PASSport Specification and Design
PASSport - D2.4

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EDIT.	DATE	§ - CHANGES	AUTHOR
1.0	29/10/2021	Issue 1.0	PASSport team
1.1	03/12/2021	Update based on DRS. Main corerctions: • Added acronyms • Added justificarion in the table reporting traceabiity between URs and SRs (section 3.3) • Added traceability of user and system requirements used for any pillal functionality/ technology identified in chapter 4. • Section 4.1. Better specified the need for GNSS interference detection • Added req SR-233. PASSPORT AERIAL- DRONE – ROTARY WINGS – ROBUSTNESS AND SAFETY OF AUTONOMOUS MISSION (FUNCTIONAL) • Moved description about GNSS equipment (MAGIC UT and STELLA ewquipment) from ch4 to ch5 (physical architectuire).	PASSport team

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1 INTRODUCTION

1.1 SCOPE

This document aims at presenting the System Requirements generated from User Needs reported in [RD 1] and recommendations derived from the experimental researches reported in [RD 2] and [RD 3]. Finally, the PASSPORT architecture is provided also based on outcomes of technological studies and market analysis ().

The proposed solution will include several technical and operational configurations. These different scenarios will be also used as input for further iterations of [RD 7] to [RD 11]) to finalise an appropriate business model and a viable sell strategy.

1.2 APPLICABLE DOCUMENTS

ID	Description
[AD 1]	GRANT AGREEMENT NUMBER - 101004234

Table 1-1 - Applicable Documents

1.3 REFERENCE DOCUMENTS

ID	Description
[RD 1]	PASSport D1.2 – PASSport user needs
[RD 2]	PASSport D3.14 - System Verification Plan
[RD 3]	PASSport D3.15 - Verification Report (On factory Test results)
[RD 4]	PASSport D2.3 - Regulation for RPAS usage in port areas (issue 1)
[RD 5]	PASSport D5.1 – Stakeholders Database
[RD 6]	PASSport D2.2 – Use cases definition
[RD 7]	PASSport D6.1 Business Model
[RD 8]	PASSport D6.2 Cost Benefit Analysis
[RD 9]	PASSport D6.3 RoadMap
[RD 10]	PASSport D6.4 Business Plan
[RD 11]	PASSport D6.5 Sales Strategy Report

Table 1-2 Reference Documents

1.4 ACRONYMS

Acronym	Description
AIS	Automatic identification system
ALC	Alcina (PASSPORT partner)

Acronym	Description
APRA	Ravenna Port Authority (PASSPORT partner)
ATZ	Air Traffic Zone
BM	Bergman Marine (PASSPORT partner)
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CRM	CEREMA (PASSPORT partner)
CTR	Control Zone
DBL	Deep Blue (PASSPORT partner)
DG1	Digi-one (PASSPORT partner)
DLR	German Aerospace Agency (PASSPORT partner)
DPO	Data Protection Officer
EASA	European Union Aviation Safety Agency
ECAT	EURECAT (PASSPORT partner)
ENV	Environment
FAL	IMO Facilitation Committee
FVP	Valencia Port Foundation (PASSPORT partner)
G7I	G7 International (PASSPORT partner)
GDPR	General Data Protection Regulation
GMV	GMV (PASSPORT partner)
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAMSAR	International Aeronautical and Maritime Search and Rescue
ICAO	International Civil Aviation Organization
ICS	International Chamber of Shipping
IHMA	International Harbour Master Association
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ISPS	International Ship and Port Facility Security
IVEF	Inter VTS Exchange Format
M3S	M3 Systems (PASSPORT partner)
MI	Monitoring and Inspection
MSC	Maritime Security Committee

Acronym	Description
MUS	Maritime University of Szczecin (PASSPORT partner)
OL	Operation and Logistics
OTG	Other Target Groups
PASSPORT	Operational Platform managing a fleet of semi-autonomous drones exploiting GNSS high Accuracy and Authentication to improve Security & Safety in port areas
RPAS	Remotely Piloted Aircraft Systems
SIST	Sistematica S.p.A. (PASSPORT partner)
SOLAS	Safety of Life at Sea
TOP	Topview (PASSPORT partner)
UAV	Unmanned Aerial Vehicle; Drone
UNI-FI	University of Florence (PASSPORT partner)
UR	User Requirement
U-space	Air Traffic Management for drones (UAV)
VLOS	Visual Line of Sight
VTS	Vessel Traffic Service
PFSA	*Port Facility Security Assessment*
PFSP	*Port Facility Security Plan*
PFSO	Port Facility Security Officer
PL	Protection Level
JRC	Joint Research Center
TAPS	Study on the technical aspects of port security
E-GNSS	Enhanced (European) GNSS
GNSS	Global Navigation Satellite System

Table 1-3 Acronyms

2 PASSPORT CONTEXT

2.1 THE NEED FOR IMPROVING SECURITY AND SAFETY

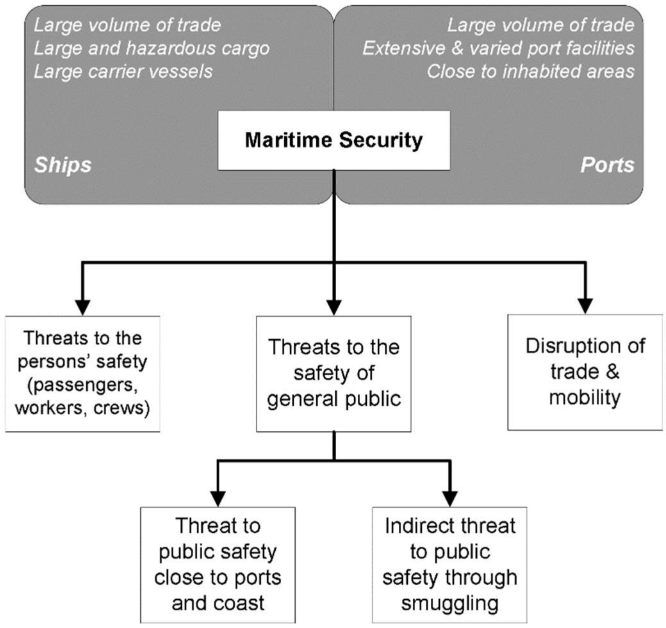

Figure 2-1 Breakdown of the maritime security threats

In response to the tragic events of 11th September 2001 and the growing concern for the security, the International Maritime Organization (IMO) agreed to define and implement a new security regime of maritime transport, the cornerstone of which is the International Ship and Port Facility Security (ISPS) code operative since 2004,. The **ISPS code** constitutes an amendment to the **(SOLAS) convention** on minimum security arrangements for ships and port facilities. It establishes international cooperation to take preventative measures against any threats to people safety, infrastructures, and trade. The cornerstone of ISPS code is the *Port Facility Security Assessment* (PFSA), an essential and integral part of the process of developing and updating the *Port Facility Security Plan* (PFSP). The assessment is periodically reviewed and updated, taking into account changing threats and/or minor changes in the port facility and should, in any case, be reviewed and updated upon major changes to the port facility. It has been transposed to the Community legal framework by the Regulation (EC) 725/2004. The prime target of ISPS and the Regulation 725/2004 is the security of the maritime vessels and their land interfaces. Port facilities (or terminals) are the elementary vessel / land interfaces and, as such, are the building blocks of port security. It is prescribed that each port facility should have a Port Facility Security Officer (PFSO), a Port Facility Security Plan (PFSP) duly formulated after a dedicated risk analysis and approved by the National Authorities of the Member States. Member States and European Commission carry out inspections on the practical application of the above. Moreover, Regulation 725/2004 has been extended into the whole port area by the Directive 2005/65/CE to complement the mechanism provided for by establishing a security system for all of the port area, in order to ensure a high and equal level of security for all European ports. **Around one thousand European ports fall within the scope of the directives.** The European Commission (DG MOVE and DG HOME) asked the Joint Research Centre (JRC) to carry out a study on the implementation of the Directive in European ports, namely "Study on the technical aspects of port security (TAPS II)". Main threats have been identified as:

Protection against non-cooperative small craft approaching the port. Indeed, small fast crafts can move so fast and in such agility that it is difficult to track them with radar systems in the complex and cluttered port environment.
Daily operations monitoring: identification of threats to improve the flow of trade (e.g. terrorism). In particular, critical threats are represented by: ✓ Underwater objects approaching the port area form the sea side ✓ Attack against critical infrastructures

Table 2-1 Main security threats as identified by TAPS II

TAPS II also clearly indicates that surveillance is a key element to prevent smuggling or attack from the sea. Surveillance systems include two broad classes of systems:

- ✓ *Cooperative reporting or messaging systems*: such systems rely mainly on the complying ships that furnish, automatically or on request, the necessary information. They include Vessel Monitoring System (VMS), Automatic Identification System (AIS) and many non-automatic reporting systems and regimes;
- ✓ *Non-cooperative sensor based systems* such as radars and cameras that collect information about ships even without their cooperation.

In the past, serious maritime accidents occurred close to European coastlines; in particular, on 12th December 1999, during severe weather conditions, the Maltese registered tanker Erika broke in two pieces 70 km off the coast of Brittany, France, whilst carrying approximately 30000 tons of heavy oil. This accident has led to severe pollution of 450 km of coastline. The economic consequences of the incident have been felt across the region: a drop in the income from tourism, loss of income from fishing and, as a more recent development, a ban on the trade of sea products, including oysters and crabs, have added to the discomfort of local populations.

Now, based on the above reference, safety management in port areas involves the identification of the most significant hazards and the systematic assessment of the risks that those hazards pose under foreseeable circumstances.

Moving Vehicles and Equipment: Movement of vessels/ships | Loading and unloading roll on roll off ferries | Movement of tractors on dockside | Container lifting and handling plant | Forklift trucks | Positioning of dockside plant and equipment (risk of collision, risk in poor visibility in holds)
Fire and Explosions: Flammable liquids and gases | Explosive or chemically unstable cargo | Spontaneous combustion (e.g. bulk coal) |Airborne dusts
Hazardous or asphyxiant atmospheres: Volatile hazardous chemicals | Respiratory sensitizers (flour) | Confined spaces containing low oxygen, high carbon dioxide (holds containing ripening fruit) | Confined spaces containing toxic residues (tankers with residual hydrocarbons, fumigated holds or containers).
Weather Hazards: Cold or wet weather makes manual handling tasks more difficult | Hot weather heat exhaustion, sunstroke | Wet, icy conditions cause slips, trips and falls.
Tidal Movement Hazards: Access and egress from vessels | Reduction of visibility during loading operations | Collision between dockside equipment and vessel.
Slips and trips: Wet or icy surfaces | Badly stowed ropes, cables, lashings and other equipment| Discarded packing, pallets or rubbish.
Falling objects: Lifting and suspension of loads and stacks of cargo (paper, timber, steel etc.) | Lashing bars and fittings for freight containers | Loose items on pallets.
Falls from height: Pedestrian access to ships – gangways | Working on container tops| Container lashing | Open holds on ships | Falling from stowed cargo| Covering cargo on trucks| Wind conditions and wave movement.

Table 2-2 Environmental Hazard in port area

2.2 PASSPORT SOLUTION: EXTENDED SITUATIONAL AWARENESS TO FEED SECURITY AND SAFETY MANAGEMENT PLATFORM

The vision of PASSport is based on the introduction of a **fleet of automated aerial (rotary wings and fixed wings) and underwater drones** concept to provide a tangible contribution on operational procedures to mitigate the risks in port areas. Whereas in the last month a lot of activities are initiated in port areas involving drones, the **concept of a fleet represents a complete novelty making the solution more resilient against external attacks or accidental events** (e.g. bad weather conditions)

In particular, the drones will combine state of the art technologies to collect on field data in real time. This allows **surveillance with an extended situational awareness (by covering larger areas)**. Indeed, to date, operational activities to guarantee security and safety are dealing with static sensors (radar, CCTV, cooperative systems as AIS, e-navigation), whereas collected data **cannot automatically trigger dedicated operational procedures**. This approach represents a KEY limitation of current practices which PASSport vision aims to overcome by proposing **a holistic surveillance solution**.
The solution will be connected with **already deployed (installed in port facilities) operational platforms** and exploits the innovation brought by **RPAS assisted with EGNSS technology,** in particular as an input for the Guidance, Navigation and Control system allowing the planning and execution of **safe and accurate trajectories**.

The number of configurable fleet elements including aerial rotary wings/fixed wings/ tethered and underwater shall allow to cover extended areas. It is noted that the fixed wing drone contributes definitely to this achievement. Moreover, the installed payload (mainly optical cameras) shall allow to cover large areas also using drones hovering at a fixed point (as the tethered drone use case).

3 SYSTEM REQUIREMENTS

3.1 METHODOLOGY

3.1.1 REQUIREMENTS CLASSIFICATION

3.1.1.1 FUNCTIONAL REQUIREMENTS

This kind of system requirements identifies the functionalities to be implemented by the PASSport system.

3.1.1.2 PERFORMANCE REQUIREMENTS

This kind of system requirement identifies the performances to be attained by the PASSport system.

3.1.2 VERIFICATION METHODS

The following verification methods have been taken into account:

- Test
- Analysis
- Review of Design
- Inspection

3.1.2.1 TEST (T)

Compliance with requirements is validated by executing an item under controlled conditions, configurations, and inputs in order to observe the response. Results are quantified and analyzed in dedicated test reports

3.1.2.2 ANALYSIS (A)

Compliance with requirements is determined by interpreting results using established principles as statistics, qualitative design analysis, modelling and computer simulation.

3.1.2.3 REVIEW OF DESIGN (ROD)

Compliance with requirements is validated by using existing records or evidences as Validated design documents, approved design reports, technical descriptions, engineering drawings

3.1.2.4 INSPECTION (I)

Compliance with requirements is determined by by visual determination of physical characteristics which include constructional features, hardware conformance to document drawing or workmanship requirements, physical conditions, software source code conformance with coding standards

Further details are reported in [RD 2]

3.2 REQUIREMENTS CATALOGUE

SR ID	ReqTitle	Type	Verification Method
SR-010	PASSport solution	Functional	A
SR-020	PASSport aerial drone - rotary wings	Functional	A
SR-030	PASSport aerial drone - rotary wings tethered	Functional	A
SR-040	PASSport aerial drone - fixed wings	Functional	A
SR-050	PASSport underwater drone	Functional	A
SR-060	PASSport ground - control	Functional	A
SR-070	PASSport ground - mission	Functional	A
SR-080	PASSport ground - Security Monitoring Procedures	Functional	T
SR-090	PASSport ground - Vessels traffic monitoring – drones and vessels positions	Functional	T
SR-095	PASSport ground - Vessels traffic monitoring - AIS-based vessels positions	Functional	T
SR-100	PASSport ground - GNSS Interference Detection	Performance	T
SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication	Performance	T
SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy	Performance	T
SR-140	PASSport aerial drone - rotary wings - communications availability	Performance	T
SR-150	PASSport aerial drone - rotary wings - operations continuity	Performance	T
SR-160	PASSport aerial drone - rotary wings - environmental conditions	Performance	T
SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree	Performance	T
SR-175	PASSport aerial drone - rotary wings - coverage	Performance	T
SR-190	PASSport aerial drone - rotary wings tethered - GNSS Rx payload - accuracy	Performance	T
SR-200	PASSport aerial drone - rotary wings tethered - communications availability	Performance	T
SR-210	PASSport aerial drone - rotary wings tethered - operations continuity	Functional	T
SR-220	PASSport aerial drone - rotary wings tethered - environmental conditions	Performance	T
SR-230	PASSport aerial drone - rotary wings tethered - autonomy of mission degree	Performance	T
SR-235	PASSport aerial drone - rotary wings tethered - coverage	Performance	T
SR-250	PASSport aerial drone - fixed wings - GNSS Rx payload - authentication	Functional	T
SR-260	PASSport aerial drone - fixed wings - GNSS Rx payload - accuracy	Functional	T
SR-270	PASSport aerial drone - fixed wings - communications availability	Performance	T
SR-280	PASSport aerial drone - fixed wings - operations continuity	Performance	T
SR-290	PASSport aerial drone - fixed wings - environmental conditions	Performance	T
SR-300	PASSport aerial drone - fixed wings - autonomy of missions degree	Performance	T
SR-305	PASSport aerial drone - fixed wings - coverage	Performance	T
SR-306	PASSport underwater drone - operations	Functional	A
SR-310	PASSport underwater drone - GNSS Rx payload (buoy) - accuracy	Performance	T
SR-320	PASSport underwater drone - communication availability	Performance	T
SR-330	PASSport underwater drone - operations continuity	Performance	T
SR-340	PASSport underwater drone - environmental conditions	Performance	T
SR-350	PASSport underwater drone - autonomy of mission degree	Performance	T
SR-355	PASSport underwater drone - coverage	Performance	T
SR-360	PASSport algorithms - vessels recognition	Performance	T
SR-370	PASSport algorithms - vessels location	Performance	T
SR-380	PASSport algorithms - ground object recognition	Performance	T

SR ID	ReqTitle	Type	Verification Method
SR-390	PASSport algorithms - ground object location	Performance	T
SR-400	PASSport algorithms - air monitoring	Performance	T
SR-405	PASSport algorithms - water monitoring	Performance	T
SR-410	PASSport algorithms - mixed reality support	Functional	T
SR-420	PASSport algorithms - Sentinel 5P - air pollution	Performance	T
SR-430	PASSport algorithms - Sentinel 1 - small ship detection	Performance	T
SR-440	PASSport algorithms - Sentinel-1 - wind speed map	Performance	T
SR-450	PASSport algorithms - EGMS	Performance	T
SR-470	PASSport ground - data and process management	Functional	T
SR-480	PASSport ground - data archiving and retrieving	Functional	T
SR-490	PASSport ground - data export and final report	Functional	T

Table 3-1 Requirements Summary

3.2.1 SR-010. PASSPORT SOLUTION (A)

PASSport solution will be based on the usage of a scalable fleet of aerial and underwater (UD) drones and satellite-based technologies (GNSS +EO) providing:
- situational awareness solutions in BVLOS scenarios using video streaming (near real time) and object detection and identification
- quantitative data collection for post processing analysis
Verification method: A

3.2.2 SR-020. PASSPORT AERIAL DRONE - ROTARY WINGS (FUNCTIONAL)

The Passport solution shall include an aerial drone in the configuration free flight for surveillance and monitoring of dedicated areas for limited time
Verification method: A

3.2.3 SR-030. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED (FUNCTIONAL)

The Passport solution shall include an aerial drone in the configuration tethered for surveillance and monitoring of large areas for continuous operations
Verification method: A

3.2.4 SR-040. PASSPORT AERIAL DRONE - FIXED WINGS (FUNCTIONAL)

The Passport solution shall include a fixed wing drone which shall be able to perform autonomous and teleoperated aerial operations for surveillance and monitoring of large areas for long-range operations
Verification method: A

3.2.5 SR-050. PASSPORT UNDERWATER DRONE (FUNCTIONAL)

The Passport solution shall include an Underwater drone (UD) capable of performing autonomous as well as teleoperated underwater inspection operations. Endowed with high-grade sensors, the UD shall be able to achieve high-precision surveys while autonomously gathering knowledge of the surrounding environment. The UD shall be equipped

with a small towed buoy ensuring a Wi-Fi communication link with external control stations and the aerial drone (AD) whilst supplying GNSS measurements.
Verification method: A

3.2.6 SR-060. PASSPORT GROUND - CONTROL (FUNCTIONAL)

The PASSport solution shall have control Module Element allowing the pilot to manage C2 link with the drone fleet and to implement emergency procedures in case any failure occurs to the link. This element shall been conceived in order to be compliant with regulation for scenarios involving aerial drones.
Each drone shall have its control module physically independent.
Verification method: A

3.2.7 SR-070. PASSPORT GROUND - MISSION (FUNCTIONAL)

The PASSport platform shall allow the operator to visualise a dedicated HMI for each mission which shall include the features as in the following picture.
See table Req SR.0070
Verification method: A

3.2.8 SR-080. PASSPORT GROUND - SECURITY MONITORING PROCEDURES (FUNCTIONAL)

The Passport solution shall include a security monitoring platform including a catalogue of Threats, relevant procedures to be used in case of threats triggering and relevant profiles of actors involved in procedure execution.
Verification method: T

3.2.9 SR-090. PASSPORT GROUND - VESSELS TRAFFIC MONITORING – DRONES AND VESSELS POSITIONS (FUNCTIONAL)

The PASSport platform shall include an specific platform element showing on a map the position of all the vessels and drones involved in the scenario in near real time.
Verification method: T

3.2.10 SR-095. PASSPORT GROUND - VESSELS TRAFFIC MONITORING - AIS-BASED VESSELS POSITIONS (FUNCTIONAL)

The PASSport platform shall include an specific platform element providing the collaborative vessels data collected from AIS
Verification method: T

3.2.11 SR-100. PASSPORT GROUND - GNSS INTERFERENCE DETECTION (PERFORMANCE)

The PASSport platform shall include an interference detection platform which shall detect and report to the end-user the presence of continuous(1) RF interference (RFI) in the bands 1575.42 +/- 15.345 MHz and 1191.795 +/- 46.035 MHz.
The minimum RFI power level to be detected by the product shall be specified w.r.t. the useful GNSS signal power over the specified bandwidth. Thus the resulting minimum RFI that the product shall detect is for a J/S equal to 20 dB(2).
The product will summarize and present the occurrence of RFI events on a human-machine interface (i.e., a web control panel) and/or notify the end-user via email.
Note 1: Interference can be either continuous or pulsed in the time domain.
Note 2: J/S – jammer-to-signal ratio

Verification method: T

3.2.12 SR-120. PASSPORT AERIAL DRONE - ROTARY WINGS - GNSS RX PAYLOAD - AUTHENTICATION (PERFORMANCE)

PASSport solution shall use an authentication mechanism to increase the robustness of the drone position computation.
NOTE: Galileo OS-NMA (when available) will be able to provide GNSS navigation data authentication.
Verification method: T

3.2.13 SR-130. PASSPORT AERIAL DRONE - ROTARY WINGS - GNSS RX PAYLOAD - ACCURACY (PERFORMANCE)

PASSport solution shall provide accurate drone positioning data using E-GNSS.
NOTE: This High accuracy solution may be based on SBAS (EGNOS), Galileo High Accuracy (when available) or PPP.
Verification method: T

3.2.14 SR-140. PASSPORT AERIAL DRONE - ROTARY WINGS - COMMUNICATIONS AVAILABILITY (PERFORMANCE)

The tethered aerial drone shall be able to implement a suitable communication mechanism (i.e. 5G/ 4G LTE/4G-NB-IOT) for bidirectional real time communication
Verification method: T

3.2.15 SR-150. PASSPORT AERIAL DRONE - ROTARY WINGS - OPERATIONS CONTINUITY (PERFORMANCE)

The aerial drone shall be able to guarantee a continuity of operations in the ratio 1:2 (25 m operations - 50 minutes for recharge - 25 minutes operations -...)
Verification method: T

3.2.16 SR-160. PASSPORT AERIAL DRONE - ROTARY WINGS - ENVIRONMENTAL CONDITIONS (PERFORMANCE)

The aerial drone shall be able to sustain a wind of 10 m/s (gust 12 m/s)
Verification method: T

3.2.17 SR-170. PASSPORT AERIAL DRONE - ROTARY WINGS - AUTONOMY OF MISSION DEGREE (PERFORMANCE)

The aerial drone shall be able to guarantee an autonomy of 25 minutes at least for each flight before recharging
Verification method: T

3.2.18 SR-175. PASSPORT AERIAL DRONE - ROTARY WINGS - COVERAGE (PERFORMANCE)

The aerial drone shall guarantee an coverage of 1,5 km x 1,5 km area for inspection in free flight configuration
Verification method: T

3.2.19 SR-190. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED - GNSS RX PAYLOAD - ACCURACY (PERFORMANCE)

The tethered aerial drone shall be able to embark a GNSS Rx payload which accuracy, in combination with IMU performance, shall be able guarantee the localization of a given ground object (ship) of 100 meters for each Nautical Mile of distance (100 meters of accuracy for 1852 meters of horizontal distance)
Verification method: T

3.2.20 SR-200. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED - COMMUNICATIONS AVAILABILITY (PERFORMANCE)

The tethered aerial drone shall be able to implement a suitable communication mechanism (i.e. 5G/ 4G LTE/4G-NB-IOT) for bidirectional real time communication
Verification method: T

3.2.21 SR-210. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED - OPERATIONS CONTINUITY (FUNCTIONAL)

The tethered aerial drone shall be able to perform the surveillance operations in continuity during the demonstration mission (without landing).
Verification method: T

3.2.22 SR-220. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED - ENVIRONMENTAL CONDITIONS (PERFORMANCE)

The tethered aerial drone shall be able to fly in continuity up to 70 meters with a maximum wind condition of 10 m/s (12 m/s gusts)
Verification method: T

3.2.23 SR-230. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED - AUTONOMY OF MISSION DEGREE (PERFORMANCE)

The tethered aerial drone shall guarantee an autonomy of continuous operations for 8 hours
remark: pilots handover apply as by normal UAS operator procedures.
Verification method: T

3.2.24 SR-233. PASSPORT AERIAL- DRONE – ROTARY WINGS – ROBUSTNESS AND SAFETY OF AUTONOMOUS MISSION (FUNCTIONAL)

The autonomous mission performed by the drone shall be able to respond to disruptive events (e.g., critical battery, loss of precision E-GNSS module, etc) by either re-planning the mission, returning to starting point or switching to manual control and waiting for the safety pilot commands. Verification method: T

3.2.25 SR-235. PASSPORT AERIAL DRONE - ROTARY WINGS TETHERED - COVERAGE (PERFORMANCE)

The tethered aerial drone shall guarantee an coverage of 7 NM in day conditions or 2 NM in night conditions
Remark: A small boat of 12 meters is detected at 7 NM of distance in daylight conditions or 2 NM in night conditions.
Verification method: T

3.2.26 SR-250. PASSPORT AERIAL DRONE - FIXED WINGS - GNSS RX PAYLOAD - AUTHENTICATION (FUNCTIONAL)

The fixed wing drone shall allow the recording of the GNSS SiS during each mission to feed post treatment for OS NMA Galileo service evaluation
Verification method: T

3.2.27 SR-260. PASSPORT AERIAL DRONE - FIXED WINGS - GNSS RX PAYLOAD - ACCURACY (FUNCTIONAL)

The fixed wing drone shall allow the recording of the GNSS SiS during each mission to feed post treatment for HAS Galileo service evaluation
Verification method: T

3.2.28 SR-270. PASSPORT AERIAL DRONE - FIXED WINGS - COMMUNICATIONS AVAILABILITY (PERFORMANCE)

The PASSport fixed wing drone shall have a
- C2 communication (operator in control) range of 50km needed to achieve mission (50 Nm available today via SATCOM)
- Payload control: bandwidth to allow live stream image (today capability: 70-80km in HF, NOT SATCOM)

Verification method: T

3.2.29 SR-280. PASSPORT AERIAL DRONE - FIXED WINGS - OPERATIONS CONTINUITY (PERFORMANCE)

The PASSport fixed wing drone shall be able to perform missions of maximum 8hours / 800km
Verification method: T

3.2.30 SR-290. PASSPORT AERIAL DRONE - FIXED WINGS - ENVIRONMENTAL CONDITIONS (PERFORMANCE)

The PASSport fixed wing drone shall be able to operate in the VMC conditions under a maximum wind of 60km/h. The operation shall be in VMC conditions which implies that below 3000ft

- ✓ the visibility will need to be minimum of 5000m
- ✓ clear of clouds (1500m horizontally and 300m vertically)

Moreover, PASSport fixed wing drone shall be able to operate in temperature conditions above 0 degrees Celsius (no de-icing for motor or wings).

Verification method: T

3.2.31 SR-300. PASSPORT AERIAL DRONE - FIXED WINGS - AUTONOMY OF MISSIONS DEGREE (PERFORMANCE)

The PASSport fixed wing drone shall be able to perform mission with partial automation:
- Management of flight: System Lateral/Longitudinal and vertical control + Object and event detection and response: Pilot-in-command
- Management of flight fallback: Pilot-in-Command
- Operational Design Domain: Limited

Verification method: T

3.2.32 SR-303. PASSPORT AERIAL- DRONE – ROTARY WINGS – ROBUSTNESS AND SAFETY OF AUTONOMOUS MISSION (FUNCTIONAL)

The autonomous mission performed by the drone shall be able to respond to disruptive events (e.g., critical battery, loss of precision E-GNSS module, etc) by either re-planning the mission, returning to starting point or switching to manual control and waiting for the safety pilot commands. Verification method: T

3.2.33 SR-305. PASSPORT AERIAL DRONE - FIXED WINGS - COVERAGE (PERFORMANCE)

The PASSport fixed wing drone shall be able to detect at 600m altitude and give a clear identification at 200m altitude. Verification method: T

3.2.34 SR-306. PASSPORT UNDERWATER DRONE - OPERATIONS (FUNCTIONAL)

The UD shall be able to perform the following operations:
- Sensor-driven coverage planning strategies for AUVs seabed inspections
- 2D underwater optical and acoustic mosaicking and bathymetric analysis
- Scene understanding for unmanned vehicles, from optical and acoustic payloads
- Underwater autonomous navigation for AUVs supported by visual and acoustic payloads

Verification method: A

3.2.35 SR-310. PASSPORT UNDERWATER DRONE - GNSS RX PAYLOAD (BUOY) - ACCURACY (PERFORMANCE)

The buoy physically linked to the UD shall have a localization accuracy of 2 m in order to have an underwater navigation error: < 5% of the travelled distance
Verification method: T

3.2.36 SR-320. PASSPORT UNDERWATER DRONE - COMMUNICATION AVAILABILITY (PERFORMANCE)

The buoy physically linked to the UD shall have a coomunciation range of 100 m (using Wi-Fi channel)
Verification method: T

3.2.37 SR-330. PASSPORT UNDERWATER DRONE - OPERATIONS CONTINUITY (PERFORMANCE)

The UD shall guarantee operation continuity for at least 4h
Verification method: T

3.2.38 SR-340. PASSPORT UNDERWATER DRONE - ENVIRONMENTAL CONDITIONS (PERFORMANCE)

The underwater drone (UD) shall be used up to sea state 2 (wave height: 0.1 to 0.5 metres), navigating autonomously facing underwater currents up to 1 kn. The UD shall operate with a water temperature varying from 0°C up to 30°C. The UD shall dive up to a maximum depth of 30 m scanning the sea bottom at a higher depth (of about 100 m with a FLS) depending on the considered acoustic of optical payload.
Verification method: T

3.2.39 SR-350. PASSPORT UNDERWATER DRONE - AUTONOMY OF MISSION DEGREE (PERFORMANCE)

The underwater drone (UD) shall have a E2/E3 autonomy levels (ESA standard):
- E2 - Execution of pre-planned mission operations on-board.
- E3 - Execution of adaptive mission operations on-board.

Verification method: T

3.2.40 SR-355. PASSPORT UNDERWATER DRONE - COVERAGE (PERFORMANCE)

The underwater drone (UD) shall cover an area of 10.000 m^2 per mission considering an acoustic mosaicing task using a Forward Looking Sonar
Verification method: T

3.2.41 SR-360. PASSPORT ALGORITHMS - VESSELS RECOGNITION (PERFORMANCE)

The vessel detection algorithm shall be able to detect multiple vessel objects captured within the on-board sensors field of view. The maximum detection range will be between 3 km, with a detection accuracy higher than 90%.
Verification method: T

3.2.42 SR-370. PASSPORT ALGORITHMS - VESSELS LOCATION (PERFORMANCE)

The detected vessels shall have a localization accuracy below 20 m.
Verification method: T

3.2.43 SR-380. PASSPORT ALGORITHMS - GROUND OBJECT RECOGNITION (PERFORMANCE)

The detection algorithm shall be able to detect multiple ground objects captured within the on-board sensors field of view. The maximum detection range will be of approximately 500 m, with a detection accuracy higher than 90%.
Verification method: T

3.2.44 SR-390. PASSPORT ALGORITHMS - GROUND OBJECT LOCATION (PERFORMANCE)

The detected ground objects shall have a localization accuracy between 5-10 m.
Verification method: T

3.2.45 SR-400. PASSPORT ALGORITHMS - AIR MONITORING (PERFORMANCE)

Passport solution shall be able to monitor air quality, including in particular the following sensors:
- PM (0,3 – 10 um)

- O3 sensor (0-10 ppm)
- SO2 sensor (0- 10 ppm)
- NO2 sensor (0-10 ppm)

Verification method: T

3.2.46 SR-405. PASSPORT ALGORITHMS - WATER MONITORING (PERFORMANCE)

Passport solution shall be able to remotely monitor water quality, including in particular the following sensors:

- UV camera (PCO-UV 14 bit CCD camera - 1392x1040, 190nm – 1100nm)
- Visible spectrum camera (Zenmuse H20t, 1/1.7 CMOS, 20 MP, 20x zoom)
- Multi spectrum visible light camera (Mica sense RedEdge MX dual camera with spectrum: coastal blue 444nm, blue 475nm, green 531nm, green 560nm, red 650nm, red 668nm, red edge 705nm, red edge 717nm, red edge 740nm, NIR 842nm, 1280 x 960 – 1.2 MP per band))
- IR (thermal) camera (640×512 @ 30 Hz)
- Laser range finder (1200m +/-0,2m)

Verification method: T

3.2.47 SR-410. PASSPORT ALGORITHMS – MIXED REALITY SUPPORT (FUNCTIONAL)

PASSport shall provide advanced 3d, realtime visualization of mission status by the use of a dedicated Mixed Reality device. Basic functionality shall provide real-time visualisation of aerial drone position in relation to the area, planned mission trajectory and access to available real-time data streams
Verification method: T

3.2.48 SR-420. PASSPORT ALGORITHMS - SENTINEL 5P - AIR POLLUTION (PERFORMANCE)

PASSport solution shall use Copernicus Sentinel-5P mission to perform atmospheric measurements with high spatio-temporal resolution, to be used for air quality and to assess the air pollution. Measurements of pollutant shall include Methane, Tropospheric Ozone (Offline); Carbon Monoxide, Formaldehyde, Nitrogen Dioxide, Sulphur Dioxide, etc.
Note. The Sentinel-5P has spatial resolution up to 5.5 km (in azimuth direction) x 3.5 km (range direction) with a revisit time of the orbit of about one day.
Verification method: T

3.2.49 SR-430. PASSPORT ALGORITHMS - SENTINEL 1 - SMALL SHIP DETECTION (PERFORMANCE)

PASSport solution shall use Copernicus Sentinel-1 to potentially detect small ships having a spatial resolution of 5x20 m.
Note. Sentinel-1 uses wide area coverage with revisit times up to 6 days. The mission's ability to observe in all weather and in day or night time makes it ideal for precise cueing and location of ship activities at sea, allowing for more efficient and cost-effective use of other security assets, such as patrol aircraft and ships.
Verification method: T

3.2.50 SR-440. PASSPORT ALGORITHMS - SENTINEL-1 - WIND SPEED MAP (PERFORMANCE)

Sentinel-1 IW (Wide swath) data can be also processed in order to retrieve wind speed maps at various resolution (up to a few tens of meters) through Geophysical Model Functions (GMF) which relate the calibrated radar return to the wind

speed at a height of 10m. Indeed, the wind speed across a water surface induce wave roughness which affect the radar signal.
Verification method: T

3.2.51 SR-450. PASSPORT ALGORITHMS - EGMS (PERFORMANCE)

PASSport solution shall use Copernicus Sentinel-1 data being processed in the framework of the European Ground Motion Service. Interferometric techniques shall be implemented in order to retrieve consistent, regular, standardised, harmonised and reliable information regarding natural and anthropogenic ground motion phenomena over Europe and across national borders, with millimetric accuracy.
Verification method: T

3.2.52 SR-470. PASSPORT GROUND - DATA AND PROCESS MANAGEMENT (FUNCTIONAL)

The PASSport platform shall be able to manage operational processes including
- near real time video for context awareness
- materiel sample gathering
- dedicated campign planning
- data acquistion including optical/thermal pictures, optical/thermal videos, orthomosaics, 3D reconstructions
- data processing
- data validation
- final reporting
- alerting

Verification method: T

3.2.53 SR-480. PASSPORT GROUND - DATA ARCHIVING AND RETRIEVING (FUNCTIONAL)

PASSport system shall have functionalities to archive and catalogue the processed/ captured foto/video streams. Moreover, when needed, such data has to be accessed an retrieved for further investigations (performed by an operator)
Verification method: T

3.2.54 SR-490. PASSPORT GROUND - DATA EXPORT AND FINAL REPORT (FUNCTIONAL)

PASSport system shall have functionalities to export (i.e. download) the catalogued data (photo/video and relevant metadata) allowing the operator to access it also outside the PASSport main application.
Verification method: T

3.3 SYSTEM REQUIREMENTS SUMMARY AND TRACEABILITY VS USER REQUIREMENTS

In this section, a table summarising the requirements is reported also indicating

- ✓ type and the verification method according to the methodology reported in [RD 4]
- ✓ traceability versus User needs is reported in Table 3-2

<table>
<tr><th>UR_ID</th><th>Title</th><th>SR ID</th><th>ReqTitle</th></tr>
<tr><td>UR-010</td><td>Scope</td><td>SR-010</td><td>PASSport solution</td></tr>
<tr><td colspan="4">Justification
Directive 2005/65/CE to complement the mechanism provided for by establishing a security system for all of the port area, in order to ensure a high and equal level of security for all European ports. Accordingly, PASSport solution shall provide a solution based on a fleet aerial and underwater drones extending situational awareness and providing a holistic surveillance solution to improve safety and security in port areas</td></tr>
<tr><td>UR-020</td><td>Reliability in Port environment</td><td>SR-160
SR-220
SR-290
SR-340</td><td>PASSport aerial drone - rotary wings - environmental conditions
PASSport aerial drone - rotary wings tethered - environmental conditions
PASSport aerial drone - fixed wings - environmental conditions
PASSport underwater drone - environmental conditions</td></tr>
<tr><td colspan="4">Justification
PASSport solution shall be reliable when operating in port environment which is characterised by:
✓ large steel construction like ships, cranes towers, warehouses, containers stacks generating possible GNSS multipath and calibration of compasses:
✓ traffic of ships and cars and rail
✓ hazardous materials
✓ transitional area between water and land
✓ salinity and humidity
✓ strong wind
✓ fog
✓ presence of birds
Accordingly, the proposed fleet of drones has to be designed to cope with these environmental conditions usual of port areas.</td></tr>
<tr><td>UR-030</td><td>Operating weather conditions</td><td>SR-160
SR-220
SR-290</td><td>PASSport aerial drone - rotary wings - environmental conditions
PASSport aerial drone - rotary wings tethered - environmental conditions
PASSport aerial drone - fixed wings - environmental conditions</td></tr>
</table>

UR_ID	Title	SR ID	ReqTitle
		SR-340	PASSport underwater drone - environmental conditions

Justification

UR-30 is a complement to UR-20 concerning weather conditions (e. g. operating temperature, winds velocity and light rain, wave conditions).
The selected drone fleet shall be in compliance to operate in thiese environment conditions

UR_ID	Title	SR ID	ReqTitle
UR-040	Safety and security missions	SR-010	PASSport solution

Justification

This UR identifies the expected missions/ operations which can be improved with PASSport technology, namely:

- ✓ Pollution monitoring (safety)
- ✓ Support to e-navigation (safety)
- ✓ Critical buildings/ Infrastructures protection (security)
- ✓ Protection against non-cooperative small craft approaching the port areas (security)
- ✓ Underwater threats monitoring (security)

It is traced to the SR identifying the PASSport solution composition.

UR_ID	Title	SR ID	ReqTitle
UR-050	Pollution monitoring	SR-020	PASSport aerial drone - rotary wings
		SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication
		SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy
		SR-140	PASSport aerial drone - rotary wings - communications availability
		SR-150	PASSport aerial drone - rotary wings - operations continuity
		SR-160	PASSport aerial drone - rotary wings - environmental conditions
		SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree
		SR-400	PASSport algorithms - air monitoring
		SR-410	PASSport algorithms - mixed reality support
		SR-420	PASSport algorithms - Sentinel 5P - air pollution
		SR-440	PASSport algorithms - Sentinel-1 - wind speed map
		SR-470	PASSport ground - data and process management
		SR-480	PASSport ground - data archiving and retrieving
		SR-490	PASSport ground - data export and final report

UR_ID	Title	SR ID	ReqTitle
Justification			
This UR identifies a dedicated mission about Pollution monitoring. Relevant traced system Requirements identifies the expected architecture, algorithm and configuration			
UR-060	E-navigation support	SR-020	PASSport aerial drone - rotary wings
		SR-030	PASSport aerial drone - rotary wings tethered
		SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-080	PASSport ground - Security Monitoring Procedures
		SR-090	PASSport ground - Vessels traffic monitoring - drones and vessels positions
		SR-095	PASSport ground - Vessels traffic monitoring – AIS-based vessels positions
		SR-100	PASSport ground - GNSS Interference Detection
		SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication
		SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy
		SR-140	PASSport aerial drone - rotary wings - communications availability
		SR-150	PASSport aerial drone - rotary wings - operations continuity
		SR-160	PASSport aerial drone - rotary wings - environmental conditions
		SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree
		SR-190	PASSport aerial drone - rotary wings tethered - GNSS Rx payload - accuracy
		SR-200	PASSport aerial drone - rotary wings tethered - communications availability
		SR-210	PASSport aerial drone - rotary wings tethered - operations continuity
		SR-220	PASSport aerial drone - rotary wings tethered - environmental conditions
		SR-230	PASSport aerial drone - rotary wings tethered - autonomy of mission degree
		SR-233	Passport aerial- drone – rotary wings – robustness and safety of autonomous mission
		SR-360	PASSport algorithms - vessels recognition
		SR-370	PASSport algorithms - vessels location
		SR-430	PASSport algorithms - Sentinel 1 - small ship detection
		SR-450	PASSport algorithms - EGMS
		SR-470	PASSport ground - data and process management
		SR-480	PASSport ground - data archiving and retrieving

UR_ID	Title	SR ID	ReqTitle
		SR-490	PASSport ground - data export and final report
Justification			
This UR identifies a dedicated mission about e-Navigation support. Relevant traced system Requirements identifies the expected architecture, algorithm and configuration			
UR-070	Infrastructures protection	SR-020	PASSport aerial drone - rotary wings
		SR-030	PASSport aerial drone - rotary wings tethered
		SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-080	PASSport ground - Security Monitoring Procedures
		SR-090	PASSport ground - Vessels traffic monitoring – drones and vessels positions
		SR-095	PASSport ground - Vessels traffic monitoring - AIS-based vessels positions
		SR-100	PASSport ground - GNSS Interference Detection
		SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication
		SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy
		SR-140	PASSport aerial drone - rotary wings - communications availability
		SR-150	PASSport aerial drone - rotary wings - operations continuity
		SR-160	PASSport aerial drone - rotary wings - environmental conditions
		SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree
		SR-380	PASSport algorithms - ground object recognition
		SR-390	PASSport algorithms - ground object location
		SR-430	PASSport algorithms - Sentinel 1 - small ship detection
		SR-450	PASSport algorithms - EGMS
		SR-470	PASSport ground - data and process management
		SR-480	PASSport ground - data archiving and retrieving
		SR-490	PASSport ground - data export and final report
Justification			
This UR identifies a dedicated mission about Infrastructures' protection. Relevant traced system Requirements identifies the expected architecture, algorithm and configuration			
UR-080	Protection against non-cooperative small crafts approaching the port areas	SR-020	PASSport aerial drone - rotary wings

UR_ID	Title	SR ID	ReqTitle
		SR-030	PASSport aerial drone - rotary wings tethered
		SR-040	PASSport aerial drone - fixed wings
		SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-080	PASSport ground - Security Monitoring Procedures
		SR-100	PASSport ground - GNSS Interference Detection
		SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication
		SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy
		SR-140	PASSport aerial drone - rotary wings - communications availability
		SR-150	PASSport aerial drone - rotary wings - operations continuity
		SR-160	PASSport aerial drone - rotary wings - environmental conditions
		SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree
		SR-250	PASSport aerial drone - fixed wings - GNSS Rx payload - authentication
		SR-260	PASSport aerial drone - fixed wings - GNSS Rx payload - accuracy
		SR-270	PASSport aerial drone - fixed wings - communications availability
		SR-280	PASSport aerial drone - fixed wings - operations continuity
		SR-290	PASSport aerial drone - fixed wings - environmental conditions
		SR-300	PASSport aerial drone - fixed wings - autonomy of missions degree
		SR-360	PASSport algorithms - vessels recognition
		SR-370	PASSport algorithms - vessels location
		SR-430	PASSport algorithms - Sentinel 1 - small ship detection
		SR-450	PASSport algorithms - EGMS
		SR-470	PASSport ground - data and process management
		SR-480	PASSport ground - data archiving and retrieving
		SR-490	PASSport ground - data export and final report

Justification

This UR identifies a dedicated mission about Protection against non-cooperative small crafts approaching the port areas. Relevant traced system Requirements identifies the expected architecture, algorithm and configuration

UR_ID	Title	SR ID	ReqTitle
UR-090	Protection against Underwater threats	SR-020	PASSport aerial drone - rotary wings
		SR-050	PASSport underwater drone
		SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-080	PASSport ground - Security Monitoring Procedures
		SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication
		SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy
		SR-140	PASSport aerial drone - rotary wings - communications availability
		SR-150	PASSport aerial drone - rotary wings - operations continuity
		SR-160	PASSport aerial drone - rotary wings - environmental conditions
		SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree
		SR-310	PASSport underwater drone - GNSS Rx payload (buoy) - accuracy
		SR-320	PASSport underwater drone - communication availability
		SR-330	PASSport underwater drone - operations continuity
		SR-340	PASSport underwater drone - environmental conditions
		SR-350	PASSport underwater drone - autonomy of mission degree
		SR-380	PASSport algorithms - ground object recognition
		SR-390	PASSport algorithms - ground object location
		SR-470	PASSport ground - data and process management
		SR-480	PASSport ground - data archiving and retrieving
		SR-490	PASSport ground - data export and final report
		SR-306	PASSport underwater drone - operations
Justification This UR identifies a dedicated mission about Protection against Underwater threats. Relevant traced system Requirements identifies the expected architecture, algorithm and configuration			
UR-100	Solution scalability	SR-010	PASSport solution
Justification This UR ask to the proposed solution to be configurable and scalable depending on the mission to be covered.			

UR_ID	Title	SR ID	ReqTitle
UR-105	Integrated centralised mission and control data	SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-360	PASSport algorithms - vessels recognition
		SR-370	PASSport algorithms - vessels location
		SR-380	PASSport algorithms - ground object recognition
		SR-390	PASSport algorithms - ground object location
		SR-400	PASSport algorithms - air monitoring
		SR-410	PASSport algorithms - mixed reality support
		SR-420	PASSport algorithms - Sentinel 5P - air pollution
		SR-430	PASSport algorithms - Sentinel 1 - small ship detection
		SR-440	PASSport algorithms - Sentinel-1 - wind speed map
		SR-450	PASSport algorithms - EGMS
		SR-470	PASSport ground - data and process management
		SR-480	PASSport ground - data archiving and retrieving
		SR-490	PASSport ground - data export and final report
Justification This UR asks for a unique mission platform collecting data. The proposed solution shall manage any information gathered form drone and from external services (as Copernicus). The platform shall manage the complete operational process from planning, data gathering, acquisition, ingestion, processing, validation and reporting.			
UR-110	Autonomy Of The Mission	SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree
		SR-230	PASSport aerial drone - rotary wings tethered - autonomy of mission degree
		SR-233	Passport aerial- drone – rotary wings – robustness and safety of autonomous mission
		SR-300	PASSport aerial drone - fixed wings - autonomy of missions degree
		SR-350	PASSport underwater drone - autonomy of mission degree
Justification Autonomy of the mission is an important feature in order to adopt a viable solution in an operational environment with a reduced and efficient training			
UR-120	Robust And Reliable Positioning	SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication
		SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy
		SR-190	PASSport aerial drone - rotary wings tethered - GNSS Rx payload - accuracy

UR_ID	Title	SR ID	ReqTitle
		SR-250	PASSport aerial drone - fixed wings - GNSS Rx payload - authentication
		SR-260	PASSport aerial drone - fixed wings - GNSS Rx payload - accuracy
		SR-310	PASSport underwater drone - GNSS Rx payload (buoy) - accuracy
Justification Protection of Positioning of any collected data either used for GNC of the drones and for mission data is compulsory. Related system requirements identify part of the system expected to be supported by a reliable GNSS tecnology			
UR-130	Robust And Reliable Communications	SR-140	PASSport aerial drone - rotary wings - communications availability
		SR-200	PASSport aerial drone - rotary wings tethered - communications availability
		SR-270	PASSport aerial drone - fixed wings - communications availability
		SR-320	PASSport underwater drone - communication availability
Justification Protection of Communication is compulsory. Related system requirements identify part of the system expected to be supported by a reliable GNSS tecnology			
UR-140	Coverage	SR-175	PASSport aerial drone - rotary wings - coverage
		SR-235	PASSport aerial drone - rotary wings tethered - coverage
		SR-305	PASSport aerial drone - fixed wings - coverage
		SR-355	PASSport underwater drone - coverage
Justification The identified system requirements allocate the need of the coverage to the relevant PASSport elements			
UR-150	Influence of drones on technical systems in ports	SR-020	PASSport aerial drone - rotary wings
		SR-030	PASSport aerial drone - rotary wings tethered
		SR-040	PASSport aerial drone - fixed wings
		SR-050	PASSport underwater drone
Justification This User Requirements asks for the proposed solution not to interfere to already existing systems already installed in port area. Related System Requirements distribute this need to impacted elements.			
UR-155	Frequencies Selection in Compliance With EMC	SR-020	PASSport aerial drone - rotary wings
		SR-030	PASSport aerial drone - rotary wings tethered
		SR-040	PASSport aerial drone - fixed wings
		SR-050	PASSport underwater drone

UR_ID	Title	SR ID	ReqTitle
Justification This User Requirements asks for the proposed solution not to interfere to already existing systems already installed in port area. Related System Requirements distribute this need to impacted elements.			
UR-160	Duration of operations	SR-150	PASSport aerial drone - rotary wings - operations continuity
		SR-210	PASSport aerial drone - rotary wings tethered - operations continuity
		SR-280	PASSport aerial drone - fixed wings - operations continuity
		SR-330	PASSport underwater drone - operations continuity
Justification Duration of operations is an important feature in order to adopt a viable solution in an operational environment with a reduced and efficient training			
UR-170	Security Policies	SR-070	PASSport ground - mission
Justification The proposed PASSport solution shall be built in compliance with security policies in port environment			
UR-180	Portability and usability	SR-010	PASSport solution
Justification This UR is a specific detail expanding UR-100 (solution scalability). In particular, depending on the configuration used, it shall be possible also to use the platform in a portable way			
UR-190	Legal aspects in ports	SR-010	PASSport solution
Justification The proposed PASSport solution shall be built in compliance with legal aspects typical in port environment			
UR-210	Data privacy	SR-480	PASSport ground - data archiving and retrieving
Justification The solution shall manage any collected or manually entered data. This activity shall be done in compliance with data privacy apsctes (particularly GDPR)			
UR-220	Human Factors	SR-060	PASSport ground - control
		SR-070	PASSport ground - mission
		SR-080	PASSport ground - Security Monitoring Procedures
Justification The identified SRs distribute the need for a proper data presentation on all PASSport Ground Segment element where an operator is involved. Such platform shall be developed endorsing Human Factors perspective.			

Table 3-2 User Needs vs System Requirements Traceability

SR ID	ReqTitle	UR_ID	Title
SR-010	PASSport solution	UR-010	Scope
		UR-040	Safety and security missions
		UR-100	Solution scalability
		UR-180	Portability and usability
		UR-190	Legal aspects in ports
SR-020	PASSport aerial drone - rotary wings	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-150	Influence of drones on technical systems in ports
		UR-155	Frequencies Selection in Compliance With EMC
SR-030	PASSport aerial drone - rotary wings tethered	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-150	Influence of drones on technical systems in ports
		UR-155	Frequencies Selection in Compliance With EMC
SR-040	PASSport aerial drone - fixed wings	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-150	Influence of drones on technical systems in ports
		UR-155	Frequencies Selection in Compliance With EMC
SR-050	PASSport underwater drone	UR-090	Protection against Underwater threats
		UR-150	Influence of drones on technical systems in ports
		UR-155	Frequencies Selection in Compliance With EMC
SR-060	PASSport ground - control	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas

SR ID	ReqTitle	UR_ID	Title
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
		UR-220	Human Factors
SR-070	PASSport ground - mission	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
		UR-170	Security Policies
		UR-220	Human Factors
SR-080	PASSport ground - Security Monitoring Procedures	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-220	Human Factors
SR-090	PASSport ground - Vessels traffic monitoring - drones and vessels positions	UR-060	E-navigation support
		UR-070	Infrastructures protection
SR-095	PASSport ground - Vessels traffic monitoring - AIS-based vessels positions	UR-060	E-navigation support
		UR-070	Infrastructures protection
SR-100	PASSport ground - GNSS Interference Detection	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication	UR-050	Pollution monitoring
		UR-060	E-navigation support

SR ID	ReqTitle	UR_ID	Title
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-120	Robust And Reliable Positioning
SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-120	Robust And Reliable Positioning
SR-140	PASSport aerial drone - rotary wings - communications availability	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-130	Robust And Reliable Communications
SR-150	PASSport aerial drone - rotary wings - operations continuity	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-160	Duration of operations
SR-160	PASSport aerial drone - rotary wings - environmental conditions	UR-020	Reliability in Port environment
		UR-030	Operating weather conditions
		UR-050	Pollution monitoring

SR ID	ReqTitle	UR_ID	Title
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-110	Autonomy Of The Mission
SR-175	PASSport aerial drone - rotary wings - coverage	UR-140	Coverage
SR-190	PASSport aerial drone - rotary wings tethered - GNSS Rx payload - accuracy	UR-060	E-navigation support
		UR-120	Robust And Reliable Positioning
SR-200	PASSport aerial drone - rotary wings tethered - communications availability	UR-060	E-navigation support
		UR-130	Robust And Reliable Communications
SR-210	PASSport aerial drone - rotary wings tethered - operations continuity	UR-060	E-navigation support
		UR-160	Duration of operations
SR-220	PASSport aerial drone - rotary wings tethered - environmental conditions	UR-020	Reliability in Port environment
		UR-030	Operating weather conditions
		UR-060	E-navigation support
SR-230	PASSport aerial drone - rotary wings tethered - autonomy of mission degree	UR-060	E-navigation support
		UR-110	Autonomy Of The Mission

SR ID	ReqTitle	UR_ID	Title
SR-233	Passport aerial- drone – rotary wings – robustness and safety of autonomous mission	UR-060	E-navigation support
		UR-110	Autonomy Of The Mission
SR-235	PASSport aerial drone - rotary wings tethered - coverage	UR-140	Coverage
SR-250	PASSport aerial drone - fixed wings - GNSS Rx payload - authentication	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-120	Robust And Reliable Positioning
SR-260	PASSport aerial drone - fixed wings - GNSS Rx payload - accuracy	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-120	Robust And Reliable Positioning
SR-270	PASSport aerial drone - fixed wings - communications availability	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-130	Robust And Reliable Communications
SR-280	PASSport aerial drone - fixed wings - operations continuity	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-160	Duration of operations
SR-290	PASSport aerial drone - fixed wings - environmental conditions	UR-020	Reliability in Port environment
		UR-030	Operating weather conditions
		UR-080	Protection against non-cooperative small crafts approaching the port areas
SR-300	PASSport aerial drone - fixed wings - autonomy of missions degree	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-110	Autonomy Of The Mission
SR-305	PASSport aerial drone - fixed wings - coverage	UR-140	Coverage
SR-310	PASSport underwater drone - GNSS Rx payload (buoy) - accuracy	UR-090	Protection against Underwater threats
		UR-120	Robust And Reliable Positioning
SR-320	PASSport underwater drone - communication availability	UR-090	Protection against Underwater threats
		UR-130	Robust And Reliable Communications

SR ID	ReqTitle	UR_ID	Title
SR-330	PASSport underwater drone - operations continuity	UR-090	Protection against Underwater threats
		UR-160	Duration of operations
SR-340	PASSport underwater drone - environmental conditions	UR-020	Reliability in Port environment
		UR-030	Operating weather conditions
		UR-090	Protection against Underwater threats
SR-350	PASSport underwater drone - autonomy of mission degree	UR-090	Protection against Underwater threats
		UR-110	Autonomy Of The Mission
SR-355	PASSport underwater drone - coverage	UR-140	Coverage
SR-360	PASSport algorithms - vessels recognition	UR-060	E-navigation support
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-370	PASSport algorithms - vessels location	UR-060	E-navigation support
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-380	PASSport algorithms - ground object recognition	UR-070	Infrastructures protection
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
SR-390	PASSport algorithms - ground object location	UR-070	Infrastructures protection
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
SR-400	PASSport algorithms - air monitoring	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data
SR-410	PASSport algorithms - mixed reality support	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data
SR-420	PASSport algorithms - Sentinel 5P - air pollution	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data
SR-430	PASSport algorithms - Sentinel 1 - small ship detection	UR-060	E-navigation support
		UR-070	Infrastructures protection

SR ID	ReqTitle	UR_ID	Title
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-440	PASSport algorithms - Sentinel-1 - wind speed map	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data
SR-450	PASSport algorithms - EGMS	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-470	PASSport ground - data and process management	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
SR-480	PASSport ground - data archiving and retrieving	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
		UR-210	Data privacy
SR-490	PASSport ground - data export and final report	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
SR-306	PASSport underwater drone - operations	UR-090	Protection against Underwater threats

Table 3-3 System Requirements vs User Needs Traceability

4 DESIGN JUSTIFICATION

This section includes the description of main techniques and technologies used in PASSport project framework as a flow down from user requirements to system requirements identified in section 3

4.1 GNSS USAGE AS ENABLING TECHNOLOGY

The PASSport system will be used in a range of operational scenarios where an operator in a control room plans a trajectory (intended as configured waypoints to be flown). for **an automated RPAS flying in a challenging environment**. Indeed, the presence of obstacles - including buildings and other ground assets - and potentially unfavourable weather conditions (e.g. wind) can generate risks impacting the level of port safety. As a consequence, a combination of independent sensors has to be used to complement the information managed by the drone pilot, allowing drones to **safely fly** the planned trajectory.

Moreover, a contribution to the solution also impacts security topics. Indeed, port facilities are potentially subject to threats which have to be managed in accordance to the *Port Facility Security Assessment* (PFSA) and e *Port Facility Security Plan* (PFSP). So, as soon as an RPAS is inserted to operate in a port area, also additional measures have to be included in security management processes; in particular, as the RPAS relies on EGNSS, the **GNSS signal has to be robust and protected** against any possible attack.

The following system requirements have been identified calling for GNSS usage as enabling technology:

SR ID	ReqTitle	UR_ID	Title
SR-090	PASSport ground - Vessels traffic monitoring - drones and vessels positions	UR-060	E-navigation support
		UR-070	Infrastructures protection
SR-095	PASSport ground - Vessels traffic monitoring - AIS-based vessels positions	UR-060	E-navigation support
		UR-070	Infrastructures protection
SR-100	PASSport ground - GNSS Interference Detection	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
SR-120	PASSport aerial drone - rotary wings - GNSS Rx payload - authentication	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-120	Robust And Reliable Positioning

SR ID	ReqTitle	UR_ID	Title
SR-130	PASSport aerial drone - rotary wings - GNSS Rx payload - accuracy	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-120	Robust And Reliable Positioning
SR-190	PASSport aerial drone - rotary wings tethered - GNSS Rx payload - accuracy	UR-060	E-navigation support
		UR-120	Robust And Reliable Positioning
SR-310	PASSport underwater drone - GNSS Rx payload (buoy) - accuracy	UR-090	Protection against Underwater threats
		UR-120	Robust And Reliable Positioning
SR-370	PASSport algorithms - vessels location	UR-060	E-navigation support
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data

Table 4-1 System Requirements related to GNSS technology

It is noteworthy that **EGNSS necessity comes not only to support the Guidance, Navigation and Control location of the automated RPA, but also to make the surveillance service more accurate and reliable,** allowing the imagery obtained from RPAS to detect and localise any potential target.

So, the novelty of PASSport is to use of E-GNSS capabilities as enabling technology - together with specific algorithms and smart processing - to contribute to safety and security for operations in ports. This requirement calls for a solution based on a **GNSS with high accuracy, integrity and any possible measure to protect signal (as authentication and interference detection)** As PASSport solution is based on usage of drones (using GNSS receivers) there is a need to improve protection against deliberate attack (spoofing, meaconing,…), by identifying and locating threats against the GNSS SiS

In that sense, GNSS is a preconceived requirement as long as it is a requirement linked to the EU funding mechanism in which this solution is being developed.
The use of GNSS, and in particular EGNSS is one of the key drivers of PASSport solution as long as this technology is being used to provide the assets position within the affected area (drones, vessels, etc.) and in some cases this position information is leveraged thanks to EGNSS contributions (e.g. high accuracy, integrity, authentication). Due to the vulnerability of GNSS to interference events, and also considering the nature of the activities involved in PASSport solution, PASSport design includes different mechanisms, such as a GNSS interference detector to increase the robustness of the position and integrity computations based on GNSS data

The consortium considers that these services for sure will bring many benefits that are not currently available by other GNSS and that implies a high level of innovation. However, these capabilities may not be operational by the timeframes managed by the project, so alternative solutions may be considered at design, implementation and verification levels.

4.2 EO TO SUPPORT PORT OPERATION MONITORING

EO data will be used in PASSport solution as shown in the following sections.

The following system requirements have been identified calling for EO usage as enabling technology:

SR ID	ReqTitle	UR_ID	Title
SR-420	PASSport algorithms - Sentinel 5P - air pollution	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data
SR-430	PASSport algorithms - Sentinel 1 - small ship detection	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-440	PASSport algorithms - Sentinel-1 - wind speed map	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data
SR-450	PASSport algorithms - EGMS	UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data

Table 4-2 System Requirements related to EO technology

4.2.1 SENTINEL-5P ACQUISITIONS TO MONITOR POLLUTION AND AIR QUALITY IN KOŁOBRZEG

UNIFI (DST-UNFI) will contribute to the definition of the air quality scenario in Kołobrzeg (Poland) through the use of Earth observation data, in particular of Sentinel-5P imagery. The main objective of the Copernicus Sentinel-5P mission is to perform atmospheric measurements with high spatio-temporal resolution, to be used for air quality, ozone & UV radiation.

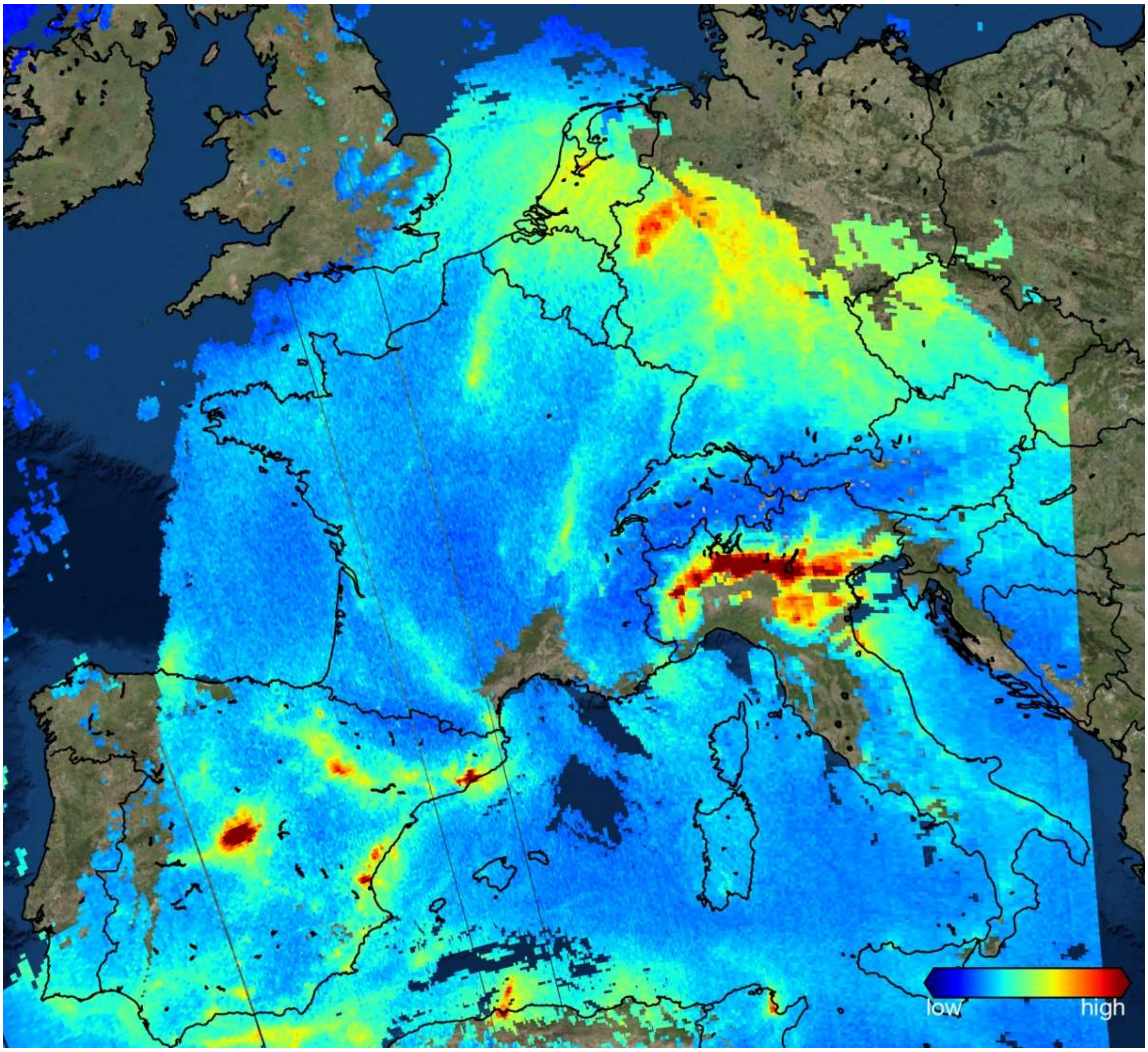

Figure 4-1 Sentinel-5P nitrogen dioxide concentration over Europe.

In particular, UNIFI will provide a constant and periodical monitoring of a wide range of pollutants such as carbon monoxide (CO), formaldehyde (CH2O/H2CO), methane (CH4), nitrogen dioxide (NO2), ozone (O3), and sulphur dioxide (SO2). These products are not measured directly. Indeed, the satellite's 8-band spectrometer instrument, called TROPOMI (TROPOspheric Monitoring Instrument), takes measurements in the ultraviolet, visible, near and short-wavelength infrared light spectrum. In combination with auxiliary input data (e.g., air pressure, snow/ice masks), the concentration of each atmospheric gas is then modeled based on their absorption characteristics at specific wavelengths of the light. In particular, UNIFI will also monitor the temporal evolution of the concentrations of pollutant in the area of the port of Kołobrzeg, also quantifying their concentration in the port area and analyzing the possible influence of seasonal variations or of the port traffic.

4.2.2 EUROPEAN GROUND MOTION SERVICE (EGMS) PRODUCTS TO MONITOR INFRASTRUCTURE AND BUILDING STABILITY IN HAMBURG

UNIFI will use Sentinel-1 data processed by means of Persistent Scatterers and Distributed Scatterers radar interferometry approach in order to retrieve information on deformations occurring on the Earth surface.

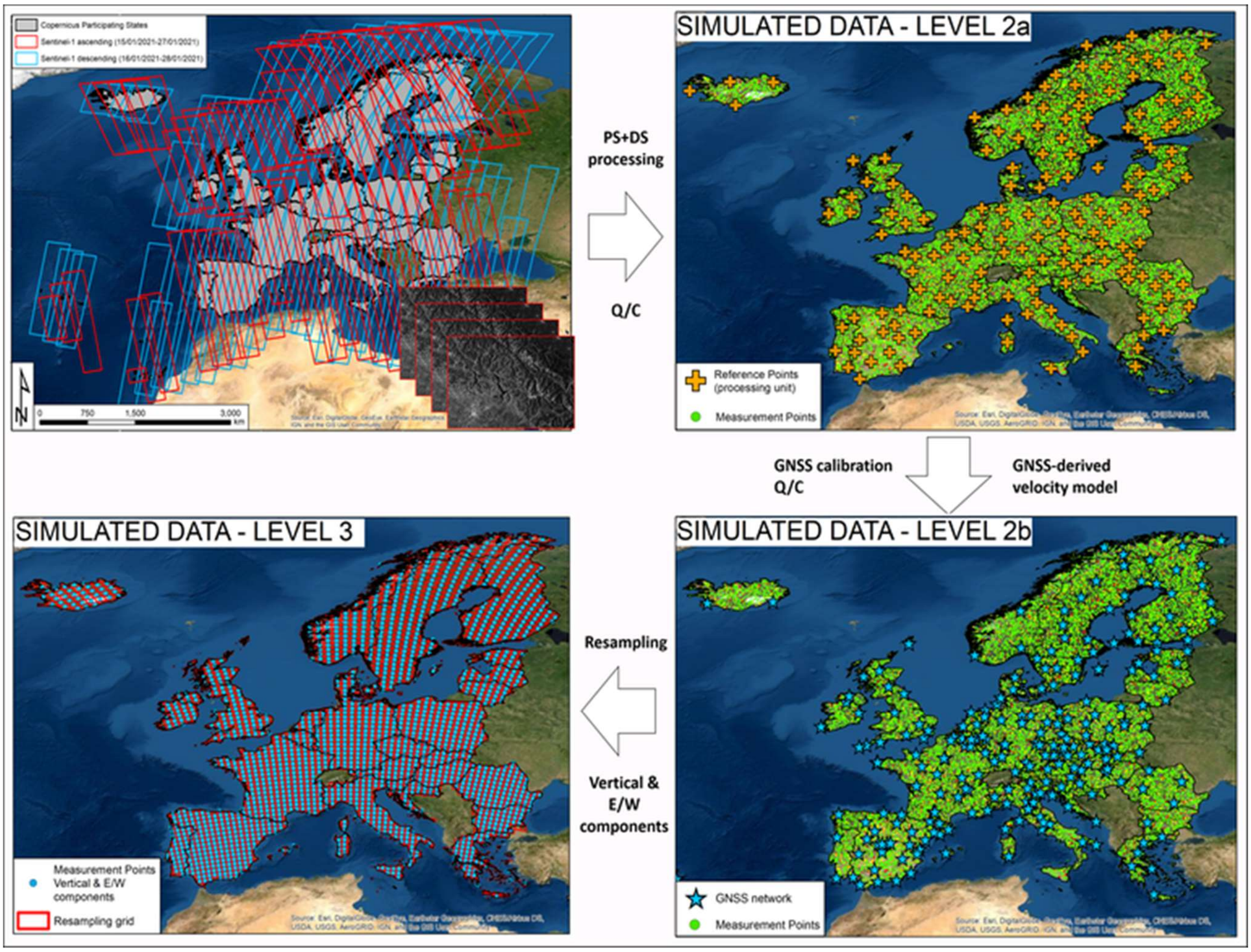

Figure 4-2 EGMS levels: on the top left, Sentinel-1 frames; on the top right, Level 2a products; on the bottom right, Level 2b data; on the bottom left, Level 3 data.

These data will be provided in the framework of the European Ground Motion Service (EGMS), which aims to provide consistent, regular, standardised, harmonised and reliable information regarding natural and anthropogenic ground motion phenomena over Europe and across national borders, with millimetre accuracy. The basic product output of any InSAR based ground motion estimation is a database of measurement points, each with a time series of line-of-sight ground motion measurements relative to a local reference point and a given reference time. The EGMS will include three main products: Level 2a, which includes deformation maps and time series of displacement; Level 2b, consisting in A-DInSAR deformation map combined with a reference GNSS network, and finally the Level 3, a more advanced product which contains information on the displacement on the two main deformation components, the horizontal east–west and up–down vertical deformation, at a resolution of 100 x 100 m. All the products updates are provided every 12 months on the entire continental scale. Such data will be specifically used to monitor the deformation ongoing in the port area of Hamburg (Germany), to assess the stability of the port facilities and to analyze if land reclamation practices may have induced any settlement.

4.2.3 PIXEL-BASED ALGORITHM BASED ON SENTINEL-1 IMAGERY FOR THE DETECTION OF MARINE OBJECTS IN VALENCIA AND LE HAVRE

UNIFI (DST-UNFI) proposes to design and implement a specific methodology to automatically recognize, identify and extract the coordinates of boats and vessels within the port areas.

A semi-automated procedure is proposed, based on SAR (Synthetic Aperture Radar) acquisitions taken from satellite platforms. The procedure for the extraction of reflecting elements (i.e., vessels) is possible thanks to their amplitude signature that results significantly higher with respect to the seawater. This diversity is due to the different reflectance of the material of the boats (high reflectance which corresponds to white/bright colour in the image) and the water (low reflectance which corresponds to dark colours).

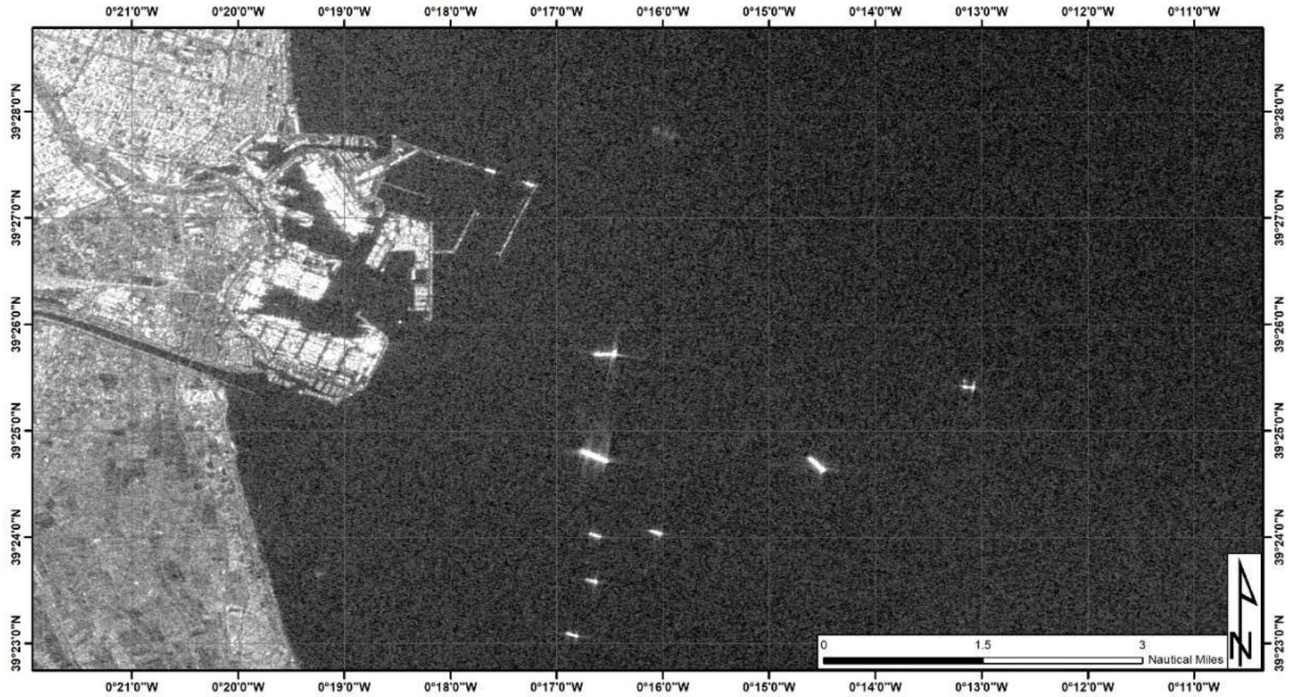

Figure 4-3 Amplitude radar image of the Valencia port acquired from Sentinel-1 satellite platform.

The proposed methods will rely on ESA (European Space Agency) Sentinel-1 constellation of satellites, which couples some favourable characteristics: regional-scale mapping capability, systematic and regular SAR observations (unprecedent revisiting time of 6 days) and rapid product delivery (typically in less than 3 hours from data acquisition). Sentinel-1 SAR products are freely accessible, thus providing the scientific community, as well as public and private companies, with consistent archives of openly available radar data, suitable for a wide range of applications, such as marine object detection. This procedure will be specifically design and implemented and then tested in the port areas selected within the PASSport project.

4.2.4 SENTINEL-1 IMAGERY FOR THE DETECTION AND THE VELOCITY ASSESSMENT OF WINDS IN RAVENNA

UNIFI (DST-UNFI) will provide an estimation of the wind speed in port areas through the implementation of a semi-automatic procedure which exploits Sentinel-1 data. free and open access Sentinel-1 SAR data may be used to assess the direction and the speed of winds flowing around the port areas.

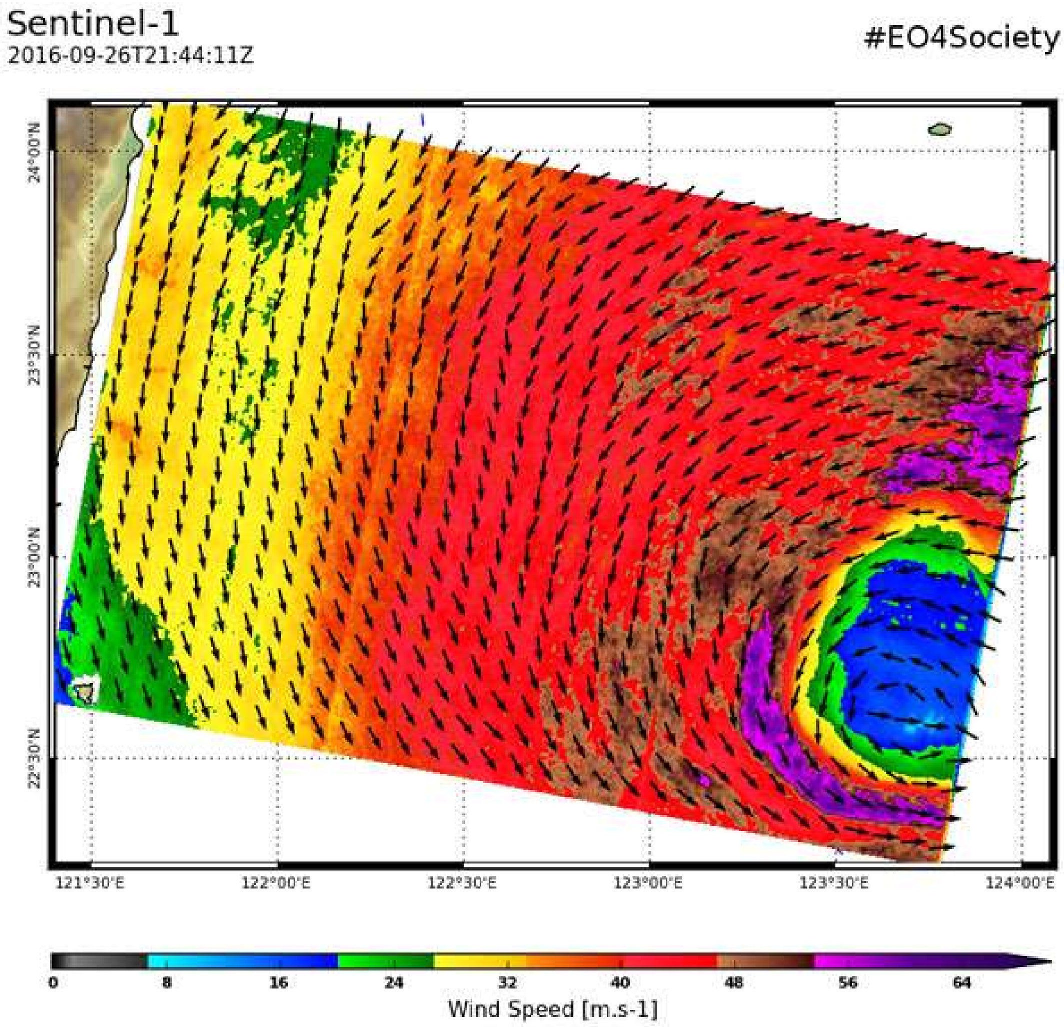

Figure 4-4 Wind speed derived from Sentinel-1 data over the Typhoon Megi (Philippines).

The SAR beam interacts with the fine, centimetre scale surface roughness of water to affect the scattered return radar signal received by the SAR instrument. Wind speed across a water surface affects the degree of roughness and hence the received radar signal. This is the basis for measuring offshore wind speeds with SAR. Empirically derived Geophysical Model Functions (GMF) are used to relate the calibrated radar return to the wind speed at a height of 10m. The spatial griding of the wind information can vary according to the user requirements. Long-term statistics retrieved using this product, such as the average wind power, the wind main direction, etc. can be used by port authorities in order to have a up to date map of the waves which may affect the correct navigation of the ships or affect the stability of main port facilities. Wind field estimates also play an important part in oil spill monitoring to help discriminate look-alikes from actual spills. All data retrieved from this procedure will be further validated with data obtained by existing weather and marine buoy networks.

4.3 ARTIFICIAL INTELLIGENCE AND DEEP LEARNING FOR RPAS AUTOMATED OPERATIONS AND PORT SURVEILLANCE

Artificial Intelligence and Deep Learning techniques will be applied in PASSport as a complementary technology to EGNSS in order to guarantee the required robustness and safety of operations of a commercial-grade Port Surveillance solution. These techniques will be integrated at different levels within the localization and navigation stack proposed for the automated RPAS operation. The overall system architecture proposed in the framework of this project is shown in Figure 5.3.

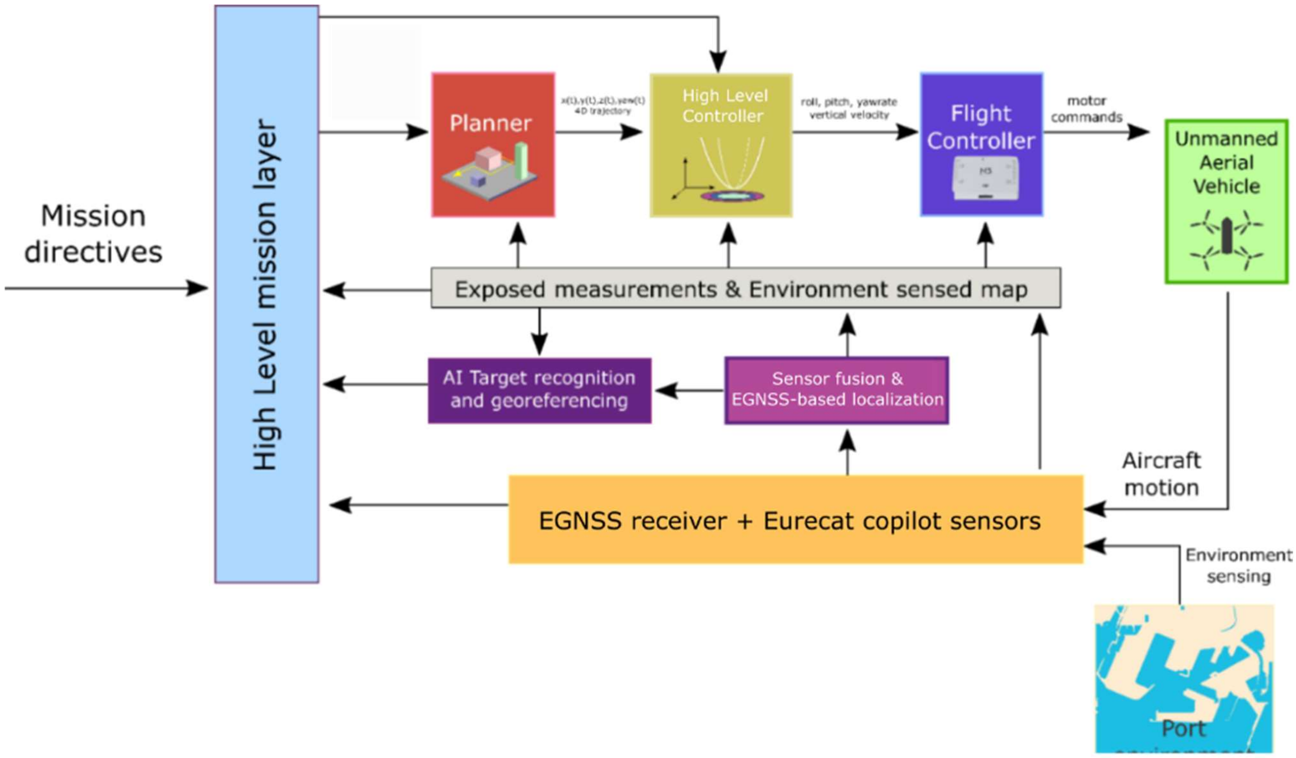

Figure 5-3. Overall system architecture for the automated RPA

To ensure the continuous availability of accurate and reliable position estimation required for Port Area operations, a hybridization of technologies will be implemented. The data provided by an E-GNSS receiver will be fused with additional on-board sensor measurements (e.g., IMU measurements, magnetometer, range-sensor) in order to increase the precision of position and robustness of the entire system by preventing accuracy degradation in scenarios prone to multipaths and occlusions. In this scenario, the data provided by the MagicUT unit will be compared against a commercially available E-GNSS receiver. The sensor fusion solution will provide complete awareness of the platform's position and orientation along the entire automated operation which will revert in safer, more reliable, and smoother aerial autonomous operations in the Port area.

The high-definition visual and thermal cameras equipped on-board the autonomous platform, together with the position estimation solution provided by the sensor fusion form the basis of the AI target recognition and georeferentiation module. First of all, the target detection of different types of vessels moving in the port area will be performed exploiting the multimodality of the equipped sensors (visual and thermal image stream). The variable sunlight in natural scenes combined with the water reflections present in this type of complex environment can affect the quality of the RGB data captured, leading to over-exposed or under-exposed images. Thus, opposite to traditional detection methods used for in land objects which generally rely only on visual cameras, this approach tries to integrate two sources of information in order to mitigate some of the challenges encountered when dealing with above water object detection. Algorithms based on Deep Learning techniques will be employed to detect target objects in the Port area making use of already available labelled open datasets. Once the target is detected within the visual and thermal images, a georeferentiation algorithm will be implemented which will make use of the precise position and orientation estimation provided by the sensor fusion module. The 3D pose (position and orientation) of the detected object will be computed relative to the location of the RPA platform. Using the precise position given by the EGNSS receiver, a further step of this algorithm will be able to retrieve the position of the detected object with respect to the global coordinate system.

The high-level mission command will account for any loss of precision of the E-GNSS module and other unexpected behaviour by returning the control of the operation to the safety pilot.

The entire autonomous operation will be governed by a high-level mission layer which implements an AI planning technique. The mission directives will be implemented within this module as dictated by the Port operators. Pre-defined interest areas, take-off and landing spots as well as different safety constraints will be defined and taken into account within the high-level mission planning. The perceived data of the environment as well as the sensor fusion solution will be shared across the network to the high-level mission planning module. Having full awareness of the platform's status and its nearby environment, the AI planning technique will generate a feasible mission plan, being able to adapt to different environment circumstances. Examples of mid-level functionalities included in the mission plan are autonomous take-off and landing, polygonal area patrolling, return-to-launch among others. In the event of an object being detected, the platform could engage in active target tracking while monitoring the battery drainage level. The algorithm would then compute the maximum distance from the landing spot which would allow a safe return-to-launch operation with the remaining battery level. The high-level mission planning is responsible of triggering the remaining low-level planning and control modules which will ensure the plan execution. The AI planning technique implemented in this module removes the need of having to create a specific plan for each situation, by providing a general framework which can adapt to the platform and environment status at each time. This method results in safer and more robust autonomous missions which comply with the requirements imposed by the port operators.

The following system requirements have been identified calling for EO usage as enabling technology:

SR ID	ReqTitle	UR_ID	Title
SR-360	PASSport algorithms - vessels recognition	UR-060	E-navigation support
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-370	PASSport algorithms - vessels location	UR-060	E-navigation support
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-105	Integrated centralised mission and control data
SR-380	PASSport algorithms - ground object recognition	UR-070	Infrastructures protection
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data
SR-390	PASSport algorithms - ground object location	UR-070	Infrastructures protection
		UR-090	Protection against Underwater threats
		UR-105	Integrated centralised mission and control data

Table 4-3 System Requirements related to AI technology

4.4 IMPLEMENTATION OF MIXED REALITY DEVICE FOR DRONES PERFORMED MISSION

For a large and complex port areas it is becoming more important to provide a solution for controlling and monitoring ongoing mission and status of autonomous and semi-autonomous vehicles operating on site. More ports are deploying digital twin systems that provide a full 3D reconstruction of port with real-time data about all objects and operations taking place. With a larger port areas and drones operating in the air, on the water surface and underwater it is challenging to present all available data in a way that will improve situational awareness and decision-making process leading to a better management and faster, more efficient response during an emergency.

To address this issue PASSport project will develop a novel solution based on Mixed Reality (MR) technology that will provide end user with an advanced 3d visualization of the port area via dedicated Head Mounted Display (HMD) that tracks user's location and movement.

State of technology:

There is a range of MR devices available on consumer market including so called smartglasses with varying parameters and functionalities, industrial smart-helmets and more advanced devices, so called Spatial Mixed Reality devices, that are capable of sensing surroundings and generating 3D imagery.

There are single devices that are certified for drones operations and provide the user with a dedicated app, that allows for streaming data and video feed directly from the drone.

All above systems are, in majority, based on Android Operating System and allow for creation and installation of custom software.

Assumption:

1. The interface will provide full 3D, accurate overview of the port area.
2. A real-time position of all active drones will be presented on the 3D overview of the port area.
3. The user will be able to use dedicated controllers or his/her own hands to perform basic interactions with the interface.
4. The interface will allow to select a drone and access information about its mission's status.
5. Where possible, the interface will allow for data stream from the selected drone.
6. The interface will be dedicated for the port operator and/or pilot assistant.

System architecture:

Assuming that more than one drone can be performing mission inside the port area it is necessary to set up a dedicated central server that will collect all the data from all active drones for means of data acquisition, data logging and data analysis, including video filtering and analysis. All active AR devices will connect with the server and will be provided with processed data.

The following system requirements have been identified calling for mixed reality usage as enabling technology:

SR ID	ReqTitle	UR_ID	Title
SR-410	PASSport algorithms - mixed reality support	UR-050	Pollution monitoring
		UR-105	Integrated centralised mission and control data

Table 4-4 System Requirements related to Mixed reality technology

4.5 AUTOMATED OPERATIONS WITH RPAS

Automation of flight is still a challenging task considering the proximity of the power line and the severity of damage in case of collision with wires or structures. **EGNSS High Accuracy represents a compulsory item to automate inspections**. In fact, through **automation of flight**, it is possible to map geographically the position of potential hot spots of the powerlines and instruct a software to recognize and classify potential issues. Such process can be achieved through the following enabling technologies:

- ✓ *Automated (or semi-automated) flight (high accuracy in navigation is mandatory);*
- ✓ *Computer Vision Algorithm (even scaled versions working only on temperature gradients – no shapes recognition)*
- ✓ *Optical/ thermal real time imageries and thermal video stream.*

Considering the payload to be embarked on the aircraft (e.g. Thermal/Optical payload and Lidar), and the resolution needed for the acquisition of the elements to be mapped (e.g. section of cable), **it is requested to RPA to fly as close as possible to the electric powerline, but at the same time with sufficient clearance (MOC – Minimum Obstacle Clearance) to mitigate the risk of impact**.

For this reason, a good approach to address this problem is founded on the **correct geo-reference on local cartography of the powerlines (trellis and cables) and the utilization of GNSS technology with high accuracy positioning capabilities, as primary navigation sensors, to perform automated navigation of the aircraft**.

The ICAO defines in the document Doc 9613 (Paragraph 2.2 in Part A of Volume II of the PBN Manual) the components of the navigation error that should be considered to address minimum clearance with ground obstacles. In particular, the lateral navigation is defined as the inability to achieve the required lateral navigation accuracy; it may be due to navigation errors related to aircraft tracking and positioning.

The three main errors in the context of RPA on-board performance monitoring and alerting are represented by the following errors:

- ✓ Path Definition Error (PDE). PDE occurs when the path defined by the aircraft does not correspond to the desired path, i.e. the path expected to be flown over the ground. This error is mainly due to cartographic/ mapping errors.
- ✓ Flight Technical Error (FTE). FTE relates to the autopilot's ability to follow the defined path or track, i.e. in presence of wind gusts the performance of the autopilot can lower as well as if velocity of RPA (True Air speed) is high so that the FTE will quickly increase.
- ✓ Navigation System Error (NSE) on one side of the desired path. NSE refers to the difference between the aircraft's estimated position and actual position. NSE refers mainly to the errors introduced by the GNSS sensor of the RPA used as primary navigation instrument.

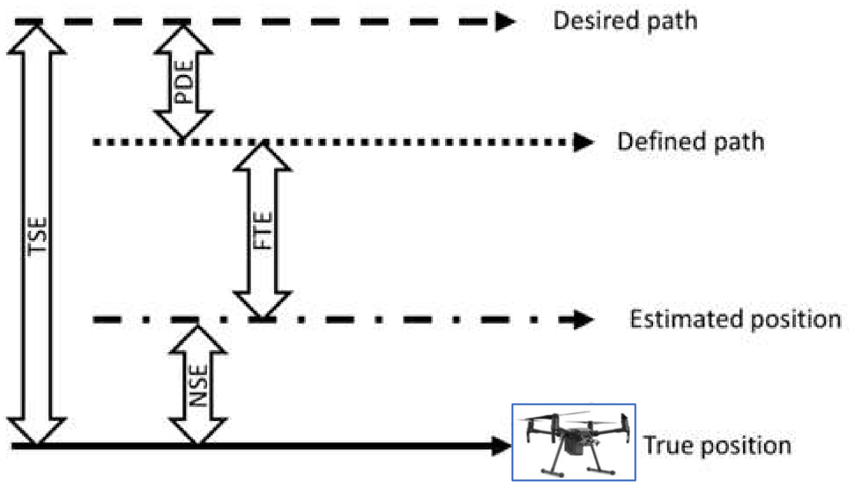

Figure 4-5– Errors to be taken into account for the automated navigation algorithm.

The distribution of these errors are assumed to be independent for the determination of the Total System Error (TSE); in fact, the RPA position information, the velocity of RPA and other external variables such as cross wind, can strongly increase the FTE (i.e., the capability of the autopilot to keep a solid response to the defined flying path needed for powerline inspections).

The first **significant contribution by using Galileo High Accuracy Service is the reduction of the Navigation System Error**. In fact, High accuracy positioning and "integrity" of position is needed in order to

- keep under control the NSE;
- allow repeatability of the inspection missions

The baseline of the Automated algorithm will consider these first parameters to lower as much as possible the buffer area (MOC – Minimum Obstacle clearance):

- ✓ velocity of RPA during inspections;
- ✓ cross wind velocity
- ✓ Accuracy of Navigation sensor
- ✓ Response function of autopilot

The following system requirements have been identified calling for mixed reality usage as enabling technology:

SR ID	ReqTitle	UR_ID	Title
SR-170	PASSport aerial drone - rotary wings - autonomy of mission degree	UR-050	Pollution monitoring
		UR-060	E-navigation support
		UR-070	Infrastructures protection
		UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-090	Protection against Underwater threats
		UR-110	Autonomy Of The Mission
SR-230	PASSport aerial drone - rotary wings tethered - autonomy of mission degree	UR-060	E-navigation support
		UR-110	Autonomy Of The Mission
SR-233	Passport aerial- drone – rotary wings – robustness and safety of autonomous mission	UR-060	E-navigation support
		UR-110	Autonomy Of The Mission
SR-300	PASSport aerial drone - fixed wings - autonomy of missions degree	UR-080	Protection against non-cooperative small crafts approaching the port areas
		UR-110	Autonomy Of The Mission
SR-350	PASSport underwater drone - autonomy of mission degree	UR-090	Protection against Underwater threats
		UR-110	Autonomy Of The Mission

Table 4-5 System Requirements related to automated operations concept

5 PASSPORT ARCHITECTURE

PASSport system architecture is reported in *Figure 5-1*, where the following segments are identified:

- ✓ PASSport Aerial Segment (PAS)
- ✓ PASSport Underwater Segment (PUS)
- ✓ PASSport Ground Segment (PGS)

The interface for the end-user the PGS gathering from both the aerial/ underwater segments (PAS/ PUS) and from External Operational Entities, i.e.

- ✓ *Shiplocus,* developed by GMV
- ✓ Srx-10i/ DINTEL*,* developed by GMV

PASSport is thought in order to guarantee the following main functionalities:

- ✓ **Measurement of threats awareness and awareness-raising among players (security).** Once the assets and infrastructure which need to be protected are identified against the threats and risks of intentional illegal action facing port activities, the PASSport platform proposes the design and implementation of appropriate measures which can be used to counteract threats. This follows the identification of a risk level i (normal, increased, high), and is achieved by means of specific procedures and by using technical equipment tailored to the needs of ports. This makes possible to provide the right response to the potential vulnerability of infrastructure.
- ✓ **Inspection and supervision of port areas (security and safety)**. The PASSport platform provides a suitable HMI to monitor, in an appropriate and regular manner, port security&safety and to implement relevant procedures.

Images captured by the RPAS are processed in real time by a local computer at RGMS level. RPAS is equipped with high accuracy GNSS receivers leveraging on GALILEO differentiators[1] that are OS-NMA (for the reliability and security of the position), HAS/PPP (for the positioning accuracy), and multi-frequency (for robustness and accuracy) in order to provide a proper positioning and combined with modern robotics technologies (vision-based navigation, AI and Deep Learning algorithms) to guarantee automated, secure and continuous operations. Finally, the RPAS Ground Control Segment (RGCS) offers the possibility to command and control the RPAS in case of any emergency, as a possibility to recover contingent malfunctioning on the RGMS to RPAS link (Command and Control link loss).

Note: Several configurations are built on for PASSport campaign. Relevant info is reported in [RD 6]

[1] NOTE: Not all the Galileo differentiators may be used simultaneously. This will depend on the drone and scenario configuration.

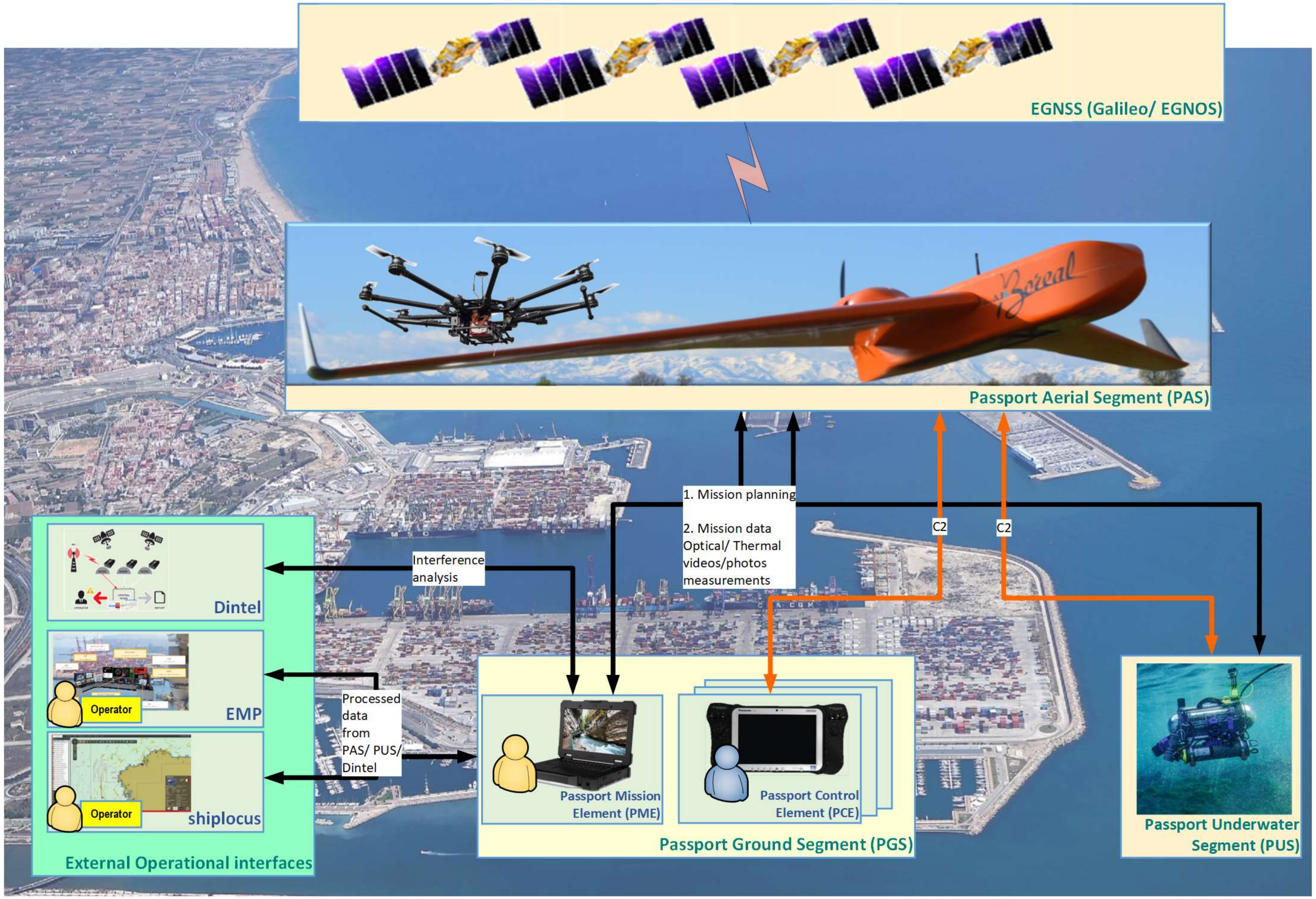

Figure 5-1 PASSport Architecture

5.1 PASSPORT AERIAL SEGMENT (PAS)

To fleet of aerial drones will be composed by both rotary and fixed wings vehicles.

5.1.1 ROTARY WINGS DRONES

PASSport vision is about to manage **drone operating in a semi-automated way**; in other words, drones are commanded to implement a mission planned in advance and consisting in a series of waypoints that the drone has to reach in a safe and efficient way to collect surveillance information. To do that, in compliance with current regulatory framework (**EGNSS and artificial intelligence (AI) have to be used as enabling technologies to** be integrated on board the RPAs (*both tethered and free to fly versions*) to allow **automated operations**.

A fleet of five different rotary wings drone are envisioned in Passport solution

5.1.1.1 TETHERED DRONE SOLUTION (MASTER TETHERED DRONE, MTD)

This drone is planned in the following campaigns:

- Ravenna (Italy),
- Hamburg (Germany)
- Le Havre (France),
- Valencia (Spain)

Further details are reported in is reported in [RD 6]

This solution implements a tethered drone solution which main function is to provide persistent surveillance to port operations. In fact, this drone placed in a suitable and strategic position of the harbour, will be capable of many hours of operations without the need of recharging the batteries, since its main power is fed directly by the tether. Furthermore, the tether provides a physical limitation to the flight envelope of the drone for enhanced safety. The main added value brought by this drone to the Passport platform can be summarized as follows:

- ✓ Persistent surveillance during operations (no interruption in video stream acquisition due to take-off and landing operations)
- ✓ Live video feed from up to 70 meters of height with the possibility to zoom in – zoom out up to 180x Optical/digital in day conditions and 8x (digital) in night conditions. The video is forwarded directly in real time through Internet to the main SW platform for ships (or objects) detection and identification with A.I. algorithm.
- ✓ Zoom Optical or Thermal infrared Camera payload available for day and night operations.
- ✓ Estimation of position of ships or object thanks to EGNSS Receivers and Stable and accurate IMU with a reasonable accuracy compliant with the ship dimensions and distance.

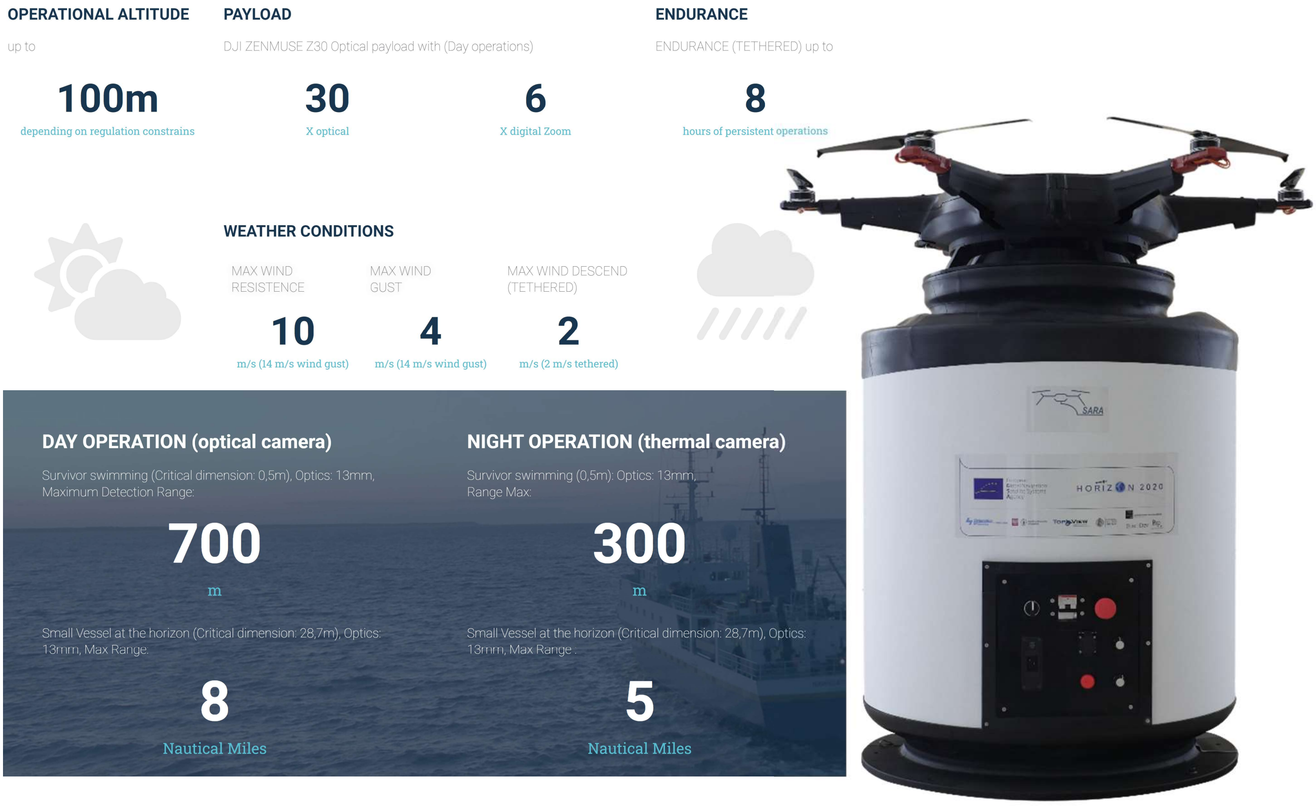

Figure 5-2 – Master tethered drone

5.1.1.2 MATRIX M300 RTK

This drone is planned in the following campaigns:

- Kolobrzeg (Poland)

Further details are reported in is reported in [RD 6]

One of the most advanced drones in the class <25 Kg on the market (State-of the art), is represented by the DJI M300 RTK. This drone takes inspiration from modern aviation systems, offering up to 55 minutes of flight time, advanced AI capabilities, 6 Directional Sensing & Positioning and more, the M300 RTK sets a whole new standard by combining intelligence with high-performance and unrivaled reliability.

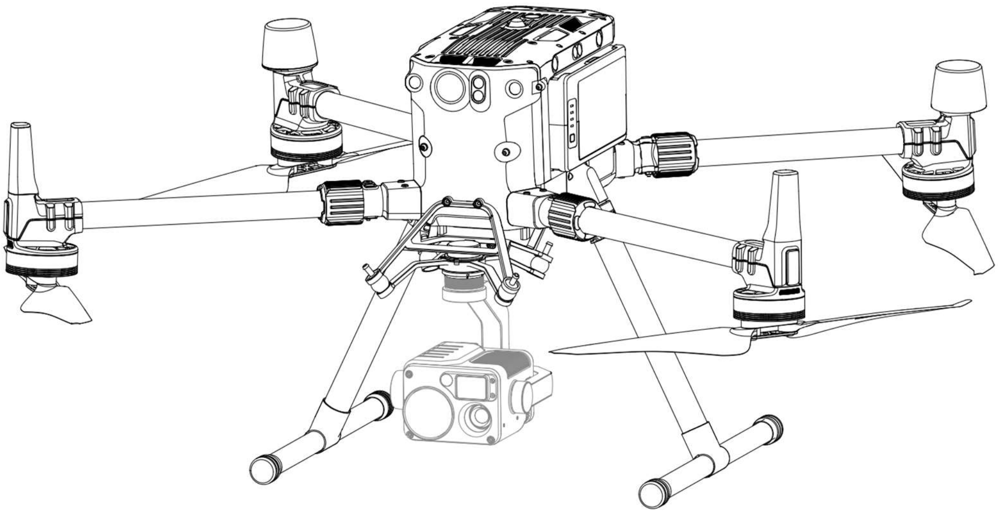

Figure 5-3 – DJI M300 RTK drone

The C&C transmission link guarantees communication up to 15 km away and supports triple-channel3 1080p video. Real-time auto-switching between 2.4 GHz and 5.8 GHz4 enables more reliable flight near high-interference environments, while AES-256 encryption offers secure data transmission.

The M300 RTK mounts up to 3 payloads simultaneously, with a maximum payload capacity of 2.7 kg.

Finally, it can accept RTCM 3.0 stream from GNSS permanent stations (private or public network), to enhance even more navigation performance.

5.1.1.3 MAVIC DUAL ENTERPRISE OR SIMILAR

This drone is planned in the following campaigns:

- Ravenna (Italy), together with recharging station
- Hamburg (Germany)

Further details are reported in is reported in [RD 6]

The selection of this COST drone can change depending on evolution of regulations allowing simplified procedures for drone with weight less than 900g (instead of 250g)

Current selection: https://www.dji.com/it/mavic-2-enterprise/specs

5.1.1.4 RECHARGING STATION WITH MAVIC DUAL ENTERPRISE

This drone is planned in the following campaigns:

- Ravenna (Italy), together with AMVIC enterprise 2 or similar

Further details are reported in is reported in [RD 6]

Recharging station for autonomous drones: This solution implements a recharging station for small autonomous free flight drones capable of monitoring and surveillance operations in a given area of the port (i.e. 1,5 km x 1,5 km).

Figure 5-4 – Recharging station concept

The drone in combination with the recharging station is capable to implement a fully autonomous missions (i.e. inspections of port areas with a given flight path on a programmed schedule) without the pilot in the loop that will be present only for regulatory reasons or for interrupt the mission if needed. The drone used will be a small drone (about 1 Kg) but still capable to acquire very detailed pictures and live video streams that can be forwarded in real time to the Main Platform. The functionalities can be hereafter summarized as follows:

- ✓ Automatic Recharging for small drones that allows the drone to have a operative cycle of about 30 miutes of operations and 1 hour of recharging.
- ✓ Recovery of the drone after landing with a sliding door hangar for bad weather / tampering.
- ✓ EGNSS Receivers + A.I. Real time vision algorithm for precise landing on the Hangar (80 cm x 80 cm)
- ✓ Possibility to broadcast live the video stream in real time for surveillance application
- ✓ Acquisition of images of a given area for orthophoto generation (GEOTIFF images) in order to provde future additional added values services (i.e. Change detection of Port every hour for goods mornitoring,…)

5.1.1.5 DJI MATRICE 210 RTK V2

This drone is planned in the following campaigns:

- Valencia (Spain)

Further details are reported in is reported in [RD 6]

To support the e-navigation objective set for the Valencia port campaign, an autonomous rotary wing platform will be deployed. This platform will act as a mobile sensor providing additional information and situational awareness related with the port safety and security status. The hardware and software components required to enable the autonomous mission inside the port area using the rotary wing platform are described below.

Hardware

- Platform

  Currently the DJI Matrice 210 RTK and the Aeronavis SkyJib platforms are considered (see *Figure 11*). The main specifications for each model are presented in *Table 6*. Although both platforms are suitable for the intended operation, the DJI Matrice 210 is not able to carry as much payload as the SkyJib platform. The final sensor selection will determine the required payload weight, and thus, the final selection of the platform.

*Figure 11. **Left:** DJI Matrice 210 RTK v2 platform. **Right**: Aeronavics SkyJib quadrotor*

Table 6. Rotary wing platform specifications

	DJI Matrice 210 RTK v2	***Aeronavics SkyJib***
Max. Payload weight	1.23 kg	5 kg
Max. Flight time with max. Payload	24 min	15 min
Max. velocity	61,15 km/h	70 km/h

- On-board computing

  The rotary wing platform will be equipped with a powerful embedded computer to enable the autonomous capabilities of the aircraft. All on-board sensors will be interfaced with the embedded computer guaranteeing high-frequency, real-time data. The algorithms for the localization, detection and navigation of the platform will be implemented on the embedded computer. The status of the mission and the platform will be sent via Wi-Fi to a ground computer which will be used to monitor the entire operation.
- Localization and Navigation sensors

  To enable precise and robust position estimation of the platform, the E-GNSS data will be fused with additional sensors. The on-board IMU and magnetometer will provide real-time orientation measurements which will enhance the precise position data from the E-GNSS receiver. A commercially available E-GNSS will be used during the flight and, the MagicUT unit will also be mounted on-board. Its output will be fused with the remaining on-board sensors in post-processing to provide a second and more precise position estimation measurement which will be compared with the output of the commercial E-GNSS receiver.

The rotary-wing platform will also be equipped with a long-range sensor, the output of which will be used to improve the Z-axis position estimation. During the autonomous take-off and landing, this additional measurement will mitigate potential multipath and occlusion scenarios which could degrade the E-GNSS data. Other sensors (e.g., visual cameras, depth cameras, LiDar) will be evaluated and potentially incorporated if the specific operation characteristics require it (e.g., presence of obstacles, uneven terrain during take-off and landing, etc).

- Inspection sensors

  The rotary wing platform will be equipped with a high-definition visual camera and a thermal camera. Regardless of the platform choice, a custom support will be designed to mount these sensors on-board the aircraft. The position and orientation of these sensors will be optimized to ensure that their field-of-view maximizes the area of interest captured. For the visual sensor, a global shutter system will be chosen to avoid the blurriness of the images caused by the platform's motion.

Software

- Localization

  The data provided by an E-GNSS receiver will be fused with additional on-board sensor measurements (e.g., IMU measurements, magnetometer, range-sensor) to increase the precision of position and robustness of the entire system by preventing accuracy degradation in scenarios prone to multipaths and occlusions. The sensor fusion solution will provide complete awareness of the platform's position and orientation along the entire automated operation which will revert in safer, more reliable, and smoother aerial autonomous operations in the Port area.

- Detection and Georeferentiation

  The target detection of different types of vessels moving in the port area will be performed exploiting the multimodality of the equipped sensors (visual and thermal image stream). Algorithms based on Deep Learning techniques will be employed to detect target objects in the Port area making use of already available labelled open datasets. Once the target is detected within the visual and thermal images, a georeferentiation algorithm will be implemented which will make use of the precise position and orientation estimation provided by the sensor fusion module. The 3D pose (position and orientation) of the detected object will then be computed.

- High-level mission planning

  The entire autonomous operation will be governed by a high-level mission layer which implements an AI planning technique. Pre-defined interest areas, take-off, and landing spots as well as different safety constraints will be defined and considered within the high-level mission planning. The perceived data of the environment as well as the sensor fusion solution will be shared across the network to the high-level mission planning module. Having full awareness of the platform's status and its nearby environment, the AI planning technique will generate a feasible mission plan, being able to adapt to different environment circumstances. The AI planning technique implemented in this module removes the need of having to create a specific plan for each situation, by providing a general framework which can adapt to the platform and environment status at each time.

- Guidance and Navigation

  The mission plan generated by the high-level planning module will be sent to lower levels of planning and control. These modules will convert the high-level directives to desired positions and orientations of the rotary-wing platform.

The described hardware and software components will allow the platform to perform different inspection and patrolling missions in an autonomous manner. Nonetheless, a GUI will be available such that the Port operators can give high-level mission commands to the platform and interrupt the operation if necessary. Moreover, during the validation campaign, a safety pilot will also be present to take control over the mission execution in the event of any unexpected behaviour.

5.1.1.6 MAGIC GNSS UT

MAGIC GNSS UT will be embarked on the following rotary wings drones:

- ✓ TETHERED DRONE SOLUTION (MASTER TETHERED DRONE, MTD) (see chapter 5.1.1.1);
- ✓ DJI MATRICE 210 RTK V2 (see chapter 5.1.1.5);

For the purposes of PASSport concept, E-GNSS capabilities will be introduced by embarking a magicGNSS User Terminal **(magicUT) unit in the RPA**. A magicUT configuration (i.e. PDA) is reported in **Errore. L'origine riferimento non è stata trovata.**. Along with the PASSport project the unit will be efficiently engineered to be embarked on the RPA.

The combination of technologies based on E-GNSS can provide the required level of performance in different ways:

- **High accuracy:** E-GNSS can provide RPAS position very accurately, even in the level of centimetres depending on the technology used (e.g. PPP) or Galileo HAS in which a positioning accuracy in the **order of decimeters** (20 cm) is expected. This level of accuracy will be a key element for the operations in terms of *security (image geo-referencing for surveillance analysis)* and *safety (RPAS automated navigation).* As Galileo HAS will not be available in the timeframes managed by the project, use of PPP corrections will be the baseline for the provision of High Accuracy performance in the magicUT unit to be embarked in the drone.

Figure 5-6 MagicUT terminal (current PDA version, 2018)

- **Integrity and reliability** of the solution is required not only for the safety of the operations but also as means of measuring the confidence in the correctness of the positioning information provided by the navigation system. In particular, two different concepts linked to integrity are conceived:
  - On the one hand, the so-called system level integrity, which means that the user would be warned of system malfunctions or discontinuities, so that the user should not use such system for navigation. This is the concept traditionally linked to the IALA DGNSS infrastructure and aligned with IMO A.1046(27) resolution.
  - On the other hand, the concept of integrity at user level, in is related to the implementation of error bounds at user level with certain integrity risk probability, which are called the protection levels. These position error bounds also cover local errors. This is in line with IMO A.915(22) resolution and also with the IMO Multi-system shipborne receiver concept proposed in IMO Circ. 1575. These protection levels are also used in aviation domain.

Different technologies based on E-GNSS can be used to provide the required level of integrity for PASSport purposes such as SBAS (EGNOS) and the use of integrity algorithms, both of them based on the concept of protection levels that calculate user position error bounds in real time up to certain level of probability (the integrity risk). The reliability on the RPAS position provided by the magicUT thanks to the PL computation will also be very useful to increase the reliability of the images taken from the RPA.

- **Robustness against interferences or spoofing attacks**. The use of multi-constellations and more than one frequency as allowed by Galileo will improve not only accuracy but also the resiliency and robustness of the positioning computation. The concern on GNSS interferences, mainly the intentional ones, recommends the use of additional GNSS solutions that are robust against interferences. In the context of PASSport, this will be achieve thanks to (i) the use of GALILEO OS-NMA feature to ensure authentication of the navigation information sent by the Galileo system and (ii) the deployment of an interference detector in port infrastructures. For what concerns the implementation of OS-NMA capability, the candidate options would be on the GMV magicUT unit embarked in the RPAS or on a devoted additional equipment for instance, at port premises, as it can be assumed that the navigation received by the drone is the same as in the port. In terms of interference detection, the proposed solution, SRX-10i/DINTEL (see section 5.4.2), has been successfully used by Spanish Air Navigation Service Provider (ENAIRE) in different airports and has also been used in Maritime context in MARGOT and RIPTIDE projects (in Rumania). This tool will allow detecting interferences in port areas which may degrade GNSS performances.

5.1.2 FIXED WINGS DRONE

In complement to rotary wings UAVs, fixed-wings drone will be used in PASSport for long range flight/missions. In this respect, M3S will bring to the project its long range fixed-wing RPA, named BOREAL. It is a system that consists of a vector of type fixed-wing (4 m wingspan) with rear engine. This configuration gives it a great stability in flight, associated with a significant payload capability (up to 5 kg) and flight duration of up to 10h (see key feature in *Figure 5-7*).

The main interest on this solution is to ensure the surveillance on area size that cannot be covered by rotary wings solutions.

Figure 5-7 BOREAL fixed-wing RPA picture and key features

The ISR configuration of the BOREAL, which is a COTS product, will be used for the project. It consists of a BOREAL vector equipped with a long-range VHF radio link for C2 and datalink (up to 80km), satcom link for C2 once beyond VHF reach. A day EO / night IR optronic turret is already installed in the ISR configuration. For the purpose of PASSport, a GNSS record solution will be installed as well, and the interface with the project infrastructure will be developed.

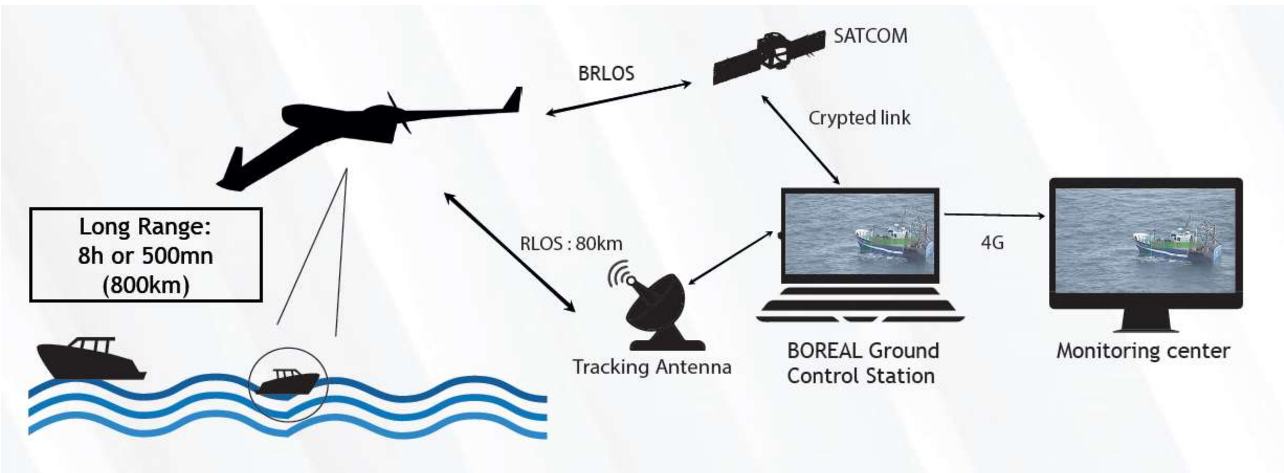

Figure 5-8 BOREAL ISR configuration

Errore. L'origine riferimento non è stata trovata., here after, provides an initial estimation about platform and sensors will be installed in the RPAS to achieve the safe and efficient guidance, navigation and control (GNC).

Item	*Product*	*Action*
RPAS platform	*BOREAL ISR*	*Reuse (interface to be tailored)*
Thermal and visual optronic	ASIO 155	*Reuse*
Inertial measurement unit	*SBG ellipse 2t*	*Reuse*
GNSS Recorder	Portable Dual Frequency GNSS IQ Recorder (M3S)	*Reuse and integration*

Table 5-7 Initial procurement identification

5.1.2.1 STELLA

STELLA equipment will be embarked on rotary wings drones.
M3S will provide the required systems to perform the post operation processing and testing that will be assessing the performance and the usability of the Galileo services and more particularly the OS NMA which is today not easily testable in a real time environment.

The added value of HAS and OS-NMA will be assessed and quantified via lab testing **using M3S GNSS test platform solution STELLA**, especially the record and playback tool and the GNSS interference attack generator.

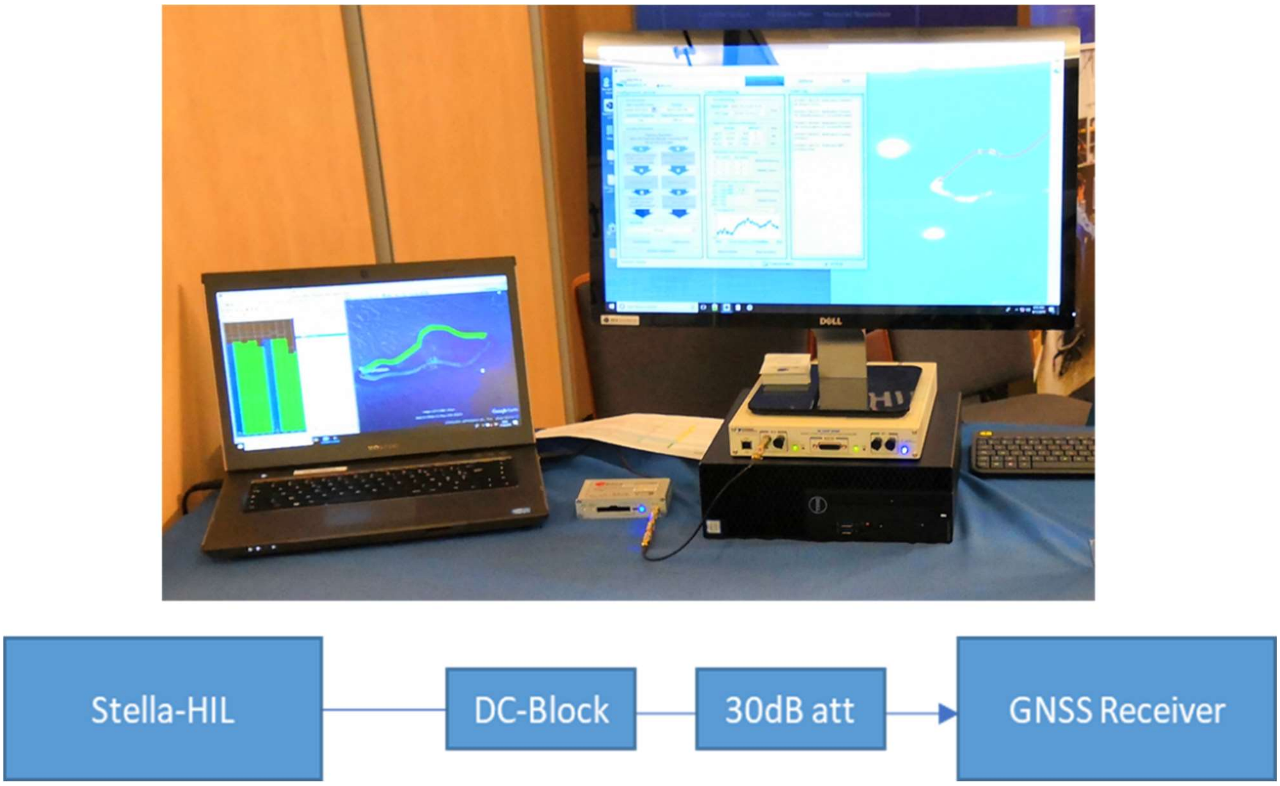

Figure 5-9 StellaNGC System Overview

The concept will be to equip some of the RPAS with a record solution in order to collect SiS in real operational conditions and then to use these signal records in the lab for playback and GNSS performances assessment. The proposed record solution is the Portable Dual Frequency GNSS IQ Recorder developed by M3 Systems that will be added to the payload of the RPAS (displayed below in the Dual board case configuration)

Non è possibile visualizzare l'immagine collegata. Il file potrebbe essere stato spostato, rinominato o eliminato. Verificare che il collegamento punti al file e al percorso corretti.

Figure 5-10 Portable Dual Frequency GNSS IQ Recorder

In addition to repeatability of the tests and the fact that it relies on real life signals, one of the key advantage of the record and playback testing approach is that it provides the opportunity to add various interference attacks (jamming, meaconing, spoofing) on top of the original signals. Last but not least, thanks to test automation, it offers the possibility to multiply the number of tests and therefore to perform easily sensitivity analysis and statistics (not be possible based on flight tests).

5.2 PASSPORT UNDERWATER SEGMENT (PUS)

Autonomous Underwater Vehicles (AUVs) are valuable tools for coastal and seabed monitoring. Up to date, they are commonly used as a passive tool to acquire data in a pre-planned mission. Once the AUV has completed its mission, the collected data are analyzed by a human operator, which is in charge of detecting anomalies and potential hazards for fleet and the seaport traffic. An example of utmost importance is the Mine CounterMeasure (MCM) application, where different AUV types are indeed needed. A first AUV, endowed with a Side Scan Sonar (SSS) or a Forward-Looking Sonar (FLS), is used for large-area seabed inspection. Then, based on the inspection results, a non-magnetic vehicle, either an AUV or a Remotely Operated Vehicle (ROV), is exploited for a close potential hazard inspection. The whole process could be improved both in hazard detection accuracy and in time demand by using AUVs capable of autonomously detecting targets of interest and possible dangers, such as mines. In this context, Artificial Intelligence (AI)-based Automatic Target Recognition (ATR) has emerged as the state-of-the-art approach, potentially overcoming human-eye results. However, it is well known that due to the shallow range of optical cameras and the lack of features in acoustic images, the underwater domain is particularly challenging.

By using Deep Learning (DL), these limitations can be overcome, and ATR applied to acoustic images, acquired by an FLS or an SSS, can be achieved. To obtain real-time monitoring of the ATR process (e.g., detected objects, estimated coordinates) and to gather online data from the AUV (exteroceptive devices outputs, AUV state), information sharing is crucial. Given the unavailability of electromagnetic signals in the underwater domain and considering the limitations of acoustic communications, a WiFi network is often employed to exchange information among the actors involved in ATR procedures, typically an AUV (if on surface or attached to a small gateway buoy) and a ground station. More recently, to speed up the coverage of the operation site and to obtain information from multiple sources, which is likely to improve the performance of the ATR system, heterogeneous swarms of autonomous vehicles, such as AUVs or ROVs, and Unmanned Aerials Vehicles (UAVs) have gained attention. In such a situation, usually, the ground station acts as an access point for the WiFi network to which each vehicle, as a station, is connected. The AUV can represent one of the nodes of the relay network.

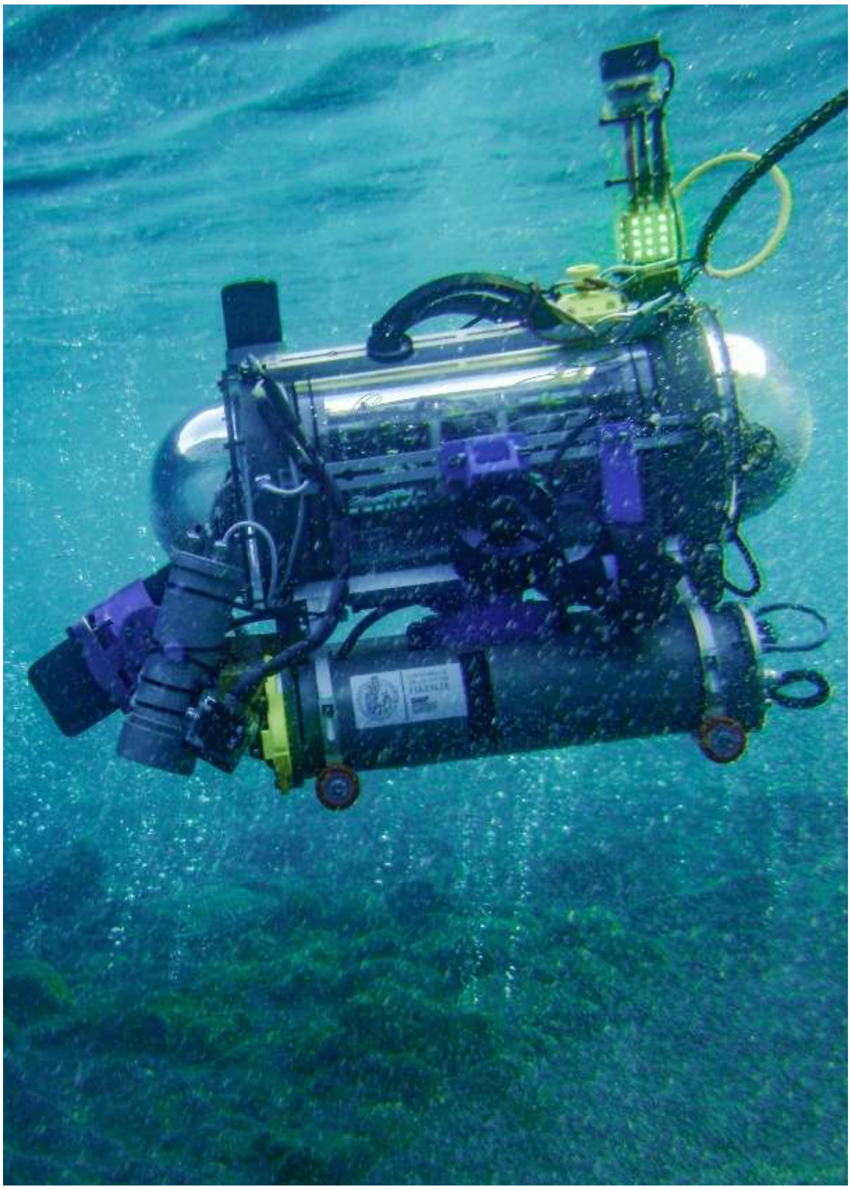

Figure 7-5 FeelHippo (UNIFI) AUV at Vulcano Island, Messina (Italy) in 2019

Moreover, due to the enhancement of the processing capabilities of the modern processor computers, AUVs have being further exploited for an increasing number of missions and operations. For instance, since the creation of detailed seafloor maps has been arisen as crucial in monitoring the seabed changes and possible threats, the employment of AUVs for bathymetric map analysis may produce cheaper, more straightforward operations rather than traditional bathymetric surveys. In this perspective, although standard surface vessel-based bathymetry methodologies can provide higher-resolution maps, the AUV-onboard seabed bathymetric outcomes may represent a suitable tradeoff between logistic constraints and performance. Furthermore, the AUV can complement the bathymetric mission with more close and detailed inspections by means of optical and acoustic payload sensors.

As far as this project is concerned, the exploited underwater drone is represented by FeelHippo AUV, a compact and lightweight autonomous vehicle developed by the Department of Industrial Engineering of the University of Florence (UNIFI DIEF). Its main features as well as onboard devices are reported hereafter.

Dimensions [mm]	approx. 600×640×500
Dry mass [kg]	35
Max longitudinal speed [m/s] (kn)	approx. 1 (2)
Max lateral speed [m/s] (kn)	approx. 0.2 (0.4)
Max depth [m]	30
Autonomy [h]	2-3

Onboard devices:

- Intel i-7-based LP-175-Commel motherboard (used for onboard processing);
- U-blox NEO-M8 precision Global Positioning System (GPS);
- Orientus Advanced Navigation Attitude and Heading Reference System (AHRS);
- KVH DSP 1760 single-axis high precision Fiber Optic Gyroscope (FOG);
- Nortek DVL1000 *Doppler* Velocity Log (DVL), measuring linear velocity and acting as Depth Sensor (DS);
- EvoLogics S2CR 18/34 acoustic modem;
- Teledyne BlueView M900 2D Forward-Looking SONAR (FLS);
- Ubiquiti Bullet M2 WiFi access point;
- 868+ RFDesign radio modem;
- two Microsoft Lifecam Cinema cameras;
- one NVIDIA Jetson Nano.

Table 5-8 FeelHippo AUV main characteristics

5.3 PASSPORT GROUND SEGMENT (PGS)

PASSport Ground Segment (PGS) is composed by several elements and aims to organise proper HMIs to provide relevant authorities in charge of operations with subsequent procedures according to the maritime code.

It will be composed by a mission Element (PME) and Control Element (PCE).

PME will include the feature of Flee Drones Management (FDM) where several functionalities will be implemented for a different environment and will be adapted to include:

- ✓ command and control the drones generating dedicated missions per way-points
- ✓ collect payload data, mainly optical/ thermal images/ videos, as well as relevant metadata
- ✓ allow an operator to perform high level analysis for both security (threats management) and safety (hazards management) topics.

PCE will be the element allowing the pilot and command to manage C2 link with the RPAS and to implement emergency procedures in case any failure occurs to the RGMS to RPAS link. This element has been conceived in order to be compliant with regulation) for scenarios involving automated RPAs.

In particular, a comprehensive operational scenario has been identified composed by the following missions:

- *Context awareness, RT-NRT Video Monitoring and Surveillance* as reported in section 5.3.1
- Data analysis (post processing), as reported in section 5.3.2

Note that detailed configurations are reported in [RD 6] for each scheduled campaign.

Figure 5-11 Possible Mock-up for PGS (core platform)

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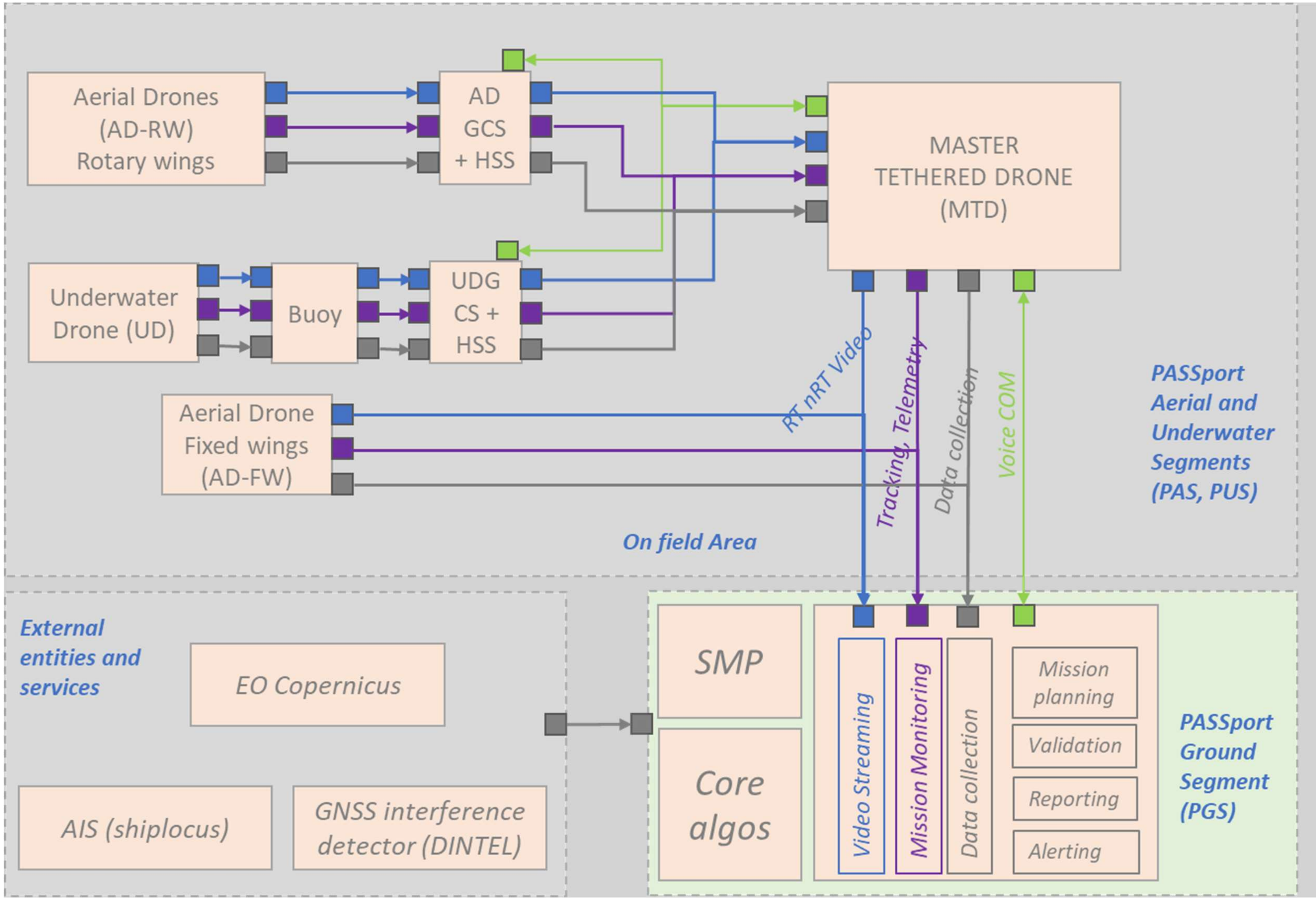

Aerial Drones (AD-RW) Rotary wings
AD GCS + HSS
MASTER TETHERED DRONE (MTD)
Underwater Drone (UD)
Buoy
UDG CS + HSS
Aerial Drone Fixed wings (AD-FW)
RT nRT Video
Tracking, Telemetry
Data collection
Voice COM
PASSport Aerial and Underwater Segments (PAS, PUS)
On field Area
External entities and services
EO Copernicus
AIS (shiplocus)
GNSS interference detector (DINTEL)
SMP
Core algos
Video Streaming
Mission Monitoring
Data collection
Mission planning
Validation
Reporting
Alerting
PASSport Ground Segment (PGS)

Figure 5-12 P

5.3.1 CONTEXT AWARENESS: RT-NRT VIDEO MONITORING AND SURVEILLANCE

Urgent missions involves the usage of fleet of Underwater (UD) and aerial (AD) drones managed from a single ground Mission Platform (GCMP) where all video streams and other data (e. g. 3D maps, placemarks,…) incoming drone data are sent for real-time overviews, analysis and in-depth investigation. Accordingly, GCMP is deemed as a scalable solution, offering RT-nRT video monitoring/ surveillance functionality and an intuitive interface, and tailored to manage complex investigation or surveillance operations from any remote site.

Emergency missions are currently the most widespread use for PATHfinder, where a dedicated GCMP operation centre can be conveniently set up near the area that is to be surveyed. The GCMP platform allows users to simultaneously view multiple video streams and a 3D map of the mission terrain with the actual coordinates of the drones. Both the operator and the pilots can manually control the drones when needed, as well as adding placemarks for particular areas with attached geolocation and images for more in-depth inspection.

In particular, the platform is a customization on tailoring of product inherited form Sistematica (Visual Track and Hedronics merged with other COTS product) experience for mission preparation and execution. It will include the following benefits:

- ✓ Drone pilot and mission operator don't have to be in the same location, a sthe pilot will be in charge to manage flight operations and a remote operator will be in charge to mission surveillance with low latency and reliable livestream from drones fleet
- ✓ Video recording is thought to be a full Motion Video compatible with ArcGiS Full Motion Video module which will be in charge to show the drones and pilot (GCS station) positions displayed on the map.

5.3.2 DATA ANALYSIS (POST PROCESSING)

5.3.2.1 AERIAL MAPPING

Mapping, also known as photogrammetry mapping is the science of making measurements from photographs. The output from photogrammetry software is typically a 3D map, a 3D drawing or a 3D model of some real world object or land mass.

In order to create a 3D map of a land mass from aerial photos, the camera is mounted on the AD drone or aircraft and will be pointed vertically towards the ground.

The drone camera will capture hundreds, even thousands of overlapping photos of the ground, structure or model. The photos will overlap each other, with an overlap of 80 to 90%. The 3D map or 3D model is then created using aerial image stitching photogrammetry software.

The drone will fly using autonomous programmed flight paths called waypoints. To overlap photos of an object or land mass by 80 to 90% would be impossible to complete accurately by pilot navigation. It is essential to have a drone, which has waypoint navigation technology.

Each photo captured will also have it's GNSS coordinates (Geotagging saved, which also assists to build the 3D map. A geotagged photograph is associated with a geographical location. Usually this is done by assigning at least a latitude and longitude to the image. Other fields may be optionally included such as altitude and compass bearing.

For the scenario as presented in section, the following product will be prepared:

- DEM / DTM / DSM (surface models)
- Orthophotos (geospatially corrected aerial images)

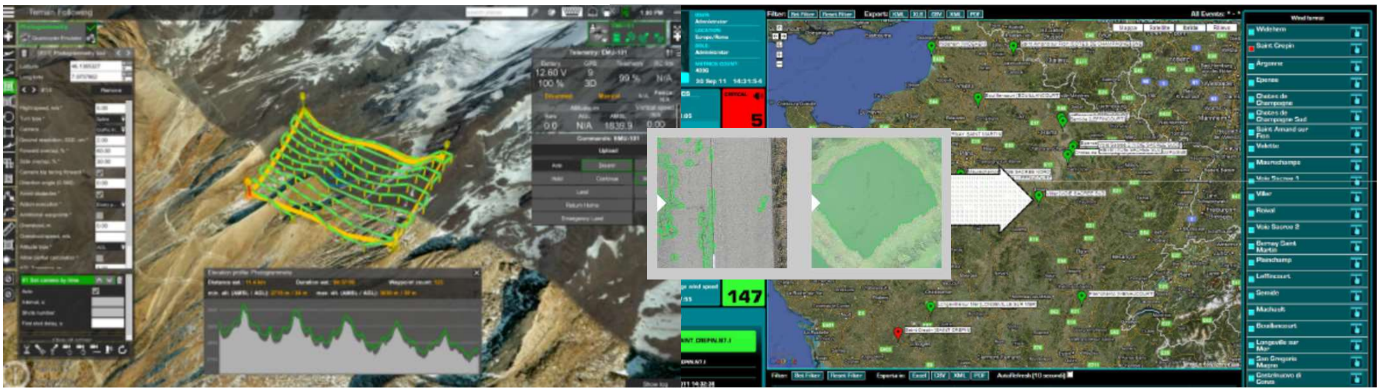


Figure 13 – Sample of possible platform for context awareness scenarions

5.3.2.2 UNDERWATER MAPPING

FeelHippo AUV, the underwater drone of UNIFI DIEF, has an image mapping software tailored to both acoustic (e.g., obtained with a Forward-Looking Sonar (FLS)) and optical imagery, obtained with cameras, able to cope with different and mutable underwater scenarios. Optical cameras can provide high-quality images at high frame rates, but water turbidity and poor lighting conditions limit their usage. On the other hand, acoustic payload devices acquire lower resolution images but can penetrate the water for longer ranges, depending on the water and environmental conditions, and they are not influenced by illumination conditions.

During the project some data will be processed on-board, e.g. to provide 2D acoustic mosaics; moreover, post-processing activities will also lead to 3D optical and/or acoustic reconstructions and to bathymetry.

Mapping solutions' accuracy depends on the imagery registration and georeferentation precision that is based on the AUV navigation data. The more accurate the AUV localization, the greater is the accuracy of the acquired images' georeferentation, which constitutes the fundamentals for constructing consistent underwater maps. Consequently, the precision of the AUV navigation strategy is of utmost importance. UNIFI will use during the project a high-precision navigation solution, integrating GNSS measurements provided by the passive towed buoy, which could prevent the long-term drift typical of GPS-denied operations, and thus allow to accurately map large areas.

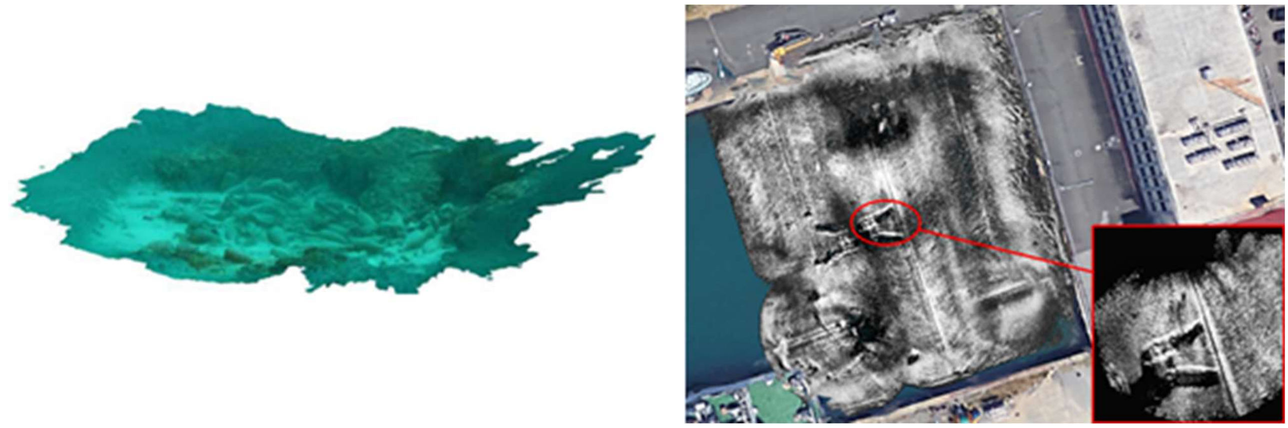


Figure 14 Examples of underwater mapping. On the left, an optical 3D reconstruction of Cala Minnola site (Trapani, Italy). On the right, a 2D acoustic reconstruction of the NATO STO CMRE basin (La Spezia, Italy).

5.3.3 SECURITY MANAGEMENT PLATFORM (SMP)

SMP Security Management System is an innovative software solution managed by G7. The scope of SMP is to support Port Authorities, harbour masters, border control authorities and Companies to ***manage*** port **security** emergencies in the proper way, ***saving precious time*** identifying ***the causes of the accident.***

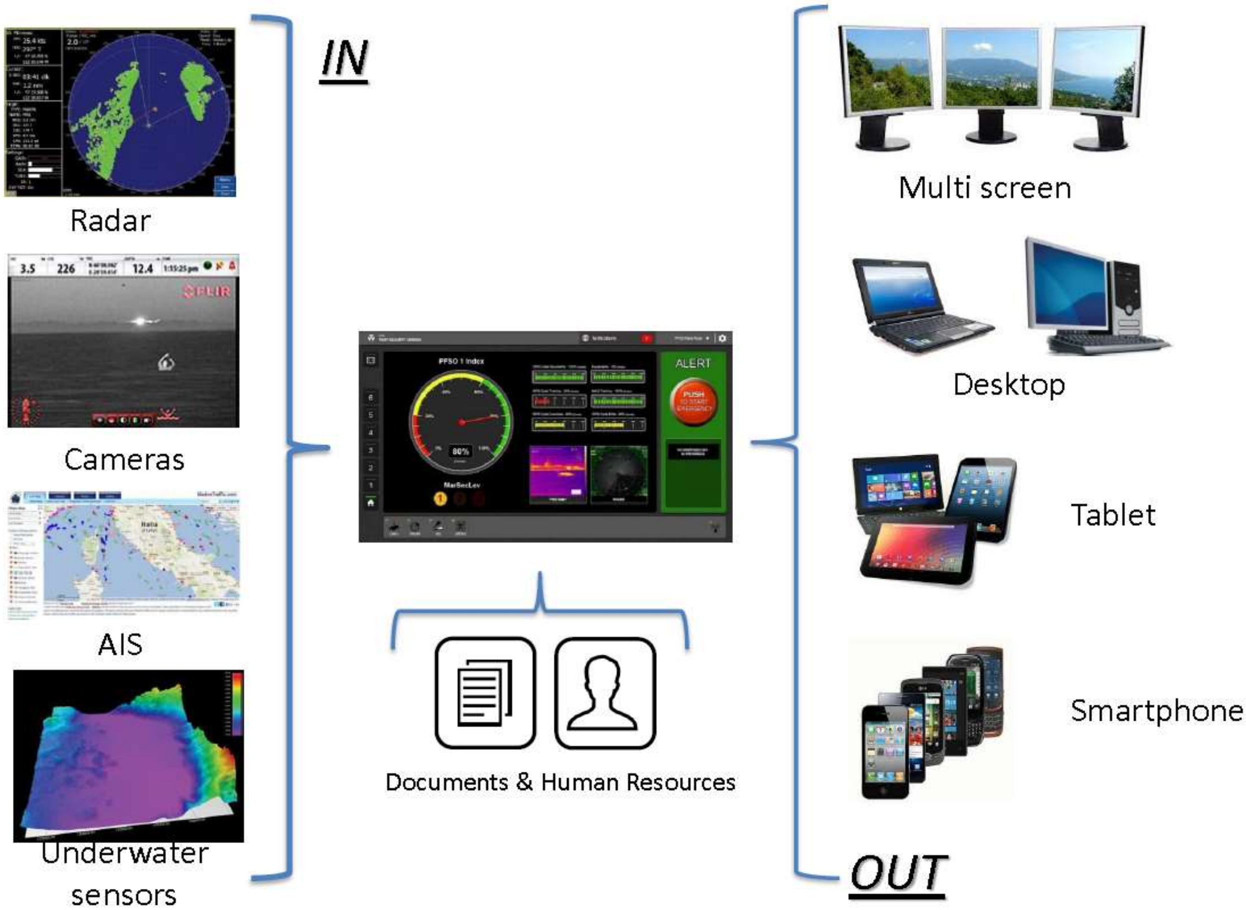


Figure 5-15 SMP concept

Two main operative modes are identified:

- ✓ In the ***Consultant mode***, EMP shows to the operator, in real time, the security capability of the port facility (% ***security index***), to manage the threat, based on the availability of the main resources:
    - o Human resources (emergency security training; applied psychology; emergencies security drills and exercises)
    - o Port equipment resources deal with the emergencies (i.e.: LRIT; AIS; Radar; CCTV; ….)
    - o Documents resources (Ship or port facility security plan; ISPS Code; Risk assessment; …)
- ✓ In the ***Alert mode*** the system warms the operator of a current security emergency. The operator confirming the emergency, starts up the list of specific procedures to follow in order to manage efficiently the threat. The system allows to send a notification to the others operators or managers involved in the emergency management, that the emergency is in progress. Furthermore, ***all the people*** involved in the emergency management, with the right permission recognize by the system, can actively make a contribution to manage the emergency or simply advisory the operating theatre just viewing the specific sensors (radar, AIS, thermal camera, etc…) connected to the system and the state of the art regarding both ***TIME AND PROCEDURES.***

The **SMP Security Management Platform** will be the point of collection and analysis of all the information (images, videos, signals, alarms ….) coming from the site.

The SMP will be designed as modular and scalable for each expansion and/or integration needed.

The basic architecture of the Platform will consist of the following modules:

- **DATABASE MANAGEMENT CONTROLLER SCENARIOS**: this module will be the core of the system, in which a list of possible emergency and non-emergency scenarios will be created, standard for all the ports covered by the project and specific scenarios tailored to specific needs. The scenarios database will be kept constantly updated, considering the continuous evolution of threats.

  Main Mission's Categories

  - Monitoring and Inspection (MI)
  - Environmental (ENV)
  - Operation and Logistics (OL)

  Possible Scenarios (non exaustive List)

Atmospheric	Structural Failure / Accident	Biological
Geologic	Fires / Explosions	Radiological
Hydrologic	Energy / Utility Incidents	Terrorism
Seismic and Volcanic	Transportation Incidents	Civic Disruption
Other Natural disasters	Hazardous & Pollutant Materials	Cyber Attacks

- **DATABASE MANAGEMENT CONTROLLER PROCEDURES:** for each type of scenario, security procedures and guidelines will be implemented to mitigate threats and resolve emergencies. the procedures will refer to a specific scenario associated to an emergency level. Given the organizational complexity of a port, these procedures will have to consider the existing coordination of contingency or emergency plans of the port, the scalability of the contingency or emergency plan of the port and the structure and content of the contingency or emergency plan. The procedures database will be kept constantly updated, considering the continuous evolution of threats and the multiple figures in charge of security.

- **DATABASE MANAGEMENT CONTROLLER CONTACTS/DISTRIBUTION LIST:** to make a procedure operational, distribution lists will be created for personnel in charge of managing emergencies, alarms and other information generated from the SMP. The more accurate and calibrated the distribution list is according to the type of scenario and the level of emergency, the more effective the emergency procedures will be.

- **ALGORITHM & DATA FILTERING:** all data and signals from the field will be filtered and categorized according to a specific Location/Situation/Risk/Emergency structure

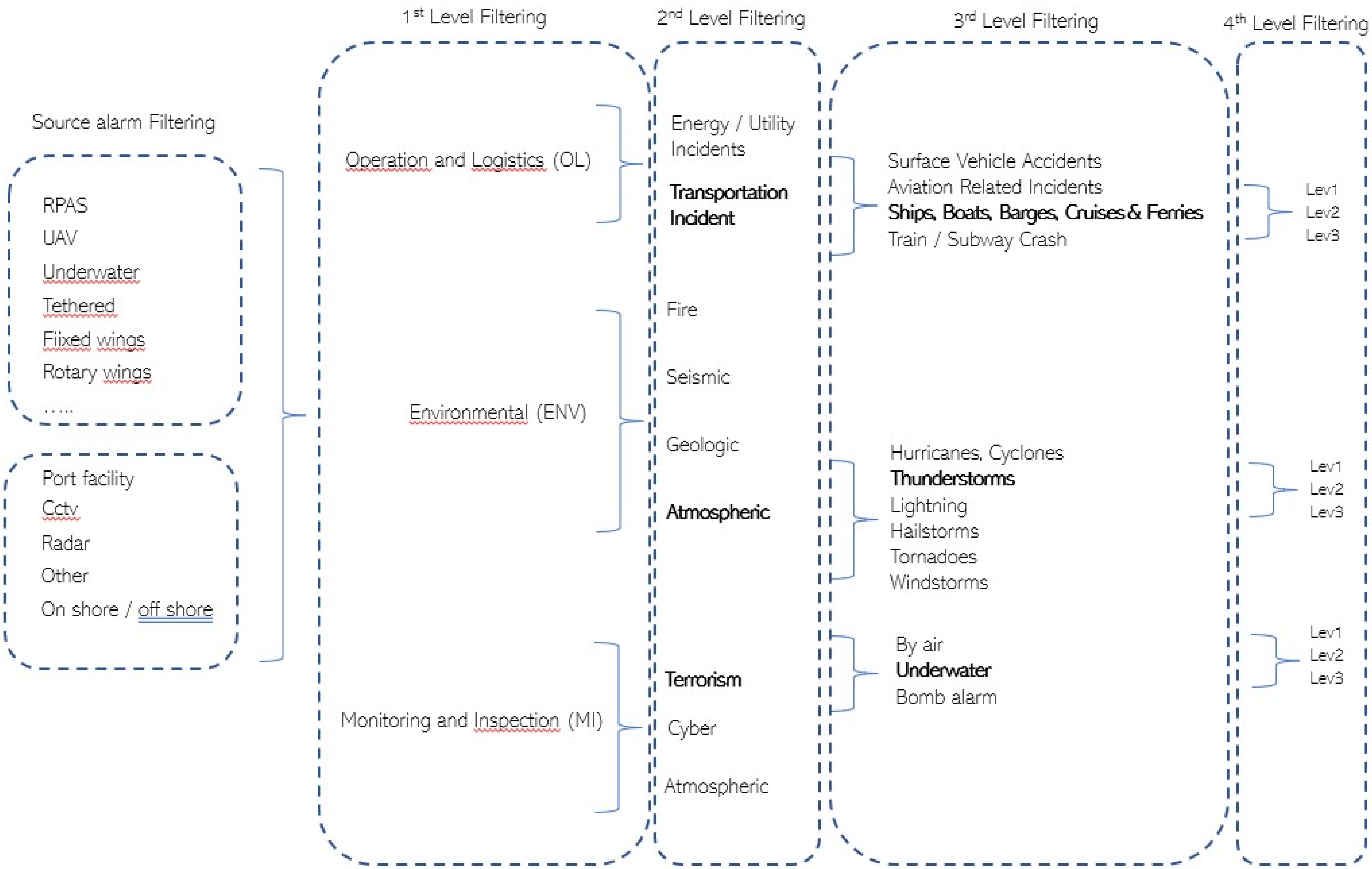
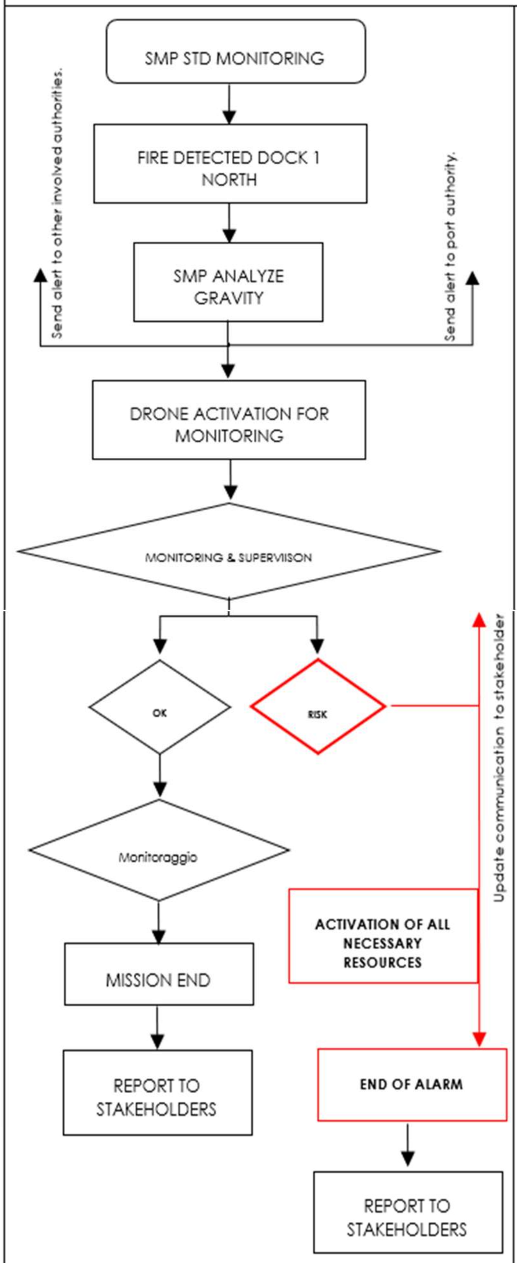


Figure 5-16 SMP data architecture

SMP Monitor Process – STANDARD MONITORING & REPORTING
Process owner: CTRLRoom / Port Authority
Table 1



Fase	Decription	Resp.
	The SMP is collecting videos & data from the field (Standard RPAs Patrolling activity / existing port facility security infrastructure).	CtrlRoom
	Detection of fire through port facility existing thermal camera	CtrlRoom
	The SMP analyze through internal algo the gravity of the event and start security communication procedures.	CtrlRoom PA
	The SMP activate the RPAS to monitor the event according to site security scenarios.	CtrlRoom PA
	The Drone start the monitor mission and send in real time images and videos to the Control Room.	CtrlRoom PA
	The Control Room operators, analyze the ongoing event	
	The Control Room operators activate all necessary resources according to security procedures, to mitigate the Alarm	CtrlRoom PA

Figure 5-17 SMP Operational Process example

5.4 EXTERNAL OPERATIONAL ENTITIES

5.4.1 SHIPLOCUS

Shiplocus® covers the needs of harbour authorities and port operators in different service areas, providing for the real-time monitoring of ships, the streamlining of port planning, integration of intermodal transport, management of stopovers, running marinas and the monitoring and control of navigation aids.

Shiplocus will be used as a supporting tool for the proposed PASSport platform for Valencia and Hamburg trials. **Shiplocus is already operational supporting E-Navigation operations for Ports of Spain and in particular in Valencia Port**. The objective of including this capability in the project is to experiment the integration with an automated RPAS providing situational awareness.

The PSG of PASSport will interface Shiplocus tool in order to share the key data that shall be showed. In particular, Shiplocus will be able to visualize the trial elements (RPA, vessel, others) in an easy way and additional features obtained thanks to E-GNSS (e.g. safety margins or protection levels, authentication). This will improve safety thanks to the guarantee of positioning that GNSS can provide. The visualization of these assets in Shiplocus tool (and especially, with its safety margins) may increase the operations capability of the port thanks to the certainty of the positioning of the assets (guarantee of positioning and resilience).

Shiplocus will also act as a data source injecting information from the collaborative vessels into PASSPORT.
Format or identification of the parameters that will be shared from Shiplocus to PGS:

- AIS data

Format or identification of the parameters that will be shared from PGS to Shiplocus:

- Drone position together with available information of magicUT (e.g. positions, protection levels)
- Non-collaborative vessels position.

Shiplocus will be installed in a specific device (tablet o laptop) linked to PASSport module. Shiplocus will need to get access to AIS data source provided by the Port Authority.

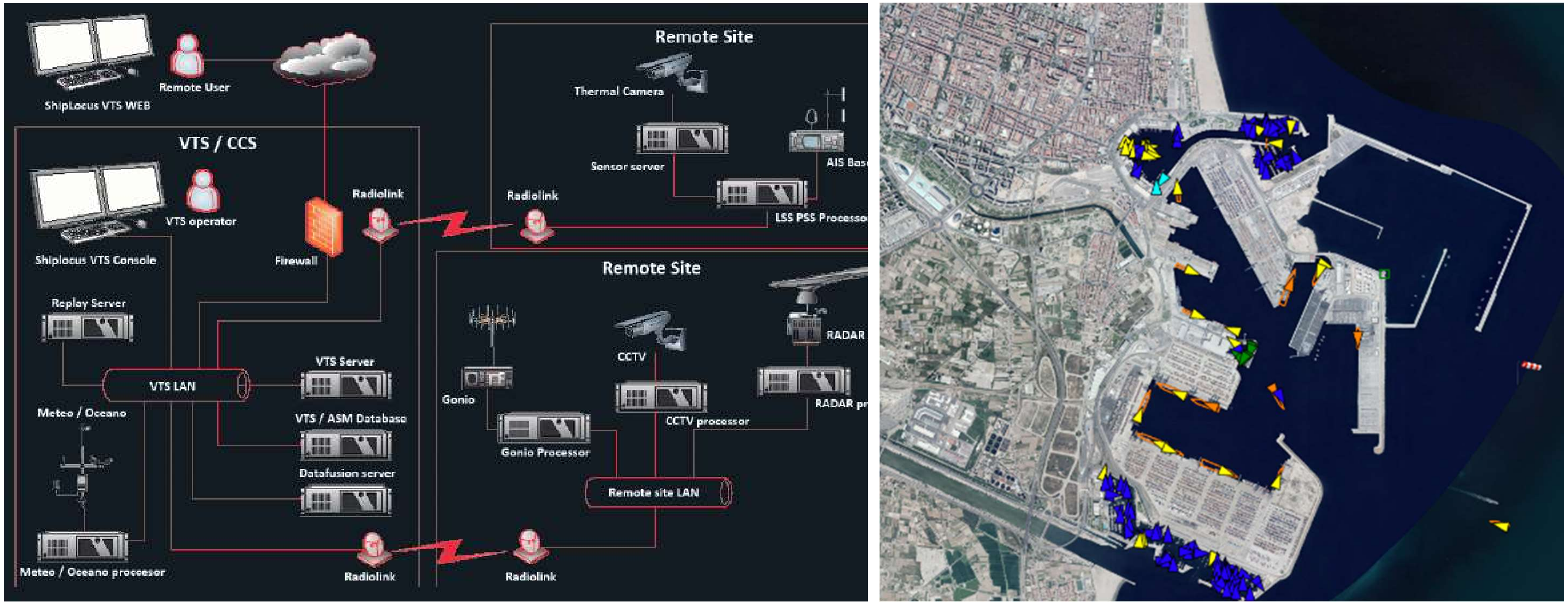


Figure 5-18 Maritime traffic management and supervision with shiplocus

Figure 5-19 Port planning and control system with shiplocus

5.4.2 SRX-10I/DINTEL

Port areas are characterized by a large amount of infrastructures which makes that unintentional interferences can occur more than desired. Nevertheless, maritime community is increasingly be concerned about intentional attacks such as jamming and spoofing. The former may not critically affect to maritime safety since GNSS signal disruption would lead to service not being available. However, spoofing could potentially provoke accidents, vessel misrouting or theft.

For this reason, **PASSport includes as external interface also SRX-10i interference detector in the port to detect interference events that could compromise the security and the safety of port operations**. In particular, the GMV Interference Detector product (SRX-10i, aka DINTEL), a complete GPS/Galileo spectrum monitoring, interference detection and analysis system in configurable dual band (e.g. L1/E1 and L5/E5a) fully developed by GMV will be used during the campaign in Valencia, Hamburg and Le Havre.

The system offers the following benefits:

- Uninterrupted, automatic operation for continuous monitoring of interferences in GNSS bands.
- Dual-band simultaneous monitoring (e.g. GPSL1/Galileo E1 and GPSL5/GalileoE5a).
- Identification and characterization of interference sources
- Interference sensors designed to optimize production costs and enable deployment in multiple points in the area to be monitored
- Connectivity to customer and/or national alert management systems
- Raw data acquisition whenever an interference event is detected,

It has been designed to fulfil the need of spectrum monitoring whenever GPS and Galileo is used in the support of the operation in critical infrastructures. SRX-10i product is a complete GPS/Galileo spectrum monitoring, interference detection and analysis system in configurable dual band (typically L1/E1 and L5/E5a) that has successfully been used by ENAIRE (Spanish Aviation Safety State Agency) operation at 10 Spanish airports to monitor GNSS interferences and used in experimental technical campaigns for maritime applications in Romania (ESA MARGOT and RIPTIDE projects). Even if SRX-10i has been used in such studies for interference monitoring in maritime, **the novelty of PASSport project is to use GNSS interference detector integrated in Port Operations.** Indeed**,** GNSS vulnerabilities in Maritime are a well-known limitation that is somehow slow down the uptake of GNSS in Maritime sector. Galileo is a very innovative GNSS that could somehow overcome this limitation and in consequence increasing the use of E-GNSS in Maritime.

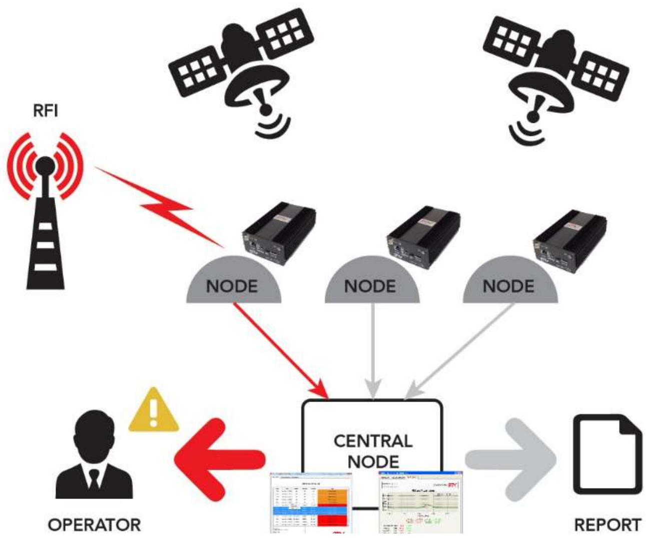


Figure 5-20 SRX-10i system infrastructure

As it can be seen in Figure 5-20, SRX-10i system infrastructure is composed by a network of nodes which are responsible for the spectrum monitoring acquisition, and a central node which processes the information and reports it to the user. Table 5-9 contains the specifications of SRX-10i system. A CAD model of a SRX-10i node is shown in Figure 5-21.

Figure 5-21. SRX-10i remote node

Description	**Simultaneous GNSS dual-band spectrum monitoring and interference detection system. Any pair of GNSS bands can be configured from factory**
Bandwidth	20 MHz. Up to 50 MHz
Frequency resolution	Configurable. Typically 1.5 kHz
Interference detection	Detection of continuous-wave (CW), broadband and pulsed interference signals when they exceed a predefined (calibrated) threshold
Probability of detection/false alarm	Function of configurable threshold
Sensitivity	Displayed Averaged Noise Level (DANL): -150 dBW/Hz (-90 dBm @ 1.2 kHz RBW) Values measured using active antenna/front-end with G=45 dB
Network configuration	Static/dynamic IP options
Memory	32GB non-volatile memory
Data output – Alert message	Message sent to a central server including: • Node ID • Timestamp • Peak power [dBm] • Frequency [MHz]
Data output – Raw data	Both Power Spectral Density (PSD) and baseband raw data options available.
Data output – Presentation	User-friendly website with the following information: • Remote station (node) health status. • Interference counting. • Spectrogram (plot of power spectral density vs timestamp).
Node Size	150x110x60.8 mm
Node Weight	< 1 kg
Node Enclosure	Extruded aluminium
Node Power	5 VDC/4A max
Node Ports	RF in (TNC) Power supply (female barrel 2.1 mm) HDMI video out (maintenance interface) USB Ethernet LAN adapter (maintenance)
GNSS antenna	Compatible with multiband active antennas
CE marking	EMC 2014/30 EU
Environmental conditions	Operating temperature: -10 to +50°C 65% RH No IP rating

Table 5-9. SRX-10i specifications

PASSport Configuration

The system architecture proposed for PASSport is shown in Figure 5-22. A single SRX-10i remote node is continuously monitoring the spectrum for the presence of interferences. Any event detected by the node is pushed to a server located in GMV premises via an encrypted link. PASSport operator(s) will have access to the server via a web interface to request:

- **Interference summary data** such as:
  - Duration, frequency and bandwidth of interference.
  - Power spectral density (PSD) of an individual event and spectrogram of many events.
- Node **status** (active/inactive).
- Node **management** (installation/removal).

In addition to that, the server keeps an **alert daemon** which will notify via an email a distribution list of contacts and/or machines.

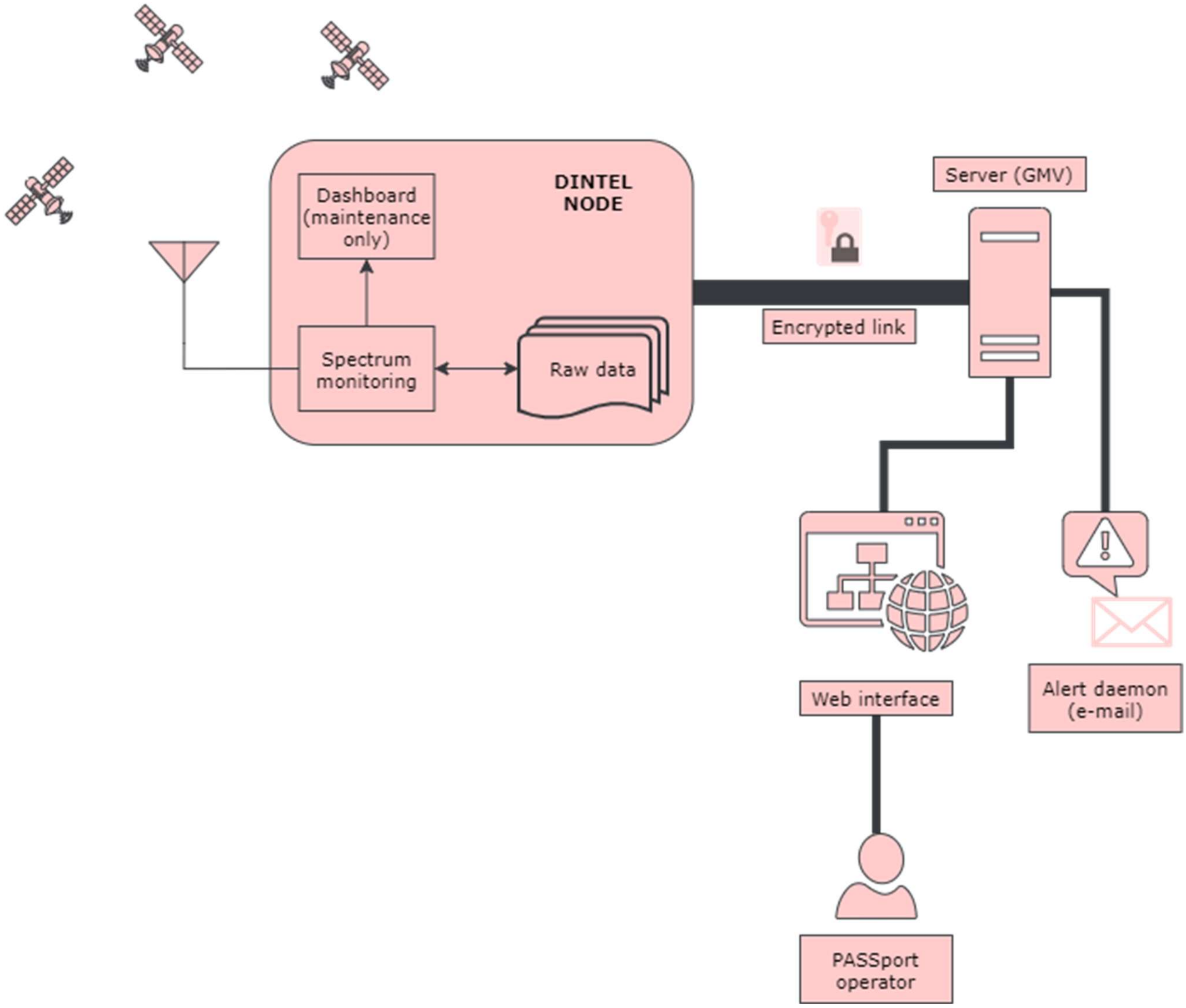


Figure 5-22. SRX-10i proposed architecture for PASSport

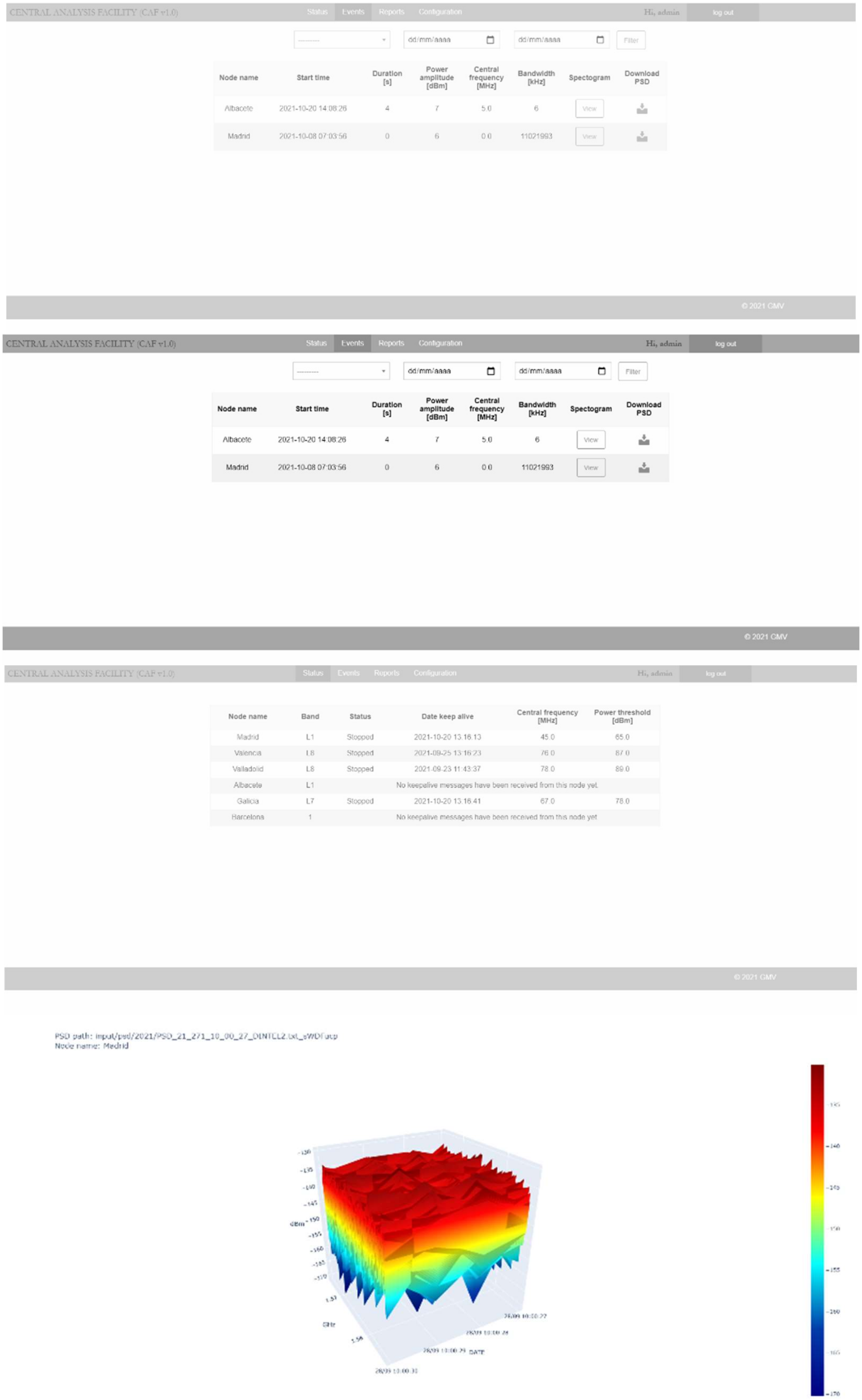


Figure 5-23 Web interface of SRX-10i/DINTEL *(PASSport configuration)*

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