event, the participants discussed the opportunity linked to the use of Galileo EWSS in C-UAS operations. It was concluded that this opportunity could be pursued, in particular it was recommended to explore to the use/value/role of Galileo EWSS in C-UAS operations, in border management and law-enforcement operations, for swiftly transmitting alert messages to affected populations and to deployed assets, for early warnings, effective risk management and response.

2.4.10 Application GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade

Application description, user needs and requirements

Drug trafficking, also known as illegal drug trade or narcotrafficking, is a global illicit trade involving the cultivation, manufacture, distribution and sale of substances which are subject to drug prohibition laws. It is a global criminal enterprise involving complex networks that profit from widespread drug abuse. Activities related to trafficking are becoming concentrated in particular geographic areas. The situation is escalating, with an unprecedented increase in illicit drugs available in Europe, particularly cocaine from South America.

In general, ports are crucial for the transport of goods across the EU and criminals use a variety of methods to transport drugs via maritime shipping containers (source: Europol, the European Police Office). The strategic role of ports makes them vulnerable to drug smuggling and exploitation by high-risk criminal networks. Large quantities of cocaine are trafficked through Europe's seaports, which has led to unprecedented availability of cocaine in the EU and a growing consumer market.

Additionally, the trafficking in illicit goods spans a number of illegal practices including counterfeiting, piracy, falsification, adulteration of products, smuggling of genuine products, and tax evasion. Therefore, strengthening law enforcement operations in ports has a key role in drug trafficking, and the use of advanced technology is expected to have a great value. Major European harbours like Antwerpen and

Rotterdam are primary entry points for drug smuggling via containers. Moreover, there seems to be a prevalence of smuggling operations using boats, often yachts, originating from South America.

Intelligence and data exchange enabling advanced risk evaluation plays a key role in combatting these threats: suspicious vessels are identified thanks to intelligence information. Involved competent authorities (i.e., security forces, such as National Navy, Police and customs administrations, Border Authorities and Coast Guards, and government agencies such as Frontex, EMSA, European Union Drug Agency (EUDA) and Europol at EU level, INTERPOL and UNODC - United Nations Office on Drugs and Crime - at international level) trigger advanced risk analysis procedures. The main reference is the Entry Summary Declaration (ENS) providing cargo information before arrival in the EU. ENS plays a crucial role in international trade for the safety and compliance of transported goods. ENS is a mandatory customs declaration, which must be submitted before the arrival of goods on EU territory. The ENS's main function is to provide detailed information on the cargo, allowing authorities to assess any safety risks. It includes data about the shipper, recipient, cargo contents, and transportation details.

Risk analysis determines the necessity for checks in the case of suspicious vessels (for example, in the event of a vessel making an unplanned stop). A particular challenge is the use of "mother boats" that release smaller, unidentified "daughter-boats", i.e. vessels suspected of transporting drugs to a European country. Authorities feed the alert by transmitting information confirming the suspicion. The scenario makes it possible to verify the ability of each authority to monitor the navigation. Thanks to all these contributions, the competent authority can prepare the reception and inspection visit of the ship upon its arrival in the country.

International and European organisations are involved at global and European level, to cooperate with and help governments, national customs administrations, LEAs compliance officials to respond more effectively. Illegal trafficking can generate substantial illicit flows and proceeds, posing a significant threat to international security. International and European organisations explore the nature of the threat from global illicit flows, the harm they cause and how best to respond. These flows cross multiple jurisdictions worldwide, encompassing trafficking in drugs, weapons, humans and wildlife, as well as a range of lower-risk crimes such as illicit trade in counterfeit and other commodities, whose harm is more difficult to demonstrate. The flows generate substantial illicit financial movements, which undercut development, undermine national economies and fuel further insecurity.

Locating and monitoring suspected "vessels of interest" (VOI) combined with additional information (AIS positions and documentation, e.g. cargo manifest) sharing among the national competent authorities, facilitate decision-making and responsiveness. Data fusion and improved communication/data sharing and exchange between customs administrations and LEAs are fundamental. Satellite technology, through AIS, is already employed to track suspicious ship movements, such as when AIS signals are interrupted, or vessels remain stationary for extended periods.

Satellite-based tracking and tracing through GNSS devices is widely used in logistics and freight transport, often with commercial SATCOM (such as Iridium, Globalstar, and Eutelsat communications) to overcome the lack of terrestrial network coverage in open seas. Solutions for the remote monitoring, tracking and tracing of dangerous goods and waste luxury, and specific goods (such as "white industry", perishables and special foods) are used for commercial purposes. For example, to reduce insurance' premiums or provide added-value services to customers, such as the real-time localisation of the parcel/container/etc. However, the data remains property of the business stakeholders (e.g., the shipper companies)/economic operators (e.g., the owner of the goods), though they may be useful to governmental entities/LEAs.

Customs administrations have access to this information through specific agreements and Memorandum of Understanding (MoUs). Furthermore, the value of drones empowered by AI techniques and ML algorithms is particularly appreciable in maritime environments, as they allow for the autonomous detection of objects in the water and for keeping track of their changing position. Unmanned vehicles (aerial, sea surface, and submarine) are often used to enhance current maritime border surveillance operations for the detection of drug smugglers.

The transmission relies on information/data gathered from the GNSS device(s) combined with various sensors., in open environments, rural, and urban areas. Moreover, the information/data are transmitted through a communication mean, for the requirements related to Availability, Robustness, Integrity and reliability are referred to the integrated positioning and communication services, i.e., they depend on the GNSS related performances combined with the quality of the specific communication mean(s). According to the stakeholders involved in the consultation, the distinction between the requirements for the GNSS and the communication components does not make any sense, and the specified requirements are for the overall integrated positioning and communication services as needed to implement the specific application.

GNSS Requirements		
ID	EUSPA-GN-UR-EUBIS-0901	
Application	GNSS for prevention and suppression of international drug trafficking trade	
Accuracy	Horizontal	2 m
	Vertical	2 m
Availability	Urban canyon	No
	Natural canyon	Yes
	Canopy	Yes
	Indoor	Yes
	Better than 95%	High
	Better than 99%	Medium
Robustness		High
Integrity and reliability		High
Size, weight, autonomy[30]	Relevance	Yes
	Time a device can run	>12 months
TTFaF	In hot start	About 1 minute
Service area	Geographical coverage	National/Regional/European
Other		Requirements related to the combination of GNSS and communication. Moreover, Information from AIS positions, cargo documentation (ENS), data from customs administrations and LEAs, and intelligence contributions from EUDA, Europol, INTERPOL, UNODC, Frontex and EMSA

Table 13: Application GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade

Case Study/User Story

Case Study/User Story
The use of GNSS-based tracking and monitoring in maritime transport has proven essential in enhancing the detection and prevention of international drug trafficking along containerised cargo

[30] The time that a device can run on its internal battery

routes between South America and Europe. A vessel in route to a major European port (e.g., Rotterdam) is identified as a Vessel of Interest (VOI) through international intelligence cooperation. Continuous GNSS monitoring detects an anomalous route deviation, including an unplanned stop and temporary AIS signal loss, suggesting potential illicit activity.

The incident triggers an alert through a monitoring system that integrates GNSS data with other relevant information sources, such as AIS, cargo documentation, and satellite imagery, to support risk assessment. The integrated dataset allows the competent authorities (customs administrations, Coast Guards, Frontex and/or LEAs, depending on the organisation of each country) to conduct a comprehensive risk analysis and coordinate an inspection operation prior to the vessel's arrival.

The use of high-accuracy GNSS positioning ensures traceability of the vessel's movements, supports anomaly detection, and enhances the integrity and reliability of the information exchanged among stakeholders. This case shows how GNSS plays a key role in improving situational awareness, supporting coordination between agencies, and enabling timely responses in efforts to prevent and combat maritime drug trafficking. This application contributes to MDA and law enforcement actions, towards the suppression of illegal cross-borders trafficking of drugs and narcotics.

There are similarities with several other applications:
- GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods;
- GNSS 2 - GNSS for cargo security in ports and customs operations:
- EO 9 - EO data for the prevention and suppression of international drug trafficking trade;
- EO 7 - EO data for fighting against transnational firearms trafficking.

Identified novelties, gaps, opportunities, recommendations

Based on the inputs collected from the interviewees, main novelties, gaps, opportunities, and recommendations can be elaborated.

Novelties

Found novelties are similar to those highlighted for the GNSS applications listed above in the description of the Case Study/User Story. The common novelties are in the on-going regulatory framework towards digitalisation, also representing opportunities as explained below.

Gaps

Gap 1 There is a fragmented approach and lack of harmonisation among MSs, partly due to different national regulations and roles assigned to customs administrations. In some countries, Customs also act as regulatory authorities, while in other countries they also act as LEAs (performing law enforcement actions). This uneven landscape creates operational inconsistencies and challenges for effective coordination at the EU level. Sometimes, GNSS (from tracking and tracing devices and drones) are used in combination with EO technologies, which are especially valuable for large areas/land and marine borders in isolated and remote regions. Using high-resolution images from satellites, aerial photography, and drones, it is possible to analyse large sets of historical data and draw up measures to prevent violations, improve awareness across regions, and aid in the identification and prevention of cross-border threats such as drug trafficking or large-scale smuggling operations.

Gap 2 Limited integration and systematic use of GNSS (in combination with EO technologies) for preventive measures and situational awareness can hinder a suitable exploitation and adoption.

Opportunities

Opportunity 1 Advanced technologies, including satellite-based technologies, is part of the digital innovation being at the foundation of automating customs operations and leading to modern customs concepts. By embracing advanced technologies, regulators can ensure that processes are streamlined, security is enhanced, and the seamless flow of goods across borders is facilitated.

Digital transformation of customs operations consists of implementing electronic systems for customs declarations, risk assessment, and data exchange between traders and customs administrations. Its main objectives are:

- Trade facilitation focuses on reducing barriers and improving processes, helping governments to become more efficient and reducing costs. By simplifying procedures, governments can boost economic growth and encourage greater international collaboration.
- Effective customs processes are crucial for regulating and controlling the flow of goods across borders. Streamlining customs operations can significantly improve trade speed and transparency, benefitting both governments and businesses.
- Efficient logistics and shipment tracking systems are essential for monitoring the movement of goods. By leveraging real-time data, stakeholders can monitor cargo and swiftly respond to disruptions, enhancing the overall supply chain performance.
- Implementation of advanced risk management techniques by employing sophisticated risk assessment algorithms to identify high-risk shipments while facilitating the smooth flow of low-risk cargo. As a fact, managing risk and ensuring security is vital to protect supply chains from potential threats. Implementing risk management strategies and security protocols helps safeguard nations, ensuring that goods are transported safely and efficiently.

Risk management supports law enforcement operations. Therefore, the digital transformation of customs administrations is a key opportunity. Establishing an EU Customs Data Hub could address fragmented governance and improve risk management strategies.

Opportunity 2 Reliability and robustness are a must, and the information from satellite technologies can be used in combination for cross check the information from other sources. In the respect, the integration of satellite technology with complementary tools (OCR, RFID, IoT, AI - predictive analytics) play a fundamental role.

Opportunity 3 Automating customs operations through advanced technologies, including satellite-based tools, to streamline processes, enhance risk assessment procedures and security. Moreover, similarly to some of the applications, the adoption of multi-GNSS/Galileo OSNMA enabled solutions can result in a value added in terms of robustness and trust on the position and time information.

Recommendations

Recommendation 1 It is important to leverage the on-going regulatory framework towards digitalisation, including the eFTI mandatory implementation timeline[1], the establishment of the EU Customs Data Hub, and of the EU Customs Authority expected by 31 December 2032 [1], the Maritime Single Window[1] obligation, the CISE platform of EMSA[1], and the set-up of the new Customs Code (UCC) on which DG TAXUD is already working. The suggested path envisages the cooperation with the main entities at EU level, particularly DG TAXUD and DG MOVE, that are in charge of key regulations in EU, and between customs and port authorities as recommended by WCO and IAPH[31].

Recommendation 2 Taking advantage of the new UCC and the envisaged establishment of the EU Customs Data Hub is a common recommendation to some of the applications mentioned above. Synergies and commonalities among different applications should be pursued.

Recommendation 3 Facilitating satellite data access to customs administrations is a specific request directly coming from the interested interviewees. Customs administrations have access to satellite images through the relevant authority (e.g., Coast Guards), and the accessibility through third party can hinder the proper utilisation. Facilitating the access, may be useful for the customs administrations to better understand what can be done with what is available, and to identify a suitable trade-off between what would be desired (e.g., continuity, world-wide coverage, and sufficient resolution in terms of space and time) and feasible (mainly from an economic point of view).

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[31] International Associations of Ports and Harbors, https://www.iaphworldports.org

Recommendation 4 Promoting proof-of-concept development involving the testing and validation of emerging technologies, can encourage broader adoption, and can help in clearly understand the needs and further possible utilisations supporting informed decision making.

2.4.11 Application EO 1 - EO data for the safe and secure cross-border transport of dangerous goods

Application description, user needs and requirements

The application strengthens, EU border and land border surveillance by enhancing the safe and secure cross-border transport of Dangerous Goods (DG) across open, rural, and urban environments. It is intended for use by governmental authorities, including environmental and transport agencies, LEAs at local, national, and EU levels, as well as in maritime contexts in organisations such as EMSA.

The transport of DG is increasingly organised along intermodal routes using specialised tank containers that can be adapted to different transport modes. This model combines various types of vehicles along the supply chain to optimise energy consumption and reduce travel times. In this context, the application integrates EO data, GNSS data from onboard tracking devices, sensors monitoring the status of the goods, cameras supervising infrastructure, traffic flows, and, where relevant, imagery from drones.

By integrating traffic information on DG transport with geographical data derived from satellite images (such as natural parks, schools, and residential areas) and information on social events, and by applying dedicated algorithms, the system enables the optimisation of traffic flows and the identification of routes that minimise travel time while reducing risks to both the population and the environment. The solution also supports operational planning, such as assisting drivers in selecting safer and more secure rest areas, avoiding congested or high-risk locations.

Georeferenced EO data are further used to implement advanced risk assessment models associated with DG transport. In the event of an accident, precise knowledge of the DG position and load characteristics enables faster and more effective emergency response, investigation, evidence collection, disaster management, and recovery activities, including the assessment and remediation of environmental damage such as spillages or pollution.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-001
Application	EO data for the safe and secure cross-border transport of dangerous goods
Users	Governmental entities, LEAs, EMSA at EU level
End Users Application Needs	
Operational scenario	Open areas, rural areas, urban areas, maritime environments
Size of area of interest	Variable and context dependent can range from local routes (tens of kilometres to transnational corridors and extensive maritime zones
Frequency of information needed	Variable from pre-planned operations to continuous monitoring and emergency triggered data
Type of service (continuous, forecasting, one-off)	Planning, monitoring and emergency response services
Satellite EO Data Requirements	
Spatial resolution	Land transport/urban-rural monitoring: 1 to 10 m resolution Maritime/oil spill detection: 10-100 m resolution
Temporal resolution	Variable according to the case: daily to weekly (pre-planning), minutes to hours for transport monitoring, on-demand for emergency response
Spectral resolution	Specific multispectral bands (visible, shortwave infrared, for EO imagery supporting environmental and pollution monitoring)

Other requirements (if applicable)	Ability to integrate EO with drone imagery
Technology used	SAR imagery is primarily used because of images through clouds, darkness, smoke or other occlusions. Multi sensor, multi-platform approach combining EO satellites, GNSS tracking, sensors, cameras, etc.
Data supplements	Traffic, historical or environmental datasets

Table 14: Application EO 1 - EO data for the safe and secure cross-border transport of dangerous goods

Case Study/User Story

Case Study/User Story

As explained in section 2.3. Key Market Drivers, at EU level, three key laws regulate the international land transport of Dangerous Goods, namely: ADR[32] for road, RID[33] for rail, and ADN[34] for inland waterways.

UNECE is a fundamental player and regulator for these laws. Safety and security of operations are a concern common to involved industries and authorities in the transport of dangerous goods. In the case of cross-border shipments, it also involves protection and overseeing of EU borders.

The use of EO data in the case of the transport of dangerous goods is similar to the case of environmental monitoring and eco-crimes fighting. In Europe, remote sensing satellite imagery is widely adopted by LEAs, involved scientists, agencies, and organisations in several land and maritime contexts. Moreover, the INSPIRE Directive (Directive of the European Parliament and Council 2007/2/EC), entered into force in 2007, establishes an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. INSPIRE is based on the infrastructures for spatial information established and operated by the MSs of the European Union.

The added functionality of satellite images coupled with GIS maps is in covering vast or inaccessible regions. Advancements in sensor technologies and miniaturisation have expanded the capabilities of remote sensing and increased the availability of very-high-resolution images also not weather or daylight-dependent, through SAR, as well as thermal and spectral data.

In maritime scenarios, SAR images from polar orbiting satellites are largely adopted and are particularity suitable, as they can:

- Provide very wide area monitoring over remote sea areas (one image can cover up to 500 000 km^2)
- Be used day and night
- Detect oil spills on the sea surface
- Detect of strong radar reflectors such as vessels and offshore installations which are potential sources of oil spills.

Occasionally, very high-resolution optical satellite images may be used to monitor specific events on the request of coastal States, usually linked with support to large accidental spills and pollution response operations. In land scenarios, over smaller areas, aircrafts and drones complement satellite imagery providing remote sensing data in real-time, and with greater detail and precision. Equipped with specific sensors, drones analyse vegetation health, biodiversity, and habitat disruptions. They also monitor water bodies, identifying pollution sources, and changes in water quality, contributing to the overall health assessment of aquatic ecosystems, and ensuring a prompt response to possible threats.

[32] European Agreement concerning the International Carriage of Dangerous Goods by Road [RD12]

[33] Regulations concerning the International Carriage of Dangerous Goods by Rail [RD 13]

[34] European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways [RD 14]

There are synergies with the combination with GNSS tracking capabilities, as described in the application GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods. Competent national authorities often adopt a multi-layered approach, envisaging GNSS tracking information on top of satellite images, allowing to monitor in real-time the traffic of dangerous goods across their territory. Commonalities are with the application EO 6 - EO data for surveillance of waste disposal, for the cases of dangerous waste.

Identified novelties, gaps, opportunities, recommendations

Novelties

No major novelties were found from the inputs collected from the interviewees.

Gaps

Gap 1 As written above, remote sensing satellite imagery is widely adopted in several land and maritime contexts and situations by LEAs, involving scientists, agencies, and organisations. In general, the provided performances in terms of spatial and temporal resolutions are satisfactory for implementing the today's tasks. They overcome possible more stringent needs by integrating additional technologies:

- Combination with GNSS, for example EO is often used in combination with GNSS, especially for geolocating objects (such as land and maritime sensors).
- Integration with drones and buoys/sensors, as possible, though oil spill detection monitoring across the sea by satellite imagery enables a much larger area to be monitored, compared to surveillance by aircraft/drones, vessels, buoys/sensors.

Higher temporal and spatial resolution of the EO images is perceived as useful in specific cases, however there is a general concern raised especially by the involved scientists and agencies, about the relevant costs from commercial providers. In the majority of the cases, integrating other technologies, as discussed above, is essential to address a range of conditions.

Gap 2 The lack of a sufficient interoperability among existing legacy systems hinders and creates difficulties and risk for implementation. Close cooperation and the use of open software and standard protocols are strongly recommended.

Opportunities

Opportunity 1 The integration with other technologies and techniques, as detailed above, is considered important also for a wider adoption of satellite technologies, in order to:

- Enhance resilience and reliability (often GNSS is used to complement EO and vice versa)
- Fill the gaps (especially the temporal resolution of the EO images)
- Depending on the specific application and use case to cope with the specific needs.

Opportunity 2 Fostering the use of EO in environmental laws enforcement may be a key for a further exploitation also in the cross-border transport of dangerous goods (this is linked with the application EO 8 - EO data in environmental crime investigations). The use of satellite imagery in court cases to establish facts related to illegal activities and wrongdoing, that would otherwise be difficult to prove, is expected to positively lead to a wider utilisation.

Opportunity 3 The combination with advanced techniques, such as IoT principles, digital twin representations, AI, ML, and data analytics-based tools, enables to develop automation and deep interpretative understanding of the satellite images. This generates the ability to cope with a major number of specific contexts and situations, and therefore to possibly provide further opportunities for utilisation.

Opportunity 4 Monitoring the movements of dangerous goods through EO has a relevance also for the utilisation of advance telematics (ITS – Intelligent Transport Systems), for a higher efficiency and safety.

An opportunity is also given by the updated EU regulation on ITS (EU 2022/670 of 2 February 2022 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services).

Recommendations

Recommendation 1 The main recommendation is to pursue the potential of satellite images as proves in legal settings This is related with the application EO 8 - EO data in environmental crime investigations.

Recommendation 2 Research and development effort should be directed in the use of open software and standard protocols to overcome the challenges caused by the insufficient interoperability among existing legacy systems, implying developments risks and associated costs.

Recommendation 3 Linked with the previous recommendation, provide easier access to commercial services. Copernicus data are limited to 20 m resolution while the cost of commercial satellite imagery can be high for public entities that need to acquire specific images.

Recommendation 4 A wider exploitation of EO data can benefit from the synergy among different research efforts should be pursued, for example with the on-going initiatives dealing with the deployment of ITS, as explained above.

2.4.12 Application EO 2 - EO data to support port and cargo security

Application description, user needs and requirements

This application contributes, in ports areas and maritime environments, to EU sea border and maritime surveillance by enhancing port and cargo security through the use of EO data. It is designed for operations in port areas and maritime environments and targets governmental stakeholders primarily involved in port and Customs activities, including port authorities, customs authorities, LEAs, judicial authorities, and other competent bodies operating at national and EU level.

The application relies on satellite imagery, in particular very high-resolution SAR data, to enable continuous monitoring of port areas regardless of weather conditions, cloud cover, fog, or darkness. Awareness of activities in ports often located in remote or difficult-to-access areas and of vessels operating within and around them is critical for national security. Satellite imagery provides a non-intrusive and efficient means to observe large areas without the need for on-ground assets, addressing the challenges of limited accessibility from air or sea. EO data constitute a key component of MDA solutions used by competent LEAs and contribute to broader border surveillance covering both land and maritime domains.

Satellite data can be complemented by drone imagery when higher spatial resolution or more detailed, localised observations are required. The collected data are analysed using geospatial techniques supported by GIS to assess spatial relationships between geolocated objects and activities within ports. In addition, AI and ML algorithms are applied to satellite imagery to enable automated monitoring, detection of anomalies, and prediction of port and cargo-related activities.

The information generated by the application is shared with relevant stakeholders involved in port and cargo security, including port authorities, police forces, customs authorities, coast guards, municipalities, and transport operators. Given that cargo and port-related security incidents may have implications at national security level, the application supports an integrated, multi-stakeholder approach to ensure effective cooperation and information sharing. In particular, it enables the detection of intensified or unusual transportation of goods and equipment that may indicate emerging security threats.

EO data are processed and transmitted on a regular basis, with commercial satellite providers offering daily or even sub-daily imagery. When necessary, drone-based observations are used to support more timely and precise detection. The application delivers information that is difficult to obtain through conventional means, enabling the monitoring of cargo shipments and container activity zones, including the transport of bulk commodities, oil, and dangerous materials. The identification of changes and patterns that may signal security risks. Furthermore, the provision of actionable intelligence to support timely and effective responses to threats in port environments.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-002
Application	EO data to support port and cargo security
Users	Governmental entities (mainly port and customs authorities), judicial authorities, LEAs involved in port and customs operations
End Users Application Needs	
Operational scenario	Monitoring ports and maritime environments to support port security, cargo surveillance, and MDA
Size of area of interest	Port areas and surrounding maritime zones, often remote and inaccessible
Frequency of information needed	Daily or sub-daily, complemented with drone imagery when higher granularity is required
Type of service (continuous, forecasting, one-off)	Continuous monitoring, on-demand for specific events or incidents, forecasting of potential security threats based on observed patterns
Satellite EO Data Requirements	
Spatial resolution	Very high resolution (SAR images, <1m for modern SAR satellites, typically 1-3m to detect small vessels) suitable for detecting vessels, containers, and other port activities
Temporal resolution	Daily or sub-daily acquisitions; more frequent monitoring when needed
Spectral resolution	SAR-based (active radar), so not spectrally dependent; can be complemented by optical imagery if available
Other requirements (if applicable)	All-weather, day-and-night capability; non-intrusive observation without on-ground infrastructure
Technology used	Satellite EO (mainly very high-resolution SAR), drones for higher granularity; GIS for spatial analysis; AI and ML for automated monitoring and prediction
Data supplements	Drone imagery, port and cargo databases, intelligence from other stakeholders (Coast Guard, customs, police), GIS layers

Table 15: Application EO 2 - EO data to support port and cargo security

Case Study/User Story

Case Study/User Story

EU ports are one of the main European critical gates across the European territory. Ports are potential targets for crime because of their strategic role in international trade and logistics. The vast scale of containerised trade offers substantial concealment opportunities, thereby posing significant threats to the safety, security, and quality of life in port areas, as well as negative impacts on ports and their surroundings.

Ports are also vulnerable to cargo theft. Criminal networks often target high-value cargo such as electronics, luxury goods, pharmaceuticals, cars, and consumer products. Port operations can be affected by sabotage actions that disrupt logistics and cause economic harm. Overseeing port and cargo security is part of a more general MDA and border surveillance framework, including land and maritime borders.

Borders surveillance

EO data on the EU's external land and sea borders, combined with in-situ geospatial data, allow national and EU LEAs to achieve an enhanced situational awareness. Through Geospatial Intelligence (GEOINT) and Imagery Intelligence (IMINT) tools, GNSS precise and reliable in-situ information strengthens the resilience in situational awareness, enables a prompt detection of suspicious activities, and ensures effective responsiveness and reduced intervention times.

A wide range of in-situ information elements is utilised, depending on the considered type of border (land, sea, coastal) and the area to be covered. In-situ data include also images from airborne assets (aircrafts and drones), complementing the satellite images, especially for specific targets and zones. In maritime environments, in-situ data comprise the information coming from IoUT network of underwater multi-sensor objects. Satellite images with in-situ geospatial data, reference, and auxiliary data are essential for borders surveillance functions (e.g. measurements, mapping, monitoring, risk assessments functions and statistical evaluations for field operations).

Land border surveillance

EO images are used in combination with intrusion monitoring and detection systems, different types of sensors and cameras. GNSS allows for geo-locating the target, for the visualisation on digital maps of suspicious activities and for facilitating law enforcement operations in the field. The data collected from the several technology components of the surveillance system and from the sensors are processed and used in conjuncture with the satellite imagery (overlayed on the top of satellite imagery), to produce multilayered maps of a surveyed area that can be visually assessed by the LEAs. Geo-located information from the sensors and cameras can be aggregated into georeferenced maps. Satellite communication is also used for the real-time transmission of data from the sensors, providing coverage to remote and hard-to-access areas (e.g., in areas without reliable terrestrial connections), without the need for terrestrial infrastructure.

Sea border surveillance and IoUT

In sea border surveillance, GNSS technology on top of EO data, provides the position of in-situ data from several sources, such as:

- Active and passive sensors (radar, electro-optical) mounted on seaborne (patrol boats) and airborne assets
- Coastal surveillance stations (also providing wind, wave and atmospheric parameters)
- Buoy offshore platforms
- Harbour infrastructure (berthing structure, breakwater)
- Hydrology along the coastline (shoreline, river)
- Bathymetry and punctual depth measures and meteorological/oceanographic data (wind, sea wave height, current, temperature and salinity)
- IoUT networks, composed by heterogenous sensors, also equipped with cameras and acoustic modems for shallow and deep waters.

In-situ data collected through IoUT networks rely on the usage of GNSS to locate the sensors and the nodes. Acquired data are sent through terrestrial networks or SATCOM in the case of remote areas, for integration with EO images.

This application has to be seen in complementarity with other applications dealing with MDA and border surveillance, in particular in combinations with other applications, namely:

- GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
- GNSS 3 - GNSS for ports security operations and virtual security gates
- GNSS 2 - GNSS for cargo security in ports and customs operations
- GNSS 4 - GNSS data for locating cultural heritage looting
- GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
- GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
- EO 1 - EO data for the safe and secure cross-border transport of dangerous goods
- EO 3 - EO data for preventing and suppressing cultural heritage looting and illegal trafficking
- EO 6 - EO data for surveillance of waste disposal
- EO 7 - EO data for fighting against transnational firearms trafficking
- EO 9 - EO data for the prevention and suppression of international drug trafficking trade

Identified novelties, gaps, opportunities, recommendations

Key novelties, gaps, opportunities, and recommendations can be outlined, on the basis of feedback gathered from the interviewees.

Novelties

Novelty 1 EO data for port and cargo security are increasingly used within integrated, multi-layered surveillance frameworks covering both land and maritime domains.

Novelty 2 EO data are tightly integrated with GNSS, enabling enhanced situational awareness and positioning capabilities.

Novelty 3 Port and cargo security applications are not standalone but embedded in broader surveillance ecosystems.

Gaps

Gap 1 Due to the strong integration of EO with GNSS and other surveillance layers, it is difficult to isolate specific requirements for EO data alone.

Gap 2 The complexity of multi-domain surveillance systems limits the identification of application-specific performance needs.

Opportunities

Opportunity 1 There is potential to exploit synergies and commonalities across different EO-based applications.

Opportunity 2 Shared technological components and data infrastructures can support multiple security use cases simultaneously.

Opportunity 3 Cross-application alignment may reduce duplication of effort and improve system efficiency.

Recommendations

Recommendation 1 Prioritise ready-to-use, cost-effective, and easy-to-integrate technologies and solutions.

Recommendation 2 Promote solutions that are interoperable across land and maritime surveillance domains.

Recommendation 3 Encourage approaches that build on common architectures and shared capabilities across applications.

2.4.13 Application EO 3 - EO data for preventing and suppressing cultural heritage looting and illegal trafficking

Application description, user needs and requirements

As explained above in the section Market Overview and Trends, EO 3 was analysed during UCP 2023. In the frame of UCP 2025, the relevant requirements were confirmed during the new assessment for UCP 2025. The reason for considering EO 3 also in UCP 2025 is linked to new needs raised for this application with respect to UCP 2023, which are cumulatively reported in this document.

This application enhances EU border and customs operations by contributing to the prevention, detection, and suppression of illegal cross-border trafficking and smuggling of cultural heritage. It addresses the growing threat of looting and illicit trade of cultural goods, including antiquities and artworks, which often occurs in remote areas, conflict zones, and regions affected by natural disasters, and exploits maritime and port environments as key transit points.

The application leverages EO data to monitor cultural heritage sites and assess damage caused by looting, environmental degradation, armed conflict, or natural hazards, particularly in areas that are difficult or impossible to access on the ground. EO data provide a non-intrusive means to observe large and remote territories and to detect physical changes at heritage sites. When combined with frequent acquisitions, EO observations can potentially identify the presence of vehicles, vessels, or other indicators of looting activities in exposed areas.

A core innovation of the application is the integration of EO data with AI tools to enable automated surveillance, change detection, and early warning. AI-based algorithms analyse large volumes of satellite imagery to detect unusual patterns, site alterations, or the appearance of vehicles in protected or high-risk areas, generating alerts and risk scores for further investigation. This capability is particularly relevant for maritime and port environments, where EO and AI-enabled monitoring can enhance the detection of illicit trafficking routes and suspicious cargo movements, recognising that maritime transport remains one of the most vulnerable modes for cultural property smuggling.

The application combines EO data with complementary technologies, including multispectral imagery to identify subtle surface changes, high spatial resolution imagery (ideally down to 30 cm) to detect small-scale disturbances, and, where available, LiDAR, 3D data, drone imagery, and positioning information to enrich situational awareness. GIS are used to integrate spatial data layers and contextual information, supporting advanced analysis and visualisation.

The system is designed for use by national, European, and international LEAs, customs authorities, central LEA services, and specialised organisations involved in the protection of cultural heritage, including UNESCO, WCO, and academic and research institutions. It operates as a multidisciplinary platform bringing together enforcement personnel, data analysts, archaeologists, and subject-matter experts to support coordinated decision-making.

Data processing and analysis are performed on a frequent basis ranging from daily to weekly depending on risk levels and operational needs. While current limitations in real-time EO acquisition remain a challenge, the application aims to maximise the use of near-real-time data and automated processing to deliver timely alerts, contextual information on looted objects, and actionable intelligence. This supports early intervention, prioritisation of inspections, investigation activities, and the provision of contextual evidence to help trace and recover trafficked cultural goods across borders.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-003 PITCH project[35]
Application	EO data for preventing and suppressing cultural heritage looting and illegal trafficking
Users	WCO and UNESCO, LEAs and academics
End Users Application Needs	
Operational scenario	Ports and open sea, throughout the shipment/journey
Size of area of interest	Local/Regional/Worldwide
Frequency of information needed	Every hour
Type of service (continuous, forecasting, one-off)	Availability of the service to the involved authorities throughout the shipment

[35] Prevention of Illicit Trafficking of Cultural Heritage, https://www.wcoomd.org/en/topics/enforcement-and-compliance/activities-and-programmes/cultural-heritage-programme.aspx

EO Requirements	
Satellite EO Data Requirements	
Spatial resolution	ANCHISE project[36] 50 cm to 15 m (images from satellites)/5 cm to 5 mm (images from drones)
Temporal resolution	Prevention and suppression of illegal cross-borders trafficking and smuggling of cultural heritage Variable, depending on the coverage/source. 1 to 16 days
Spectral resolution	Optical, synthetical (SAR) (images from satellites)/spatial, volumetric (images from drones) LEAs and Academics
Other requirements (if applicable)	eds Not applicable Sites protection and data processing alert system
Technology used	SAR technology Local/Regional (Mediterranean area)
Data supplements information needed	NASA and ESA[37] open data + proprietary imagery (Airbus, Maxar, Planet) Every day
Type of service (continuous, forecasting, one-off)	Utilising photogrammetric scanning technology for the comprehensive examination of archaeological sites

Table 16: Application EO 3 - EO data for preventing and suppressing cultural heritage looting and illegal trafficking (PITCH and ANCHISE projects)

Case Study/User Story

Case Study/User Story

Several suitable use cases are identified, linked to three relevant projects PITCH, ANCHISE, and AURORA. Already considered in UCP 2023, PITCH is a joint WCO and UNESCO initiative established in 2018, to set-up of a tool, utilising images from Copernicus combined with the information of the vessel's Cargo Manifest, to carry-out border management of sensitive areas (with historical and cultural sites) and continuous monitoring of relevant container flow in order to:

- Effectively and promptly detect crimes due to the illicit withdrawal and transfer of cultural assets
- Intercept the illegal cargo during the shipment
- Prevent possible events, by reinforcing the intelligence functions within specific territories, thanks to crime mapping and risk assessment for decision-making processes.

The Cargo Manifest details the information on the transported goods. Maritime traffic monitoring is supported by mandatory reporting systems, namely AIS, LRIT, and VMS. For these systems, GNSS is the source of position and time information. EO images (e.g., from the Copernicus Maritime Service) are used to detect inconsistencies or suspect behaviour of the tracked vessels.

However, in this context, the present use of geospatial information and space related services is limited and in the form of pilot projects, if compared with the potential that they can have to launch a wide use of operational techniques oriented to customs authorities and police officers in the domain of enforcement for the safeguard of cultural heritage. Furthermore, the lack of the necessary awareness among customs administrations and involved authorities regarding the potential of geospatial data and the restricted use of Copernicus data (only to EU MSs) is seen as a barrier.

Innovative remote-sensing technologies are transforming how looted heritage sites are monitored. Merging satellite imagery, photogrammetry, and computational analysis allow to detect and document looting events without on-site intervention. EO becomes an independent, scalable source of situational awareness and corroborating evidence that complements on-the-ground intelligence, GNSS telemetry, and forensics (e.g., chemical markers, deep scans). For customs and border authorities, EO can detect suspicious movements or transshipment events, EO can monitor vulnerable sites and

[36] https://www.anchise.eu

[37] https://www.esa.int

storage/port areas, EO allows validate chain-of-custody claims, and create court-admissible evidence bundles that accelerate interdiction and prosecution.

EO presents notable potential for documenting crimes like looting of cultural heritage. On-going projects like ANCHISE and recent project like the EU AURORA project38 represent forward-looking initiatives, addressing a critical gap in cultural heritage protection: the need for non-invasive, cost-effective, digitally-enabled tracking and authenticity tools for artefacts. With their multidisciplinary approach and real-world orientation, they hold strong promise for transforming how cultural assets are managed, secured and valued.

Identified novelties, gaps, opportunities, recommendations

As explained above, EO 3 was analysed during UCP 2023, and the relevant requirements confirmed. With respect to UCP 2023, new needs raised for this application, is linked to new needs raised for this application with respect to UCP 2023. The new needs are mainly generated by the increased and widespread utilisation of innovative technologies, especially AI which can support automation in the analysis of the huge amount of data available. Moreover, there is an increased need for more connection to central database and better temporal resolution above endangered archaeological zones:

- Depending on the specific case, EO data characteristics optical (0.3–10 m) and radar (1–3 m), multispectral, weekly–monthly revisit may be required
- Global QGIS database to visualize data for potential looted typologies and group of objects per looted areas
- Geo-chrono dynamics maps using operational AI tool for combatting illicit trafficking, linking sites and alert list of objects with expert knowledge and updated context
- Interconnection of people and technologies
- Centralised and permanent platform (allow getting access to historical data)
- Lack of sub-meter optical imagery within Copernicus missions
- Low revisit frequency for targeted small Areas of Interest (AOI)
- Limited rapid tasking capability for emergency monitoring (e.g. looting, flooding, fires).

Finally, as part of the UCP 2025 consultation, a lack of insufficient awareness and training among law enforcement agencies regarding EO's forensic capabilities, especially in cultural heritage crime prevention (e.g., looting) were identified. Utilisations of EO for the prevention and suppression of trafficking and smuggling of cultural heritage are limited to a few best practices and pilots. The interviewees highlighted the following main aspects in terms of gaps, opportunities, and recommendations. No major novelties were identified.

Novelties

No novelties of relevance were found from the inputs collected from the interviewees.

Gaps

Gap 1 The main difficulty with EO-based technologies aimed at preventing or punishing looting activities is that there is no significant commercial market for such products. Pilot projects are not operationally ready and usually abandoned after completion.

Gap 3 Moreover, the organisation of law enforcement varies across countries, shaped by historical, legal, and cultural factors—for instance, some nations maintain both civilian police and militarised gendarmerie forces, while others rely solely on unified civilian police. Indeed, historically, legal, and cultural factors shape how each country's authorities maintain order. For example, some nations (such as France and

[38] https://www.aurora-euproject.eu

Italy) have dual police systems that include civilian police alongside militarised gendarmerie forces, whereas others (like Poland and Slovakia) rely on unified civilian forces. Federal states like Germany decentralize policing to regions, while more centralised states like Bulgaria or France concentrate authority nationally affecting how policies and innovations are implemented.

Funding levels and equipment can vary widely: wealthier members in Western Europe tend to invest more in advanced technology and personnel, whereas smaller or newer members often face budget constraints and rely on EU funds to modernize. Public order strategies also differ. For instance, methods of crowd control can range from robust riot police deployments with water cannon (commonly seen in France or Germany) to a stronger emphasis on community policing and negotiation (practiced in some Northern European countries).

All states share the goal of ensuring public safety, but the balance between security measures and civil liberties (like privacy or freedom of assembly) can lead to different policy choices, as later sections will explore. The Italian Carabinieri and the French Cultural Property Unit OCBC (Office Central de lutte contre le traffic de Biens Culturels) may be exceptions. A dedicated unit, Carabinieri Tutela Patrimonio Culturale (in English "Protection of Cultural Heritage"), the DNRED (La Direction Nationale du Renseignement et des Enquêtes Douanières), and the OCBC are specialised in the protection of cultural heritage and arts and involved in several research initiatives exploiting remote sensing for the identification of looting activities.[39]

To demonstrate the value of such applications to police forces, they should be offered ready-to-use solutions tailored to their specific needs and areas of interest, and with transparent associated costs and compatibility with their certified tools, allowing seamless integration into official IT systems. Europol, which has a group dedicated to illicit trafficking of cultural heritage, could have a role in sensitising national police forces on the usefulness of space-based products or it could directly transfer space-based analyses and intelligence to them.

<u>Gap 4</u> Insufficient awareness and training among law enforcement agencies regarding EO's forensic capabilities, especially in cultural heritage crime prevention (e.g., looting). Utilisations of EO for the prevention and suppression of trafficking and smuggling of cultural heritage are limited to a few best practices and pilots. Moreover, in forensics, GNSS data are frequently used to trace suspects' movements. EO presents notable potential for documenting crimes like illegal deforestation or looting of cultural heritage, but it faces significant legal hurdles related to evidentiary admissibility. Furthermore, governments are overall not yet aware of the potential of space data for the purposes of forensics.

<u>Opportunities</u>

<u>Opportunity 1</u> The extension to forensics, i.e. to the possibility not only to recover and investigate, but also to provide evidence in a way that maintains its integrity and admissibility in court, may give an impulse to the use of satellite imaging for Customs Operations/safeguard of cultural heritage.

<u>Opportunity 2</u> The synergy with the use of GNSS as described in application GNSS 4 - GNSS data for locating cultural heritage looting.

<u>Recommendations</u>

Recommendation 1 Development of proof-of-concept and pilot projects in real-life operational conditions, through EU research and innovation dedicated funds. These initiatives shall:

- Foster collaborative initiatives among archaeologists and specialists/practitioners, space experts and law enforcement agencies
- Establish working groups to share experience and know-how (for example from more mature practitioners, e.g., Carabinieri Tutela Patrimonio Culturale in Itay, the DNRED and OCBC in France)
- Launch case studies to raise attention and mobilise resources and effort.

[39] An example is ALCEO. Centre for Cultural Heritage Technology (CCHT) or ANCHISE (Monitoring Toolbox)

Recommendation 2 To implement a specific awareness and promotion campaign, aimed to:

- Include training on AI models to detect looting activities using satellite imagery
- Inform the general public and potential looters that satellites are used to observe looting activities "from the sky"
- Create clusters and synergies with existing EU and national initiatives.

Recommendation 3 Be clustered and conducted in synergy with existing initiatives and Task Forces, already involving key experts especially at EU level (such as PROCULTHER-NET 2[40]). An optimal and suitable approach can be to establish study cases, putting together the experience of big players (such as the French ICONEM[41] that cooperates with PLANET one of the largest commercial image providers), EU-funded projects (such as ANCHISE and ENIGMA[42]) and existing use cases.

Recommendation 4 Synergy with the combination with GNSS as envisaged in application GNSS 4-GNSS data for locating cultural heritage looting should be encouraged.

2.4.14 Application EO 4 - EO data in damage and conflict zone mapping

Application description, user needs and requirements

This application focuses on utilising EO data for mapping and quantifying physical damage in conflict zones. This application is crucial for governments, NGOs, public agencies, multilateral organisations (organisations including the United Nations and the World Bank), and legal experts involved in humanitarian monitoring and response in areas affected by conflict. The use of EO enables the mapping and quantification of physical damage to buildings, infrastructure, and terrain in conflict-affected areas, supporting humanitarian and operational monitoring. The approach has been applied in several conflict zones, including Gaza, Sudan, Lebanon, and other countries.

The application applies in open environments. It employs a variety of space-based data sources, including Sentinel satellites (1, 2, 3, 5), EUMETSAT data, and the Copernicus Climate Change Service (C3S), along with commercial VHR[43] imagery from providers like ESRI[44] and Google Earth, Data Space Ecosystem catalogues and affordable or free very high-resolution commercial imagery. Space-based data are complemented by non-space data gathered through in-situ sampling via drones, OSINT, and ground validation efforts.

Data are processed using advanced geospatial and statistical tools and platforms, including cloud-based environments, change detection and pattern recognition algorithms, and techniques such as coherent change detection, which significantly improves damage detection accuracy. Data processing and analysis are conducted using programming languages and tools such as MATLAB, Python, R, QGIS, and Google Earth Engine. The application utilizes both in-house and off-the-shelf change detection and pattern detection algorithms, including coherent change detection techniques that enhance accuracy significantly compared to traditional methods. Cloud-based processing platforms facilitate efficient data analysis, while statistical analysis and data visualization are derived from structured interviews with stakeholders.

The processed data is transmitted to humanitarian organisations, government decision-makers, analysts, and legal experts engaged in conflict response. It supports various functions, including damage assessment, infrastructure status monitoring, humanitarian needs assessment, operational decision-making, and providing legal evidence in conflict zones.

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[40] Source: https://civil-protection-knowledge-network.europa.eu/projects/proculther-net-2
[41] Source: https://iconem.com
[42] Source: https://eu-enigma.eu
[43] Very High Resolution
[44] https://www.esri.com

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-004
Application	EO data in damage and conflict zone mapping
Users	Governments, Non-Governmental Organisation (NGOs) (e.g., CEOBS, HOTOSM), public agencies (e.g., EU SatCen), multilateral organisations (e.g., UN, World Bank), lawyers involved in conflict monitoring and response
End Users Application Needs	
Operational scenario	Open environments
Size of area of interest	From the state of building damages to larger scope like neighbourhoods or even entire cities
Frequency of information needed	Weekly to yearly
Type of service (continuous, forecasting, one-off?)	Continuous
Satellite EO Data Requirements	
Spatial resolution	30-50 cm
Temporal resolution	Weekly for high-end, yearly for low-end
Spectral resolution	Hyperspectral
Other requirements (if applicable)	Not applicable
Technology used	EO as well as in-situ sampling through drones and ground validation or OSINT
Data supplements	Not applicable

Table 17: Application EO 4 - EO data in damage and conflict zone mapping

Case Study/User Story

Case Study/User Story
In Ukraine, satellite EO was used to monitor infrastructure damage, land-use changes, and looting in conflict zones such as Donetsk and Kherson. Data from optical and radar satellites, combined with OSINT and field validation, supported humanitarian agencies, governments, and NGOs in damage assessment, land-rights protection, and operational decision-making. Forensics architecture (https://forensic-architecture.org) is a very interesting case study to be taken into account.

Identified novelties, gaps, opportunities, recommendations

The outcomes resulted from the survey conducted are detailed here below.

Novelties

No important novelties of relevance were identified.

Gaps

Many civil society organisations operate with extremely limited resources while attempting to assess conflict damage and humanitarian needs using EO data. Although the Sentinel missions provide valuable and accessible capabilities, there remains a significant unmet need for timely, high-quality, and affordable VHR imagery.

Gap 1 Data availability and affordability: Access to VHR and HR optical imagery remains limited due to high commercial costs and restricted availability in sensitive regions. While they previously used Maxar, policy changes restricted NGO access.

Gap 2 Processing capacity: Many organisations face technical and financial constraints in processing large EO datasets, highlighting the need for scalable cloud-computing solutions beyond existing platforms such as Google Earth Engine and ESRI.

Gap 3 Skills and capacity building: There are persistent gaps in EO data analysis and interpretation skills among user organisations, underscoring the importance of training and technical support.

Gap 4 Policy and access barriers: Governmental restrictions and data access limitations (generally linked to security and confidential related reason) continue to impede the acquisition of comprehensive EO data in conflict zones.

Gap 5 Response capacity: Civil society actors have limited ability to conduct rapid assessments following emergency incidents due to access and resource constraints.

Gap 6 Spectral and temporal limitations: Sentinel-2's spectral resolution and revisit frequency are often insufficient for detailed damage assessments, while Sentinel-3's spatial coverage is too coarse for localised analysis.

Opportunities

Opportunity 1 Generative AI as disinformation could become a problem in the future. EO with a clear chain of custody can push back against this.

Recommendations

Recommendation 1 Enhanced Spectral and Temporal Coverage: Improve spectral resolution beyond what Sentinel-2 currently provides and increase revisit frequency to enable more timely and detailed monitoring.

Recommendation 2 Generative AI and Data Integrity: Use EO data with a clear chain of custody to counter disinformation generated by AI. The sector is generally behind in AI adoption, not only due to technical constraints but also because of reproducibility requirements and the need for data credibility in legal or operational contexts.

Recommendation 3 Training and capacity building:

- Develop in-house EO expertise to accurately interpret and operationalize EO data, particularly when processed with AI-led algorithms, ensuring users understand both the capabilities and limitations of the data.
- Provide targeted courses for mid-career professionals without prior EO experience. These programs should be institutionally supported by academia, government bodies, or organisations such as Copernicus, ESA, or EUSPA and designed to strengthen practical EO skills within participating organisations.

2.4.15 Application EO 5 - EO data for monitoring illegal fishing

Application description, user needs and requirements

This application contributes to EU sea border and maritime surveillance by strengthening the monitoring, detection, and prevention of illegal, unreported, and unregulated (IUU) fishing activities in open sea environments. It is designed to assist governmental entities and LEAs operating at local, national, EU, and international levels, including environmental and transport authorities, fisheries control bodies, and maritime safety organisations. Key stakeholders include the European Fisheries Control Agency (EFCA), the EMSA, UNESCO, and relevant NGOs involved in maritime governance and environmental protection.

The application relies on MDA solutions that integrate multiple space-based and non-space data sources. Satellite imagery particularly SAR plays a central role, as it enables the detection of vessels regardless of weather conditions, cloud cover, or daylight. This capability is essential for monitoring vast and remote maritime areas where traditional surveillance assets are limited. SAR imagery is complemented by optical EO data to enhance vessel characterisation and activity assessment.

In addition to EO data, the application integrates GNSS-based AIS signals and Radio Frequency (RF)-derived vessel detection data to identify and track maritime traffic. These datasets are further complemented, where relevant, by aerial imagery, photogrammetry, and drone-based observations. The fusion of these heterogeneous data sources provides continuous and reliable coverage of maritime areas and enables cross-verification of vessel behaviour.

AI and advanced analytics are applied to the combined datasets to detect anomalies, identify suspicious behaviours, and track illegal fishing patterns over time. By correlating vessel detections from SAR imagery with AIS and RF signals, the application can highlight dark vessels, identify inconsistencies in declared activities, and support risk-based targeting of inspections and enforcement actions.

The information generated by the application is transmitted to relevant authorities to support operational decision-making, enforcement, and policy implementation. By providing a comprehensive and timely picture of fishing activities, the application enhances situational awareness, supports coordinated responses among maritime stakeholders, and contributes to the protection of marine resources, the enforcement of fisheries regulations, and the security of EU and international sea borders.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-005
Application	EO data for monitoring illegal fishing
Users	Governmental entities (environmental and transport agencies), LEAs, EFCA, EMSA, UNESCO, and NGOs involved in maritime protection and resource management
End Users Application Needs	
Operational scenario	Open sea and coastal waters, focusing on detection of illegal, unreported, and unregulated (IUU) fishing activities.
Size of area of interest	Very large covering extensive maritime zones, including exclusive economic zones (EEZs) and high seas regions
Frequency of information needed	Near-real-time to daily monitoring, depending on vessel activity and risk levels
Type of service (continuous, forecasting, one-off?)	Continuous operational monitoring with event-based alerting; complemented by periodic reporting and analysis
Satellite EO Data Requirements	
Spatial resolution	Medium to high (3–30 m): sufficient to detect and classify vessels of various size From typical SAR missions (for example Sentinel-1, RADARSAT)
Temporal resolution	Daily to sub-daily (at time step during the day) to ensure timely vessel detection and tracking
Spectral resolution	Primarily SAR
Other requirements (if applicable)	All-weather, day-and-night capability; wide swath coverage; near-real-time data delivery; integration with AIS and RF detection data
Technology used	SAR and optical EO satellites, GNSS-based AIS tracking, RF-derived vessel detection, drones, and AI-powered data analytics for anomaly detection and pattern recognition

Data supplements	AIS signals, RF data, aerial imagery, drone observations, and other in situ data sources for validation and correlation

Table 18: Application EO 5 - EO data for monitoring illegal fishing

Case Study/User Story

Case Study/User Story
Some ships go "dark," turning off their transponders so they do not broadcast their coordinates. Others use readily available technology to spoof AIS signals, transmitting false information to deceive public maritime surveillance systems. These "dark vessels" are often associated with illicit operations, notably IUU fishing. RF tracking can help track dark ships that have deactivated their AIS, but this technology also has limitations. Dense urban coastlines, mountainous terrain, or electromagnetic interference can obstruct the radar, communications, and navigation signals upon which RF tracking relies. It can also be hard to pick apart overlapping RF signals from multiple vessels. When AIS and RF data are not capable to detect dark vessels, HF satellite imagery is a highly-effective way to detect and track vessels especially in vast or remote maritime areas. Methods like aerial photography or photogrammetry, drones, and VHR imagery also provide visual content. Still, across wide regions, the data from these sources tend to be incomplete, also because of airspace restrictions, and AOI limitations. Satellite data, including optical and SAR imagery in conjunction with AIS information and AI are a very powerful source of information for enhanced marine surveillance capabilities, enabling to reveal improper behaviours.

Identified novelties, gaps, opportunities, recommendations

The following considerations can be drafted from the survey conducted.

Novelties

No key novelties of relevance were found from the inputs collected from the interviewees.

Gaps

No major gaps were found.

Opportunities

Opportunity 1 The advanced in technologies and techniques, especially in AI and & ML can enhance satellite imagery analysis by automating data processing tasks and identifying complex patterns in vast datasets more efficiently than ever before.

Opportunity 2 Similarity to application EO 8 - EO data in environmental crime investigations, fostering the use of EO in environmental laws enforcement may be a key for a further exploitation also in monitoring deforestation. The use of satellite imagery in court cases to establish facts related to illicit actions and incorrect behaviours, that would otherwise be difficult to prove, is expected to positively lead to a wider utilisation.

Recommendations

Recommendation 1 The main recommendation is to pursue the potential link to satellite images as pieces of evidence in legal settings (this is linked with EO 8 - EO data in environmental crime investigations), by:

- Increasing awareness among legal professionals about the capabilities of remote sensing technology
- Incentivising cooperation between different and complementary competences.

This may be done by means of focused research and development efforts. Satellite images are already largely used in MDA enabling coverage or reliability in vast or remote maritime areas, also to provide capabilities for fighting against IUU fishing. The possible admissibility of satellite images in legal settings as proof of crimes (for persecuting criminals in court) can generate a snowball effect towards a wider exploitation.

2.4.16 Application EO 6 - EO data for surveillance of waste disposal

Application description, user needs and requirements

This application enhances internal security and law enforcement efforts in the fight against environmental crimes, including illegal waste disposal, illegal logging, mining, and poaching across open, rural, and urban environments. The application is intended for governmental entities and LEAs at local, national, EU, and international levels. Practitioners such as scientists, researchers, and archaeologists may also support operational and investigative activities.

The application leverages remote sensing satellite technology as a cost-effective solution to detect, monitor, and assess the evolution of illegal waste disposal sites over time. Modern EO satellites equipped with high-resolution sensors provide broad coverage, repeated acquisitions, and sub-meter resolution imagery, enabling the monitoring of large regions and fine-scale changes. Multi-temporal analyses allow law enforcement and environmental authorities to track the evolution of sites, detect new illegal activities, and evaluate environmental impact.

For this application, data sources integration is key. For example, satellite sensors like multispectral, thermal infrared, and SAR allow providing complementary views of landfills and surrounding areas; Drones and aerial imagery are used for high-resolution local monitoring. Atmospheric and hyperspectral sensors allow for the detection of gas emissions (e.g., methane) and assessment of environmental impact. Data fusion is of high value for integrating multiple sensor types and temporal acquisitions improves sensitivity to changes in spatial geometry and surface characteristics.

AI and computer vision are applied to satellite and drone imagery for automated detection, visual interpretation, and change monitoring. GIS integrate satellite, drone, and historical data to provide a comprehensive situational picture, support risk assessment, and guide enforcement actions. Multi-temporal and multi-sensor approaches enhance detection accuracy, monitor landfill evolution, and quantify environmental impacts over time. In addition, continuous monitoring of illegal waste sites to support risk management, prevention, and law enforcement actions have been highlighted.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-006
Application	EO data for surveillance of illegal waste disposal sites, landfills and dumps
Users	Governmental entities and LEAs, environmental protection authorities, waste management regulators, scientists and researchers.
End Users Application Needs	
Operational scenario	Open environments, rural and urban areas. Applicable for both large-scale landfills and small, scattered illegal dumpsites
Size of area of interest	Variable from localised landfill sites (a few hectares) to regional or national scales. Repeated acquisitions enable monitoring of entire sites and comparative assessments across time
Frequency of information needed	Daily or repeated acquisitions over time. Multi-temporal monitoring to follow the evolution of landfills through modern constellations (e.g. Sentinel-2, Worldview, Pleiades Neo)
Type of service (continuous, forecasting, one-off?)	Continuous through regular satellite passes and drone images Historical trend analysis Not strictly forecasting, but time-series analysis supports predictive insights
Satellite EO Data Requirements	

Spatial resolution	Sub-meter resolution for detecting small illegal dumps and differentiating waste materials. Fine resolution needed to detect small changes in landfill sites. Medium-resolution sensors (10-30m) sufficient for large landfill monitoring (e.g. Sentinel-2, Landsat 8/9)
Temporal resolution	Daily acquisitions feasible due to modern satellite revisit times: frequent revisits (1-5 days) from Sentinel-1/2, SPOT6/7, WordlView-3, Pleiades Neo Multi-temporal methods to monitor site evolution
Spectral resolution	Multispectral bands: visible, near-infrared, thermal-infrared. Radar (SAR: Sentinel-1, COSMO-SkyMed) for structural deformation and moisture monitoring
Other requirements (if applicable)	Detection of gas emissions (e.g. CH_4, CO_2) via atmospheric sounders (IASI) Support for law enforcement and environmental decision-making
Technology used	SAR, drones, data fusion, GIS for data integration and analysis
Data supplements	Drone imagery, atmospheric sensors for gas detection, GIS datasets (land use, population density)

Table 19: Application EO 6 - EO data for surveillance of waste disposal

Case Study/User Story

Case Study/User Story

Waste crime involves illegal activities related to the disposal, treatment, recycling and overall management. This includes unauthorised dumping, burning, and mismanagement of waste materials. The perpetrators of waste crime can range from individuals and small businesses to organised crime groups, and there are a number of ways criminal groups make money from waste, including:

- Dumping and illegal waste sites
- Deliberated or negligent misdescription of waste, for example categorising it as less polluting to evade regulations
- Illegal export, some types of clean waste can be legally exported to other countries for processing without prior approval and with little paperwork, misdescribed waste may be unexpected exported.

For the cases of illegal export, EO data can be used in combination with GNSS data provided by tracking devices as described in the application GNSS 6 - Fight against environmental crime (e.g. illegal pollution, illegal logging, illegal mining, poaching), GNSS to support digitalisation in transboundary shipments of waste. Specifically concerning the potentialities of EO data, there are several similarities and commonalities in relation to the utilisation of EO data between the fight against environmental crimes related to waste disposal, and eco-crime investigations (addressed in the application EO 8 - EO data in environmental crime investigations).

Satellite data potentialities in waste landfill detection and monitoring are not only for enforcement actions but may be also for court-proof evidence collection. A major goal of waste detection is to identify illegal disposal and prosecute environmental crime. Such objective entails that the evidence collected meet the legal requirements for the use in court. The collection and processing of satellite images for the investigation and prosecution processes poses several changes, especially regarding privacy and veracity. Privacy concerns raise from the collection of very high-resolution images, which may infringe the right to privacy of individuals. Veracity demands that the data collected via EO images are trustworthy and demonstrably tamper-free.

This is far from trivial because satellite images are the outcome of a multistep processing chain that transforms raw data into the products used for analysis. In addition to data trustworthiness, also the downstream analysis process that leads to an illegal site detection must meet admissibility criteria, such as the transparency and reproducibility of the machine-computed evidence. The use of automated waste detection tools in court poses formidable challenges, which demand the interdisciplinary collaboration of researchers from fields such as EO, sensor design, ML, data management, laws and social science.

Another interesting story in transboundary trafficking in waste is Operation DEMETER, involving WCO. Operation DEMETER has been carried almost annually since 2009 (last time was in 2024[45]). It is organised and coordinated by the WCO in conjunction with national environmental regulatory bodies. More than 100 countries take part across Europe, Asia, Africa, and South America. The purpose is to disrupt illegal cross border trade in waste materials, including hazardous and environment damaging materials. These trafficking covers land/maritime movements in areas of import/export and transit, depending on geographical location and nature of the trade. Within the EU, the focus is on export and transit, whereas in Asia/Africa it would be import and transit. Essentially, customs perform controls on waste movements on behalf of the responsible regulatory body. In Ireland[46], for example, the Environmental Protection Agency is the responsible agency. However, the National Transfrontier Shipment Office (TFS) of Dublin City Council act as the enforcement agency. The TFS issues the appropriate licences for waste movement (mostly export in Ireland`s case). While the TFS and Customs work together on an ongoing basis, during DEMETER they dedicate additional resources to the waste area and come together to develop intelligence and risk assessment to identify targets for inspection. The potential risk areas include:

- Mixing of prohibited and non-prohibited waste at waste facilities for export from IE
- Intentional export of prohibited waste without required licence from IE
- Diversion of prohibited waste in transit through IE
- Export of quantities in excess of amounts covered by licence
- Substitution of different types of waste for that specified on licence
- Diversion of consignments away from intended country of destination

Export from IE without appropriate controls being in place in country of destination. Based on these criteria, the TFS select specific consignments for attention/inspection. Customs facilitate inspection at ports of export including by carrying out X-ray scans. The island of Ireland has problems with illegal waste movements from IE and to IE, as well as transits and exports from IE's ports. Already there is some use of drones in risk areas, but satellite technology could bring additional benefits, including by monitoring of waste disposal facilities and the movement between waste operators` premises and declared point of export. Waste is exported both in bulk vessels and in containers on container ships. A crucial point arises at the intended place of import in the destination country. Potentially, bulk vessels could divert to a non-approved port in either the declared country of destination, or in another country. Container ships are less likely to be diverted, but individual containers can be following unloading. So, potential exists for monitoring of some vessels and containers. It is worth noting that where waste consignments are discovered to have been diverted or to be not in compliance with requirements, there is a legal requirement for the consignment to be returned to the country of export at the exporter`s expense. GNSS tracking capabilities may contribute to this type of initiatives.

In the case of surveillance of waste disposal, there are commonalities with these applications:
- GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
- EO 1 - EO data for the safe and secure cross-border transport of dangerous goods
- EO 8 - EO data in environmental crime investigations

Identified novelties, gaps, opportunities, recommendations

The outcomes resulted from the survey conducted are similar to those outlined for the application EO data for monitoring deforestation.

[45] https://www.wcoomd.org/en/media/newsroom/2024/november/operation-demeter-x.aspx

[46] IE

Novelties

No major novelties of relevance were found from the inputs collected from the interviewees.

Gaps

Gap 1 The major driver is in the possibility to access to higher temporal and spatial resolution of the EO images. The involved scientists and agencies are mainly concerned about the costs associated with commercial providers. In the majority of the cases, the integration with other technologies, as explained above, is key to cope with several conditions. For the deforestation, satellite images remain the most effective tool also compared with drones whose deployment may be too expensive and not suitable for extensive coverages.

Gap 2 As described above and similarly to the application the application EO 8 - EO data in environmental crime investigations, the lack of standardised validation and evidence protocols hinders the admissibility of EO data as acceptable proof in forensics to prosecute criminals in court. So far, satellite imagery data have been successfully used in several court cases to establish facts that would otherwise be difficult to prove. Despite these advances, there are still a number of legal and technical obstacles preventing the widespread use of EO data in enforcing environmental laws enforcement.

Many times, if the court does not already doubt the legitimacy or correctness of EO data, the opposing party will challenge the satellite data's validity. Technical issues involve data calibration and chain of custody, critical to maintaining the integrity of satellite data used in court. Legal obstacles include privacy concerns, intellectual property issues, and restrictions related to national security that can limit access to and the use of satellite data. For these and further reasons, such as a lack of understanding of satellite technology and/or concerns about the timeliness, accuracy and confidentiality of the data, there is a certain reluctance among the EU MSs' legal bodies to accept satellite data as court evidence.

Opportunities

Opportunity 1 The advanced in technologies and techniques, especially in AI and in ML can enhance satellite imagery analysis by automating data processing tasks and identifying complex patterns in vast datasets more efficiently than ever before.

Opportunity 2 Open Data Initiatives is perceived a huge opportunity. The increasingly accessible open-source platforms allow practitioners, especially researchers, to collaborate on monitoring efforts without financial constraints.

Opportunity 3 Similarity to application EO 8 - EO data in environmental crime investigations, fostering the use of EO in environmental laws enforcement may be a key for a further exploitation also in the field of waste. Using satellite imagery to prove illicit activities in court is expected to drive broader use of this technology.

Recommendations

Recommendation 1 The main recommendation is to pursue the potential linked to satellite images as proves in legal settings (this is linked with EO 8 - EO data in environmental crime investigations), by:

- Increasing awareness among legal professionals about the capabilities of EO technology
- Incentivising cooperation between different and complementary competences.

This may be done by means of focused research and development efforts. Despite its potential in this respect, the application of EO data in legal settings faces significant technical and legal challenges. To maximise the impact of EO data in environmental protection, it is essential to address and overcome the challenges currently limiting its use. This includes establishing a baseline set of requirements for data quality, improving legal cooperation, and increasing awareness among legal professionals about the capabilities of remote sensing technology.

Recommendation 2 Research and development effort should be directed in the use of open sources and platforms, for a higher accessibility to suitable EO images and consequent wider exploitation.

Recommendation 3 Satellite data potentialities in waste landfill detection and monitoring should be fully exploited, for EO images and GNSS tracking information, in order to provide comprehensive crime-fighting capabilities.

2.4.17 Application EO 7 - EO data for fighting against transnational firearms trafficking

Application description, user needs and requirements

This application supports internal security and law enforcement efforts in the fight against transnational firearms trafficking, as well as drug trafficking and cybercrime, across land, open sea, and port areas. It is designed for governmental entities and LEAs at local, national, EU, and international levels. Customs authorities, coast guards, and other competent agencies are also key users.

The application leverages EO data to conduct covert, large-scale surveillance of illicit goods movements, significantly reducing risks associated with traditional ground or aerial surveillance. High-resolution satellite imagery, capable of distinguishing objects at sub-meter to one-meter resolution, allows law enforcement to:

- Detect warning sites and known trafficking routes
- Track illegal supply chains
- Strengthen surveillance and intervention strategies

Data processing and analysis:

- Satellite imagery is combined with ground-truth information and additional geo-intelligence sources.
- AI and ML tools are applied for pattern detection, change analysis, and predictive modelling of trafficking routes.
- Temporal and spatial sequences of satellite observations are analysed to identify movement patterns, clusters, and risk areas.

Integration with operational workflows:

- EO data complements in situ surveillance, enabling authorities to monitor national borders, remote regions, and port areas that are otherwise difficult to control.
- Unlike aircraft or other open monitoring methods, satellites provide continuous, covert coverage, reducing the risk of alerting suspects and enhancing officer safety.

Operational benefits:

- Early identification of trafficking routes and supply chains for proactive tactical planning
- Support for raid preparation, including mapping obstacles (fences, trees, vehicles) and estimating numbers of people involved
- Enhanced situational awareness to guide law enforcement responses and optimize resource allocation

By integrating EO imagery with AI-driven analytics and operational intelligence, this application provides LEAs with a powerful, safe, and effective tool to combat firearms trafficking and associated transnational crimes.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-007

Application	Fighting against transnational firearms trafficking
Users	LEAs, customs authorities, Coast Guards, and other governmental entities (e.g., environmental and transport agencies) operating at local, national, and EU/international levels
End Users Application Needs	
Operational scenario	Surveillance of land areas, open sea, and ports to detect and monitor illicit firearms trafficking routes and activities
Size of area of interest	Expansive territorial coverage, including cross-border regions and remote areas difficult to monitor through traditional means
Frequency of information needed	Near-continuous monitoring to detect early trafficking routes and support tactical response planning
Type of service (continuous, forecasting, one-off)	Continuous service for situational awareness and tactical support
Satellite EO Data Requirements	
Spatial resolution	≤ 1 meter (to distinguish between objects at least one meter apart)
Temporal resolution	Frequent: daily to weekly are often sufficient for strategic/long term monitoring, sub daily to hourly to enable tactical tracking and temporal sequence analysis of suspected activities
Spectral resolution	Multispectral or high-resolution optical imagery suitable for object and activity recognition
Other requirements (if applicable)	Integration with AI and ML for automatic detection and pattern recognition
Technology used	EO combination with AI, ML, SAR, AIS, and geo-intelligence data fusion for automated analysis of satellite imagery
Data supplements	Ground reference data, in situ information, and other geo-intelligence sources for cross-validation and enhanced situational awareness

Table 20: Application EO 7 - EO data for fighting against transnational firearms trafficking

Case Study/User Story

Case Study/User Story

Firearms trafficking or gunrunning is the illicit trade of contraband small arms, explosives, and ammunition.

- It constitutes part of a broad range of illegal activities often associated with transnational criminal organisations. For example, gunrunning facilitates the trade in illegal drugs and trafficking in human beings
- It fuels conflicts, fosters violence across borders and enriches and strengthens criminal networks.
- Its transnational nature with multiple criminal groups operating in different regions makes it difficult for countries to combat it alone. A weapon may be manufactured in one country and carried through a second country by a national of a third country and travel on a vessel registered in a fourth.

Therefore, firearms trafficking is a cross-border crime, customs authorities and Coast Guards are widely involved. There are similarities with several other applications:

- EO 1 - EO data for the safe and secure cross-border transport of dangerous goods
- EO 2 - EO data to support port and cargo security
- EO 6 - EO data for surveillance of waste disposal
- EO 7 - EO data for the prevention and suppression of international drug trafficking
- GNSS 2 - GNSS for cargo security in ports and customs operations
- GNSS 10 - GNSS for prevention and suppression of international drug trafficking

Identified novelties, gaps, opportunities, recommendations

The results of the survey conducted shows convergent conclusions with the application EO 7 - EO data for the prevention and suppression of international drug trafficking.

Novelties and Gaps

No major novelties and gaps were found as:

- High-resolution satellite images are available on the market and offered by commercial providers to quickly feed actionable intelligence to law enforcement actions.
- LEAs already leverage on cutting-edge technology to integrate the satellite images, for enhancing their situational awareness in both maritime and land scenarios.

Opportunities and Recommendations

Opportunity 1 and Recommendation 1 The key opportunity arises from the overlap with other related applications, offering potential for broader outcomes. It is recommended to build on these shared elements through collaborative initiatives, with specific emphasis on tangible actions for fighting against transnational firearms trafficking and cybercrime.

Opportunity 2 & Recommendation 2 Promote capacity-building initiatives to strengthen the analytical and operational use of EO data by LEAs and customs authorities, exploring cooperative frameworks at EU and international level to improve data access policies, real-time sharing mechanisms, and coordinated responses to transnational firearms trafficking.

According to the collected inputs, the key pillars are:

- Undertaken pilot activities should consider pre-deployment on solutions and closely linked with innovators for the technology demonstrations in the field (with high Technology Readiness Level 7+). It will enable to understand the user needs, verify strengths and weaknesses and proceed with commercialisation if technology fits the purpose. This testing activities shall be funded in an efficient way to minimise the administrative burdens.
- Close cooperation with decision makers, to be part of testing campaigns and involved in working groups, should be pursued.
- Leveraging cutting-edge technology and new advanced performances/functionalities and services are considered useful, as long we they are integrated in trustfully solutions, and near-to-the market/ready-to-fruition products. New advanced performances/functionalities and services should be tested in operational scenarios through practical use cases involving users.

2.4.18 Application EO 8 - EO data in environmental crime investigations

Application description, user needs and requirements

The application uses EO data to support forensic and compliance investigations related to environmental crimes. This application is essential for public environmental agencies, enforcement authorities, inspectors, prosecutors, NGOs, and private sector actors engaged in environmental monitoring. It addresses scenarios in open environments, such as monitoring illegal discharges, land-use changes, unauthorized emissions, and damage assessments, providing rapid thematic mapping and surveillance products that are authenticated for legal use.

The application utilises a variety of space-based data sources, including optical multispectral and hyperspectral imagery, SAR for all-weather monitoring, and commercial very-high-resolution satellites. Key open-source data includes Copernicus Sentinel-1 SAR and Sentinel-2 optical data, as well as Harmonised Landsat-Sentinel (HLS) composites. GNSS position and time data complements these data sources, enhancing the accuracy and reliability of findings. Non-space data, such as ground truth measurements, drone imagery for high-resolution mapping, and IoT sensor data, provide additional context and detail.

Data processing involves extensive steps, including atmospheric corrections, change detection algorithms using indices like NDVI and NDWI, time-series analysis, and biophysical parameter extraction. ML techniques enhance thematic classification and anomaly detection, ensuring that the data products are analysis-ready with reproducible, evidence-grade provenance metadata. The integration of GNSS and IoT data ensures an authenticated chain of custody, while outputs are compatible with GIS platforms for visualization and custom analytics, supporting forensic-grade audit logs.

Processed data and derived insights are transmitted to enforcement authorities, prosecutors, inspectors, and judicial entities, as well as NGOs and environmental agencies for monitoring purposes. Secure delivery platforms maintain role-based access controls and generate audit logs to ensure data integrity and traceability.

The primary purpose of this application is to enable the identification, verification, and documentation of environmental crimes, supporting judicial processes and regulatory enforcement. The data aids in ascertaining illegal activities, monitoring environmental damage, supporting emergency responses, and providing legally admissible, traceable evidence. Additionally, it facilitates continuous surveillance and compliance assurance, reinforcing public environmental protection efforts.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-008
Application	EO data in environmental crime investigations
Users	The primary users are public environmental agencies, enforcement authorities, inspectors, and prosecutors responsible for environmental law compliance. NGOs and private sector actors engaged in environmental monitoring also use the application. These users require actionable, auditable EO data to enforce laws, support legal cases, and ensure public environmental protection.
End Users Application Needs	
Operational scenario	Open and rural environments
Size of area of interest	From coast point (waste dumping) to entire forests (deforestation)
Frequency of information needed	Ideally daily with a weekly baseline for routine monitoring
Type of service (continuous, forecasting, one-off)	Continuous
Satellite EO Data Requirements	
Spatial resolution	1-3m
Temporal resolution	Ideally daily with a weekly baseline for routine monitoring
Spectral resolution	Optical multispectral, SAR, with optional thermal and hyperspectral bands
Other requirements (if applicable)	Not applicable
Technology used	EO and ground truth measurements, drones, and sensors
Data supplements	Not applicable

Table 21: Application EO 8 - EO data in environmental crime investigations

Case Study/User Story

Case Study/User Story

In Brazil, the Brazil MAIS Program used daily Planet Labs satellite imagery to detect illegal deforestation and land-use changes in the Amazon. Automated change-detection alerts enabled rapid enforcement actions, leading to over 120 operations and significant fines. The system combined high-resolution EO data with field verification by environmental agencies, supporting legally defensible evidence for prosecution.[47] Commonalities are between this application and the applications EO 6 - EO data for surveillance of waste disposal, and EO 10 - EO data for monitoring deforestation.

Identified novelties, gaps, opportunities, recommendations

The following main relevant aspects can be retrieved from the interviewees, in terms of gaps, opportunities, and recommendations.

Novelties

No major novelties were found from the inputs collected from the interviewees.

Gaps

Gap 1 Current Copernicus data have limitations in very-high spatial resolution and revisit frequency, impacting some operational needs. There are insufficient standardised protocols for geospatial intelligence admissibility and use in courts. A general lack of awareness and expertise exists among prosecutors and judicial users regarding EO evidence. There are administrative and resource constraints within environmental enforcement agencies. Enterprise-grade, operational processing workflows and delivery platforms need further development. Concerns about over-centralisation of EO data insights pose risks to SME participation.

Opportunities

Opportunity 1 The application benefits from integrating AI and ML to improve detection and classification accuracy. Combining EO data with GNSS-authenticated IoT telemetry enhances evidence chain reliability. Use of drones complements satellite data with higher spatial resolution mapping. Enterprise-ready cloud processing pipelines can scale analysis and pre-processing for user needs. Improved collaboration and training between technical experts and legal authorities increases the effective use of EO in prosecutions. Access to commercial and third-party satellite data fills gaps in temporal and spatial resolution. EO data for monitoring deforestation

Opportunity 2 Synergies with the applications EO 6 - EO data for surveillance of waste disposal and EO 10 - EO data for monitoring deforestation.

Opportunity 3 Improve awareness of judges and prosecutors about the possible use of geospatial intelligence and perform requirements analysis to identify necessary information for use in the courts that can be generated by geospatial intelligence.

Opportunity 4 Improve capability of environmental agencies and competent authorities to use geospatial intelligence technology.

Recommendations

Recommendation 1 Enhance access to commercial high-resolution and high-frequency satellite data through fair-use licensing and Copernicus Contributing Missions. Develop and fund open-source, evidence-grade EO processing workflows with certified provenance metadata. Promote capacity building and multi-stakeholder forums to bridge gaps between technical EO experts and legal professionals. Support cloud-based, scalable pre-processing platforms offering analysis-ready data products. Encourage neutral brokerage platforms to foster a competitive EO analytics market, balancing public, and

[47] https://learn.planet.com/geospatial-technology-environmental-crimes-brazil-eng.htm

private contributions. Invest in training, standardisation, and legal framework development to fully enable EO integration in environmental crime investigation and enforcement.

Recommendation 2 Similarly to applications listed above, the application of EO data in legal settings faces significant technical and legal challenges, despite its potential in this respect. Therefore, common actions can be pursued, in order to explore the path towards the use of EO data to provide acceptable proof in forensics to prosecute criminals in court.

2.4.19 Application EO 9 - EO data for the prevention and suppression of international drug trafficking

Application description, user needs and requirements

This application contributes to internal security and law enforcement in the fight against organized crime and transnational drug trafficking across land, maritime, and port areas. It is designed for governmental entities and LEAs operating at local, national, EU, and international levels, including EUDA, Europol, UNODC, INTERPOL, WCO, national police, drug enforcement agencies, coast guards, and intelligence services.

Data sources and integration:

- High-resolution satellite imagery (optical and SAR) enables large-area surveillance, including remote or difficult-to-access regions. SAR imagery overcomes challenges such as cloud cover and limited nighttime visibility.
- GNSS-based AIS and VMS data are integrated with satellite observations to track vessel movements and identify unreported or non-cooperative vessels.
- Complementary data include aircraft, drones, seizure records, arrest reports, and media sources, enhancing geospatial intelligence for land and maritime domains.

Processing and analysis:

- ML and AI techniques detect narco-trafficking indicators, such as boat wakes, unusual vessel movement patterns, and probable landing or drop-off zones.
- Spatial and temporal analyses reveal trafficking routes, supply chains, and operational patterns.
- On land, EO data support monitoring of land use and cultivated areas potentially linked to controlled substances, while identifying probable illicit drop-off points.

Operational use:

- Strengthens situational awareness for LEAs, allowing proactive responses and optimized allocation of resources.
- Detects maritime illicit activities, including ship-to-ship transfers, “dark” vessels (without AIS signals), and illegal nighttime operations.
- Supports tactical and strategic decision-making by highlighting high-risk areas and tracking patterns of criminal activity.

By combining EO data, GNSS tracking, AI analytics, and geospatial intelligence, this application provides LEAs with a powerful, undetectable, and wide-area surveillance tool to combat international drug trafficking, enhance enforcement operations, and disrupt organized crime networks across multiple domains.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-009
Application	EO data for the prevention and suppression of international drug trafficking

Users	LEAs, customs authorities, Coast Guards, and governmental entities (e.g., environmental and transport agencies). Key organisations include EUDA and UNODC
End Users Application Needs	
Operational scenario	Surveillance and monitoring of land, open sea, and port areas to detect, track, and analyse narco-trafficking activities and related logistics chains
Size of area of interest	Extensive, including international waters, coastal regions, border areas, and remote land zones often used as drop-off or cultivation sites
Frequency of information needed	Near-continuous, to enable real-time monitoring of vessel movements and early detection of illegal activities
Type of service (continuous, forecasting, one-off)	Continuous monitoring with analytical capabilities for pattern recognition and trend forecasting
Satellite EO Data Requirements	
Spatial resolution	≤ 1 meter, enabling detection of vessel wakes, small boats, and specific land features associated with trafficking
Temporal resolution	High rate to support temporal pattern analysis and timely detection of vessel and cargo movements
Spectral resolution	Multispectral and SAR imagery to ensure visibility under all weather and lighting conditions (day/night, cloud cover)
Other requirements (if applicable)	Ability to integrate with AIS and VMS data; wide-area coverage for cross-border monitoring.
Technology used	EO in combination with AI, ML, imagery analytics software, and geospatial intelligence tools for automated detection of patterns and anomalous behaviours
Data supplements	GNSS data, VMS, ground intelligence, seizure and arrest records, and media reports to contextualize EO findings and validate identified trafficking activities

Table 22: Application EO 9 - EO data for the prevention and suppression of international drug trafficking

Case Study/User Story

Case Study/User Story

Drug seizures in Europe reflect an exponential increase in illegal trafficking by sea. Cocaine flows are discreetly integrated into regular routes between South America, West Africa, and Europe. Potentially contaminated vessels are complex to identify due to the large amount of data required. To make matters worse, drug trafficking often overlaps with other offences such as corruption, money laundering or obstruction of justice.

Satellite images are used to monitor primary infrastructures for the production of cocaine, and to overseeing the relevant trafficking routes. Transnational cocaine trafficking, or 'narco-trafficking', networks often move large shipments of harmful and illegal drugs by sea through the use of unregulated boats in remote maritime spaces. The transnational cocaine supply chain in the transit zone includes multiple transshipment points before the shipments reach consumption markets, by employing "non-cooperative" or "dark" or "daughter" vessels, as explained above.

EO technology serves as key weapons against drug traffickers, however it also casts a shadow where its capabilities are exploited for criminal activities. Across the seas, the use of satellite data in smuggling extends to monitoring maritime traffic patterns to avoid detection. Smugglers can access to satellite images, analyse them over time to understand patrol densities and timings in international waters or along coastlines, optimising routes for drug, weapon, or human trafficking. Satellite images could also inform sudden changes in strategy, like shifting drop points or altering transport methods in response to law enforcement activities observed from space. This is also carried out by smuggling of migrants and pirates (satellite images can help identify ships with less security or those that are isolated, making them easier targets). Additionally, satellite insights into weather patterns enable pirates to act during storms or poor weather, when rescue and response operations are less effective.

For this reason, the top priority for LEAs is strengthening the fight against drug trafficking by advanced methodology, based on the use of satellite imaging in conjunction with other technologies, such as:

- Floating acoustic sensors, a network of acoustic sensors on small buoys that detected noise signatures off drug running vessels.
- Drones designed to survey and patrol designated areas while continuously transmitting data to a central platform. Each drone is equipped with optical and thermal imaging cameras. Because of the 5G network infrastructure and satellite connectivity, they can provide real-time data to users, including video streaming.
- RF signal detection and geolocation to monitor and track "non-cooperative" or "dark" or "daughter" vessels (i.e., ships with disabled or manipulated AIS, likely involved in criminal activities, such as illicit trafficking and illegal fishing, can still be located and monitored through their RF emissions. Signals intelligence (SIGINT), otherwise called RF Geospatial Intelligence (RFGEOINT) or RF Geolocation (RFGL) allows:
    1) To identify and locate vessels based on their RF emissions, including those from communication devices or onboard systems,
    2) To cross-reference RF geolocation data with AIS to uncover spoofing, position manipulation, or dark shipping events.

This application has synergies with several other applications, more specifically with:

- EO 5 - EO data for monitoring illegal fishing;
- EO 6 - EO data for surveillance of waste disposal;
- EO 7 - EO data for fighting against transnational firearms trafficking;
- EO 8 - EO data in environmental crime investigations;
- GNSS 2 - GNSS for cargo security in ports and customs operations;
- GNSS 10 - GNSS for prevention and suppression of international drug trafficking.

Identified novelties, gaps, opportunities, recommendations

The following considerations can be drafted from the survey conducted.

Novelties

No major novelties were found.

Gaps

No major gaps were found.

Opportunities and Recommendations

Opportunity 1 and Recommendation 1 High-resolutions satellite images are available on the market and offered by commercial providers to quickly feed actionable intelligence to law enforcement actions. LEAs already leverage on cutting-edge technology to integrate the satellite images, for enhancing their situational awareness both for maritime and land scenarios.

EO 9 - EO data for the prevention and suppression of international drug trafficking - is connected to the applications listed above, sharing capabilities such as vessel and land monitoring, AI and ML analytics, and integration with law enforcement data. These synergies enable coordinated surveillance, pattern detection, and enhanced cross-border operational support.

Shared features with other applications present an opportunity for wider impact. The recommendation is to capitalize on these overlaps through coordinated efforts, especially by developing concrete measures to prevent and suppress drug trafficking.

Opportunity 2 and recommendation 2 Using AI and predictive analysis to study trafficking patterns can help law enforcement act proactively. It is recommended to consider:

- The development of ML tools that highlight emerging hotspots and support better coordination and resource allocation between agencies and institutions.
- The integration with huge volume of data as well as (semi-) automated (AI based) processing and interpretation.

According to the collected inputs, key pillars common to EO 7 have to be considered.

2.4.20 Application EO 10 - EO data for monitoring illegal fishing and deforestation

Application description, user needs and requirements

In open environments, this application enhances, internal security and law enforcement actions against environmental crimes, with a specific focus on monitoring and combating deforestation caused by illegal logging, land clearing, mining, and related activities. It is designed for use in open and often remote environments, where traditional ground-based monitoring is limited or impractical.

The primary users are governmental entities and LEAs operating at local, national, European, and international levels. At the European level, key stakeholders include the European Environment Agency (EEA), the Joint Research Centre (JRC), Copernicus Land Monitoring Service (CLMS), and the European Forest Institute (EFI). Scientists, environmental practitioners, and technical agencies support these authorities in analysis and enforcement activities.

The application relies mainly on EO satellite data, leveraging multi-sensor and multispectral imaging capabilities. Optical, infrared, and radar sensors enable detailed observation of forested areas across large territories, including remote or inaccessible regions. Infrared data is particularly valuable for assessing vegetation health, as healthy forests reflect infrared radiation differently from stressed or degraded vegetation. EO data can be complemented, where relevant, by drone imagery to provide higher spatial detail over targeted areas.

Data are analysed using multi-temporal change detection techniques, allowing practitioners to compare historical and current satellite observations to identify anomalies and sudden changes indicative of illegal deforestation. By processing visible, infrared, and radar wavelengths, the application enables the assessment of vegetation health, biomass density, and land-use changes over time. These analyses support the early detection of illegal logging and forest clearing, quantification of environmental damage, and the generation of evidence suitable for enforcement actions, including penalties and trade or import restrictions.

Geospatial analysis is performed using GIS to integrate EO data with land-use maps, ecological layers, and other relevant datasets. When combined with ground-based observations and socio-economic data, this integrated approach provides a comprehensive understanding of deforestation drivers and patterns. High temporal resolution allows for frequent monitoring and rapid detection of illicit activities, while high spatial resolution supports accurate localisation and detailed damage assessment.

Processed data, analyses, and derived evidence are made available to LEAs, environmental agencies, scientists, and relevant organisations. These outputs enable automated surveillance, investigation of illegal activities, and substantiation of reports and legal cases. Beyond enforcement, the collected information also serves as a deterrent, supports public awareness, and strengthens the ability of authorities to prevent environmental crimes, protect forest ecosystems, and prosecute offenders effectively.

EO Requirements	
ID	EUSPA-EO-UR-EUBIS-010

Application	EO data for monitoring deforestation
Users	Governmental entities (environmental and transport agencies), LEAs at local, national, EU, and international levels, European-level agencies, scientists, and relevant organisations
End Users Application Needs	
Operational scenario	Open environment; remote and inaccessible areas; forested regions where illegal activities may occur
Size of area of interest	Extensive coverage: regional to global scale, depending on the forested area under monitoring
Frequency of information needed	Regular updates; near-real-time monitoring to detect illegal activities as they occur
Type of service (continuous, forecasting, one-off)	Continuous monitoring with multi-temporal analysis; also supports one-off investigations and reporting
Satellite EO Data Requirements	
Spatial resolution	High-resolution imaging sufficient to detect illegal logging, forest clearing, and other deforestation activities (typically <10 m, ideally sub-meter where feasible)
Temporal resolution	Frequent revisits to allow near-real-time detection of illegal activities; multi-temporal analysis for trend assessment
Spectral resolution	Multi-spectral and multi-sensor (visible, infrared, radar) to assess vegetation health, biomass density, and land-use changes
Other requirements (if applicable)	Integration with GIS, GNSS, and ground-based observations; compatibility with drone imagery for finer-scale verification; support for evidence production for legal use
Technology used	EO data with high-resolution cameras and sensors; SAR technology – detects structure and texture changes under clouds (e.g. Sentinel-1) combined with optical data – detects vegetation type and colour changes (Sentinel -2) for higher accuracy; multi-sensor/multi-spectral imaging; geospatial analysis via GIS; temporal analysis tools
Data supplements	Drone imagery, ground-based observations, socio-economic datasets, land-use maps

Table 23: Application EO 10 - EO data for monitoring illegal fishing and deforestation

Case Study/User Story

Case Study/User Story

There are obvious similarities between crimes linked to deforestation and eco-crime investigations (addressed in the application EO 8 - EO data in environmental crime investigations), and there are commonalities in relation to the utilisation of EO data. Specifically for the crimes linked to deforestation, EO offers very effective fighting capabilities over an extensive coverage and in remote or inaccessible areas. Satellite images and SAR data particularly are also very valuable for detecting forest loss in cloudy tropical regions and for continuous, year-round observation often in combination with optical imagery. Over smaller areas, aircrafts, and drones complement satellite imagery providing remote sensing data in real-time, and with greater detail and precision. Equipped with specific sensors, drones analyse vegetation health, biodiversity, and habitat disruptions.

Identified novelties, gaps, opportunities, recommendations

The most important outcomes resulted from the survey conducted.

<u>**Novelties**</u>

No major novelties of relevant were found.

Gaps

Gap 1 The major driver is in the possibility to access to higher temporal and spatial resolution of the EO images. The scientists and agencies involved have expressed concern about the high costs charged by commercial providers. In the majority of the cases, the integration with other technologies, as explained above, is a key to cope with several conditions. For the deforestation, satellite images remain the most effective tool also compared with drones whose deployment may be too expensive and not suitable for extensive coverages.

Gap 2 Interoperability between EO images and data collected from drones and in-situ sources.

Opportunities

Opportunity 1 Similarly to the application EO 5 – EO data for monitoring illegal fishing, the use of satellite imagery analysis can benefit for the combination with advanced technologies and techniques, especially in AI and & ML automating data processing tasks and identifying complex patterns in vast datasets more efficiently than ever before.

Opportunity 2 Open data initiatives are perceived as a huge opportunity. The increasingly accessible open-source platforms allow practitioners, especially researchers, to collaborate on monitoring efforts without financial constraints.

Opportunity 3 Similarity to application EO 8 - EO data in environmental crime investigations, fostering the use of EO in environmental laws enforcement may be a key for a further exploitation also in monitoring deforestation. The use of satellite imagery in court cases to establish facts related to illicit actions and incorrect behaviours, that would otherwise be difficult to prove, is expected to positively lead to a wider utilisation.

Recommendations

Recommendation 1 The main recommendation is to pursue the potential linked to satellite images as proves in legal settings (this is linked with EO 8 - EO data in environmental crime investigations), by:

- Increasing awareness among legal professionals about the capabilities of remote sensing technology.
- Incentivising cooperation between different and complementary competences.

This may be done by means of focused research and development efforts.

Recommendation 2 Research and development effort should be directed in the use of open sources and platforms, for a higher accessibility to suitable EO images and consequent wider exploitation.

2.5 User Requirements Specifications

ID	Description	Type	Source
EUSPA-GN-UR-EUBIS-010101	Horizontal: 2 m (this is the required minimum distance to recognise which road/side of the road/direction) Vertical: 3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)	Accuracy	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
EUSPA-GN-UR-EUBIS-010102	Urban canyon: Yes Natural canyon: Yes Canopy: Yes Indoor: No (tunnels use other technologies such as cameras) Better than 95% High Better than 99% Medium	Availability	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
EUSPA-GN-UR-EUBIS-010103	High	Robustness	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
EUSPA-GN-UR-EUBIS-010104	High	Integrity and reliability	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
EUSPA-GN-UR-EUBIS-010105	About 1 minute in hot start	TTFaF	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
EUSPA-GN-UR-EUBIS-010106	National/Regional/European	Geographical coverage	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods

ID	Description	Type	Source
EUSPA-GN-UR-EUBIS-010107	Time a device can run: >12 months for intermodal shipment ≤1 month for road-only shipment	Size, weight, autonomy	GNSS 1 - GNSS for safe and secure cross-border transport of dangerous goods
EUSPA-GN-UR-EUBIS-020101	Horizontal: 2 m (this is the required minimum distance to recognise which road/side of the road/direction) Vertical: 3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)	Accuracy	GNSS 2 - GNSS for cargo security in ports and customs operations
EUSPA-GN-UR-EUBIS-020102	Urban canyon: Yes Natural canyon: Yes Canopy: Yes Indoor No (tunnels use other technologies such as cameras) Better than 95% High Better than 99% Medium	Availability	GNSS 2 - GNSS for cargo security in ports and customs operations
EUSPA-GN-UR-EUBIS-020103	High	Robustness	GNSS 2 - GNSS for cargo security in ports and customs operations
EUSPA-GN-UR-EUBIS-020104	High	Integrity and reliability	GNSS 2 - GNSS for cargo security in ports and customs operations
EUSPA-GN-UR-EUBIS-020105	About 1 minute in hot start	TTFaF	GNSS 2 - GNSS for cargo security in ports and customs operations
EUSPA-GN-UR-EUBIS-020106	National/Regional/European	Geographical coverage	GNSS 2 - GNSS for cargo security in ports and customs operations

ID	Description	Type	Source
EUSPA-GN-UR-EUBIS-020107	Time a device can run: >12 months for intermodal shipment ≤1 month for road-only shipment	Size, weight, autonomy	GNSS 2 - GNSS for cargo security in ports and customs operations
EUSPA-GN-UR-EUBIS-030101	Horizontal: 2 m (this is the required minimum distance to recognise which road/side of the road/direction) Vertical: 3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)	Accuracy	GNSS 3 - GNSS for ports security operations and virtual security gates
EUSPA-GN-UR-EUBIS-030102	Urban canyon: Yes Natural canyon: Yes Canopy: Yes Indoor: No (tunnels use other technologies such as cameras) Better than 95% High Better than 99% Medium	Availability	GNSS 3 - GNSS for ports security operations and virtual security gates
EUSPA-GN-UR-EUBIS-030103	High	Robustness	GNSS 3 - GNSS for ports security operations and virtual security gates
EUSPA-GN-UR-EUBIS-030104	High	Integrity and reliability	GNSS 3 - GNSS for ports security operations and virtual security gates
EUSPA-GN-UR-EUBIS-030105	About 1 minute in hot start	TTFF	GNSS 3 - GNSS for ports security operations and virtual security gates
EUSPA-GN-UR-EUBIS-030106	National/Regional/European	Geographical coverage	GNSS 3 - GNSS for ports security operations and virtual security gates

ID	Description	Type	Source
EUSPA-GN-UR-EUBIS-030107	Time a device can run: >12 months for intermodal shipment ≤1 month for road-only shipment	Size, weight, autonomy	GNSS 3 - GNSS for ports security operations and virtual security gates
EUSPA-GN-UR-EUBIS-040101	Horizontal: Sub-meter to meters preferred; ideally <30 cm for detailed site analysis Vertical: Approx. 1–3 m (to distinguish underwater depth variations and coastal elevations)	Accuracy	GNSS 4 - GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-040102	Urban canyon: Not applicable/limited relevance Natural canyon: Yes (relevant for coastal cliffs and underwater terrain) Canopy: Partial (possible signal degradation in dense coastal vegetation or near structures) Indoor: No (underwater operations rely on acoustic/INS systems) Better than 95% High Better than 99% Medium	Availability	GNSS 4 - GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-040103	High (required for harsh marine and coastal conditions)	Robustness	GNSS 4 - GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-040104	High (necessary for legal protection and enforcement activities)	Integrity and reliability	GNSS 4 - GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-040105	About 1 minute in hot start	TTFaF	GNSS 4 - GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-040106	National/Regional/European (European coastal and selected external waters)	Geographical coverage	GNSS 4- GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-040107	Time a device can run: Typically, several months for coastal stations; several hours to days for underwater sensors or drones	Size, weight, autonomy	GNSS 4 - GNSS data for locating cultural heritage looting
EUSPA-GN-UR-EUBIS-050101	Horizontal: Metre-level Vertical: Metre-level	Accuracy	GNSS 5 - GNSS in crisis resource

ID	Description	Type	Source
			management and aid management monitoring
EUSPA-GN-UR-EUBIS-050102	Urban canyon: Yes Natural canyon: Yes Canopy: No Indoor: No Better than 95% High Better than 99% Medium	Availability	GNSS 5 - GNSS in crisis resource management and aid management monitoring
EUSPA-GN-UR-EUBIS-050103	Medium	Robustness	GNSS 5 - GNSS in crisis resource management and aid management monitoring
EUSPA-GN-UR-EUBIS-050104	Medium	Integrity and reliability	GNSS 5 - GNSS in crisis resource management and aid management monitoring
EUSPA-GN-UR-EUBIS-050105	About 1 minute in hot start	TTFaF	GNSS 5 - GNSS in crisis resource management and aid management monitoring
EUSPA-GN-UR-EUBIS-050106	National/Regional/Local	Geographical coverage	GNSS 5 - GNSS in crisis resource management and aid management monitoring
EUSPA-GN-UR-EUBIS-050107	Time a device can run: Not applicable	Size, weight, autonomy	GNSS 5 - GNSS in crisis resource management and aid

ID	Description	Type	Source
			management monitoring
EUSPA-GN-UR-EUBIS-060101	Horizontal: 2 m (this is the required minimum distance to recognise which road/side of the road/direction) Vertical: 3 m (this is the required minimum distance in the case of transport road and bridges to distinguish the height, being 4,8 m the maximum height of a road vehicle allowed to transit under bridges by regulation)	Accuracy	GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-060102	Urban canyon: Yes Natural canyon: Yes Canopy: Yes Indoor: No (tunnels use other technologies such as cameras) Better than 95% High Better than 99% Medium	Availability	GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-060103	High	Robustness	GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-060104	High	Integrity and reliability	GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-060105	About 1 minute in hot start	TTFaF	GNSS 6 - GNSS for digital Waste

ID	Description	Type	Source
			Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-060106	National/Regional/European	Geographical coverage	GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-060107	Time a device can run: >12 months for intermodal shipment ≤1 month for road-only shipment	Size, weight, autonomy	GNSS 6 - GNSS for digital Waste Shipment System (DIWASS) Regulation and green-listing of waste for shipments within the EU
EUSPA-GN-UR-EUBIS-070101	Horizontal Metre-level in most cases, cm-level for high precision ones Vertical Metre-level	Accuracy	GNSS 7
EUSPA-GN-UR-EUBIS-070102	Urban canyon Yes Natural canyon: Yes Canopy: Yes Indoor: No Better than 95% High Better than 99% Medium	Availability	GNSS 7 - GNSS to support environmental crime investigations
EUSPA-GN-UR-EUBIS-070103	High	Robustness	GNSS 7 - GNSS to support environmental crime investigations

ID	Description	Type	Source
EUSPA-GN-UR-EUBIS-070104	High	Integrity and reliability	GNSS 7 - GNSS to support environmental crime investigations
EUSPA-GN-UR-EUBIS-070105	About 1 minute in hot start	TTFaF	GNSS 7 - GNSS to support environmental crime investigations
EUSPA-GN-UR-EUBIS-070106	Regional/Local/Specific site	Geographical coverage	GNSS 7 - GNSS to support environmental crime investigations
EUSPA-GN-UR-EUBIS-070107	Time a device can run: Not applicable	Size, weight, autonomy	GNSS 7 - GNSS to support environmental crime investigations
EUSPA-GN-UR-EUBIS-080101	Horizontal: cm-level Vertical: cm-level	Accuracy	GNSS 8 - GNSS in accident and crime scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-080102	Urban canyon: Yes Natural canyon: Yes Canopy: No Indoor: No Better than 95% High Better than 99% Medium High	Availability	GNSS 8 - GNSS in accident and crime scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-080103	High	Robustness	GNSS 8 - GNSS in accident and crime scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-080104	High	Integrity and reliability	GNSS 8 - GNSS in accident and crime scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-080105	About 1 minute in hot start	TTFaF	GNSS 8 - GNSS in accident and crime

ID	Description	Type	Source
			scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-080106	Local (crime scene)	Geographical coverage	GNSS 8 - GNSS in accident and crime scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-080107	Time a device can run: Not applicable	Size, weight, autonomy	GNSS 8 - GNSS in accident and crime scene reconstruction for forensics
EUSPA-GN-UR-EUBIS-090101	Horizontal: 2 m Vertical: 2 m	Accuracy	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
EUSPA-GN-UR-EUBIS-090102	Urban canyon: No Natural canyon: Yes Canopy: Yes Indoor: Yes Better than 95% High Better than 99% Medium	Availability	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
EUSPA-GN-UR-EUBIS-090103	High	Robustness	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
EUSPA-GN-UR-EUBIS-090104	High	Integrity and reliability	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade

ID	Description	Type	Source
EUSPA-GN-UR-EUBIS-090105	About 1 minute in hot start	TTFaF	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
EUSPA-GN-UR-EUBIS-090106	National/Regional/European	Geographical coverage	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade
EUSPA-GN-UR-EUBIS-090107	Time a device can run: >12 months	Size, weight, autonomy	GNSS 10 - GNSS for prevention and suppression of international drug trafficking trade

Table 24: Synthesis of Requirements Relevant to GNSS

It shall be noted that at application level, the requirements related to Availability, Robustness, Integrity, and Reliability are referred to the integrated positioning and communication services, i.e., they depend on the GNSS related performances combined with the quality of the specific communication mean(s). According to the stakeholders involved in the consultation, separating the requirements for the GNSS and communication components is not meaningful, as the specified requirements apply to the overall integrated positioning and communication service needed to implement the specific application. For GNSS 9 - Counter-UAS, the requirements were not specified.

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-EUBIS-001	EO 1 - EO data for the safe and secure cross-border transport of	Georeferenced EO data are used to monitor and implement	Variable and context dependent can range from local routes (tens of kilometres to transnational	Variable from pre-planned operations to continuous monitoring and	Land transport/urban-rural monitoring: 1 to 10 m resolution	Variable according to the case: daily to weekly (pre-planning),	SAR imagery is primarily used because of images through clouds, darkness, smoke or other occlusions.

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
	dangerous goods	advanced risk assessment models associated with DG transport.	corridors and extensive maritime zones.	emergency triggered data	Maritime/oil spill detection: 10-100 m resolution	minutes to hours for transport monitoring, on-demand for emergency response	Multi sensor, multi-platform approach combining EO satellites, GNSS tracking, sensors, cameras, etc.
EUSPA-EO-UR-EUBIS-002	EO 2 - EO data to support port and cargo security	The application relies on satellite imagery, in particular very high-resolution SAR data, to enable continuous monitoring of port areas regardless of weather conditions, cloud cover, fog, or darkness.	Port areas and surrounding maritime zones, often remote and inaccessible	Daily or sub-daily, complemented with drone imagery when higher granularity is required	Very high resolution (SAR images, <1m for modern SAR satellites, typically 1-3m to detect small vessels) suitable for detecting vessels, containers, and other port activities	Daily or sub-daily acquisitions; more frequent monitoring when needed	Satellite EO (mainly very high-resolution SAR), drones for higher granularity; GIS for spatial analysis; AI and ML for automated monitoring and prediction
EUSPA-EO-UR-EUBIS-003	EO 3 - EO data for preventing and suppressing	The application leverages EO data to monitor cultural	Local/Regional/Worldwide Local/Regional (Mediterranean area)	Every hour Every day	50 cm to 15 m (images from satellites)/5 cm	50 cm to 15 m (images from satellites)/5 cm to 5 mm	SAR technology

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
	cultural heritage looting and illegal trafficking	heritage sites and assess damage caused by looting, environmental degradation, armed conflict, or natural hazards, particularly in areas that are difficult or impossible to access on the ground.			to 5 mm (images from drones)	(images from drones)	
EUSPA-EO-UR-EUBIS-004	EO 4 - EO data in damage and conflict zone mapping	This application focuses on utilising EO data for mapping and quantifying physical damage in conflict zones.	From the state of building damages to larger scope like neighbourhoods or even entire cities	Weekly to yearly	30-50cm	Weekly for high-end, yearly for low-end	EO as well as in-situ sampling through drones and ground validation or OSINT

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-EUBIS-005	EO 5 - EO data for monitoring illegal fishing	This application contributes to EU sea border and maritime surveillance by strengthening the monitoring, detection, and prevention of IUU fishing activities in open sea environments.	Very large covering extensive maritime zones, including EEZs and high seas regions.	Very large covering extensive maritime zones, including exclusive economic zones (EEZs) and high seas regions	Medium to high (3–30 m) – sufficient to detect and classify vessels of various size From typical SAR missions (for example Sentinel-1, RADARSAT)	Daily to sub-daily (at time step during the day) to ensure timely vessel detection and tracking	SAR and optical EO satellites, combined with GNSS-based AIS tracking, RF-derived vessel detection, drones, and AI-powered data analytics for anomaly detection and pattern recognition
EUSPA-EO-UR-EUBIS-006	EO 6 - EO data for surveillance of illegal waste disposal sites, landfills and dumps	The application leverages remote sensing satellite technology as a cost-effective solution to detect, monitor, and assess the evolution of illegal waste disposal sites over time.	Variable from localised landfill sites (a few hectares) to regional or national scales. Repeated acquisitions enable monitoring of entire sites and comparative assessments across time	Daily or repeated acquisitions over time. Multi-temporal monitoring to follow the evolution of landfills through modern constellations (e.g. Sentinel-	Sub-meter resolution for detecting small illegal dumps and differentiating waste materials. Fine resolution needed to detect small changes in landfill sites. Medium-resolution sensors (10-30m) sufficient	Daily acquisitions feasible due to modern satellite revisit times: frequent revisits (1-5 days) from Sentinel-1/2, SPOT6/7, WordlView-3, Pleiades Neo Multi-temporal methods to	SAR, combined with data from drones, data fusion, GIS for data integration and analysis

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
				2, Worldview, Pleiades Neo)	for large landfill monitoring (e.g. Sentinel-2, Landsat 8/9)	monitor site evolution	
EUSPA-EO-UR-EUBIS-007	EO 7 – EO data for fighting against transnational firearms trafficking	The application leverages EO data to conduct covert, large-scale surveillance of illicit goods movements, significantly reducing risks associated with traditional ground or aerial surveillance.	Expansive territorial coverage, including cross-border regions and remote areas difficult to monitor through traditional means	Near-continuous monitoring to detect early trafficking routes and support tactical response planning	Frequent: daily to weekly are often sufficient for strategic/long term monitoring, sub daily to hourly to enable tactical tracking and temporal sequence analysis of suspected activities.	Multispectral or high-resolution optical imagery suitable for object and activity recognition	EO combination with AI, ML, SAR, AIS, and geo-intelligence data fusion for automated analysis of satellite imagery
EUSPA-EO-UR-EUBIS-008	EO 8 – EO data in environmental crime investigations	The application uses EO data to support forensic and compliance investigations related to environmental crimes.	From coast point (waste dumping) to entire forests (deforestation)	Ideally daily with a weekly baseline for routine monitoring	1-3m	Ideally daily with a weekly baseline for routine monitoring	EO in combination with ground truth measurements, drones, and sensors

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
EUSPA-EO-UR-EUBIS-009	EO 9 – EO data for the prevention and suppression of international drug trafficking	The application uses EO to enhance the fight against organized crime and transnational drug trafficking across land, maritime, and port areas.	Extensive, including international waters, coastal regions, border areas, and remote land zones often used as drop-off or cultivation sites	Near-continuous, to enable real-time monitoring of vessel movements and early detection of illegal activities	≤ 1 meter, enabling detection of vessel wakes, small boats, and specific land features associated with trafficking	High rate to support temporal pattern analysis and timely detection of vessel and cargo movements	EO in combination with AI, ML, imagery analytics software, and geospatial intelligence tools for automated detection of patterns and anomalous behaviours
EUSPA-EO-UR-EUBIS-010	EO 10 - EO data for monitoring deforestation	This application relies on the use of EO to implement actions against environmental crimes, with a specific focus on monitoring and combating deforestation caused by illegal logging, land clearing, mining, and	Extensive coverage: regional to global scale, depending on the forested area under monitoring	Regular updates; near-real-time monitoring to detect illegal activities as they occur	High-resolution imaging sufficient to detect illegal logging, forest clearing, and other deforestation activities (typically <10 m, ideally sub-meter where feasible)	Frequent revisits to allow near-real-time detection of illegal activities; multi-temporal analysis for trend assessment	EO data combined with high-resolution cameras and sensors; SAR technology – detects structure and texture changes under clouds (e.g. Sentinel-1) combined with optical data – detects vegetation type and colour changes (Sentinel -2) for higher accuracy; multi-sensor/multi-spectral imaging; geospatial analysis via GIS; temporal analysis tools

ID	Application	Abstract of the Need and Requirement	Size of the area of interest	Frequency of information needed	Spatial resolution	Temporal resolution	Type of EO data
		related activities.					

Table 25: Synthesis of Requirements Relevant to EO

3 ANNEX

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 EU Border and Internal Security 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 characterised by comparing their “response” in different spectral bands.

Radiometric resolution expresses the sensitivity of the sensor, that is to say its ability to differentiate between different magnitudes of the electromagnetic energy. The finer the radiometric resolution, the more sensitive it is to small differences in the energy emitted or reflected by an object. The radiometric resolution is generally expressed in bit, e.g. an 8-bit image has a scale of 2^8=256 nuances.

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

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

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 millimetre-scale during periods ranging from days to years.

Near-Real-Time (NRT) refers, when used in the context of EO applications, to applications, services, or 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 used GNSS performance parameters and includes additional details which are relevant for EU Border and Internal Security 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: centimetre-level: 0-10cm; decimetre level: 10-100cm; metre-level: 1-10 metres.

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

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 can mitigate. 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 Definition of key SATCOM performance parameters

Link type refers to the type of communication link used for transmitting voice or data.

Availability is qualitative indication of the reliability and uptime of the communications system. It refers to the percentage of time the communication system is operational and meets the required quality of service when the application is in use.

Latency refers to the delay between the transmission of a signal and the reception of the response. This is the time it takes for a signal to travel from the sender to the receiver and back.

Bandwidth (bit rate) is a qualitative indication of the anticipated rate of data transfer when using the application. It is the amount of data that can be transmitted over the communication link in a given amount of time, usually measured in bits per second (bps).

Coverage is an indication of the geographical area that can be reached by the service. It defines the regions where the satellite signal is available and can provide communication services.

Symmetry Up/Down is the ratio between the uplink traffic (data sent from the ground to the satellite) and the downlink traffic (data sent from the satellite to the ground). This ratio indicates whether the communication link is symmetric (equal uplink and downlink capacity) or asymmetric (different uplink and downlink capacities).

Distribution refers to the method and extent to which the communication service is distributed across different regions or users. It can include the distribution of signal strength, service availability, and user access.

Setup refers to a qualitative indication of the time required to establish a voice or data communication session with the application. It refers to the acceptable duration for setting up a communication link that is sufficient to perform the intended operation, such as railway operations.

Speed: the speed at which a user is traveling, with a maximum value specified. In satellite communication, this can affect the ability to maintain a stable communication link, especially for mobile users.

Security protection refers to the measures and protocols implemented to ensure the security of the communication link. This includes protecting the data from unauthorized access, interception, and ensuring the integrity and confidentiality of the transmitted information

A.5 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°.

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.6 List of Acronyms

Acronym	Definition
3D	Three Dimensional
ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
AI	Artificial Intelligence
AIS	Automatic Identification System
AOI	Area Of Interest
API	Application Programming Interface
AURORA	Artwork Unique RecognitiOn and tRacking through chemicAl encoded data, miniaturized devices and blockchain alliance
AUV	Autonomous Underwater Vehicle
C3S	Copernicus Climate Change Service
C-UAS	Counter-UAS
CCHT	Centre for Cultural Heritage Technology
CENTRIC	Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research
CEOBS	The Conflict and Environment Observatory
Cerema	Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement
CLMS	Copernicus Land Monitoring Service
DG	Dangerous Goods
DNRED	Direction Nationale du Renseignement et des Enquêtes Douanières
DIWASS	Digital Waste Shipment System
eDGT	electronic Dangerous Goods Transport Information
EC	European Commission
EEA	European Environment Agency
EFI	European Forest Institute
EEZ	Exclusive Economic Zone
eFTI	electronic Freight Transport Information
EFCA	European Fisheries Control Agency
EGNOS	European Geostationary Navigation Overlay System
EMSA	European Maritime Safety Agency
ENIGMA	Endorsing Safeguarding, Protection & Provenance Management of Cultural Heritage
ENS	Entry Summary Declaration
EO	Earth Observation
ESA	European Space Agency
EU	European Union, Europe. European
EUBIS	EU Border and Internal Security
EUCA	EU Customs Authority
EUDA	European Union Drug Agency

EWSS	Galileo Early Warning Service
Frontex	The European Border and Coast Guard Agency
GDPR	General Data Protection Regulation
GEOINT	Geospatial Intelligence
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite System
GSMC	Galileo Security Monitoring Centre
HLS	Harmonised Landsat-Sentinel
HOTOSM	Humanitarian OpenStreetMap Team
IAPH	International Associations of Ports and Harbors
IAEA	International Atomic Energy Agency
IE	Ireland
IMDG	International Maritime Dangerous Goods
IoT	Internet of Things
IoUT	Internet of Underwater Things
IMINT	Imagery Intelligence
IMSOC	Information Management System for Official Controls)
IT	Information Technology
ITS	Intelligent Transport Systems
IUU	Illegal, Unreported, and Unregulated
IWW	Inland Waterways
JRC	Joint Research Centre
LEA	Law Enforcement Agency
LiDAR	Light Detection and Ranging
LRIT	Long-Range Identification and Tracking
MDA	Maritime Domain Awareness
ML	Machine Learning
MoU	Memorandum of Understanding
MS	Member State
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
NGO	Non-Governmental Organisation
OCBC	Central Office for the Fight against Trafficking in Cultural Property
OCBS	Office Central de lutte contre le traffic de Biens Culturels
OCR	Optical Character Recognition
OS	Galileo Open Service
OSNMA	Galileo Open Service Navigation Message Authentication
PITCH	Prevention of Illicit Trafficking of Cultural Heritage
PNT	Positioning, Navigation, and Timing
PROCULTHER-NET	Protecting Cultural Heritage from the Consequences of Disasters-Network
RF	Radio Frequency
RFGEOINT	RF Geospatial Intelligence
RFGL	RF Geolocation
RFID	Radio-Frequency Identification

RID	Regulations concerning the International Carriage of Dangerous Goods by Rail
ROV	Remotely Operated Vehicles
RTK	Real-Time Kinematic
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communication
SEA-CLOP	Space and Radar Technology for Underwater Heritage Protection
SIGINT	Signals intelligence
SME	Small to Medium-sized Enterprise
TFS	Ireland Transfrontier Shipment Office
TRL	Technology Readiness Level
UAS	Unmanned Aircraft Systems
UCC	Union Customs Code
UCP	User Consultation Platform
UNECE	United Nations Economic Commission for Europe
UNODC	United Nations Office on Drugs and Crime
UXO	Unexploded Ordnance
VHR	Very High Resolution
VMS	Vessel Monitoring System
VOI	Vessels Of Interest
VTS	Vessel Traffic Service
WCO	World Customs Organisation

Table 26: Acronyms

A.7 Reference Documents

Id.	Reference	Title	Date
[RD1]	EUSPA Market Report	EUSPA EO and GNSS Market Report (Issue 2)	2024
[RD2]	UCP 2023	Report on Resilient Societies User Needs and Requirements	2024
[RD3]	eFTI electronic Freight Transport Information Regulation (EU) 2020/1056	https://eur-lex.europa.eu/eli/reg/2020/1056/oj	
[RD4]	Regulation on harmonised rules on fair access to and use of data	https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en	2024
[RD5]	UNECE's guidelines on eGTI	https://unece.org/transport/dangerous-goods	
[RD6]	Data Act: European data strategy/European Common Data Spaces	https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en	2024
[RD7]	New UCC - EU Communication C/2025/1035, establishing the Union Customs Code and the European Union Customs Authority, and repealing Regulation (EU) No 952/2013	https://taxation-customs.ec.europa.eu/news/milestone-eu-customs-reform-member-states-adopt-common-position-new-union-customs-code-ucc-2025-06-27_en https://eur-lex.europa.eu/eli/C/2025/1035/oj	2025
[RD8]	EU Directive 2024/1203 of 11 April 2024 on the protection of the environment through criminal law	https://eur-lex.europa.eu/eli/dir/2024/1203/oj/eng	2024
[RD9]	Waste Shipments Regulation EU Regulation 2024/1157	https://eur-lex.europa.eu/eli/reg/2024/1157/oj/eng	2024
[RD10]	IAEA Regulations and Safety Standards Series No. SSR-6 for the safe transport of radioactive material	https://www.iaea.org/publications/12288/regulations-for-the-safe-transport-of-radioactive-material	

Id.	Reference	Title	Date
[RD11]	UNECE Working Party on the transport of dangerous goods	https://unece.org/transport/dangerous-goods	
[RD12]	European Agreement concerning the International Carriage of Dangerous Goods by Road	https://unece.org/transport/standards/transport/dangerous-goods/adr-2023-agreement-concerning-international-carriage	
[RD13]	Regulations concerning the International Carriage of Dangerous Goods by Rail	https://www.era.europa.eu/era-railway-terminology-collection/rid/abbreviation_1/freight	
[RD14]	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways	https://unece.org/transport/dangerous-goods/adn-2025	
[RD15]	DRAFT POLICY ON ENVIRONMENTAL CRIMES UNDER THE ROME STATUTE	https://www.icc-cpi.int/sites/default/files/2024-12/2024-12-18-OTP-Policy-Environmental-Crime.pdf	2024
[RD16]	Earth Island Journal	https://www.earthisland.org/journal/index.php	
[RD17]	International Associations of Ports and Harbors	https://www.iaphworldports.org	
[RD18]	Prevention of Illicit Trafficking of Cultural Heritage	https://www.wcoomd.org/en/topics/enforcement-and-compliance/activities-and-programmes/cultural-heritage-programme.aspx	
[RD19]	ANCHISE project	https://www.anchise.eu	
[RD20]	AURORA project	https://www.aurora-euproject.eu	
[RD21]	DEMETER	https://www.wcoomd.org/en/media/newsroom/2024/november/operation-demeter-x.aspx	

Table 27: Reference documents

EUSPA Mission Statement

The mission of the Agency is defined by the EU Space Programme Regulation.

EUSPA's mission is to be the user-oriented operational Agency of the EU Space Programme, contributing to sustainable growth, security and safety of the EU. 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.

EUSPA:

- Provides state-of-the-art, safe and secure positioning, navigation and timing services based on Galileo and EGNOS, cost-effective satellite communications services for EU 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, EU 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.

- 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.

EUSPA: linking space to user needs

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