The Atlantic Testing Platform for Maritime Robotics

Topic	ICT-09-2019-2020 (H2020)
Acronym	ATLANTIS
Title	The Atlantic Testing Platform for Maritime Robotics: New Frontiers for Inspection and Maintenance of Offshore Energy Infrastructures.
Project number	871571
Delivery date	31.10.2020
Deliverable number	D2.2
Dissemination level	Public
Lead Beneficiary	SPACEAPPS

System Requirements and Platform Interfaces

SpaceApplications, INESC TEC, UdG, IQUA, ECA, VTT, EDP, RINA-C

Actions

	Action	Organisation	Date
Technical Manager	Requested deliverable from the Deliverable Responsible.	VTT	19.09.2020
Deliverable Responsible	Prepared draft of the deliverable.	SPACEApps	15.10.2020
Technical Manager	Approved the updated draft as the first version.	VTT	23.10.2020
Quality Manager	Approved the updated first version as the second version.	UdG	27.10.2020
Project Coordinator	Approved the updated second version as the final version and sent to the European Commission.	INESC TEC	31.10.2020

Disclaimer

This document does not represent the opinion of the European Union nor the European Commission is responsible for any use that might be made of its content. The ATLANTIS consortium cannot warrant that information contained in this document is free from risk and, neither the European Commission nor the ATLANTIS consortium parties are responsible for any use that may be made of the information contained therein.

This document may contain material, which is the copyright of certain ATLANTIS consortium parties, and may not be reproduced or copied without permission. The commercial use of any information contained in this document may require a license from the proprietor.

The sole responsibility for the content of this publication lies with the authors and all ATLANTIS consortium parties have agreed to full publication of this document.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

List of acronyms

Acronym	Meaning
ACAS	Automatic collision avoidance system
ACFM	Alternating current field measurement
AET	Acoustic emission testing
AIS	Automatic identification system
AP	Access Point
API	Application Programming Interface
ASV	Autonomous surface vehicle
AUV	Autonomous underwater vehicle
CCU	Control Command Unit
COTS	Comercial of The Shelf
CP	Cathodic protection
CPS	Cable protection system
CTV	Crew transport vessel
DDS	Data Distribution Service, communication protocol
DDS	Data Distribution Service
DOF	Degrees of Freeedom
DP	Dynamic positioning (vessel)
DS	Docking Station
DVL	Doppler Velocity Log
ECS	Electronic chart system
EU	European Union
FoV	Field of View
GNSS	Global navigation satelite system
GPS	Global positioning system
GWT	Guided wave testing
HD	High definition
HDTV	High Definition Television

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

HW	Hardware
HW	Hardware
I-AUV	Intervention autonomous underwater vehicle
IMR	Inspection, maintenance and repair
IMU	Inertial Measurement Unit
IoT	Internet of Things
LIDAR	Light detection and ranging
MBIS	Multi-Beam Imaging Sonar
MVOW	MHI Vestas Offshore Wind
NDT	Non-destructive testing
O&M	Operations and maintenance
OGC	Open Geographic Consortium
PM	Permanent magnet (machine)
PMC	Platform mooring connectors
PMC	Platform Mooring Connectors
PPC	Power plant controller
PPE	Personal protective equipment
PSU	Power Supply Unit
QoS	Quality of Service
RACON	Radar beacon
RB	Roving Bat
RC	Radio Command
RF	Radio Frequency
RIB	Rigid Inflatable Boat
ROS	Robot Operating System
ROV	Remotely operated vehicle
RTK	Real Time Kinematic
SCADA	Supervisory control and data acquisition
SCC	Suprevisory Control Centre

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SCU	Surface Control Unit
SDR	Software Defined Radio
SHM	Structure health monitoring
SOV	Support offshore vessel
SW	Software
SW	Software
TC	Telecommanding
TM	Telemetry
TRL	Technology readiness level
TRL	Technology Readiness Level
UAV	Unmanned aerial vehicle
US	Ultrasound
USB	Universal Serial Bus
USBL	Utra Short Base Line
USV	Unmanned Surface Vehicle
UxV	Unmanned Vehicle
VDSL2	Very high-speed Digital Subscriber Line
WFA	WindFloat Atlantic
WTG	Wind turbine generator

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Table of figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

1. Introduction

The activities performed during task 2.2 had the main goal to identify the links that have to be established between different systems (Figure 1). Given the Pilot scenario requirements, and the diversity of functionalities offered by the set of marine and aerial robots, the consortium have first identified the system requirements in terms of:

- functional;
- performance;
- interface;
- deployment/operational;
- safety requirements.

Based on the identified cross platform requirements a corresponding system design and specification has been proposed. The platform will support for the design of a common interoperability software module that can standardize the telemetry, supervisory telecommands (TM/TC) and fused sensor data, to operate and monitor UxVs from a remote SCC.

The task involved two main parts. Firstly, all involved technology providers have listed the requirements that the system they are providing have to fulfil in order to operate at optimal parameters for the specified scenarios. Based on the identified system specifications the second part of the task concentrated on defining the generic set of platform interfaces for software and hardware alike.

This document will be necessary in the study of the command and data centric interfaces that each robot software components provide. The robot providers (IQUA, ECA, UdG and INESC TEC) collaborated with SPACEAPPS in defining the necessary interfaces to make their robot interoperable with with the SCC. A set of generic platform interfaces are defined for each vehicle.

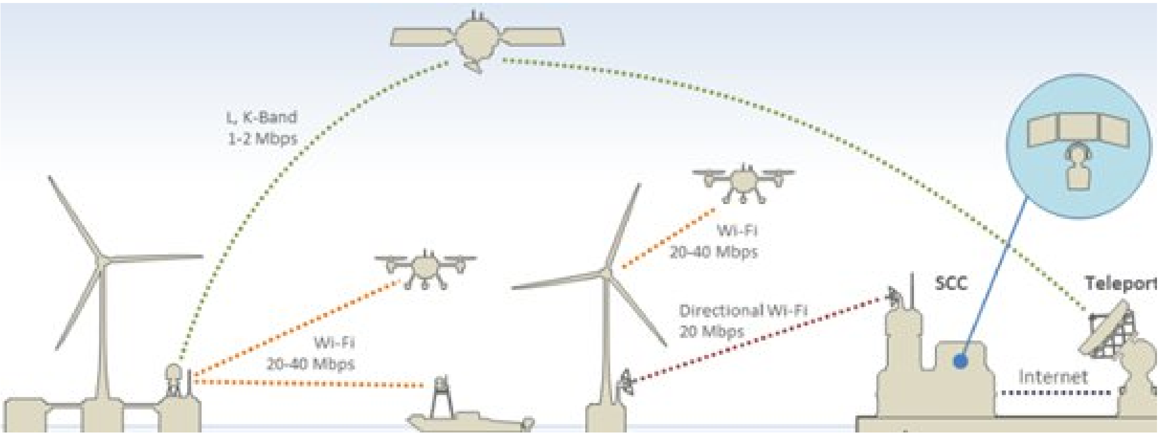


Figure 1: High Level View on ATLANTIS Testbed communications

1.1. Scope of the Document

Deliverable D2.2 has both the role of the requirements document and an interface control document. Following the proposed methodology the first part of the deliverable contains the system-wide requirements including the supervisory control centre , the communication interfaces, all robotic devices as well as the testbed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

The second part of the document describes this software and the hardware interfaces. A great emphasis has been put on the interfaces that have to be integrated between different partners. Beyond reporting the results of the activities performed in the task, this document will serve as a reference for all system integrations throughout the implementation and testing of the project.

1.2. Methodology and Formalism

The first step in defining the **requirements** was identifying the split between technology. The approach was meant to allow each of the technological partners to have control of the objectives they need to implement. Following the proposed split into sections, each one of the partners had to define the specifications for their scope of work. At the end of the process, the partners reviewed the requirements proposed for the systems they depend upon and the systems for which they are providing support. The process of fine tuning requirements was a significant technical interaction. The system requirements have been identified in strict correlation with the pilot scenario definition.

Once the requirements have been defined, a primary architecture has been proposed. The architecture connections between components created the list of interfaces to be defined and the definition of that interfaces have been done by considering:

- Pilot Specifications;
- System Requirements;
- Existing technologies.

The following section details the system requirements following the structure exemplified in the following table:

YY_uniqueID	**<<Requirement title here>>**
STATEMENT	<<Description here>>
RESPONSIBLE	<<Partner Acronym>>
LEVEL	Mandatory / Desirable / Optional
VERIFICATION METHOD	<<Simulation / Internal testing / analog testing>> + description (1-3 lines)
COVERED IN SCENARIO	<<Scenario used to prove requirement>>

The top row of the table includes:
Unique ID: identification with the structure YY_uniqueID;
YY: type of the requirement - Functional requirements (FuncR), Performance requirements (PerfR), Interface requirements (IntR);
uniqueID: unique reference with 4 characters.
The first character is a letter identifying the subsystem the requirement belongs to, following the convention in the table below.

Correspondence between first character in uniqueID and subsystem:

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

A	SCC
B	Communications Systems
C	ASV
D	AUV
E	Intervention AUV
F	Hybrid ROV
G	UAV
H	Data Management, Operation and Maintenance Analytics
I	Coastal and Offshore Testbeds

The next number identifies the type of requirement inside the subsystem;
The next two numbers identify a number assigned to each requirement in that category;
Short statement or title: gives a high level idea of the topic addressed by the requirement.

The rest of the table includes the following fields:

STATEMENT: clear and concise description of the requirement;
RESPONSIBLE: indicates which partner is responsible for the verification and follow up of the requirement;
LEVEL: indicates the level of importance of the requirement (mandatory / desirable / optional);
VERIFICATION METHOD: indicates how the requirement is going to be verified (simulation, internal testing, analogue testing) with a short description of the validation process (1 to 3 lines);
COVERED IN SCENARIO: gives indication about the scenario used to prove the achievement of the requirement. The possible scenarios are (as described in D2.1):

1. Inspection of blades and tower at WFA;
2. IMR of the transition piece of the floating structure;
3. Repair of underwater floating wind turbine cables protection systems;
4. Underwater monitoring over extended periods of time;
5. Underwater close-range inspection of foundations;
6. Underwater monitoring of scour protection interventions;
7. O&M operations supported by crew-less vessels;
8. Optimization of robotic based operations.

2. System Requirements

2.1. SCC - Supervisory Control Centre

2.1.1. Description

The SCC is a collection of technological assets (Software and Hardware) with the purpose of monitoring and controlling robotic devices over remote data links. The control centre is adaptable to be compatible with unmanned vehicles and can accommodate direct control and autonomous execution of planned

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

missions. The robotic devices communicate through the SCC system using the same communication paradigm: DDS and ROS2. Using the same communication messages ensures interoperability within a fleet of deployed devices.

SCC foreseen functionalities:

- Visualization IMR (Inspection, Maintenance, Repair);
- Receive, annotate and store data from the robotic operations;
- Display Images, videos, 3D data and NDT data;
- Manipulation of IMR data;
- Send commands to remote vehicles;
- Monitor remote vehicles. This can be done by monitoring the vehicle parameters and also by displaying the position of the system in a map or 3D view of the environment;
- Define a set of goals for system to achieve;
- Perform automatic planning of the missions to be executed;
- Launch mission plans.

2.1.2. Functional (FuncR)

FuncR_A01	**Receive IMR output**
STATEMENT	The SCC will be able to receive data from robotic devices involved in IMR operations. The SCC will store the data and annotate it with relevant information e.g. the WindFloat asset that was inspected, time, vehicles involved, operators etc.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated data from the robot side, sent to the SCC .
COVERED IN SCENARIO	1 - 7

FuncR_A02	**Display IMR output**
STATEMENT	The SCC will be able to display the output of all the IMR operations performed in ATLANTIS. The data display can be: Images Videos 3D data or NDT. The operator of the SCC will be able to navigate between different operations and access its output.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated data from the robot side, sent to the SCC .
COVERED IN	1 - 7

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SCENARIO	

FuncR_A03	Manipulation of IMR data
STATEMENT	Thanks to the SCC the user will be able to manipulate the IMR data. The operator will be able to do more advanced analyses on images / videos.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing, Generation of simulated data from the robot side, sent to the SCC.
COVERED IN SCENARIO	1 - 7

FuncR_A04	Send commands to remote vehicles
STATEMENT	The SCC will be able to send commands or actions to robots. The operator will be able to follow up on the correct transmission of the command and observe the execution feedback. The operator of the SCC will have to validate a plan before sending it. Additional commands can be sent by the operator. All plans and commands will follow the safety procedures for testing robotic platforms on site.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated actions from the SCC side, sent to robots.
COVERED IN SCENARIO	1 - 7

FuncR_A05	Monitor remote vehicles
STATEMENT	The operator of the SCC will be able to monitor the robots from the onshore station at any time the robots are online and connected.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing.
COVERED IN	1 - 7

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SCENARIO	

FuncR_A06	**Goal Oriented Task Planning for the UxVs on the SCC level**
STATEMENT	Production of a plan for the UxV(s) involved in the scenario in a centralized manner on the SCC level, considering geographical data, domain and problem description. The system should support goal directed or task level commanding of robots (in case of fully autonomous robot, i.e. AUV, that can receive a high level mission goal for execution)
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing using scenario specific problem and domain description forged from provided data of pre existing wind farms
COVERED IN SCENARIO	1 - 7

FuncR_A07	**Global Path Planning for the UxVs on the SCC level**
STATEMENT	Production of a global path for the UxV(s) involved in the scenario considering geographical data
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing using geographical data forged from provided information about pre existing wind farms
COVERED IN SCENARIO	1 7

FuncR_A08	**Deployment and execution of planned mission**
STATEMENT	The system shall allow the mission planner to execute a planned mission and transmit the plan to the UxVs
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

VERIFICATION METHOD	Simulation with hardware in the loop. Analog testing in the Coastal Tesbed
COVERED IN SCENARIO	1 - 7

FuncR_A09	**Planned Mission Monitoring**
STATEMENT	The system shall allow the mission planner to monitor progress of the ATLANTIS robots during the execution of a mission. The monitoring process will follow the execution of planned steps deployed to achieve a specific goal. The operator will be able to assess the mission progress and the data that is produced.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation with hardware in the loop. Analog testing in the Coastal Tesbed
COVERED IN SCENARIO	1 - 7

2.1.3. Performance (PerfR)

PerfR_A01	**External data aggregation**
STATEMENT	The SCC shall be able to access external data sources for augmenting its user interfaces. This can include GIS data in raster and vector data, weather forecasts, AIS, AtoN…
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing
COVERED IN SCENARIO	1 - 7

PerfR_A02	**Mission planning algorithm time range**
STATEMENT	The task planning and global path planning in the mission planning algorithm should be executed within the range of several hours maximum

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing
COVERED IN SCENARIO	1 - 7

2.1.4. Interface (IntR)

IntR_A01	**SCC internet access**
STATEMENT	Provision shall be made with the ATLANTIS Test Centre facility for a safe and reliable internet access.
RESPONSIBLE	INESC TEC, SPACEAPPS, EDP
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1 - 7

2.1.5. Physical and Resource (PhyR)

PhyR_A01	**Missions administration dedicated computers**
STATEMENT	The control centre shall be equipped with two mission administration high performance computers and six monitors with a 27 inch diagonal.
RESPONSIBLE	SPACEAPPS, INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1 - 7

2.1.6. Operational (OpR)

OpR_A01	**SCC access and availability**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	The control centre facility shall be available and accessible 24/7 for the needs of ATLANTIS operations (both their preparation and their execution).
RESPONSIBLE	INESC TEC, SPACEAPPS, EDP
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1 - 7

2.1.7. Logistics and Support (LogR)

LogR_A01	**Missions administration dedicated room and furniture**
STATEMENT	The control centre shall be established in a dedicated space near the ATLANTIS Test Centre and it will be provided with desks, chairs and other necessary equipment to enable hosting of 5 people and 5 work stations.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1 - 7

2.1.8. Safety (SafeR)

SafeR_A01	**Forensic analysis tracing**
STATEMENT	The SCC stores all the data received from the vehicles and testbed sensors timestamped and geo-tagged during operations. The data will be available to trace and perform any required analysis of previous operations.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Choice of SoA encryption methods and tests in lab conditions to ensure a level of safety.
COVERED IN SCENARIO	1 - 6

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SafeR_A02	**Follow robot-related guidelines for personnel training and skills**
STATEMENT	Robot operators should present all the necessary competences for the deployment/use of the specific robotic asset. Moreover, a clear hierarchy structure and personnel organigram is needed for each specific task. The organizational model should define clear responsibilities and duties for all the personnel involved, with the objective to ensure safety in all the operations.
RESPONSIBLE	INESC TEC, EDP, UdG, SPACEAPPS, ECA, IQUA (everyone involved in testing)
LEVEL	Mandatory
VERIFICATION METHOD	Before the tests to start, a hierarchy structure will be defined as depicted in deliverable D1.2.
COVERED IN SCENARIO	1-7

2.2. Communications Systems

2.2.1. Description

During the demonstration of the ATLANTIS scenarios, different communication setups will be deployed on site. The communication infrastructure will be set up individually for each scenario depending on the involved assets, location of the demonstration and the scenario specificity.

Looking at the scenarios we can identify a set of communication setups that can be reused for all the configurations. We take in consideration that in all the demonstrations performed we will have a subset of the following elements:

- 1-3 autonomous vehicles connected;
- 0-1 remotely control vehicles;
- inter-vehicle close range RF communication;
- underwater positioning and communications;
- close range human operated control unit;
- on shore SCC;

The communication technologies that will be available to be used in different configurations are:

- WiFi;
- Short range IP Mesh;
- Satellite communication;
- Underwater USBL;
- Wired Communication using
  - Optical fiber,
  - Ethernet.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2.2.2. Functional (FuncR)

FuncR_B01	**Satellite communications to enable remote communications**
STATEMENT	To enable remote commanding and monitoring of UxVs and assets - in some cases real time (Ex. ROV and UAV) or transfer recorded data packages (AUVs and other robots).
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Final offshore deployment tests.
COVERED IN SCENARIO	1 - 7

FuncR_B02	**WFA communications infrastructure to enable remote communications**
STATEMENT	To enable remote commanding and monitoring of UxVs and assets in real time (Ex. ROV and UAV) or transfer recorded data packages (AUVs and other robots) with high efficiency and low latency.
RESPONSIBLE	PP, EDP, SPACEAPPS
LEVEL	Desirable
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Final offshore deployment tests.
COVERED IN SCENARIO	1 - 6

FuncR_B03	**Local RF Network**
STATEMENT	To enable local communication exchange between UxVs and assets in real time (Ex. ROV and UAV) or transfer recorded data packages (AUVs and other robots) with high efficiency and low latency.
RESPONSIBLE	SPACEAPPS, ECA, INESC TEC, UdG, IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Final offshore deployment tests.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1 - 6

FuncR_B04	**Data gateway**
STATEMENT	To enable remote link between the SCC and the local network established at the Testbed premises.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Final offshore deployment tests.
COVERED IN SCENARIO	1 - 6

2.2.3. Performance (PerfR)

PerfR_B01	**Satellite communications with sufficient throughput for operations**
STATEMENT	• A minimum of 256Kbps uplink from offshore to onshore SCC. • A minimum of 500Kbps downlink from onshore to offshore.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Final offshore deployment tests.
COVERED IN SCENARIO	1 - 6

PerfR_B02	**Local RF communications with sufficient throughput for operations**
STATEMENT	A minimum of 40Mbps connection between the devices connected in the local RF local network (WiFi or of other type).

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Final offshore deployment tests.
COVERED IN SCENARIO	1 - 6

2.2.4. Interface (IntR)

IntR_B01	**Satellite communications with UxVs**
STATEMENT	The physical interface to the satellite communications will be via a central Ethernet gateway. Software interface will be via an interoperability protocol implemented in a middleware such as ROS2 (DDS), Firmware or other.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Software interface unit tests for communications
COVERED IN SCENARIO	1 - 6

2.2.5. Physical and Resource (PhyR)

PhyR_B01	**Satellite communications subsystem external segment envelope**
STATEMENT	On-board the WFA or ASV the satellite communication external segment and internal segment shall respectively fit in the following envelope: Volume/area (external): 1 m3 Volume/area (internal): 0.05 m3
RESPONSIBLE	EDP, PP, INESC TEC, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Verify COTS specifications. Test in outdoor conditions for reliability.
COVERED IN SCENARIO	1 - 6

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PhyR_B02	**Satellite Antenna**
STATEMENT	Satellite antennas have to be installed on the Coastal Testbed and Offshore Testbed if no other communication mean is available (4G, optic fiber etc.)
RESPONSIBLE	SPACEAPPS
LEVEL	Optional
VERIFICATION METHOD	Analog testing
COVERED IN SCENARIO	4

2.2.6. Operational (OpR)

OpR_B01	**Satellite communications subsystem external segment IP rating**
STATEMENT	All components of the satellite communications system that need to be in the exterior of the WFA or on the ASV. It shall meet IP66 standards and be resistant to the elements present in off-shore conditions.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Verify COTS specifications Test in outdoor conditions for reliability
COVERED IN SCENARIO	1 - 6

2.2.7. Logistics and Support (LogR)

LogR_B01	**Satellite Communications can be easily transported and mounted on the WFA**
STATEMENT	The satellite communication antenna and modem should be easily transportable to the offshore site and installed on WFA by on-site personnel efficiently.
RESPONSIBLE	SPACEAPPS, INESC TEC, EDP
LEVEL	Mandatory
VERIFICATION METHOD	Cost and time efficient mounting and commissioning of the communication module.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1 - 6

2.2.8. Safety (SafeR)

SafeR_B01	**Data Security between on-shore and off-shore systems**
STATEMENT	The system shall be able to encrypt and decrypt TC / TM / data, where appropriate, for communications and storage purposes.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Choice of SoA encryption methods and tests in laboratory conditions to ensure a level of safety.
COVERED IN SCENARIO	1 - 6

2.2.9. Configuration and Implementation (ConfR)

ConfR_B01	**Satellite Communications configuration**
STATEMENT	The system shall be configured with the data plans required for enabling communications between on-shore SCC and off-shore WFA. The configuration can be done remotely to commission the satellite modem.
RESPONSIBLE	SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Lab test of configuration of satellite modem with the selected data plan from commercial providers
COVERED IN SCENARIO	1 - 7

2.3. ASV - Autonomous Surface Vehicle

2.3.1. Description

The ASV is an autonomous surface vehicle equipped with several sensors for navigation and perception in marine environments. For navigation the ASV is endowed with distinct sensors, such as GPS (with the possibility of using RTK) and IMU, and several perception sensors that can be used for both localization and inspection such as 3D Lidar, stereo cameras, and radar for the surface region, and multibeam

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

echosounder and cameras. For communication it's commonly used a WiFi network to send and receive data. Moreover, RC controllers allow to send velocity commands with a range +1 km. The vehicle can navigate autonomously following a predefined path, while allowing to switch to remote control navigation mid-mission. The vehicle alone is capable of working for about 2h with a single charge and withstanding certain sea conditions.
In normal operations, the ASV is remotely operated to the inspection site using the RC controller and then switched to the autonomous mode. A WiFi connection is available all time to receive data from the mission. For instance, the Zarco ASV is operated using ROS framework where the vessel is the master and all external communications are passed though it. As such, a supervision station is simply done by using a laptop to visualize data acquired and a RC controller to send control commands in case of need. In the context of the project, the SCC can be connected to the ASV for monitoring the data remotely and to send new mission parameters when required. The control station initially should be defined on a support vessel nearby and remotely operated in real time, if possible it can be explored the SCC capacity to send velocity commands and to receive visual data in real-time or near.

2.3.2. Functional (FuncR)

FuncR_C01	**Remotely-operated navigation**
STATEMENT	The ASV must be capable of performing the mission partially or even totally operated via a remote Control Station.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal test on test pool in the lab and on the pilot test platform. Remote commands will be given through the control station at different ranges to determine if the vehicle responds accurately and on time to the given orders. Also, the distance for safe operation will be evaluated.
COVERED IN SCENARIO	1, 2, 6

FuncR_C02	**Autonomous navigation**
STATEMENT	The ASV shall be capable of performing the mission on site autonomously, executing a predefined route while avoiding obstacles or perform corrections of any hazardous command.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	All algorithms will be tested initially on a realistic 3D simulator of the ASV to verify if no major bugs are detected. Afterwards, several independent tests of each developed algorithm will be tested on a controlled scenario in the real vehicle. Full system checks will be performed on the pilot infrastructure to evaluate the error between the desired and the executed path and to evaluate the safety procedures.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1, 2, 6

FuncR_C03	**ASV localization system**
STATEMENT	The ASV must be capable of estimate its current pose (localization and attitude) in the world accurately. When available, GPS RTK and IMU systems will provide the ASV localization, otherwise other localization algorithms using the available perception sensors shall enhance the vehicle observations.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Tests in lab will be performed on the pool to estimate the accuracy of non-GPS based methods. Also, campaigns on outdoor scenarios capable of obtaining GPS coordinates will be performed and compared with RTK measures. On a relevant marine scenario tests with forced GPS-denied time periods will be performed to evaluate the data precision.
COVERED IN SCENARIO	1, 2, 6

FuncR_C04	**Collision avoidance algorithms**
STATEMENT	The ASV should be capable of avoiding possible collisions and navigate safely near structures and other objects.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation tests with distinct collision situations will be performed to evaluate the efficiency of the collision avoidance techniques. Tests on controlled marine scenarios with known obstacles will be performed.
COVERED IN SCENARIO	1, 2, 6

FuncR_C05	**Representing the surface components of the offshore structures**
STATEMENT	The ASV must be capable of creating a 3D map of the surface scenario and transition pieces using the available sensors and acquire geotagged images and 3D LiDAR scans of the structures, namely the “dry” part on the transition pieces and possible obstacles present in the scenario.
RESPONSIBLE	INESC TEC

This project has received funding from the European Union’s Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	Simulation tests with distinct offshore wind farm scenarios will be done to evaluate the performance of all developed methodologies. Analog tests will be performed on controlled marine scenarios to acquire reconstructions and images of several structures.
COVERED IN SCENARIO	2, 6

FuncR_C06	**Representing the underwater components of the offshore structures**
STATEMENT	The ASV must be capable of creating a 2.5D and bathymetry map of the underwater scenario using the available sensors and acquire geotagged images or sonar scans of the structures, namely the “wet” part on the transition pieces and the scour protection condition.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation tests with distinct offshore wind farm scenarios will be done to evaluate the performance of all developed methodologies. Analog tests will be performed on controlled marine scenarios to acquire reconstructions and images of several structures.
COVERED IN SCENARIO	2, 6

2.3.3. Performance (PerfR)

PerfR_C01	**Data storage**
STATEMENT	Internal storage must be available in the ASV to save all data relevant to the inspection tasks. A storage of at least 1Tb should be placed.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing will be performed on other relevant scenarios and will be estimated the Gb per second from this tests. An extrapolation of the storage size required for the mission execution time on the offshore scenario will be calculated.
COVERED IN SCENARIO	1, 2, 6

PerfR_C02	**Inspection data transmission**

This project has received funding from the European Union’s Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	Acquired data with the ASV must be broadcast to the Data Gateway for monitoring. New inspection orders or updates should be transmitted to the ASV.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1, 2, 6

PerfR_C03	**Safety critical data must be exchanged with higher priority**
STATEMENT	Safety critical data such as velocity commands and location must be exchanged with a control station with a higher priority.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1, 2, 6

PerfR_C04	**Critical control of data diagnostic**
STATEMENT	The ASV must evaluate the availability of critical sensors to diagnose if the mission is compromised. For remote operation the vehicle must receive control commands and provide at least visual information to the operator.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing will be performed to evaluate if the mandatory data is being acquired or not. During tests several critical assets will be randomly disconnected to check the system response.
COVERED IN SCENARIO	1, 2, 6

PerfR_C05	**Battery duration for the task**
STATEMENT	The ASV must have enough battery to travel to the inspection site, perform the

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	mission and return home. At least 2h operation must be available.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation tests in lab will be performed to determine the power consumption in the worst case scenario and the batteries will be selected accordingly. Analog testing will be performed to evaluate the maximum operation duration available.
COVERED IN SCENARIO	1, 2, 6

2.3.4. Interface (IntR)

IntR_C01	**Communication between ASV and Data Gateway**
STATEMENT	Communication between the ASV and the SCC to allow the exchange of information required to monitor and control the ASV.
RESPONSIBLE	SPACEAPPS, INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1, 2, 6

IntR_C02	**WiFi communication on the ASV**
STATEMENT	The ASV must provide a WiFi communication for close-range remote access.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1, 2, 6

2.3.5. Physical and Resource (PhyR)

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PhyR_C01	Acquire data from the surface domain
STATEMENT	The ASV must be endowed of sensors, such as cameras and 3D LIDAR, that will allow to visually inspect and reconstruct the dry components present on an offshore wind farm. Moreover, sensors for detecting and representing any object on surface (e.g. boats, turbines,...) must be present for collision avoidance and close-range navigation procedures.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Several sensors will be attached to the ASV and tests shall be performed on the lab to analyse the data quality and to increase the Field-of-View (FoV) of the vehicle. Some campaigns will be performed to acquire data of the scenario.
COVERED IN SCENARIO	1, 2

PhyR_C02	Acquire data from the underwater domain
STATEMENT	The ASV must be endowed of sensors, such as a Multibeam echosounder, that will allow to reconstruct the underwater components present on an offshore wind farm. It shall allow to perform bathymetric observations of the scenario.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Underwater ready sensors will be attached to the ASV and tests shall be performed on the lab to analyse the data quality and to increase the Field-of-View (FoV) of the vehicle. Some campaigns will be performed to acquire data of the scenario.
COVERED IN SCENARIO	2, 6

PhyR_C03	Simple battery replacement system
STATEMENT	The ASV must allow to easily and quickly replace the battery when discharged with other fully charged.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing. An external user will exchange battery on site.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1, 2, 6

2.3.6. Operational (OpR)

OpR_C01	**Maximum wave height for safe operation of 1m**
STATEMENT	The ASV will be able to safely operate with tidal waves of up to 1m high. All IP rating will ensure waterproofing and the floating system ensures the ASV stability.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and internal testing. The stability of the vehicle will be performed on realistic simulation systems. Tests at distinct locations with diverse sea states can be performed.
COVERED IN SCENARIO	1, 2, 6

OpR_C02	**Maximum wind speed for safe operation of 20 knots**
STATEMENT	The ASV will be able to safely operate with wind speed of up to 20 knots (~10m/s).
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and internal testing. The stability of the vehicle will be performed on realistic simulation systems. Tests at distinct locations with diverse wind speeds can be performed.
COVERED IN SCENARIO	1, 2, 6

2.3.7. Logistics and Support (LogR)

LogR_C01	**Small support vessel**
STATEMENT	A small support vessel (e.g. Rigid inflatable boat) can be required for the ASV supervision and remote operation procedures. Moreover, depending on the vessel power, towing tasks of the ASV can be performed to preserve battery or to return home if it exists any critical failure.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

VERIFICATION METHOD	The vehicle will be checked in terms of space for the equipment and personnel requirements. The vessel towing capacity will be checked.
COVERED IN SCENARIO	1, 2, 6

LogR_C02	**Power supply for the local control station**
STATEMENT	A power supply should be available at the vessel to provide external energy to the control station computer (laptop).
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	An internal test will be performed using a powerbank available to determine the charging capacity for the control station laptop.
COVERED IN SCENARIO	1, 2, 6

LogR_C03	**Space for personnel at the small support vessel**
STATEMENT	Space for two elements - ASV operator and technician - should be always available apart from the required vessel crew.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel size will be verified in size regarding the space for crew, equipment and extra personnel.
COVERED IN SCENARIO	1, 2, 6

LogR_C04	**Crane deployment**
STATEMENT	If available on shore a crane (300 kg) can be used to aid the placement and recovery of the ASV on the water. If available on a support vessel it can also be used to deploy/recover the vehicle.
RESPONSIBLE	INESC TEC
LEVEL	Optional
VERIFICATION METHOD	Documentary or experimental verification.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1, 2, 6

LogR_C05	**Toolbox available on the support vessel**
STATEMENT	At all times the support vessel should have a toolbox with the most indispensable tools for small procedures, such as battery replacement or removal of non-critical sensors in case of accident.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Experimental verification: to assess if all tools for disassemble and replace are available. For instance extra batteries or battery module should be in the toolbox.
COVERED IN SCENARIO	1, 2, 6

LogR_C06	**RTK base station on a static and clear area.**
STATEMENT	The GPS/RTK base station can be placed at a wind turbine or a secondary anchored vessel to increase the GPS reading accuracy.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Analog testing. In the pilot infrastructure a RTK base station will be placed on the structure. Test with a static vessel as base station will be performed.
COVERED IN SCENARIO	1, 2, 6

2.3.8. Safety (SafeR)

SafeR_C01	**Self-diagnostic methodologies**
STATEMENT	The ASV must perform regular self-diagnostic procedures to ensure that all systems are fully operational or to alert the SCC and the control station for any system failure. At least three levels of failure must be issued, namely fatal, critical and warning.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

VERIFICATION METHOD	Internal testing. On the lab, each system will be unplugged during testing and the alert response will be checked.
COVERED IN SCENARIO	1, 2, 6

SafeR_C02	**ASV stops with fatal failure**
STATEMENT	When a fatal failure exists, e.g. thrusters malfunction, the ASV must stop all actuators and emit a GPS location to the SCC and the control station for recover.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing. On the lab, fatal failures will be forced to test the full thruster stop and if the location is being transmitted.
COVERED IN SCENARIO	1, 2, 6

SafeR_C03	**Recover Mode**
STATEMENT	The ASV should have failure recover modes for critical and warning states. If a critical issue is presented the ASV should return home or alternate to remote operation. Warning level if it is not harmful for the mission and can be bypassed by the operator.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1, 2, 6

SafeR_C04	**Force remote operation**
STATEMENT	At any time the operator should be capable to override any mission command and take remote control of the ASV.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION	Analog testing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

METHOD	
COVERED IN SCENARIO	1, 2, 6

2.3.9. Configuration and Implementation (ConfR)

ConfR_C01	**Configuration of the robot**
STATEMENT	The ASV sensor payload configuration can be adapted.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Internal testing. According to the required data for the inspection task the best sensor payload will be selected.
COVERED IN SCENARIO	1, 2, 6

ConfR_C02	**Sensor calibration**
STATEMENT	Prior to any major mission and when any modification on the sensor payload is performed all sensors must be pre-calibrated.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Internal testing. Several calibration procedures will be tested in lab.
COVERED IN SCENARIO	1, 2, 6

2.4. AUV - Autonomous Underwater Vehicle

2.4.1. Description

The AUV is an autonomous underwater vehicle, equipped with inspection sensors. In addition to its navigation suite (e.g., IMU, DVL, USBL and GPS) and its communication systems (e.g., acoustic modem and WiFi), depending on the task to be performed, its payload can be configured with different mapping sensors such as, a multibeam sonar, a forward looking sonar, a camera, etc. The robot can navigate autonomously following a predefined path, or one being planned online, while enabling or disabling the mapping sensors. The vehicle alone is capable of working for about 8h with a single charge and withstanding certain sea conditions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

In normal operations, the AUV is operated from a surface station through its own mission control software. The surface station consists of a computer connected through WiFi to the vehicle while on surface and through an acoustic modem/USBL while submerged. In the context of the project, the control station can be connected to the SCC through a satellite link and serve as a relay for operating the vehicle remotely.
In scenario 4, the AUV will be deployed together with a docking station (DS) that will allow it to work for an extended period of time as well as to better withstand adverse sea conditions. Communication with the robot will be done through the DS. The DS will in turn be connected directly to the SCC via a satellite link or via the surface station through WiFi.

2.4.2. Functional (FuncR)

FuncR_D01	**AUV executes a predefined survey**
STATEMENT	The AUV performs a predefined survey, which consists of following a list of tracks defined by its start and end points at a specific depth/altitude and speed. At the end of each track the AUV can execute actions such as enabling or disabling a sensor.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	The requirement will be first tested in simulation, then in internal UdG tests at sea and finally in the context of a pilot mission as well as in the WFA.
COVERED IN SCENARIO	4

FuncR_D02	**Dock/Undock AUV to DS**
STATEMENT	Dock: Home close to the DS and execute a docking maneuver. Undock: leave the DS.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	The requirement will be first tested in simulation, then in internal UdG tests in a water tank and at sea and finally in a pilot mission.
COVERED IN SCENARIO	4

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_D03	Localize the DS from the AUV
STATEMENT	Using the sensors on-board the AUV, localize the DS position to prevent the AUV from drifting and to allow the homing and docking manoeuvres to be carried out.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Localization algorithms will be tested first in simulation, while DS perception will be tested in internal tests. The whole system will be tested in a pilot mission.
COVERED IN SCENARIO	4

FuncR_D04	Relay communications from DS
STATEMENT	The DS must be able, on the one hand, to establish communication with the AUV via WiFi (if the vehicle is docked) or through an acoustic modem and, on the other hand, with the SCC through a link located on a surface buoy. This buoy can communicate through WiFi with a surface station which will communicate with the SCC via satellite or other communication type.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	AUV data transmission up to the DS will be tested internally.
COVERED IN SCENARIO	4

FuncR_D05	Transmit DS monitoring
STATEMENT	Measure and transmit to the SCC the DS status (battery levels, AUV communication, internal sensors...) as well as all possible information recollected about sea status .
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	4

FuncR_D06	**Localize AUV from USBL**
STATEMENT	Localize the AUV using a USBL system. The USBL can be mounted in the DS, in the WFA or in a boat.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	The localization algorithm will be first tested in simulation and later, experiments at sea will be done internally.
COVERED IN SCENARIO	4

FuncR_D07	**Current compensation algorithm**
STATEMENT	Using an estimation of the sea current, adapt the AUV direction while docking to improve the performance of the docking manoeuvre.
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Tests will be done first in simulation and then in Internal trials at UdG.
COVERED IN SCENARIO	4

FuncR_D08	**Adapt DS direction to sea current**
STATEMENT	Measures the sea current and adapts the direction of the DS funnel accordingly.
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Verification will be done with internal tests at UdG.
COVERED IN SCENARIO	4

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_D09	Automatic surfacing in case of equipment failure
STATEMENT	The AUV will surface automatically, in a safe way, in case of technical issues. It will be always configured as slightly positively buoyant.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	4

FuncR_D10	Send IMR output
STATEMENT	The AUV will be able to send data related to the IMR operations to the SCC through the data gateway when on the surface or while docked.
RESPONSIBLE	IQUA, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated data from the robot side, sent to the SCC.
COVERED IN SCENARIO	2, 4

FuncR_D11	Receive SCC commands
STATEMENT	The AUV will be able to receive commands from the SCC to perform certain actions which will be sent to the vehicle using the WiFi or the acoustic modem.
RESPONSIBLE	IQUA, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated actions from the SCC side, sent to robots.
COVERED IN SCENARIO	2, 4

FuncR_D12	Send monitoring data to SCC

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	The AUV will send information to the SCC for monitoring of the operation. The vehicle can communicate through WiFi when on surface and through acoustic modem during immersion.
RESPONSIBLE	IQUA, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated monitoring data from the vehicle side, sent to the SCC.
COVERED IN SCENARIO	2, 4

FuncR_D13	**Execute inspection mission in AUV (exploration)**
STATEMENT	The AUV will execute a mission in which the vehicle will survey the area of interest executing the view planning algorithm developed by IQUA to determine on-board the trajectory that will ensure a full coverage with the optical sensors
RESPONSIBLE	IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Test in simulator using 3D model of the WindFloat
COVERED IN SCENARIO	2

FuncR_D14	**Online mapping in AUV**
STATEMENT	During the execution of the inspection mission, the AUV will gather information from an acoustic range sensor system and use it to build a map of the environment online that will be used by the on-line planning algorithm to determine the trajectories to be followed.
RESPONSIBLE	IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Test in simulator using 3D model of the WindFloat
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_D15	Relay communications from surface station
STATEMENT	In normal operation, the vehicle is operated from a mission control software executing on a surface station composed of a computer with a WiFi link and an acoustic modem/USBL to communicate with the vehicle over and below the water level. In scenario 2, this same surface station will serve as a relay to communicate the AUV with the SCC and will need to be connected to the SCC through a satellite link.
RESPONSIBLE	IQUA, UdG, INESC TEC, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. Generation of simulated data from the robot side, sent to the SCC.
COVERED IN SCENARIO	2

FuncR_D16	Initiate wireless charging
STATEMENT	After the docking is complete the wireless charging system initiates the charging process.
RESPONSIBLE	IQUA, UdG, INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	4

FuncR_D17	Terminate wireless charging
STATEMENT	When the batteries are completely charged, or when a command is issued from the SCC to interrupt the process (e.g. the charge is not complete, but is sufficient to execute a mission initiated by the SCC), the system terminates the charging and leaves the vehicle ready for operation.
RESPONSIBLE	IQUA, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	4

2.4.3. Performance (PerfR)

PerfR_D01	**Docking/Undocking performance**
STATEMENT	The docking/undocking performance will be measured by assessing the chances of successfully docking depending on environmental conditions like the water current, visibility.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	4

PerfR_D02	**Localization performance**
STATEMENT	The AUV localization accuracy will depend on the sensors used and its configuration/placement. The localization accuracy should be established taking into account all sensors setup (i.e., at least using the manufacturer specifications).
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	4

PerfR_D03	**Evaluation of coverage**
STATEMENT	At the end of the mission the vehicle will provide an estimate of the level of coverage for the area it has been requested to inspect. This will serve as a metric for the performance of the operation.
RESPONSIBLE	IQUA

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Optional
VERIFICATION METHOD	Simulation and analog testing.
COVERED IN SCENARIO	2

2.4.4. Interface (IntR)

IntR_D01	**Communication between DS-SCC**
STATEMENT	Communication between the DS and the SCC could be performed through a satellite link or using other existing communication infrastructure at the demonstration site.
RESPONSIBLE	SPACEAPPS, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing
COVERED IN SCENARIO	4

IntR_D02	**Communication between surface station and SCC**
STATEMENT	When no docking station is present, the AUV is normally operated from a surface station consisting on a mission control software executing on a computer equipped with a WiFi link and an acoustic modem/USBL. In scenario 2, this surface station will serve as a relay with the SCC to send and receive data through a satellite link. Once the mission is finalized, the IMR data from the vehicle needs to be retrieved at the control station and sent to the SCC. It can be done through the WiFi link (slow) or by manually connecting a tether with a Gigabit Ethernet interface (fast). The data, will likely include a rough 3d map of the structure and a set of images. If the complete set of images is needed to be sent to the SCC for visualization, it may be necessary to send large amounts of data (potentially in the order of Gigabytes).
RESPONSIBLE	IQUA, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing.
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

IntR_D03	Interfacing with the DS
STATEMENT	The vehicle needs to interface with the DS to communicate (using WiFi and acoustics) and recharge (using the wireless charger)
RESPONSIBLE	IQUA, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	4

2.4.5. Physical and Resource (PhyR)

PhyR_D01	Optoacoustic payload
STATEMENT	The AUV shall be equipped with a payload comprising an acoustic range sensor capable of perceiving 3D in the scene, and an optical system to capture images during the survey.
RESPONSIBLE	IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing
COVERED IN SCENARIO	2

PhyR_D02	Access to the infrastructure
STATEMENT	Some (or all) of the components of the surface control station may require being installed at the infrastructure to be inspected (e.g. the USBL transducer to produce the vehicle position relative to the testbed, regardless of motions in the infrastructure)
RESPONSIBLE	IQUA
LEVEL	Optional
VERIFICATION METHOD	Simulation and analog testing. Analyse the effects of the infrastructure moving due to waves or currents in simulation to determine if necessary.
COVERED IN	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SCENARIO	

PhyR_D03	**Link to the SCC**
STATEMENT	The AUV is connected to the surface control station through WiFi and/or acoustic modem. The computer on the surface control station executes a software which receives the data from these sources and will pack it following the required protocol to be then relayed to the SCC, making the process of acquiring the information from the AUV transparent to the SCC. The surface control station needs additional infrastructure to have a radio/satellite link to communicate with the SCC
RESPONSIBLE	IQUA, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing.
COVERED IN SCENARIO	2

PhyR_D04	**Charging batteries**
STATEMENT	The AUV has a charger that is required to charge the batteries. Resources need to be provided to power the charger either at a support boat or at the Testbed .
RESPONSIBLE	IQUA, UdG
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing
COVERED IN SCENARIO	2, 4

PhyR_D06	**Payload for docking**
STATEMENT	The AUV is requires a payload compatible with the DS so communications and energy transfer can be performed.
RESPONSIBLE	IQUA
LEVEL	Mandatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	4

2.4.6. Operational (OpR)

OpR_D07	**Maximum operational depth of at least 100 m**
STATEMENT	The AUV their payloads and the DS will be able to safely operate to at least 100 m of depth. All external sensors will have an adequate depth rating.
RESPONSIBLE	UdG, IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2, 4

OpR_D08	**Extended endurance using a DS**
STATEMENT	The robot will be equipped with a battery capable of delivering power for the whole day of work (8h) without recharging. However, with the help of a DS it could be able to operate for a larger period of time.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	4

2.4.7. Logistics and Support (LogR)

LogR_D01	**Small support vessel**
STATEMENT	A small support vessel (e.g., a RIB) can be required for the deployment, recovery and supervision of the AUV depending on the main vessel used for the trials.
RESPONSIBLE	INESC TEC

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	The vessel will be checked in terms of space for the equipment and personnel as well as power requirements of the system.
COVERED IN SCENARIO	4

LogR_D02	**Place for personnel**
STATEMENT	There has to be a space for at least three people on the vessel, apart from the vessel crew - the operator of the AUV and the technicians.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel will be checked in terms of space requirements.
COVERED IN SCENARIO	4

LogR_D03	**Deployment and recovery of equipment**
STATEMENT	The AUV and the docking station will need to be deployed, and recovered. A crane with at least a 300kg capacity will be required for the deployment (from a support vessel or other).
RESPONSIBLE	INESC TEC, IQUA, UdG, PPF
LEVEL	Mandatory
VERIFICATION METHOD	Pilot testing and/or Analog testing.
COVERED IN SCENARIO	2, 4

LogR_D04	**Deployment of the surface station**
STATEMENT	The surface station (computer, WiFi link, acoustic modem and satellite link) needs to be set up for the execution of the task. For debugging, personnel will need to be present and therefore, space (2 square meters on a sheltered space) and infrastructure (a table, two chairs, access to power and communications, internet access is desirable) needs to be allocated.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	INESC TEC, IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	2

2.4.8. Safety (SafeR)

Safe_D01	**Vehicles out of control switch to manual safety procedure**
STATEMENT	Fully autonomous mode shall be able to switch in safety manual mode when required
RESPONSIBLE	INESC TEC , IQUA and UdG
LEVEL	Mandatory
VERIFICATION METHOD	Verify that switch from fully autonomous to manual mode procedure operate : the partner in charge will assure a check list for each technology proposed before starting the test bed activities.
COVERED IN SCENARIO	1 - 6

Safe_D02	**Vehicles out of control homing safety procedure**
STATEMENT	Fully autonomous mode shall be able to perform homing safety procedure according safety device settings (low battery and/or severe weather, etc..).
RESPONSIBLE	INESC TEC , IQUA and UdG
LEVEL	Mandatory
VERIFICATION METHOD	Verify that switch from fully autonomous to homing procedure operate: the partner in charge will assure a check list for each technology proposed before starting the test bed activities.
COVERED IN SCENARIO	1 - 6

Safe_D03	**Vehicles radiofrequency interference**
STATEMENT	The radiofrequency used for each device must be agreed with telecomunication supervisor, Space App, during the device pre-settings activities at factory and

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	checked before starting the test bed activities.
RESPONSIBLE	INESC TEC , IQUA , and UdG, SPACEAPPS only for radio frequency check
LEVEL	Mandatory
VERIFICATION METHOD	Verify that the radiofrequency used for each device does not overlap with each other. The radiofrequency supervisor will assure two check list, one during the pre-settings activities and another one before starting the test bed activities.
COVERED IN SCENARIO	1 - 6

Safe_D04	**Deployment and recovery of the robot**
STATEMENT	The deployment and recovery of the robot involves some risks, namely heavy load manipulation and crane operation risks.
RESPONSIBLE	INESC TEC, UdG, IQUA
LEVEL	Mandatory
VERIFICATION METHOD	The personnel will be qualified to operate the crane.
COVERED IN SCENARIO	2, 4

SafeR_D05	**Work on support vessel**
STATEMENT	A licensed crew will manage vessels during activities at the Offshore Testbed, in particular, for deploy and recover of assets.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Documentary.
COVERED IN SCENARIO	2, 4

2.4.9. Configuration and Implementation (ConfR)

ConfR_D01	**Configuration of the robot**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	The AUV will be configured for the mission by equipping it with a necessary suite of sensors and tools as well as control software.
RESPONSIBLE	UdG, IQUA
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2, 4

2.5. Intervention autonomous underwater vehicle (I-AUV)

2.5.1. Description

The I-AUV is an autonomous underwater vehicle, equipped with a manipulator or two manipulators. The robot can be configured with different sensor payload and can autonomously navigate and manipulate objects underwater. Each of the manipulators can be equipped with a specific tool, passive or active, designed to fulfil mission requirements. The vehicle is capable of working for a full day on a single charge and withstand certain sea conditions. The robot is supervised through a light umbilical delivering high speed Ethernet or through acoustic communication channels.

2.5.2. Functional (FuncR)

FuncR_E01	**USBL Localization**
STATEMENT	The vehicle is able to localize itself in the structure to enable autonomous navigation to a desired part of the structure. This requires mounting an USBL on the Coastal/Offshore Testbed as well as having knowing the real 3D model of the substructure in order to allow defining target points in the structure to program the missions. It also requires an accurate calibration of the USBL position within the substructure.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA (depending on the results achieved in the pilot and the weather conditions)
COVERED IN SCENARIO	2

FuncR_E02	**Map based Localization with respect to the inspected structure**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	The vehicle is able to localize itself in the structure to enable autonomous navigation to a desired part of the structure. This requires knowing the real 3D model of the substructure in order to register sensor measurements to the actual map in order to solve for the robot position.
RESPONSIBLE	UdG
LEVEL	Optional
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA (depending on the results achieved in the pilot and the weather conditions)
COVERED IN SCENARIO	2

FuncR_E03	**Autonomous approach to the selected part of the structure**
STATEMENT	The vehicle is able to navigate autonomously to the vicinity of the selected part of the inspected structure.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

FuncR_E04	**Autonomous cleaning of soft bio-fouling**
STATEMENT	The robot will perform cleaning of the inspected surface with a rotating brush. Only soft bio-fouling and dirt are considered due to the operation taking place in floating mode.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure (Experimental testing at the WFA (TRL7) might be considered depending on the pilot results (TRL5) and the weather conditions.)
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_E05	Assessment of the state of the surface after cleaning
STATEMENT	The robot should be equipped with an algorithm that can automatically decide if the surface is ready for taking measurements.
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in testbed
COVERED IN SCENARIO	2

FuncR_E06	Autonomous non-destructive testing
STATEMENT	The robot will perform autonomous NDT testing using a specially designed tool, mounted at the end of its manipulator. The operation will be performed while floating.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure (Experimental testing at the WFA (TRL 7) might be considered depending on the pilot results (TRL5) and the weather conditions.)
COVERED IN SCENARIO	2

FuncR_E07	Autonomous cathodic protection testing
STATEMENT	The robot will perform autonomous CP testing, using a specially designed tool, mounted at the end of its manipulator. The operation will be performed while floating.
RESPONSIBLE	UdG
LEVEL	Optional
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure (Experimental testing at the WFA (TRL 7) might be considered depending on the pilot results (TRL5) and the weather conditions.)
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_E08	Autonomous navigation to the recovery point
STATEMENT	The robot will navigate autonomously to a safe recovery point, specified by the operator in the GPS coordinates.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

FuncR_E09	Automatic surfacing in case of equipment failure
STATEMENT	The vehicle will surface automatically, in a safe way, in case of technical issues. It will be always configured as slightly positively buoyant.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

2.5.3. Performance (PerfR)

PerfR_E01	Cleaning and measurements done in separate stages
STATEMENT	The robot will first perform cleaning, and come back to the recovery point. The robot will be then recovered for changing the manipulator tool. After the change the robot will be deployed again to perform the inspection.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PerfR_E02	Cleaning and measurements done in one stage
STATEMENT	The robot will perform the whole operation of navigating to the desired part of the structure, cleaning of structure surface and taking measurements on the cleaned surface, in one continuous procedure.
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure (Experimental testing at the WFA (TRL 7) might be considered depending on the pilot results (TRL5) and the weather conditions.)
COVERED IN SCENARIO	2

PerfR_E03	Ability to come back to the inspected part of the structure
STATEMENT	The robot will be able to come back to the part of the structure which was cleaned for inspection. This way it will be possible to perform the inspection in a second stage, or on a different day if needed.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

PerfR_E04	Localization in low visibility
STATEMENT	The robot will be able to localize itself in the structure even in low visibility conditions thanks to the use of acoustic sensors.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PerfR_E05	**Removal of softly attached marine growth and dirt**
STATEMENT	The robot will be able to remove softly attached marine growth and dirt, from the surface of the structure, to be able to perform NDT.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure (Experimental testing at the WFA (TRL 7) might be considered depending on the pilot results (TRL5) and the weather conditions.)
COVERED IN SCENARIO	2

PerfR_E06	**Removal of hard marine growth (molluscs)**
STATEMENT	The robot will be able to remove strongly attached marine growth lime molluscs thanks to a second manipulator used to fix the robot to the structure.
RESPONSIBLE	UdG
LEVEL	Optional
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

PerfR_E07	**Performing single point NDT measurements**
STATEMENT	The robot will be able to autonomously perform measurements in single contact points on the structure. The number of points can be designated by the operator.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure Internal testing (Experimental testing at the WFA (TRL 7) might be considered depending on the pilot results (TRL5) and the weather conditions)
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PerfR_E08	Compliant behaviour
STATEMENT	The robot will be programmed with a compliant manipulation algorithm, which will secure the inspected surface, the vehicle, the manipulator and the tools from damage.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

2.5.4. Interface (IntR)

IntR_E01	Ethernet link through a light umbilical
STATEMENT	The robot will be connected to the operator's panel through a light umbilical (VDSL2 twister-pair underwater cable).
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

IntR_E02	Ethernet link through a WiFi buoy
STATEMENT	The robot will be connected to the operator's panel through WiFi. The WiFi connection will be delivered by a buoy connected with the robot through a light umbilical (VDSL2 twister-pair underwater cable).
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

IntR_E03	Acoustic link
STATEMENT	The robot will be equipped with an acoustic modem or a USBL to enable tetherless operation and emergency communication.
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

2.5.5. Physical and Resource (PhyR)

PhyR_E01	I-AUV control panel
STATEMENT	The robot will be controlled from a high-end laptop, with a gamepad, located in the support vessel and connected to the robot through Ethernet switch.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

PhyR_E02	Dedicated charger
STATEMENT	The robot will be delivered with a dedicated charger, which has to be located on-board the support vessel.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2.5.6. Operational (OpR)

OpR_E01	**Maximum operational depth of at least 100 m**
STATEMENT	The robot will be able to safely operate to at least 100 m of depth. All external sensors and actuators will have an adequate depth rating. In this case the robot will be connected to the support vessel with a light tether for supervision.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

OpR_E02	**Maximum operational depth with the buoy of 15 m**
STATEMENT	The robot will be able to safely operate up to 15 m of depth when connected to the WiFi buoy.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

OpR_E03	**Full work day endurance**
STATEMENT	The robot will be equipped with a battery capable of delivering power for the whole day of work (8h) without recharging. There is a risk that that depending on the sensor suit this requirement may not be possible to fulfil.
RESPONSIBLE	UdG
LEVEL	Desirable
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2.5.7. Logistics and Support (LogR)

LogR_E01	**Small support vessel**
STATEMENT	A small support vessel for the deployment, recovery and supervision of the robot is required.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel will be checked in terms of space for the equipment and personnel as well as power requirements of the system.
COVERED IN SCENARIO	2

LogR_E02	**On-board crane**
STATEMENT	A crane mounted on the vessel is needed to deploy and recover the robot. The minimum capacity of the crane should be at least 300 kg.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The crane will be checked in terms of the length of the arms and the load capacity.
COVERED IN SCENARIO	2

LogR_E03	**Power supply for the control panel and charger**
STATEMENT	A power supply will be available to charge the robot as well as connect the control panel computer.
RESPONSIBLE	INESC TEC, UdG
LEVEL	Mandatory
VERIFICATION METHOD	The power supply will be checked to follow necessary power requirements.
COVERED IN SCENARIO	2

LogR_E04	**Place for personnel**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	There has to be a space for at least three people on the vessel, apart from the vessel crew - the operator of the robot and the technician.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel will be checked in terms of space requirements.
COVERED IN SCENARIO	2

2.5.8. Safety (SafeR)

SafeR_E01	**Deployment and recovery of the robot**
STATEMENT	The deployment and recovery of the robot involves some risks, namely heavy load manipulation and crane operation risks.
RESPONSIBLE	INESC TEC, UdG
LEVEL	Mandatory
VERIFICATION METHOD	The personnel will be qualified to operate the crane.
COVERED IN SCENARIO	2

2.5.9. Configuration and Implementation (ConfR)

ConfR_E01	**Configuration of the robot**
STATEMENT	The robot will be configured for the mission by equipping it with a necessary suite of sensors and tools as well as control software.
RESPONSIBLE	UdG
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2.6. Hybrid ROV - Remotely Operated underwater Vehicle

2.6.1. Description

A remote control hybrid ROV (Roving Bat, RB) capable of freely navigating and able to land and crawl on the structure, to reach the areas of interest, while keeping contact with the surface at all times will perform IMR operation on the submerged structure. The ROV is connected to a surface control Unit (SCU) and a Power Supply Unit) through an umbilical cable wound on a manual winch.
The operating mode of the Hybrid ROV is the following:

1. Launching from the vessel, a crane is needed;
2. Navigation on free water from a launching point to the WFA structure;
3. Landing on the structure (automatized operation);
4. Sticking on the structure (using vertical thrusters);
5. Crawling on the structure (using crawlers) to reach the areas of interest ;
6. IMR operations:
    a. Visual inspection of the subsea structures,
    b. Cleaning of soft marine growth on subsea structures to be inspected or measured,
    c. NDT measurements,
    d. Light maintenance work.
7. Lift-off from the structure;
8. Navigation on free water back to the recovery point;
9. Recovery to the vessel, a crane is needed;
10. Video and data post-processing and exploitation;

For these operations the ROV will be equipped with a HD TV inspection camera, a navigation low light camera and/or with multi-beam imaging sonar (MBIS) if the turbidity of the water makes it impossible to observe the structure.

The requirements include:

- Vessel equipped with a crane for launching and recovery operations;
- Installation and electrical supply of the Control Command Unit (CCU) and Power Supply Unit (PSU);
- Installation of the umbilical winch;
- Deployment of maximum of 200m Umbilical cable;
- ROV operator.

2.6.2. Functional (FuncR)

FuncR_F01	**Local Remote Control operation**
STATEMENT	The RB will perform a remote operated mission using the CCU standing on a support vessel. Manual piloting of the RB.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing in ECA pool
COVERED IN SCENARIO	2

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_F02	**Remote Control operation**
STATEMENT	In addition of local control the RB will be able to receive commands from the SCC through the CCU station.
RESPONSIBLE	ECA
LEVEL	Desirable
VERIFICATION METHOD	Generation of simulated actions from the SCC side sent to the RB / Experimental testing in pilot structure
COVERED IN SCENARIO	2

FuncR_F03	**Video transmission**
STATEMENT	The RB will be able to perform visual inspection on the submerged structure and to send images to the SCC. The output of the CCU is an Ethernet link.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Simulation by transmission of virtual video from the RB to the SCC / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

FuncR_F04	**Remote Monitoring**
STATEMENT	The RB will be able to send information to the SCC through the SCU during the mission for monitoring of the operation (depth, orientation, position, parameters feedback)
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Simulation: generation of simulated monitoring data from the RB to the SCC. / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	2

FuncR_F05	**Cleaning of soft marine growth on subsea structures**
STATEMENT	The RB will be able to perform cleaning of soft marine growth on subsea structures by water jetting of brushing.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Functional testing (refer to PhyR_RB02)
COVERED IN SCENARIO	2

FuncR_F06	**NDT measurements**
STATEMENT	The RB will be able to perform NDT measurements by using dedicated probes.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Functional testing (refer to PhyR_RB02)
COVERED IN SCENARIO	2

FuncR_F07	**Light maintenance work**
STATEMENT	The RB will be able to perform light maintenance works using a 6 DOF manipulator.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Testing in ECA pool / Experimental testing in pilot structure / Experimental testing in WFA.
COVERED IN SCENARIO	2

FuncR_F08	**RB recovery in case of umbilical break**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	In this case the RB will surface because it is configured as slightly positively buoyant. The RB is also equipped with a flasher, a ULB-350 beacon and a RF emitter for aerial or underwater recovery.
RESPONSIBLE	ECA / INESC TEC (Typically 37Khz beacon detection)
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA.
COVERED IN SCENARIO	2

2.6.3. Performance (PerfR)

Perf_F01	**Roving Bat navigation**
STATEMENT	The RB will be able to navigate from the launching point to the WF structure and then land on the structure by 1.5knts current condition.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Experimental testing in WFA of the stability of the RB
COVERED IN SCENARIO	2

Perf_F02	**Roving Bat crawling**
STATEMENT	The RB will be able to crawl on the submerged part of the WFA structure from one point to another by 1.5knts current condition.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Experimental testing in WFA of the stability of the RB
COVERED IN SCENARIO	2

PerfR_F03	**Localization in low visibility**
STATEMENT	The RB will be able to navigate and crawl in the structure even in case of low visibility conditions thanks to the use of a low light camera and multibeam sonar (typically a Blue View M900-2200)

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	ECA
LEVEL	Desirable
VERIFICATION METHOD	Internal testing in ECA pool / Experimental testing in pilot structure / Experimental testing in WFA
COVERED IN SCENARIO	2

2.6.4. Interface (IntR)

IntR_F01	**Markers for trajectory tracking**
STATEMENT	To know in real time the position of the RB on the submerged structure the RB will be equipped with an odometry system. Painted markers (metered lines and numbered circles - miles stones) will be used to check the correct / trajectory information
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing / Experimental testing in pilot structure / Experimental testing in WFA.
COVERED IN SCENARIO	2

IntR_F02	**3D mapping for obstacle avoidance - trajectory**
STATEMENT	When the RB is crawling on the submerged structure it needs to know its relative position respect to a starting reference point on the preliminary 3D mapping given from the AUV for obstacle avoidance and also for reaching point of interest.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Simulation / Internal testing / Experimental testing in pilot structure / Experimental testing in WFA.
COVERED IN SCENARIO	2

IntR_F03	**Remote Control operation**
STATEMENT	RB control from the SCC through the CCU station need a total maximum

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	transmission latency of 300-400ms (action to video feedback). A fiber optic link between the CCU and the SCC seems to be the best way for the remote control.
RESPONSIBLE	SPACEAPPS
LEVEL	Desirable
VERIFICATION METHOD	Simulation and functional testing. Generation of simulated actions from the SCC side sent to the RB.
COVERED IN SCENARIO	2

2.6.5. Physical and Resource (PhyR)

PhyR_F01	**Roving Bat crawling**
STATEMENT	The RB will be modified to crawl on a cylindrical structure. The umbilical cable has to be managed according to eventual obstacles present on the structure. The diameter of the cylindrical pile must be at least of 10m 30m depth of the submerged part of the WF structure is required.
RESPONSIBLE	ECA, INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Experimental testing in pilot structure.
COVERED IN SCENARIO	2

PhyR_F02	**Cleaning and NDT measurement capabilities**
STATEMENT	Typical structure covered with marine growth and anodes must be present on the structure to check the correct performing of the listed operation.
RESPONSIBLE	ECA, INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing in ECA pool / Experimental testing in pilot structure.
COVERED IN SCENARIO	2

2.6.6. Operational (OpR)

OpR_F01	**Maximum operational depth of at least 100 m**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	The RB will be able to safely operate to at least 100 m of depth. All external sensors and actuators will have an adequate depth rating. The RB will be connected to the support vessel through an umbilical cable.
RESPONSIBLE	ECA
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing. Equipment Specification.
COVERED IN SCENARIO	2

2.6.7. Logistics and Support (LogR)

LogR_F01	**Small support vessel**
STATEMENT	A small support vessel for the deployment, recovery and supervision of the robot is required.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel will be checked in terms of space for the equipment and personnel as well as power requirements of the system.
COVERED IN SCENARIO	2

LogR_F02	**On-board crane**
STATEMENT	The RB will need to be launched and recovered. A crane with at least a 300kg capacity will be required for these operations
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The crane will be checked in terms of the length of the arms and the load capacity.
COVERED IN SCENARIO	2

LogR_F03	**Deployment of the CCU, PSU and winch**
STATEMENT	The surface station needs to be set up for the execution of the task. Both Electrical power supply need of 400Vac (20KVA) and 230Vac (1KVA) are listed on the D1.1 document (appendixes). The winch must be correctly fixed on the Vessel deck.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Functional testing.
COVERED IN SCENARIO	2

LogR_F04	**Place for personnel**
STATEMENT	There has to be a space for at least three people on the vessel, apart from the vessel crew - the operator of the robot, a supervisor and a technician.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel will be checked in terms of space requirements.
COVERED IN SCENARIO	2

2.6.8. Safety (SafeR)

SafeR_F01	**Deployment and recovery of the RB**
STATEMENT	The deployment and recovery of the robot involves some risks, namely heavy load manipulation and crane operation risks.
RESPONSIBLE	INESC TEC, ECA
LEVEL	Mandatory
VERIFICATION METHOD	The personnel must be qualified to operate the crane.
COVERED IN SCENARIO	2

2.6.9. Configuration and Implementation (ConfR)

ConfR_F01	**Configuration of the robot**
STATEMENT	The RB will be equipped for the mission with the necessary actuators and sensors and tools. Eventual USBL transponder have to be defined or be provided (but these transponder may be not efficient while the ROV crawls on the structure - US echoes).
RESPONSIBLE	ECA, INESC TEC, UDG

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	Internal testing.
COVERED IN SCENARIO	2

2.7. UAV - Unmanned Aerial Vehicle

2.7.1. Description

The UAV is an unmanned aerial vehicle equipped with several sensors for navigation and perception in aerial environments. For navigation the UAV is endowed with distinct sensors, such as GPS (with the possibility of using RTK) and IMU, and several perception sensors that can be used for inspection such as 3D Lidar, stereo cameras, hyperspectral camera, and thermal imaging. For communication it's commonly used a WiFi network to send and receive data, and a RF link when WiFi connection drops. Moreover, RF controllers allow to send velocity commands with a range up to 1 km. The vehicle can navigate autonomously following a predefined path, while allowing to switch to remote control navigation mid-mission.

The UAV normally is prepared for autonomous and manual missions. It can be released from land and from boat, and is prepared to perform autonomous landing in a well-known landing base. The communication RF link, provide the ability to monitor all the mission (state of vehicle, position, battery status, etc.). The monitoring console consists on a laptop to visualize the data being acquired and a RC controller to send control commands. In the context of the project, the SCC can be connected to the UAV for monitoring the data remotely and send new mission parameters when required.

2.7.2. Functional (FuncR)

FuncR_G01	**Remotely-operated navigation**
STATEMENT	The UAV must be capable of performing the mission partially or even totally operated via a remote Control Station standing on a support vessel or on shore, when possible.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal tests. Remote commands will be given through the control station at different ranges to determine if the vehicle responds accurately and on time to the given orders. Also, the distance for safe operation will be evaluated.
COVERED IN SCENARIO	1

FuncR_G02	**Autonomous navigation**

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

STATEMENT	The UAV shall be capable of performing the mission on site autonomously, executing a predefined route.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	All algorithms will be tested initially on a realistic 3D simulator of the UAV to verify if no major bugs are detected. Afterward, several independent tests of each developed algorithm will be tested on a controlled scenario in the real vehicle. Full system checks will be performed on the pilot infrastructure to evaluate the error between the desired and the executed path and to evaluate the safety procedures.
COVERED IN SCENARIO	1

FuncR_G03	**UAV localization system**
STATEMENT	The UAV must be capable of estimate its current pose (localization and attitude) in the world accurately. When available GPS/RTK and IMU systems will provide the UAV localization, otherwise other localization algorithms using the available perception sensors shall enhance the vehicle observations.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Campaigns on outdoor scenarios capable of obtaining GPS coordinates will be performed and compared with RTK measures.
COVERED IN SCENARIO	1

FuncR_G04	**UAV close range localization**
STATEMENT	The UAV must be capable of evaluating the relative positioning to relevant infrastructures to accurately perform close range navigation.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Simulation tests with offshore wind farm scenarios will be done to evaluate the performance of all developed methodologies. Analog tests will be performed on controlled scenarios to localize relative to known structures.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

FuncR_G05	Autonomous take-off and landing
STATEMENT	The UAV must be capable of autonomously take-off and landing on a well-defined landing base placed either on the support vessel or on an ASV.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation tests with different vessels equipped with the predetermined landing base will be performed. Tests on controlled marine scenarios with several available vehicles will be performed.
COVERED IN SCENARIO	1

FuncR_G06	Inspection of the aerial scenario
STATEMENT	The UAV must be capable of acquiring geotagged images of the structures (blades and tower) as well as any other relevant data.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation tests with distinct offshore wind farm scenarios will be done to evaluate the performance of all developed methodologies. Analog tests will be performed on controlled scenarios to acquire images of several structures.
COVERED IN SCENARIO	1

2.7.3. Performance (PerfR)

PerfR_G01	Inspection data storage
STATEMENT	Internal storage must be available in the UAV to save all data relevant to the inspection tasks. A storage of at least 1Tb should be placed.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Analog testing will be performed on other relevant scenarios and will be estimated the Gb per second from this tests. An extrapolation of the storage size required for the mission execution time on the offshore scenario will be calculated.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1

PerfR_G02	**Inspection data transmission**
STATEMENT	A set of data acquired with the UAV must be broadcast to the SCC for monitoring. New inspection orders or updates should be transmitted to the UAV.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1

PerfR_G03	**Safety critical data must be exchanged in real-time at close-range**
STATEMENT	Safety critical data such as velocity commands on remote operation and low resolution video must be exchanged with a control station, at close range (up to 100m) in real-time.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing. Tests will be performed using the RC controller at close range and with the streaming via WiFi of a low-resolution image feedback.
COVERED IN SCENARIO	1

PerfR_G04	**Critical control data diagnostic**
STATEMENT	For remote operation the vehicle must receive control commands and provide at least visual information to the operator.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing will be performed to evaluate if the mandatory data is being acquired or not. During tests several critical assets will be randomly disconnected to check the system response.
COVERED IN	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SCENARIO	

PerfR_G05	Battery duration for the task
STATEMENT	The UAV must have enough battery to take-off, perform the mission and return to the landing base . At least 30 min endurance must be available.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing will be performed to evaluate the maximum operation duration available.
COVERED IN SCENARIO	1

2.7.4. Interface (IntR)

IntR_G01	Communication between UAV and Control Station
STATEMENT	Communication between the UAV and the Control Station to allow the exchange of information required to monitor and control the UAV.
RESPONSIBLE	SPACEAPPS, INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1

IntR_G02	WiFi communication on the UAV
STATEMENT	The UAV must use a WiFi communication for close-range remote access.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

IntR_G03	RF communication on the UAV
STATEMENT	The UAV use a RF link to be use for remote operation, emergency stop and as redundant communication system.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1

2.7.5. Physical and Resource (PhyR)

PhyR_G01	Acquire data from the aerial domain
STATEMENT	The UAV must be endowed of sensors, such as cameras (e.g. Stereo and thermal) and/or 3D LIDAR, that will allow to visually inspect the blades and tower present on an wind turbine.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Several sensors will be attached to the UAV and tests shall be performed on the lab to analyze the data quality and to increase the Field-of-View (FoV) of the vehicle. Some campaigns will be performed to acquire data.
COVERED IN SCENARIO	1

PhyR_G02	Simple battery replacement system
STATEMENT	The UAV must allow to easily and quickly replace the battery when discharged with other fully charged.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Analog testing. An external user will be given the battery replacement procedures and will perform on an available vehicle.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PhyR_G03	**Distinguishable blades through visual markers**
STATEMENT	Blades of the wind turbine should have visual markers.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1

2.7.6. Operational (OpR)

OpR_G01	**Maximum wind speed for safe operation of 20 knots**
STATEMENT	The UAV should be able to safely operate with wind speed of up to 10m/s.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and analog testing. The stability of the vehicle will be performed on realistic simulation systems. Tests at distinct locations with diverse wind speeds will be performed.
COVERED IN SCENARIO	1

OpR_G02	**Known landing base**
STATEMENT	A distinctive, known and well visible landing base must be available for the UAV take-off and landing. Besides any data emitting beacon (if available) the landing base must be visually identifiable and localized.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Simulation and internal testing. Several landing bases will be tested to evaluate the best performing platform as well as to identify the best positioning of the base on the UAV transport vehicle.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2.7.7. Logistics and Support (LogR)

LogR_G01	**Small support vessel**
STATEMENT	A small support vessel (e.g. Rigid inflatable boat) can be required for the UAV supervision and remote operation procedures. Moreover, a landing base should be available in the vessel.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vehicle will be checked in terms of space for the equipment and personnel requirements.
COVERED IN SCENARIO	1

LogR_G02	**ASV equipped with landing base**
STATEMENT	An ASV (or vessel) can be used for the UAV transportation, take-off and landing procedures. Moreover, a landing base should be available in the ASV.
RESPONSIBLE	INESC TEC
LEVEL	Optional
VERIFICATION METHOD	The ASV will be checked in terms of space for the equipment and will be performed several tests of each procedure at a controlled scenario.
COVERED IN SCENARIO	1

LogR_G03	**Power supply for the control station**
STATEMENT	A power supply should be available at the vessel to perform small charges for the control station computer (laptop).
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	An internal test will be performed using a powerbank available to determine the charging capacity for the control station laptop.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LogR_G04	**Space for personnel at the small support vessel**
STATEMENT	Space for two elements - UAV operator and technician - should be always available apart from the required vessel crew.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The vessel size will be verified in size regarding the space for crew, equipment and extra personnel.
COVERED IN SCENARIO	1

LogR_G05	**Toolbox available on the support vessel**
STATEMENT	At all times the support vessel should have a toolbox with the most indispensable tools for small procedures, such as battery replacement or removal of non-critical sensors in case of incident.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing will be performed to assess if all tools for disassemble and replace are available. For instance extra batteries or battery module should be in the toolbox.
COVERED IN SCENARIO	1

LogR_G06	**RTK base station on a static and clear area.**
STATEMENT	The GPS/RTK base station can be placed at Testbeds to increase the GPS reading accuracy.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Analog testing.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2.7.8. Safety (SafeR)

SafeR_G01	Self-diagnostic methodologies
STATEMENT	The UAV must perform regular self-diagnostic procedures to ensure that all systems are fully operational or to alert the SCC and the control station for any system failure. At least three levels of failure must be issued, namely fatal, critical and warning.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Internal testing. On the lab each system will be unplugged during testing and the alert response will be checked.
COVERED IN SCENARIO	1

SafeR_G02	UAV landing with fatal failure
STATEMENT	When a fatal failure exists the UAV must try to perform an emergency landing and emit a GPS location to the Control Station for recover.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing.
COVERED IN SCENARIO	1

SafeR_G03	UAV safety distance
STATEMENT	The UAV must maintain a safe distance to the structures and to any personnel present to minimize risks in case of a fatal failure.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Internal testing.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SafeR_G04	Recover Mode
STATEMENT	The UAV should have failure recover modes for critical and warning states. If a critical issue is presented the UAV should return home or require remote operation. Warning level if not harmful for the mission can be bypassed by the operator.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing. On several scenarios distinct alert levels will be forced to evaluate the systems response.
COVERED IN SCENARIO	1

SafeR_G05	Force remote operation
STATEMENT	At any time the operator should be capable to override any mission command and take remote control of the UAV .
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	Analog testing. In relevant scenarios remote control override command will be issued in different mission states.
COVERED IN SCENARIO	1

2.7.9. Configuration and Implementation (ConfR)

ConfR_G01	Configuration of the robot
STATEMENT	The UAV sensor payload configuration should be adapted and parametrized in accordance with the assigned mission.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Internal testing. According to the required data for the inspection task the best sensor payload will be selected.
COVERED IN SCENARIO	1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

ConfR_G02	Sensor calibration
STATEMENT	Prior to any major mission and when any modification on the sensor payload is performed all sensors must be calibrated.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Internal testing. Several calibration procedures will be tested in lab.
COVERED IN SCENARIO	1

2.8. Data Management, Operation and Maintenance Analysis

2.8.1. Description

The IMR data produced by robotic and other assets will be stored in server infrastructure for further analysis and creation of condition estimates for the various components and subsystems to guide further inspection, maintenance and repair actions. Data is sourced from robotics assets, operational systems, external systems such as weather information service, and possibly sensors installed at structures for the purposes of the ATLANTIS project. VTT Operation and Maintenance (O&M) Analytics toolbox will form the basis for condition assessment especially for continuous signals performing state recognition, anomaly detection, analysis of causality and time-frequency analysis among other analysis functions. Additional analysis tools for e.g. image, video, and NDT data will be developed according to the availability of exploitable data and domain needs. The aggregated data and analysis results will be stored in an O&M database. An amount of historical data will be stored to enable assessment of condition deterioration trends and possibly for storing the entire condition life cycle of the component or subsystem.

Operation and Maintenance Analytics subsystem will receive data from above mentioned sources, perform data analysis for producing condition assessment and prognosis information to be transmitted to SCC for displaying to human operators and to be considered in planning further IMR operations.

2.8.2. Functional (FuncR)

FuncR_H01	Ingress communication point for each ATLANTIS IMR data source
STATEMENT	O&M subsystem will provide an ingress communication point for each integrated data source from robotic assets and ATLANTIS sensors. The communication point is presented at Data Gateway.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H02	**Ingress communication point for each Testbed IMR data source**
STATEMENT	O&M subsystem will provide an ingress communication point for each integrated data source from Testbed infrastructures. Integrated meaning that various sensor modalities are correlated with each others and with time and location.
RESPONSIBLE	VTT, SPACEAPPS, (WINDPLUS S.A.)
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H03	**IMR data is correlated with time and location relative to Testbed structures and/or geotagged**
STATEMENT	Sensor data produced by robotic assets is correlated with the time, geolocation, and location with respect to the relevant wind farm structure as much as possible. The sensor data and correlated data is represented as an integrated data structure or object.
RESPONSIBLE	UdG, IQUA, ECA, INESC TEC, VTT, SPACEAPPS
LEVEL	Desirable
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H04	**Server infrastructure supports communication between asynchronous execution modules**
STATEMENT	The communication subsystem of the server infrastructure support asynchronous communication between independently executed processes.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	SPACEAPPS, VTT
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H05	**Egress communication point for each IMR analysis result**
STATEMENT	SCC provides an communication point for receiving data analysis results from O&M subsystem and forwards the data to down stream subsystems such as GUI and mission planning.
RESPONSIBLE	SPACEAPPS, VTT
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H06	**Server infrastructure supports continuous signal communications**
STATEMENT	Server infrastructure enables reception and processing of continuous data signals in data driven manner.
RESPONSIBLE	SPACEAPPS, VTT
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H07	**Server infrastructure supports discrete object communications**
STATEMENT	Server infrastructure enables reception and processing of discrete data messages in data driven manner.
RESPONSIBLE	SPACEAPPS, VTT

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H08	**Server infrastructure supports persistent data storage**
STATEMENT	Server infrastructure provides persistent database for storing integrated sensor data, enabling O&M data processing and results storage.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory / Desirable / Optional
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H09	**Server infrastructure supports sufficient amount of persistent data storage for detecting trends**
STATEMENT	Server infrastructure provides sufficient data capacity for O&M “Sufficient amount” will be defined as the data sources, volumes, and rates are defined.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H10	**Server infrastructure supports sufficient amount of persistent data storage for storing the entire life cycle data of a component or subsystem**
STATEMENT	In order to create a more representative Digital Twins of the WFA components and subsystems all the available I~~R~~MR data over the life cycle of the items should be stored for future use in modelling and identifying the item condition trajectories for predictive maintenance.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H11	Server Infrastructure supports MIMOSA OSA-CBM data model
STATEMENT	The persistent database in Server Infrastructure implements relevant parts of the MIMOSA OSA-CBM data model.
RESPONSIBLE	VTT
LEVEL	Desirable
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H12	**Server infrastructure supports multiple concurrent persistent processes**
STATEMENT	The run-time environment provided by the server infrastructure supports makes multiple concurrent persistent processes available for implementing the computation related O&M.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H13	**Server infrastructure supports streaming data processing**
STATEMENT	Server infrastructure supports timely processing of continuous sequence of small data records.
RESPONSIBLE	VTT, SPACEAPPS

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H14	**Server infrastructure supports event processing**
STATEMENT	Server infrastructure supports event driven data processing.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H15	**Server infrastructure supports compatibility to compile and run VTT O&M Toolbox**
STATEMENT	To be defined according to data processing requirements.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

FuncR_H16	**Server infrastructure supports Python Anaconda**
STATEMENT	Server infrastructure supports executing of Python Anaconda scripts.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

COVERED IN SCENARIO	1-7

FuncR_H17	**Server infrastructure supports image and video analysis**
STATEMENT	Server infrastructure support executing of video processing library such as OpenCV.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

2.8.3. Interface (IntR)

IntR_H01	**O&M subsystem has an interface to SCC for controlling analytics processing parameters**
STATEMENT	An interface between O&M subsystem and SCC should be implemented for controlling the O&M data processing parameters from SCC GUI.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Mandatory
VERIFICATION METHOD	The functionality will be unit tested internally, integration tested in simulation, and finally system tested in analog.
COVERED IN SCENARIO	1-7

2.8.4. Configuration and Implementation (ConfR)

ConfR_H01	**O&M module can be configured from SCC GUI for each specific scenario**
STATEMENT	An interface between O&M subsystem and SCC should be implemented for controlling the O&M internal run time module execution from SCC GUI.
RESPONSIBLE	VTT, SPACEAPPS
LEVEL	Desirable
VERIFICATION	The functionality will be unit tested internally, integration tested in simulation,

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

METHOD	and finally system tested in analog.
COVERED IN SCENARIO	1-7

2.9. Coastal and Offshore Testbeds

2.9.1. Description

The pilot testbed consists of a set of structures, which will be deployed in a designated area for performing IMR operations using robotic assets, and the SCC, which is a collection of systems with the purpose of monitoring and controlling the deployed robotic assets. To make this possible, both sites need to accommodate a communications infrastructure enabling the establishment of remote data channels. From the marine section of the testbed, there are explicit requirements that need to met in order to have a completely functional system according to specification, namely involving:

- pilot testbed area definition, including types of structures to be deployed there;
- technological solution to allow remote communications and streaming of local telemetry data between 3 locations (SCC, testbed site and supporting vessel);
- guidelines for maritime safety.

2.9.2. Functional (FuncR)

FuncR_I01	**Stream telemetry data**
STATEMENT	The telemetry system will produce and publish information such as localisation estimates, temperature, humidity, live video feed, etc. Such information is useful to parties interested in operating robotic assets in the testbed.
RESPONSIBLE	SPACEAPPS, INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Initial tests performed by the technology providers in an outdoor environment. Final validation takes place after deployment of IT systems and the SCC.
COVERED IN SCENARIO	1-7

2.9.3. Physical and Resource (PhyR)

PhyR_I01	**Testbed communications infrastructure to enable remote communications**
STATEMENT	A communication infrastructure is required to allow remote control and supervision of assets in real time (ex. AUV and UAV) and transfer acquired data with high efficiency and low latency.
RESPONSIBLE	SPACEAPPS, INESC TEC

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	Internal testing via simulation of data and command flows within the constrained bandwidth. Takes place after deployment of IT systems and the SCC.
COVERED IN SCENARIO	1-7

PhyR_I02	**Testbed telemetry system**
STATEMENT	The telemetry system consists on a set of payload sensors (GPS, temperature, humidity, live video feed, etc.) that provide useful information to parties interested in operating robotic assets in the testbed. This information allows a better assessment of the on site environmental conditions, which are relevant to optimize mission planning. Presumes automatic transmission of the data using the communication infrastructure to be implemented.
RESPONSIBLE	SPACEAPPS, INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Initial tests performed by the technology providers in an outdoor environment. Final validation takes place after deployment of IT systems and the SCC.
COVERED IN SCENARIO	1-7

PhyR_I03	**3D model of the testbed floating system structure (FSS)**
STATEMENT	The 3D model is an essential resource, since it needs to be produced in order to manufacture the FSS according to an agreed specification. This 3D model is also required for planning the inspection operation with the robotic assets and to aid its installation localisation systems in providing an accurate localisation estimate.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	The model will be presented during project meetings for discussion and validation. Initial tests will be performed by the technology partners in an simulation environment. Final validation takes place during the deployment of the robotics assets in the pilot testbed.
COVERED IN SCENARIO	1-7

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

PhyR_I04	Objects with bio-fouling for cleaning
STATEMENT	Additional simple structures may be deposited in the bottom of the pilot test area, promoting the growing of bio-fouling. This is required to be able to test cleaning procedures using the robotics assets.
RESPONSIBLE	INESC TEC
LEVEL	Desirable
VERIFICATION METHOD	Takes place during the deployment of the robotic assets in the pilot testbed.
COVERED IN SCENARIO	1-7

2.9.4. Operational (OpR)

OpR_I01	Testbed area definition
STATEMENT	In order to install the onshore ATLANTIS test centre, a deployment area needs to be previously agreed together with the local authorities. Navigation within this area is limited to authorised parties, within the context of the ATLANTIS project.
RESPONSIBLE	INESC TEC
LEVEL	Mandatory
VERIFICATION METHOD	This will be provided by the local authorities.
COVERED IN SCENARIO	1-7

OpR_uniqueID	Specify mission oriented layout for the pilot testbed
STATEMENT	Within the area allocated by the local authorities for the establishment of the ATLANTIS pilot testbed, distinct sub areas should be specified according to the mission objective being considered (structure inspection, mooring cable following, NDT, scour assessment, etc.).
RESPONSIBLE	INESC TEC
LEVEL	Desired
VERIFICATION METHOD	Verified before the deployment of the testbed through the delivery of a layout map.
COVERED IN	1-7

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SCENARIO	

OpR_I02	NDTs for the floating structure
STATEMENT	NDTs need to be conducted during the inspection of the floating structure. These tests allow the detection of cracks (in size and length) and the status-monitoring of welds and marine growth thickness. For what concerns the primary structure, the areas to be inspected are the following (see D1.1. for more details): • column shell; • knee braces; • lower main beams, V-braces and K-joints; • water entrapment plate (above and below). It is worth to mention that the main concern of end-users is the long time required for cleaning the surface before NDTs take place. Actions aiming to reduce the time of cleaning as well as new NDTs methodologies that require less accurate cleaning (or can avoid it) might be interesting solutions.
RESPONSIBLE	INESC TEC, EDP, UdG, SPACEAPPS, ECA, IQUA, PPF (everyone involved in NDTs)
LEVEL	Desirable
VERIFICATION METHOD	The accuracy level of the data retrieved will be considered the main KPI to evaluate the goodness of the methodology used.
COVERED IN SCENARIO	2

OpR_I03	NDTs for underwater cables protection systems
STATEMENT	Cables have to be inspected in order to detect possible faults and damages, such as: abrasion (caused by the contact with the seabed), failure of the fastening elements (buoyancy modules, bend stiffener, cable protection, etc; see D1.1 for more details). In general stress, fatigue and wear need to be assessed. For this reason, NDTs have to be performed on the following components: • Buoyancy module; • Cable protection (Uraduct). It is worth to mention that the main concern of end-users is the long time spent for cleaning the surface before NDTs take place. Actions aiming to reduce the time of cleaning as well as new NDTs methodologies that require less accurate cleaning (or can avoid it) might be interesting solutions.
RESPONSIBLE	INESC TEC, EDP, UdG, SPACEAPPS, ECA, IQUA, PPF (everyone involved in NDTs)
LEVEL	Mandatory
VERIFICATION	The accuracy level of the data retrieved will be considered the main KPI to

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

METHOD	evaluate the goodness of the methodology used.
COVERED IN SCENARIO	3

OpR_I04	**NDTs for foundations**
STATEMENT	The WFA is a floating structure, with the wind turbines anchored to the seabed through anchoring and mooring systems. These systems are paramount to ensure the stability of the overall structure: therefore, fatigue cracks and abrasion damage, that may jeopardize the integrity of the anchoring system, need to be detected in due time. The components to be inspected through NDTs are the following: • Chains; • Ropes; • Platform Mooring Connectors (PMC); • Clump weights (and soil condition around them); • Anchors. It is worth to mention that the main concern of end-users is due to the long time spent for cleaning the surface before NDTs take place. Actions aiming to reduce the time of cleaning as well as new NDTs methodologies that require less accurate cleaning (or can avoid it) might be interesting solutions.
RESPONSIBLE	INESC TEC, EDP, UdG, SPACEAPPS, ECA, IQUA, PPF (everyone involved in NDTs)
LEVEL	Desirable
VERIFICATION METHOD	The accuracy level of the data retrieved will be considered the main KPI to evaluate the goodness of the methodology used.
COVERED IN SCENARIO	6

2.9.5. Logistics and Support (LogR)

LogR_I01	**Supporting vessel for deployment and operation of robotic assets**
STATEMENT	A supporting vessel is required to transport the robotic assets to the reserved operating area. The assets will then be able to execute missions which include surveying the area of interest in the premises of the vessel. Besides allowing the deployment/recovery of the assets, the nearby presence of the vessel is also recommended for safety purposes and local mission supervision. The vessel should provide adequate work conditions to the vehicle operators, allowing safe deployment of the assets.
RESPONSIBLE	INESC TEC

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

LEVEL	Mandatory
VERIFICATION METHOD	Deployment of the robotic assets in the pilot.
COVERED IN SCENARIO	1-7

2.9.6. Safety (SafeR)

SafeR_I01	**Follow European guidelines for maritime safety**
STATEMENT	Adhering to international safety standards improves safety at sea, prevents marine pollution and ensures regulations are interpreted in the same way across the EU (which is useful since we are a multi-national consortium). This relates to: • the type of equipment being used; • operational procedures; • training of the personnel; • marking of structures which may present danger to navigation
RESPONSIBLE	INESC TEC, EDP, UdG, SPACEAPPS, ECA, IQUA (everyone involved in testing)
LEVEL	Mandatory
VERIFICATION METHOD	Before testing starts, review the legislation identified in the Ethics deliverable D9.2.
COVERED IN SCENARIO	1-7

3. Overview of Platform Architecture

"The overall aim of the ATLANTIS project is to establish a pioneer pilot infrastructure capable of demonstrating key enabling robotic technologies for inspection and maintenance of offshore wind farms that will be installed in the Atlantic Ocean, in particular, the coast of Viana do Castelo in Portugal."

ATLANTIS proposes the development and validation of a robotics IMR Testbed in the context of offshore wind-turbine energy production facility. The testing and validation facility will have a coastal and a offshore component where different types of robots will perform O&M in a representative environment. All the interactions between the involved systems need to be defined The success of the project depends on the ability of the involved parties to combine technologies in order to:

- Deploy the robotic devices in the pilot;
- Perform the relevant IMR operations specified in the scenario descriptions;

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

- Track and report all the operations;
- Analyse the results in a centralized and accurate way;
- Communicate with all the unmanned assets;
- Have a unified digital world representation of the WFA pilot.

In addressing the projects objectives with the proposed methodologies, we can identify a set of technological layers that will be working together in the final setup (see Figure 2).

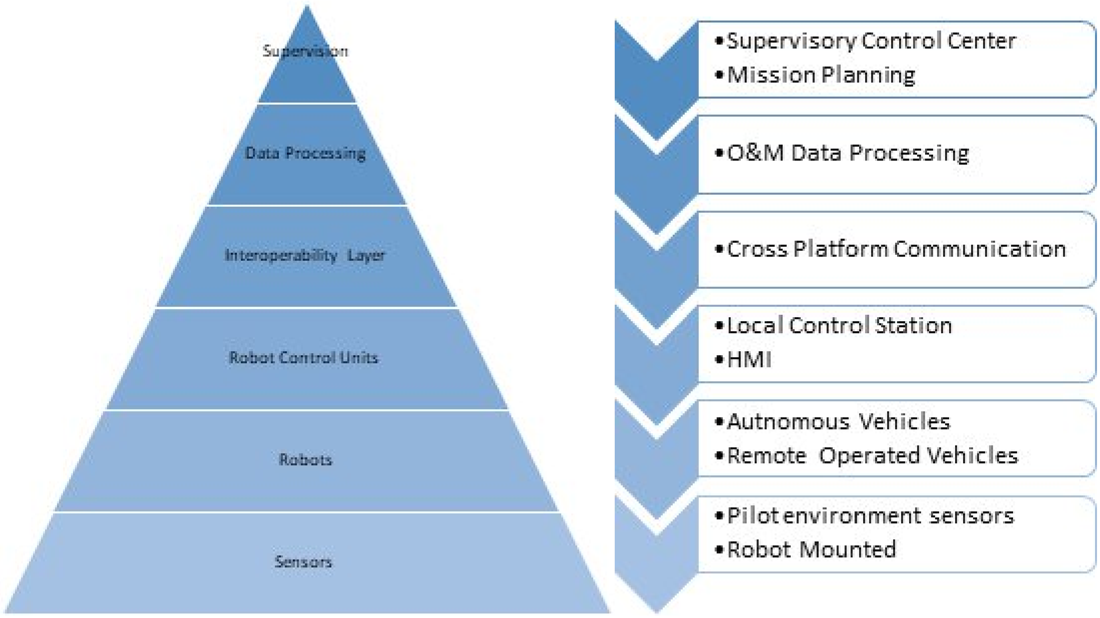


Figure 2: Technological layers in ATLANTIS System

The design of the system is based on the perspective of the end user. As defined in WP1, the end users goal is to improve the efficiency of IMR operations for the offshore wind-turbine infrastructure. Since the focus is heavily targeted on the energy producing assets,a *Supervisory Control Centre (SCC)* is proposed. The SCC has the role to provide a single point of control to the robotics operations and the capacity to consistently deliver the operations result in a consistent way, regardless of the type of robot performing the operation. The SCC provides the tools specific for a control centre, which include monitoring of environmental data, deployment of operations, planning and data visualization. The information represented by the SCC comes from the data processing units. As an intermediate level between the supervision and the robots, the data processing layer is responsible for performing transformations on the data samples for it to be stored and visualized. Apart from compression and filtering mechanisms, a set of algorithms meant for operations and maintenance analysis and predictions will be deployed. All these components will be deployed on local servers or in the cloud and will exchange information between them using web protocols like HTTP, WebSockets or OGC Standards.

The communication between different components deployed onshore will be based on the client-server architecture. At the centre of the deployment will be a database containing the information gathered from the operations. All the other components will act like clients to the database and will read or write information using decoupled endpoints that offer a RESTFul API and an OGC Standardized interface.

The layer that links the deployed robots and the onshore control centre is the *Interoperability Layer*. This layer has the main role of unifying the data types coming and going to the deployed robots. The higher layers will be able to have a unified access point and the robots will be able to interact with each others.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

There are three main data exchanges that are supported between the interoperability layer and the robots: command, monitoring and data retrieval. Each one of the robots has a specific set of commands that can be engaged by the control centre. The interoperability layer has the role to advertise towards the control centre which are the capabilities of each robot and to accept from the supervisory control centre a command format that is generic for all the robots. Inside the interoperability, the commands received from the control centre are translated into each robot's command specifications.

In order to translate the generic command structure to the specific format, the interoperability layer has to understand each of the robot's capabilities. This will be done in an automatic way the first time a robot is connected to the ATLANTIS Testbed system. The configuration of the robot will be passed to the interoperability layer through a configuration file. The configuration file will be stored on the robot on-board computer and it will contain the list of supported commands, telemetry and data payloads, along with the robot namespace.

From a deployment view, the interoperability layer software will run on both the onshore facility and the offshore unmanned vehicles. The module running on shore will act as a data gateway between the SCC/Data Processing units and the rest of the system. The physical link between the onshore and offshore parts of the interoperability layer can be a satellite link, 4G, or through the existing wind-float communication infrastructure.

The communication protocol that is used within the interoperability layer for onshore to offshore communication is DDS. DDS is is a messaging exchange protocol developed by the industry in order to communicate within a distributed system having strict operations requirements. Using this protocol will allow us to strictly control the delivery of data from one side to the other. DDS is designed as a publish-subscribe system in which any component can broadcast data for any of the other components to listen. When the data are broadcast, parameters can be set in order to configure the messaging system for management of message delays, delivery failure, communication latency etc.

DDS existed in the Industrial ecosystem for a long time. In recent years there was a high interest presented by the robotics communities to integrate DDS standard as the main message exchange modality in the robotics system. The choice is based on the long history of DDS being successfully used in safety-critical systems. Due to this risen interest, the second generation of Robot Operating System (the most used middleware for robotics projects) is built on top of the DDS protocol. In ATLANTIS , most of the robots support ROS natively, so the main way of message exchange between the robots and the interoperability layer will be done through it.

On the robot side, the module is deployed as a library. The library can be a dependency for the robot or the local robot control centre.

From the Interoperability layer each robot control unit or robot will be linked through an API.

As the added value of the system is based upon the IMR operation efficiency, the scenarios depicted in D2.1 are identifying the infrastructure components and logistics operations that should be addressed in the first place.

Each of the scenarios addressing one IMR operation required for an offshore wind energy production unit which can be performed by using robotics systems. The vehicles to be used for each case are listed in the scenario description (D2.1). Depending on the scenario the involved vehicles can be autonomous or remotely operated. In the case of autonomous vehicle deployment, there are also cases in which two or more robots collaborate for achieving a common goal. In the current document, we are addressing all the

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

particular cases by describing the necessary interfaces that have to be established between various systems in order to successfully demonstrate all the planned scenarios.

From a deployment view, there are three main operation locations that interact with each other: The onshore SCC, the Coastal Testbed and the Offshore Testbed. As the SCC is the point of access for the end user, we must establish the best possible communication connection with the other two locations. In the case of the Coastal Tesbed directional WiFi, 4G. 5G or Software Defined Radio (SDR) could be used, while for the offshore communication we can either establish a satellite link or make use of existing communication lines if available. Apart from the communication from the SCC, each of the pilot sites have to have a means of accessing the other devices and a mechanism to send that data to through the SCC established connection. The two cases are solved in the same way by first setting a data gateway that bridges the local and remote network. As for the local communication, WiFi, SDR, USBL (for underwater) and cable (Ethernet or fiber optics) are potential solutions to, depending on the specific hardware configurations and operational requirements.

Looking at the deployment view from Figure 3 we can observe that our system is split into two parts: the onshore and offshore. On the onshore side, the infrastructure consists of local servers or cloud deployed software modules. Regardless of being deployed on the local server or in the cloud, the supervisory and the data processing layers will have the same functionality. The supervisory control centre will be accessible by operators through a web-based user interface. The user interface will be configurable depending on the operator profile and needs. The system is designed in such a way that multiple operators can access the data using their custom interface in the same time. The data that is manipulated by the operators comes from the data storage and management unit. All the information that is stored in the database is time-stamped and geotagged. This allows all the operators to visualise operations data in timeline views and in two-dimensional or three-dimensional spatial views. Another important module deployed on the shore is the offline collaborative task planner. The task planner gathers input data from the testbed, the predefined domain and the operator request and computes a list of tasks to be executed by the unmanned vehicle in order to achieve the specified goal. Along with the SCC on the onshore servers the O&M processing unit will be launched. Both the control centre and the O&M will communicate with the offshore or the coastal test band through the same remote communication endpoint.

Communication between the testbed and the control centre will be done using the 4G network or satellite communication or the wind flow communication infrastructure. The communication architecture from the Coastal Testbed is similar to the one foreseen on the Offshore Testbed. In both cases, data will be received through a remote communication endpoint. The testbed has to accommodate the necessary hardware for the remote communication endpoint and for a local communication network.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

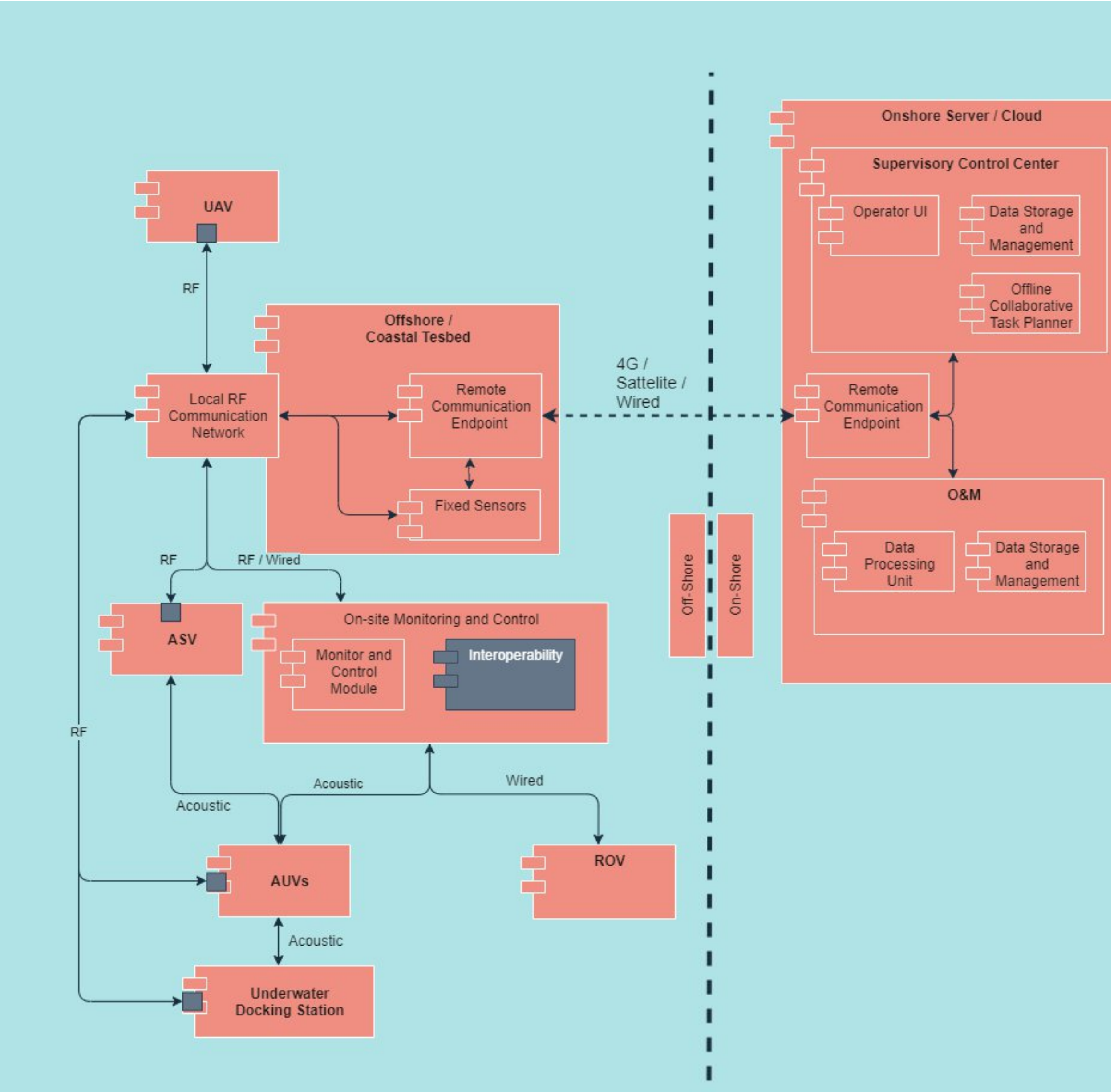


Figure 3: Deployment Diagram

The communication hardware installed on the testbed platform acts like a data gateway by linking the unmanned vehicles, local control units and the tesbed sensor nodes to the remote link and implicitly to the SCC.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

4. Software Interfaces

From a software perspective, the proposed design follows the layer structure described. At the lowest level sensory devices are responsible for the data acquisition. As this data is the core input for the whole operation, there is a path of communication all the way to the Server Infrastructure where the data is (1) stored, (2) analysed and (3) displayed on the operator views. There are two possible end points for the sensors: the testbed which can support fixed sensors continuously gathering environment characteristics and the robots where we have mobile sensors that gather on demand information related to a specific component of the testbed.

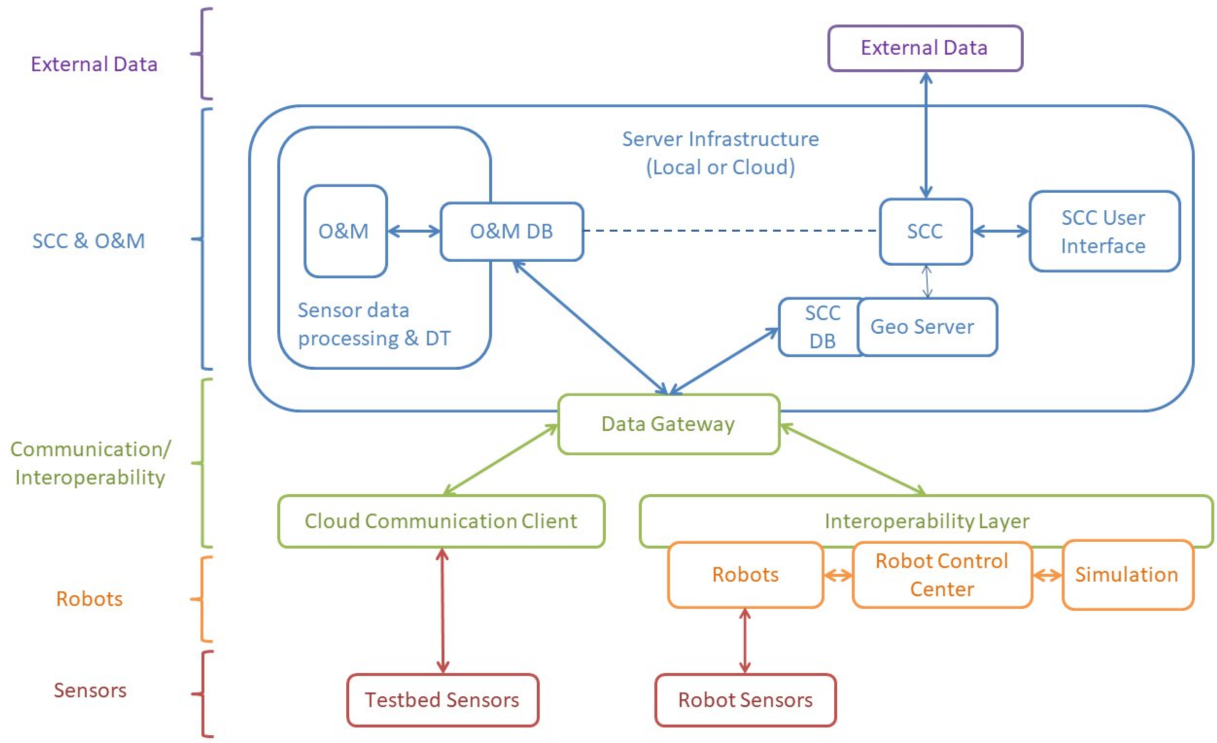


Figure 4: Atlantis Software Architecture

The robots (in simulation or deployment), together with their control units, are performing the IMR actions in the Pilot. They get, preprocess and send away the data from the sensors, advertise their state and receive instructions from the supervisory control centre. While each of the robotic devices have its own on-board sensors with a particular software interface, the data exchange with the control centre is done in a unified way from all the robots. Communicating using a similar convention will be possible due to an interoperability software that has the role to translate the commands and data from the SCC format to the robot specific format. Most of the robotic devices are using the Robot Operating System (ROS) middleware to exchange data on-board and with the robot control centres.

The communication software layer that links the Pilot with the server infrastructure from the shore is composed of:

- Interoperability Layer;
- Cloud Communication Client;

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

- Data Gateway.

Using the DDS protocol: DDS is an OMG communication standard represented as a middleware providing publish-subscribe communications with robust characteristics. DDS features control of QoS parameters, including reliability, bandwidth, delivery deadlines, and resource limits. DDS standard enables it's implementation by different vendors to remain interoperable while providing the flexibility for defining data specific structures to be communicated between software components.

The SCC is able to receive and store the data from the robots in its own database which is accessible from the user interface. Data can be telemetries, images, point clouds, positions etc. Since numerical telemetries are represented in graphs or tables and geographical data are shown on a map, the user can follow the position of the robots as well as their sensor data in real time or by accessing the history. Through this interface, the user can also define an objective for an action or a mission and sending it to the desired robots. An automated planning feature is embedded in the SCC. It can be used to compute a plan for the robot(s) involved in the mission using informations stored in the database (such as initial position and robot characteristics) and input from the operator. A plan is composed of actions (possibly timestamped) aiming to satisfy the mission goal and a list of points to visit. Feedback and result of these actions / mission are received by the SCC and is displayed on the UI.

The O&M module receives and stores inspection data from the robots in a MIMOSA OSA-CBM compliant database. It further processes the inspection data in a pipeline to operation and maintenance advisories that are sent to the SCC for displaying. An ISO 13374 compliant processing pipeline is considered but adapted as needed. Image and video acquisitions are stored and processed in MIMOSA OSA-CBM DABLOBData objects, other data acquisitions are stored in their complying data objects. In addition to data from robots, O&M may also receive external data from infrastructure sources on the Coastal Testbed and Offshore Testbed.

4.1. Software Interface Description

The Software Interface Matrix (see Table 1) is a square matrix defining the data exchange between software components. The matrix expressed information exchange between two components by marking an "x" on the row of the first component and the column of the seconds. The purpose of the matrix is to serve as a reference for the interface tables described below. The software components used in the matrix are the high level components and the main goal is to make sure that we cover the interactions that have to be made between partners. The matrix follows the system architecture presented in Figure 4.

The software links where the component on the row is providing the API are marked with "x>", while the ones that have to implement the interface are marked with ">x".

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Table 1: Software Interface Matrix

		Supervisory Control Centre	O&M	Interoperability	Robot Control Centre & UxV	Testbed Sensors	External Services
Component		**A**	**B**	**C**	**D**	**E**	**F**
Supervisory Control Centre	**A**		x>	x>			>x
O&M	**B**	>x		>x			
Communication/ Interoperability	**C**	>x	>x		>x	>x	
Robot Control Centre & UxV	**D**			x>			
Testbed Sensors	**E**			x>			
External Services	**F**	x>					

For each of the components we list the data payloads that are incoming or leaving by highlighting:

- Physical communication channel;
- Source and destination;
- Project partner in charge with the implementation of the interface;
- A reference core with the format "SW_XY_ID" where "X" is the matrix letter for the source and "Y" for the destination;
- Interface title which should provide the reader with a high level description of the data or payload content;
- A description of the data. It can be an estimation of how the data structure would look like or it can be a text describing the payload.

4.2. Supervisory Control Centre

The supervisory control centre acts as a master towards the O&M component. From the SCC UI, an operator can request the analysis of specific sequences of data gathered from the testbed in the same mission. The SCC will receive from the O&M in return the summary of the data analysis once it is

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

performed. The summary will be stored and the operators will be able to consult it from the same view like the one in which they visualise the data.

To perform the analysis, O&M will query the data store managed by the SCC server. Data queries can be made by my passing a time window, specific testbed component or an executed mission identifier.

The survey data of big dimensions is stored by the SCC as files in a data-store. Each one of the files has an associated URL and the database keeps track of it. While O&M will consume large data types like images videos or point clouds, the SCC will provide the table containing mission id, the testbed component that was inspected, the time stamp, the position and orientation of the robot and the URL from which the data can be retrieved. Even though different onshore components can run either locally or deployed in a cloud service, the components which are foreseen to exchange a large amount of data like the SCC data-store and O&M, will be launched in such way that there is a high-speed communication link between them (gigabit Ethernet).

SCC To O&M			
Channel	**From**	**To**	**Partner**
Eth	SCC	O&M	VTT / SPACEAPPS

Ref	**Title.**
SW_AB_001	Active Robots by Time
The list of active robots at a moment in time.	
SW_AB_002	Data by Time and Asset
Data acquired from the robotic devices from a specific location and time window.	
SW_AB_003	Analyse Mission
Request to the O&M to process a specific mission performed by the robots.	
SW_AB_004	Retrieve Analysis Result
Request to retrieve a report for a performed analysis.	

O&M To SCC			
Channel	**From**	**To**	**Partner**
Eth	SCC	O&M	VTT / SPACEAPPS

Ref	**Title.**
SW_BA_001	Get active Robots by Time
Query to get all robots state at a time point.	
SW_BA_002	Get data by Time and Asset.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Query to get data samples acquired during a time window, from a specific asset. The query will be done using a HTTP request to the SCC server. The request will contain the start-time, end-time and the asset.	
SW_BA_003	Mission Report
Results of a mission analysis.	

SCC To Interoperability			
Channel	**From**	**To**	**Partner**
RF	SCC	Interop Layer	SPACEAPPS

Ref	**Title.**
SW_AC_001	Get Robot Configuration
Send request to retrieve robot configuration.	
SW_AC_002	Get Robot State
Send request to retrieve robot state.	
SW_AC_003	Execute Plan
Deploy execution of a plan. The message will contain: • mission • robots • plan - list of actions • parameters • timeout - the time for the robot to react to the request	
SW_AC_004	Execute Command
Deploy the execution of a single command. The message will contain: • robot • command • parameters • timeout - the time for the robot to react to the request	
SW_AC_005	Get Data Payload
Send request to retrieve data payload. The message will contain: • robot • data type • time interval • mission - optional	
Get System Overview	
Query to the interoperability layer to retrieve the full map of the system. This will include the registered robots, their types and their capabilities.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

4.3. Interoperability Layer

The Interoperability Layer has the purpose of connecting a set of heterogeneous robots to a single system that in which the devices are aware of each other and that can be observed and controlled from a single point of operations. The main role of the layer is to expose the deployed assets using a common language that can be understood by other parts of the systems like the supervisory control centre, the sensor data processing units and even by other robots. The functionality of the layer includes one part that focuses on the interaction unification and the other that focuses on the operations requirements.

Features

- Registration
- Discovery
- State Monitoring
- Commanding
- Data retrieval
- Mission based operations
- Cross robot interaction

Architecture

The data **gateway communication** component is deployed on the onshore computers. The role of the Gateway is to convert DDS messages to protocols used by the the other SCC modules and vice versa. The conversion will be done according to each of the module specifications and can be in the form of http or websocket json payloads, files or binary data. The data is than passed from the gateway to the storing services and, if configured in such way, to the live data providers.

Robot interface and Capabilities Description. Each of the robots will register to the SCC by publishing their available and supported data types. The configuration will be stored in a file (e.g. YAML) on the processing unit that runs the interoperability layer robot interface (could be on-board or on the robot specific control centre).

Given that we are dealing with devices with different characteristics and capabilities, the generic configuration structure will be subject to change during the development phases of the project.

Configuration will imply a set of required fields that help for the device identification, position and generic mission deployment. These elements will be mandatory for all the configuration, so the other systems can have basic interaction. The rest of the configuration can be specific, with certain limitations.

The options from the configuration tells the interoperability layer and the SCC which are the types of interactions available. The two can be split into available telemetry and available commands. As an effect to the SCC, depending on the configuration, the operators interface will adapt to display certain data types and make available specific actions that will be labelled as defined in the configuration files.

The proposed list of configuration elements can be split in required and optional elements. The required information that a robot provider has to configure is:

- **Namespace**: The name of the robot. It has to be unique and it will have the role to help the SCC to identify it. The operators will see this string associated with the robot.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

- **Pose:** The position of the robot. It will be done by calling the interoperability layer of by adding the name of a ROS topic in the configuration.
- **Mission Execution:** Routine to execute mission. If using ROS it will be an *action server* capable of receiving a plan as a goal, otherwise it will be a registered callback.

For each robotic device, the robot owner can register to the interoperability layer data types that can be send and commands that are supported. The number of interfaces is not limited. The supported types of telemetry data is boolean or numeric and the commands can have four types of payloads: no payload, point, path or period. Figure 5 represents a possible configuration file for an unmanned vehicle.

```
### ROS Namespace
namespace: /robot_namespace
### Telemetry (for ROS: name of topics)
boolean_telemetry_topics:
 - /submerged
 - /in_flight
 - /WiFi_on
 - /docked
 - /lidar_on
numeric_telemetry_topics:
 - /battery
 - /altitude
 - /motor1/current
pose_topic: /my_robot_pose
### Commands (for ROS: name of action servers)
mission_execution: /my_plan_execution_srv
command_plain: #no parameters
 - /publish_all_images:
   conditions:
     - WiFi_on
 - /recharge
   conditions:
     - docked
 - dock
command_waypoint: #point payload
 - /fly_to_point
 - /land_to_point
 - /submerge_to_point
 - /survey_point
command_path: #path payload
 - /my_robot_follow_path
 - /scan_path:
   conditions:
     - /submerged
     - /lidar_on
command_time:
 - dock_until_timestamp:  #time payload
```

Figure 5: Sample robot configuration file

To SCC			
Channel	**From**	**To**	**Partner**
RF	Interoperability	SCC	SPACEAPPS

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

<table>
<tr><th>Ref</th><th>Title.</th></tr>
<tr><td>SW_DA_001</td><td>Register Robot / Device</td></tr>
<tr><td colspan="2">Configuration of the Robot containing at least:
• namespace
• robot type
• telemetry types
• sensor data types
• supported commands</td></tr>
<tr><td>SW_DA_002</td><td>Robot Alive</td></tr>
<tr><td colspan="2">Periodic signal send to the SCC confirming that the robot is available. The packet has two functions:
• inform the operator about the robot being active
• check the communication link
The “robot alive” data packet will contain the namespace of the robot, and the time stamp from the emission time.</td></tr>
<tr><td>SW_DA_004</td><td>Mission Plan Execution Feedback</td></tr>
<tr><td colspan="2">For each of the mission deployed on the robot, the operator will view the state of the execution for each of the task, including any replanning activities. The feedback will contain the current action that is performed, together with the time stamp.
Since we are working in a multi-agent system, the feedback can contain information from multiple robots.</td></tr>
<tr><td>SW_DA_005</td><td>Mission Plan Execution Result</td></tr>
<tr><td colspan="2">At the end of an automatic plan, the SCC will receive the outcome of the mission plan execution. This can be:
• SUCCESS
• ABORTED
• CANCELED_BY_OPS</td></tr>
<tr><td>SW_DA_006</td><td>Command Execution Feedback</td></tr>
<tr><td colspan="2">Execution for an ongoing requested command. The ongoing command feedback is not mandatory for all commands. The feedback can be:
• Boolean
• Numerical
• Positional
• Binary Payload
It can contain one or multiple data formats listed above. Each data payloads will be named.</td></tr>
<tr><td>SW_DA_007</td><td>Command Execution Result</td></tr>
<tr><td colspan="2">• SUCCESS
• ABORTED
• CANCELED_BY_OPS</td></tr>
<tr><td>SW_DA_008</td><td>Numeric Telemetry</td></tr>
<tr><td colspan="2">Numeric data associated with the state of robotic subsystem. For example: battery level, motor current, speed etc.</td></tr>
<tr><td>SW_DA_009</td><td>Position</td></tr>
<tr><td colspan="2">Robot Position and Orientation</td></tr>
</table>

This project has received funding from the European Union’s Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SW_DA_010	Image
Visual data acquired by the on board perception sensors. It can be the output of a camera or the output of a processed sensor (e.g. bathymetry map).	
SW_DA_011	Point Cloud
A list of positioned points containing various metadata.	
SW_DA_012	3D Mesh
A list of 3D vertices and a list of edges that link the vertices.	
SW_DA_013	Device Wakeup
Data packet send at the startup of the robot. It contains the robot namespace and the time stamp. This message will be followed up by the alive periodic message.	
SW_DA_014	Error
Error code associated with a robot or the communication units.	

To Robot Control Centre / UxV

Channel	From	To	Partner
RF	Interoperability	RCC / UxV	SPACEAPPS

Ref	Title.
SW_DF_001	Get Robot Configuration
Get configuration request.	
SW_DF_002	Get Robot State
Get State Request.	
SW_DF_003	Execute Plan
Request to execute a plan. The plan will be send as a list of actions that are supported by the robot.	
SW_DF_004	Publish Data
Request for the robot to publish data acquired during an IMR mission.	
SW_DF_005	Execute Command
Request to execute a command. The message will contain: • Command • Timeout - the time for the robot to react to the request	
SW_DF_006	Execute Position Command
Request to execute a command with a positional payload. The message will contain: • Command • Position • Timeout - the time for the robot to react to the request	
SW_DF_007	Execute Path Command

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Request to execute a command with a path as a payload. The message will contain: • Command • Path • Timeout - the time for the robot to react to the request
SW_DF_008 — Execute Time Command
Request to execute a command with a temporal payload. The message will contain: • Command • Time window • Timeout - the time for the robot to react to the request

From UxV / Robot CC

Channel	From	To	Partner
LIB / API	UxV	Interoperability	SPACEAPPS

Ref	Title.
SW_DC_001	Robot Configuration
Robot configuration will be provided as a yml file. The configuration file will be used to configure the SCC with the elements necessary to display and command the robot .	
SW_DC_002	Robot State
State of the vehicle at a given time.	
SW_DC_003	Mission Plan Execution Feedback
Feedback for the execute plan command. It will contain: • time stamp • executed step id	
SW_DC_004	Mission Plan Execution Result
Result of the plan execution.	
SW_DC_005	Command Execution Feedback
Feedback for a command. The feedback structure can contain multiple fields with: • numbers • pose • images • point clouds The interop layer will send them to the SCC	
SW_DC_006	Command Execution Result
Result of the command execution.	
SW_DC_007	Numeric Telemetry
Numeric data associated with a characteristic of the robot.	
SW_DC_008	Position

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Robot Position in 3d space and Orientation as quaternion.	
SW_DC_009	Image
Visual data acquired by the on-board perception sensors. It can be the output of a camera or the output of a processed sensor (e.g. bathymetry map).	
SW_DC_010	Point Cloud
A list of 3D points containing various metadata.	
SW_DC_011	3D Mesh
A list of 3D vertices and a list of edges that link the vertices.	
SW_DC_012	Error
Error code associated with the robot.	

To O&M

Channel	From	To	Partner
RF	Interoperability	O&M	VTT

Ref	Title.
SW_CB_001	Image
Visual data acquired by the on-board perception sensors. It can be the output of a camera or the output of a processed sensor (e.g. bathymetry map).	
SW_CB_002	Point Cloud
A list of 3D positioned points containing various metadata.	
SW_CB_003	3D Mesh
FA list of 3D vertices and a list of edges that link the vertices.	

Sensors To Communication Client

Channel	From	To	Partner
RF	Testbed Sensors	Interop Layer	SPACEAPPS / INESC TEC / VTT

Ref	Title.
SW_EC_001	Position
Position of the sensor node	
SW_EC_002	Temperature and Humidity
Temperature and Humidity	

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SW_EC_003	Wind Speed
Wind speed measured by the weather station	
SW_EC_004	Precipitation
Precipitation level measured by the weather station	
SW_EC_005	Video Feed
Video feed from camera mounted on the Testbed. H.264 Encoding.	

4.4. Robot Control Center and UxV

UAV (INESC TEC)			
From Interoperability Layer (Commands)			
Channel	**From**	**To**	**Partner**
RF	Interop	UAV	INESC TEC

Ref	**Title.**
SW_CD_001	Mission Definition
- Home location - type of landing platform (int) and expected position (latitude, longitude) - Types: 1) Area Survey • Target area (list of latitude/longitude coordinates defining the area bounding box) • Survey parameters (lawn mowing spacing, speed*, track orientation, payload configuration) 2) Predefined path • Exploration path - list of points (latitude, longitude, altitude) • Path parameters (speed* and payload configuration) • Speed - Linear (x,y,z), angular (roll , pitch, yaw)	
SW_CD_002	Mission Commands
• Start mission - Mission execution starting in take-off • Abort mission - Cancel mission and return home • Remote operation - Pauses the mission and becomes teleoperated • Pause Mission - Halt mission and hover • Restart mission - Carry on the mission execution from the last waypoint visited • Emergency stop - Abort mission and lands on a nearby location, emits last known location	
SW_CD_003	Motion Commands
• Go to Position • Go home • Velocity (remote operation) • Keep position	

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

<table>
<tr><th colspan="4">To Interoperability Layer (Data & TM)</th></tr>
<tr><th>Channel</th><th>From</th><th>To</th><th>Partner</th></tr>
<tr><td>RF</td><td>UAV</td><td>Interop</td><td>INESC TEC</td></tr>
</table>

<table>
<tr><th>Ref</th><th>Title.</th></tr>
<tr><td>SW_DC_013</td><td>Telemetry</td></tr>
<tr><td colspan="2">UAV estimated Position
Position (x,y,z)
Orientation (w,x,y,z)
UAV Altitude
altitude (h)
RTK estimated odometry
Position (x y z)
Velocity (linear)</td></tr>
<tr><td>SW_DC_014</td><td>Mission Status</td></tr>
<tr><td colspan="2">RUNNING | BLOCKED |PAUSED | CANCELED | DONE Emergency State (Bool) Current waypoint</td></tr>
<tr><td>SW_DC_015</td><td>Diagnostics</td></tr>
<tr><td colspan="2">Emergency State (bool)
Low Battery (bool)
Watchdog (bool)
Sensor Status (vector<bool>) - [Sensor 1, Sensor 2, ..., Sensor n]
Mission Failure (int):
1 - Path blocked
2 - Actuation failure
3 - Insufficient battery
Battery status
voltage</td></tr>
<tr><td>SW_DC_016</td><td>Data Retrieval</td></tr>
<tr><td colspan="2">Survey Image
time stamp
position
image
Point Cloud
Image (landing gear)</td></tr>
</table>

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

ASV (INESC TEC)

From Interoperability Layer (Commands)

Channel	From	To	Partner
WiFi	Interop	ASV	INESC TEC

Ref	Title.
SW_CD_004	Mission Definition
Home location - type of landing platform (int) and expected position (latitude, longitude) Types: 1) Area Survey • Target area (list of latitude/longitude coordinates defining the area bounding box) • Survey parameters (lawn mowing spacing, speed, track orientation, payload configuration) 2) Predefined Path • List of tracks (endpoint latitude, longitude coordinates, speed)	
SW_CD_005	Mission commands
• Start mission: Execute mission plan • Abort mission: Stop executing mission plan • Pause mission: Pause mission execution • Restarts mission: Continues executing paused mission • Remote operation: Pauses the mission and becomes teleoperated • Emergency stop - Abort mission and halts, emits last known location	
SW_CD_006	Motion commands
• Keep position: Hold the ASV in the current position • GoTo: Directs the ASV to a given position (latitude/longitude coordinates, speed) • Go home: Return to home position • Velocity (remote operation)	
SW_CD_007	Data commands
Retrieve data: Gets data stored on the ASV on-board computer	

To Interoperability Layer (Data & TM)

Channel	From	To	Partner
RF	ASV	Interop	INESC TEC

Ref	Title.
SW_DC_017	Telemetry
ASV position (latitude/longitude) ASV pose (roll/pitch/yaw or quaternion)	

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

ASV speed ASV position accuracy RTK estimated odometry: • Position (x y z) • Velocity (linear)	
SW_DC_018	Mission status
Mission state: RUNNING | PAUSED | COMPLETED | ABORTED Mission data: Current leg, mission time, estimated % completion	
SW_DC_019	Diagnostics
Battery level Error codes • Mission aborted • Low battery • Navigation data (bad or no data) • High temperature • Water inside • HW failure • Sensor Status - [Sensor 1, Sensor 2, ..., Sensor n]	
SW_DC_020	Payload data retrieval
Survey Image • time stamp • position • image Point Cloud Sonar data Laser scan	

AUV (INESC TEC)

From Interoperability Layer (Commands)

Channel	From	To	Partner
RF/Acoustic/ WiFi	Interop	AUV	INESC TEC

Ref	Title.
SW_CD_008	Mission Definition
• Home location - expected position (latitude, longitude) • Types: 1) Area Survey • Target area (list of latitude/longitude coordinates defining the area bounding box) • Survey parameters (lawn mowing spacing, speed*, track orientation, payload configuration)	

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

2) Predefined path • Exploration path - list of points (latitude, longitude, altitude) • Path parameters (speed* and payload configuration) *Speed - Linear (x,y,z), angular (roll , pitch, yaw)	
SW_CD_009	Mission Command
• Start mission - Mission execution starting on the homing position • Abort mission - Cancel mission and return home • Pause Mission - Halt mission and hover • Restart mission - Carry on the mission execution from the last waypoint visited • Emergency stop - Abort mission and surfaces, emits last known location	
SW_CD_010	Motion Command
• Go to Position • Go home • Keep position	

To Interoperability Layer (Data & TM)

Channel	From	To	Partner
RF/Acoustic/ WiFi	AUV	Interop	INESC TEC

Ref	Title.
SW_DC_021	Telemetry
USBL estimated Position • position (x, y, z) • orientation (w, x, y, z) AUV Estimated Position • position (x, y, z) • orientation (w, x, y, z) AUV Estimated Velocity • linear (x, y, z) • angular (w, x, y, z)	
SW_DC_022	Mission Status
RUNNING | BLOCKED |PAUSED | CANCELED | DONE • Emergency State (bool) • Current waypoint • Battery status	
SW_DC_023	Diagnostics
• Emergency State (bool) • Low Battery (bool) • Watchdog (bool) • Water inside (bool) • Sensor Status (vector<bool>) - [Sensor 1, Sensor 2, ..., Sensor n] • Navigation failure	

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

• Mission Failure (int): 1. Path blocked 2. Actuation failure 3. Insufficient battery • Battery status (double)- voltage	
SW_DC_024	Data Retrieval
Survey Image • time stamp • position • image Point Cloud Sonar data Laser scan	

ROV (ECA)

From Interoperability Layer (Commands)			
Channel	**From**	**To**	**Partner**
RF	Interop	ROV	ECA

Ref	**Title.**
SW_CD_011	Get state
Get ROV state • Communication between CCU and ROV status (Ok - NOK) • Functionning status - (Nominal - Alarms)	
SW_CD_012	Operation commands
Commands for manage operations: • Launch - abort mission • Standby mode • Launch auto docking (Navigation -> crawling mode) • Stop docking (Crawling mode -> Navigation)	
SW_CD_013	Motion commands
Will be made available trough a TCP Client. The SCC must operate within a latency limit in sending commands and receiving feedback • ROV control - Navigation mode : thruster control - autodepth mode - autoheading mode • ROV control - Crawling mode : crawler and thruster control - autoheading mode • Camera control : camera selection - sight position - zoom - lights • Video control : local recording - On Screen Display selection • Arm control : articular - Cartesian • Cleaning tool control	
SW_CD_014	Retrieve data

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Collect data from ROV

To Interoperability Layer (Data & TM)			
Channel	**From**	**To**	**Partner**
RF	ROV	Interop	ECA

Ref	**Title.**
SW_DC_025	Send estimate position
Send ROV estimate position. The package will contain: • Depth • Altitude • Orientation vector (w, x, y, z) • 3D point (x, y, z) in navigation mode • 2D point (x, y) from a starting point on the structure	
SW_CD_012	Send ROV State
Send the ROV state. The package will contain the state code. • Nominal mode (Navigation - Crawling)	
SW_DC_026	Send Error
Send error code from ROV. • Alarms (Overcurrent, OverVoltage, Overtemperature) • Thrusters faults • Crawlers faults	
SW_DC_027	Send power Status
Send the battery status. The package will contain: • Power status (Current - Voltage) • Electronic pod temperature	
SW_DC_028	Send camera video stream
Send the on-board camera video stream from ROV.	

AUV (UdG & IQUA)

From Interoperability Layer (Commands)			
Channel	**From**	**To**	**Partner**
WiFi/Acoustic	Interop	AUV	UdG / IQUA

Ref	**Title.**
SW_CD_015	Mission definition

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Survey area[1] • Mission area (latitude1, longitude1, latitude2, longitude2, latitude3, longitude3) 3 points defining the bounding box of the mission area • Mission parameters (track spacing, altitude/depth , speed, sensor configuration) Explore area [ONLY S2][2] • Bounding box (centre_latitude, centre_longitude, centre_depth, size_x, size_y, size_z, yaw) • Timeout • Sensor parameters	
SW_CD_016	Mission commands
• Start mission: Execute the actions in the mission plan • Abort mission: Stops the execution of the current mission plan • Abort and surface: Stops the execution of the current mission plan and surfaces • Emergency surface: Stops the execution of the current mission plan and surfaces using thruster commands directly (no navigation required)	
SW_CD_017	Motion commands
• Go to position (latitude, longitude)[1] • Keep position (enable/disable, latitude, longitude)[1]	
SW_CD_018	Docking commands [ONLY S4]
• Dock[3] • Undock[4]	
SW_CD_019	Retrieve data commands [WiFi only]
Retrieve data (data type) Data type will be Images , point cloud, or sonar data file.	

To Interoperability Layer (Data & TM)			
Channel	**From**	**To**	**Partner**
WiFi/ Acoustic	AUV	Interop	UdG / IQUA

Ref	**Title.**
SW_DC_029	Telemetry
• USBL Estimated Position (x, y, z) • AUV Estimated Pose (x, y, z, roll, pitch, yaw) • AUV Altitude • AUV Speed	
SW_DC_030	Mission status
• Mission status (status) Status can be Running, Cancelled, Done • Current waypoint [for survey missions] / Completion percentage [exploration missions] • Docked/Undocked [S4]	

[1] Can be included in a mission plan

[2] Can be included in a mission plan only in S2

[3] Can be included in a mission plan only in S4 as the last action

[4] Can be included in a mission plan only in S4 as the first action

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SW_DC_031	Vehicle status
Error code (boolean structure): • Emergency surface • Abort and surface • Abort mission • Low battery • Battery error • Watchdog timer • Navigation error • No altitude error • Water inside • High temperature Battery charge [WiFi only] Temperatures (CPU , batteries, hulls) [WiFi only]	
SW_DC_032	Retrieve data commands [WiFi only]
Retrieve data (data type) Data type will be Images (jpg 512Kb each) , point cloud (*.pcd), or sonar data file (proprietary data format hundreds of MBs).	

Docking Station (UdG)

From Interoperability Layer (Commands)

Channel	From	To	Partner
Eth. or WiFi	Interop	DS	UdG

Ref	Title.
SW_CD_020	Get charge
Returns current AUV/DS charge	
SW_CD_021	Start
Starts charging the AUV	
SW_CD_022	Stop
Stops charging the AUV	

To Interoperability Layer (Data & TM)

Channel	From	To	Partner
Eth. or WiFi	Interop	DS	UdG

Ref	Title.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

SW_DC_033	Send error
The package contain the error code, it could include, but not limit to: • Low battery charge • Modem not working • DVL not working • Orientation motor not working	
SW_DC_034	Send status
Send the DS status, it can be: • Battery charge • Orientation • Water currents	

5. Hardware Interfaces

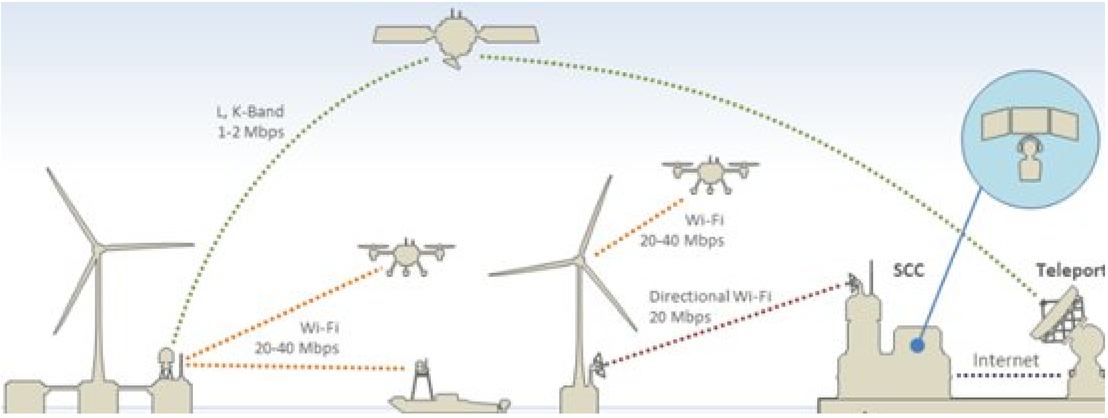


Figure 6: Atlantis communication links

5.1. Hardware Interface Matrix

Hardware Interface Matrix (Table 2) is a square matrix defining the mechanical links between existing systems and hardware components **that have to be added in the scope of ATLANTIS** . The matrix depicts a the hardware extensions for Pilot components (Figure 6): Testbed, Robots and Docking station, and SCC. The hardware extensions are categorized into:

- Communication:
  - Satellite;
  - Wired Ethernet;
  - Acoustic;
  - RF WiFi or SDB.
- Sensors
  - Weather;
  - Vibrations;
  - Multi-Beam;
  - LIDAR;
  - Visual.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

- Robotic Extensions
  - Manipulator;
  - Crane.

The link between a platform and a component is described by an “x” on the row of the platform (labelled with a capital letter) and the column of the hardware component (labelled with a low case letter). The purpose of the matrix is to serve as a reference for the interface tables described below. The hardware components used in the matrix are to be further defined in T2.3 (Testbed), T2.4 (Robots) and T2.5 (SCC).

Table 2 – Communication Hardware Interface Matrix

	Communication	Satellite	Wired Ethernet	Wired Optic	Acoustic	RF WiFi / SDR	**Sensors**	Weather	Position and orientation	Multi-Beam	LIDAR	Visual	**Robotic Extensions**	Manipulator	Computers
		a	**b**	**c**	**d**	**e**		**f**	**g**	**h**	**i**	**j**		**k**	**l**
Testbed	**A**	x	x	x	x	x		x	x						x
UAV	**B**					x			x		x	x			
ASV	**C**	x				x			x	x	x	x			x
ROV	**D**		x	x								x		x	
AUV	**E**				x	x				x	x	x		x	
Docking Station	**F**				x	x									
SCC	**G**	x	x	x											x

For each of the hardware interfaces we list the following characteristics:

- A reference with the format “HW_Xy_ID” where “X” is the matrix letter for the platform and “y” for the hardware component;
- Description containing the platform and hardware component name;
- Reference to the diagram;
- Interface specifications;
- Partner in charge with the implementation of the interface.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

5.2. Testbed

The testbed communication infrastructure (Figure 7) consists of links to the SCC, the sensors mounted on the platform, the robot local control centres and the robots.

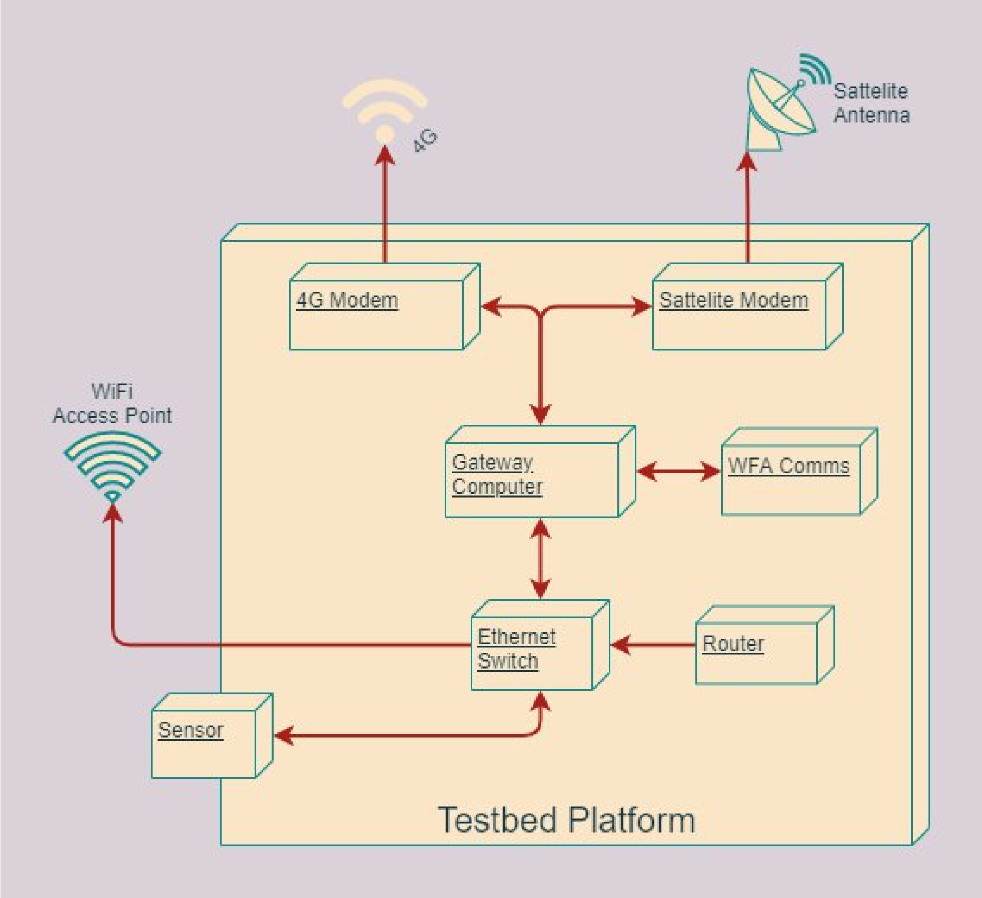


Figure 7: Offshore Testbed Communication Infrastructure

Ref	HW_Aa_1
Description	**Testbed Satellite Communication** The Offshore Testbed will be equipped with a satellite link. A connection between the testbed and the onshore control will be established. On-board the testbed, an on-board computer will serve as a gateway between the remote communication and the local networks containing the robots, sensors or other assets.
Specifications	https://www.iridium.com/products/vesselink-by-thales/

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	
Partner In Charge	SPACEAPPS, INESC TEC

Ref	HW_Ab_1
Description	**Testbed Wired Ethernet Connection** On the testbed, different peripherals will be connected via Ethernet. These connection lines will make the connection between: • Gateway computer to 4G or Satellite modems • Gateway to access points • Gateway to the WFA communication infrastructure
Specifications	1 Gbit Ethernet connection Ethernet Switch with minimum 8 ports Router Protective casing Cable mounts
Partner In Charge	SPACEAPPS, INESC TEC

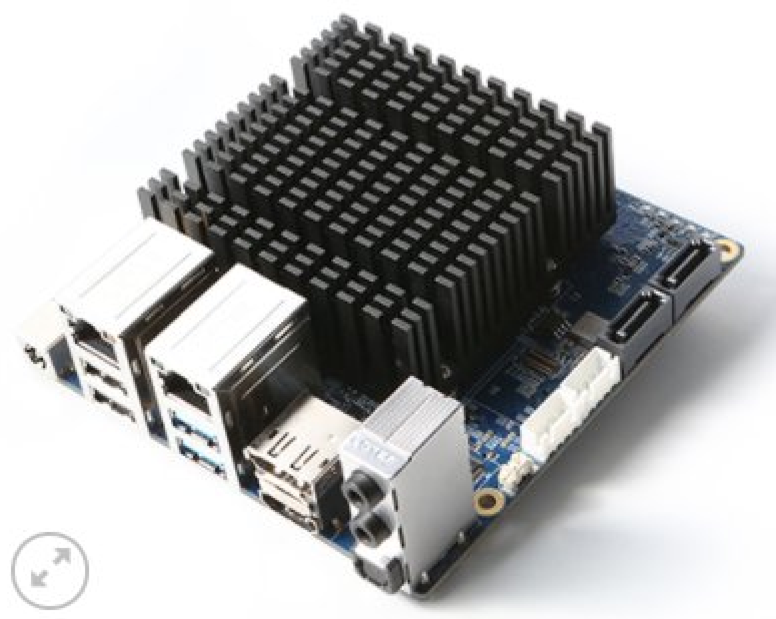
Ref	HW_Ac_1
Description	**Testbed to WFA infrastructure connection** The Offshore Testbed could use the existing WindFloat line communication infrastructure. If that will be made available, an Ethernet connection from the gateway computer to the WFA dedicated network will be put in place.
Specifications	Ethernet gigabit connection to existing local network.
Partner In Charge	SPACEAPPS, INESC TEC, ECA

Ref	HW_Ad_1
Description	**Testbed Acoustic Localisation System Mounting Points** Robotic asset operators may wish to install their acoustic localisation beacons on the floating structure. Hence, there should be adequate mounting points to strap the transducers and electronics.
Specifications	The mount points specifications will be provided by the robot providers during the first stage of T2.4.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Partner In Charge	INESC TEC/IQUA

Ref	HW_Ae_1
Description	**Testbed RF Local Communication** The local communication with the robots will be done mostly by short range RF Communication.
Specifications	2.4/5GHz WiFi with omni or multiple directional antennas, 200m range APs: Ubiquiti Networks® airMAX® BaseStation M2 (2.4 GHz)/M5 (5 GHz) Product page: https://www.ui.com/airmax/rocketm/ Antenas: Ubiquiti Networks® airMAX® Omni Antenna (2.4 + 5GHz) Product page: https://www.ui.com/airmax/airmax-omni-antenna/
Partner In Charge	SPACEAPPS / INESC TEC

Ref	HW_AI_1
Description	**Testbed Gateway Computer** The embedded computer will receive data from the sensors and robots and forward it to the remote link. It will have large data storage drives attached to buffer information from the robots if the remote connection is not fast enough.
Specifications	ODROID H2+ https://www.hardkernel.com/shop/odroid-h2plus/ 
Partner In Charge	SPACEAPPS, INESC TEC

Ref	HW_Af_1

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Description	**Testbed Weather Sensors** A set of payload sensors (GPS, temperature, humidity, wind speed, precipitation, live video feed, etc.) provides useful information to parties interested in operating robotic assets in the testbed.
Specifications	See 10.2.2 pf Deliverable about System Requirements https://www.elsner-elektronik.de/shop/en/p03-3-rs485.html The connection will be done by using a RS485 to USB converter and plug in the gateway computer to parse and publish the data online.
Partner In Charge	SPACEAPPS, INESC TEC

Ref	HW_Ag_1
Description	**Power source** Both the communications infrastructure and sensing equipment on-board the testbeds need a power source. While an external power source is available on the offshore testbed, on the coastal testbed a battery is required since there will be no power source on the floating structure. Therefore a battery should be integrated in the standalone communication package (embedded computer + router + APs + Satellite link + battery). This package can be mounted both on the floating structure or the supporting vessel when required.
Specifications	The battery will provide at least power for: • 5V • 12V • 15V The battery capacity from the coastal testbed will be enough to power the mounted devices for 10h. One backup charged battery will be available onsite.
Partner In Charge	INESC TEC, SPACEAPPS, EDP

5.3. UAV

Ref	HW_Be_1
Description	**UAV RF Local Communication Link** The UAV will be able to communicate with the control station using radio communication. This will be achieved by mounting a WiFi modem and antenna on-board the UAV (5 GHz).
Specifications	D1.1 - Annex Datasheet - Stork I - 6. Specifications | Communication devices | WiFi (5GHz)
Partner In Charge	INESC TEC

Ref	HW_Bj_1
Description	**UAV Visual Sensors** Different visual sensors could be mounted on board of the UAV : • a 5MP camera (5MP Dalsa Nano Gige) • a 12MP camera (12MP Dalsa Nano GiGe)

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	• a hyperspectral camera
Specifications	D1.1 - Annex Datasheet - Stork I - 6. Specifications | Sensors | Camera  Dalso Nano Camera
Partner In Charge	INESC TEC

Ref	HW_Bi_1
Description	**UAV LIDAR** A LIDAR will be mounted on board of the UAV. The selected device can be a Velodyne VLP16.
Specifications	D1.1 - Annex Datasheet - Stork I - 6. Specifications | Sensors | LiDAR  VLP 16
Partner In Charge	INESC TEC

Ref	HW_Bg_1
Description	**UAV GPS** A GPS will be mounted on board of the UAV. The selected device is a UB382.
Specifications	D1.1 - Annex Datasheet - Stork I - 6. Specifications | Sensors | GPS
Partner In Charge	INESC TEC

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Ref	HW_Bg_1
Description	**UAV FMU sensor** A FMU (with accelerometer, barometer, gyroscope, magnetometer) will be mounted on board of the UAV. The selected device is a Pixhawk PX4.
Specifications	D1.1 - Annex Datasheet - Stork I - 6. Specifications | Sensors | FMU  Pixhawk PX4
Partner In Charge	INESC TEC

Ref	HW_Bg_1
Description	**UAV IMU sensor** An IMU (Inertial Measurement Unit) will be mounted on board of the UAV. The selected device can be a STIM300.
Specifications	D1.1 - Annex Datasheet - Stork I - 6. Specifications | Sensors | IMU  STIM300
Partner In Charge	INESC TEC

5.4. ASV

Ref	HW_Ca_1
Description	**ASV Satellite communication** The ASV (ZARCO and ROAZ) will be able to communicate with the onshore control center using a satellite link. This will be achieved by mounting a satellite antenna

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	on-board the ASV. The chosen hardware is Thales VesseLINK.
Specifications	D1.1 - Annex Datasheet - Communications and RMCC - 2.2 VesseLINK Satellite VesseLINK
Partner In Charge	INESC TEC

Ref	HW_Ce_1
Description	**ZARCO Local RF communication** The ASV will be able to communicate with the control station and the testbed using radio communication. This will be achieved by mounting a WiFi modem and antenna on-board the ASV.
Specifications	D1.1 - Annex Datasheet - ZARCO | 5. Specifications | Communication devices | WiFi
Partner In Charge	INESC TEC

Ref	HW_Ce_2
Description	**ROAZ II Local RF communication** The ASV could be able to communicate with the control station and the testbed using radio communication. This will be achieved by mounting a WiFi modem and antenna on-board the ASV.
Specifications	D1.1 - Annex Datasheet - ROAZ II | 6. Specifications | Communication devices | WiFi
Partner In Charge	INESC TEC

Ref	HW_Ch_1
Description	**ROAZ II Multi-Beam sensor** The ASV could be equipped with at least one multi beam sensor (multi beam sonar). The chosen hardware is the Imagenex 837B delta T model 1000m and the KONGSBERG M3.
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | Mutilbeam  Imagenex 837B  KONGSBERG M3

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Partner In Charge	INESC TEC

Ref	HW_Ch_2
Description	**ZARCO Multi-Beam sensor** The ASV could be equipped with at least one multi beam sensor (multi beam sonar). The chosen hardware is the Imagenex 837B delta T model 1000m .
Specifications	D1.1 - Annex Datasheet - ZARCO - 5. Specifications | Sensors | Mutilbeam (MBES) Imagenex 837B
Partner In Charge	INESC TEC

Ref	HW_Ci_1
Description	**ZARCO LIDAR sensor** The ASV could be equipped with at least one LIDAR. The Velodyne VLP-16 will be used.
Specifications	D1.1 - Annex Datasheet - ZARCO - 5. Specifications | Sensors | LIDAR VLP 16
Partner In Charge	INESC TEC

Ref	HW_Ci_2
Description	**ROAZ II LIDAR sensor** The ASV could be equipped with at least one LIDAR. The Velodyne 32P and FARO Focus 3D will be used (or similar devices)
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | LIDAR  Focus 3D
Partner In Charge	INESC TEC

Ref	HW_Cg_1
Description	**ROAZ II GPS** A GPS will be mounted on board of the ASV. The selected device is Dual antenna L1/L2, L5 RTK GNSS.
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | RTK GPS

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

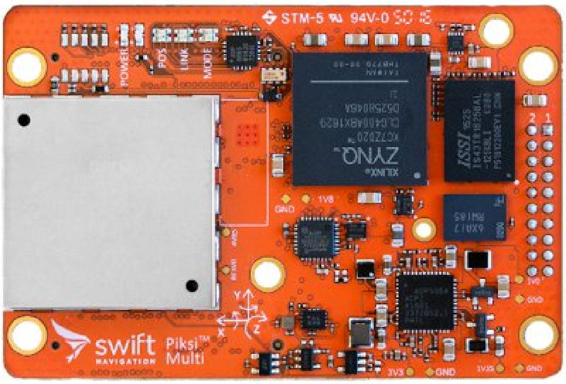
Partner In Charge	INESC TEC

Ref	HW_Cg_2
Description	**ROAZ II FOG INS** A FOG INS can be mounted on board of the ASV (ROAZ II). The selected device is Advanced Navigation Spatial FOG.
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | FOG INS
Partner In Charge	INESC TEC

Ref	HW_Cg_3
Description	**ROAZ II RADAR** A RADAR will be mounted on board of the ASV. The selected device is Lowrance Broadband Radar.
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | RADAR  Lowrance Broadband Radar
Partner In Charge	INESC TEC

Ref	HW_Cg_4
Description	**ZARCO GPS** A RTK GPS will be mounted on board of the ASV. The selected device is Swift Navigation Piksi Multi.
Specifications	D1.1 - Annex Datasheet - ZARCO - 5. Specifications | Sensors | L1+L2 RTK GPS

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	 Swift Navigation Piksi Multi
Partner In Charge	INESC TEC

Ref	HW_Cg_5
Description	**ZARCO IMU** An IMU will be mounted on board of the ASV (ZARCO). The selected device is Xsens MTi-30.
Specifications	D1.1 - Annex Datasheet - ZARCO - 5. Specifications | Sensors | IMU  Xsens MTi-30
Partner In Charge	INESC TEC

Ref	HW_Cj_1
Description	**ZARCO Visual sensor** One stereo camera will be mounted on board of the ASV. The selected device is Mynt Eye D.
Specifications	D1.1 - Annex Datasheet - ZARCO - 5. Specifications | Sensors | Stereo Camera

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	 MYNT EYE D
Partner In Charge	INESC TEC

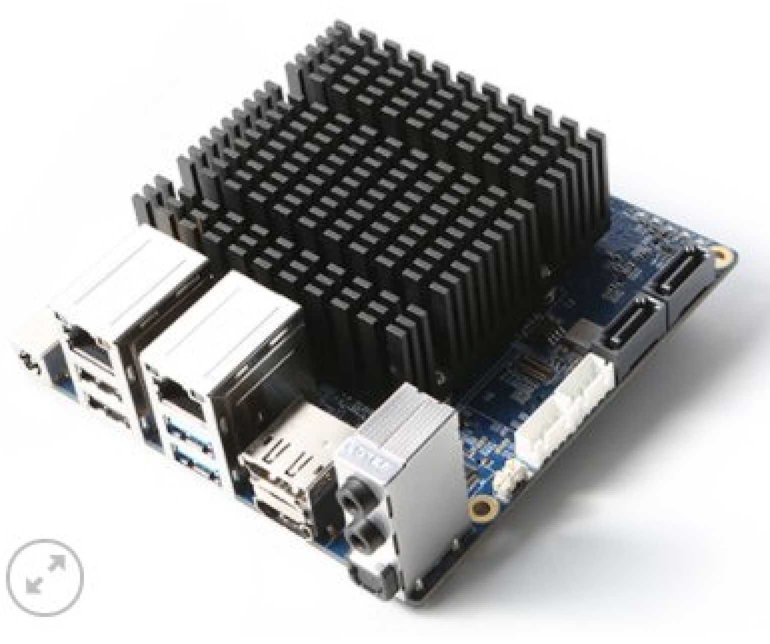
Ref	HW_Cj_2
Description	**ROAZ II Visual sensor** Two digital cameras will be mounted on board of the ASV. The selected device are DALSA Genie Nano C2020 and Basler acA1300-30gc.
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | Digital Camera   DALSA C2020 Basler acA1300
Partner In Charge	INESC TEC

Ref	HW_Cj_3
Description	**ROAZ II Video camera** A video camera will be mounted on board of the ASV. The selected device is PTZ HK video camera.
Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | Video Camera
Partner In Charge	INESC TEC

Ref	HW_Cj_4
Description	**ASV Thermal camera** A thermal camera will be mounted on board of the ASV. The selected device could be a L3 Communications 3000XP.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Specifications	D1.1 - Annex Datasheet - ROAZ II - 6. Specifications | Sensors | Thermal Camera
Partner In Charge	INESC TEC

Ref	HW_CI_1
Description	**ASV computer** A on board computer will be placed on the ASV to perform real-time data processing, navigation and communication. The selected device will be a commercial pc alike solution.
Specifications	ODROID H2+ https://www.hardkernel.com/shop/odroid-h2plus/ 
Partner In Charge	INESC TEC

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

5.5. ROV

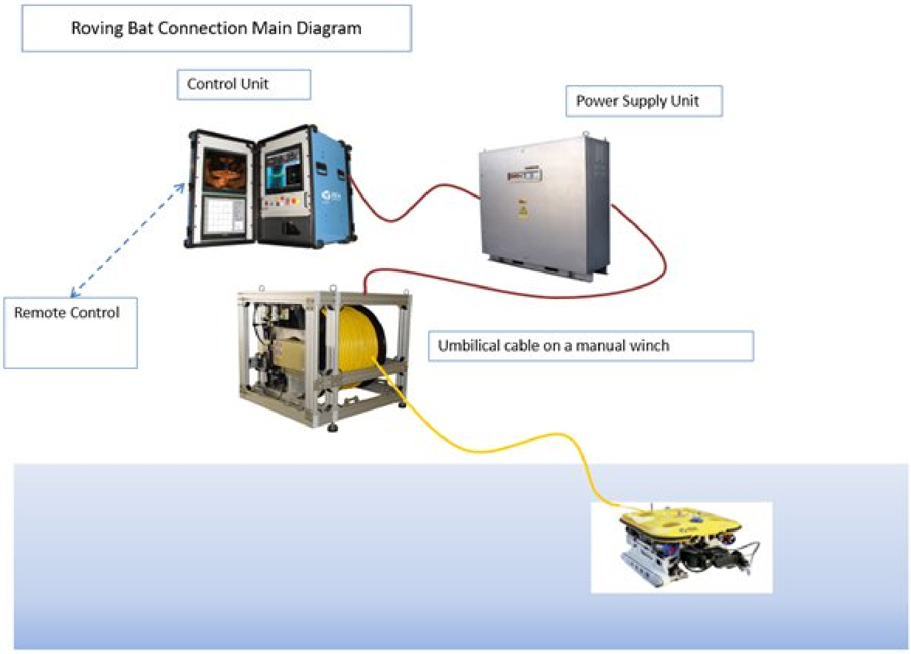


Figure 8: Roving BAT Connection Main Diagram

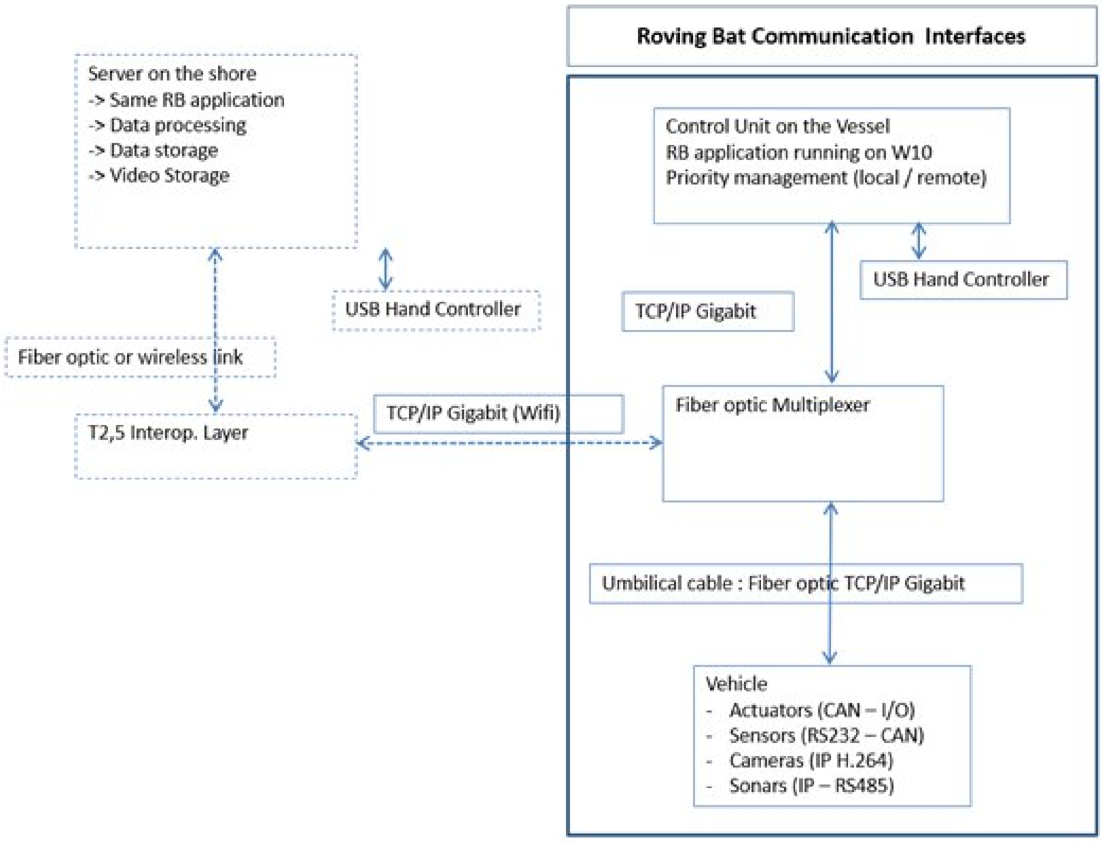


Figure 9: Roving Bat Communication Diagram

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Ref	HW_Db_1
Description	**ROV wired Ethernet communication** TCP/IP communication trough gigabit Ethernet: Figure 9
Specifications	D1.1 - Annex Datasheet - ECA Roving Bat - 5. Specifications | Communication devices | Serial
Partner In Charge	ECA

Ref	HW_Dc_1
Description	**ROV wired communication** ROV will be connected to the CCU through its umbilical cable: Figure 8
Specifications	D1.1 - Annex Datasheet - ECA Roving Bat - 5. Specifications | Communication devices | Serial
Partner In Charge	ECA

Ref	HW_Dj_1
Description	**ROV perception sensors** The Roving bat will be equipped with the following cameras: • Zoom colour TV camera with swivelling head (DTR100Z) • Fixed wide angle BW high sensitivity navigation camera (VS300) • Camera with laser measurement and integrated LED lighting (VS669FHR)
Specifications	D1.1 - Annex Datasheet - ECA Roving Bat - 5. Specifications | Sensors | Camera    DTR-100Z VS-300 VS-669-FHR
Partner In Charge	ECA

Ref	HW_Dg_5
Description	**MICROSTRAIN IMU** An IMU is installed on the ROV. The selected device is Micro Strain 3DM-GX1
Specifications	D1.1 - Annex Datasheet - ECA Roving Bat - 5. Specifications | Sensors

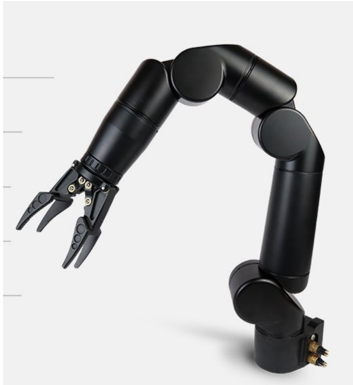
This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	
Partner In Charge	ECA

Ref	HW_Dj_1
Description	**ROV perception sensors** The Roving bat will be equipped with the following sonar : • Super Seaking Sonar (Tritech) • 2D imaging Sonar (BlueView)
Specifications	D1.1 - Annex Datasheet - ECA Roving Bat - 5. Specifications | Sensors | Camera  
Partner In Charge	ECA

Ref	HW_Dk_1
Description	**ROV manipulation** For manipulations tasks the ROV will be equipped with a Bravo BluePrint Arm
Specifications	D1.1 - Annex Datasheet - ECA Roving Bat - 5. Specifications | Actuators | Manipulator

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	
Partner In Charge	ECA - (INESC TEC)

5.6. AUV

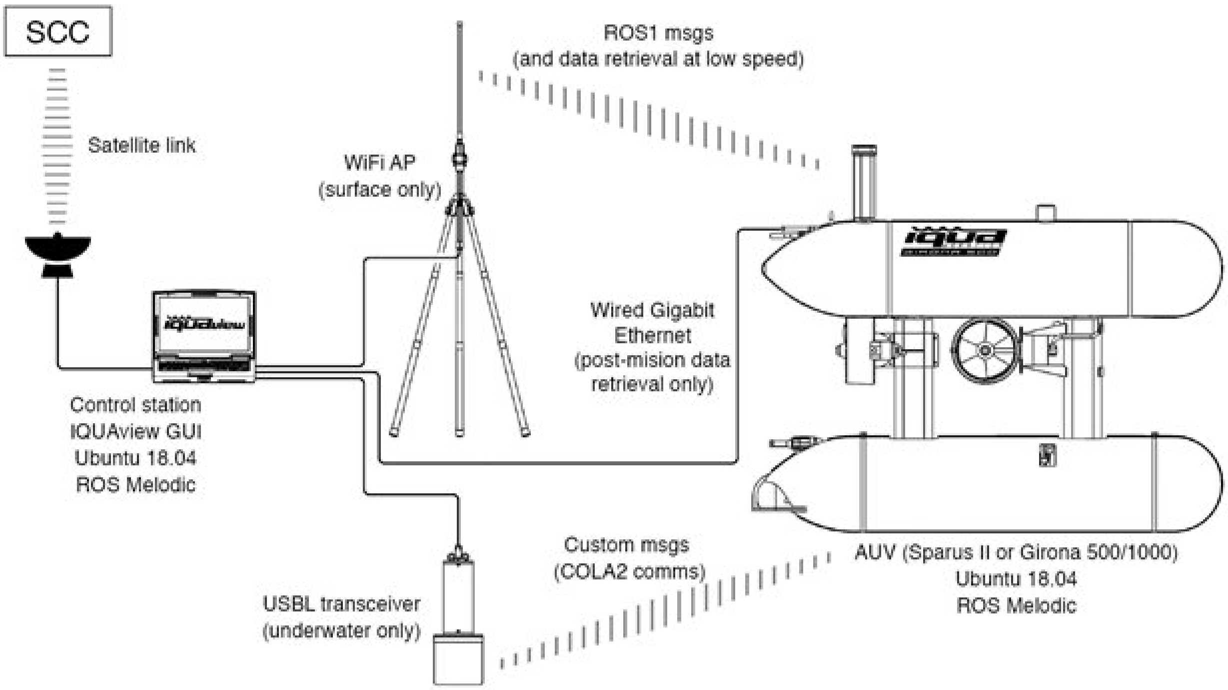


Figure 10: System Architecture Sparus or Girona AUV

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

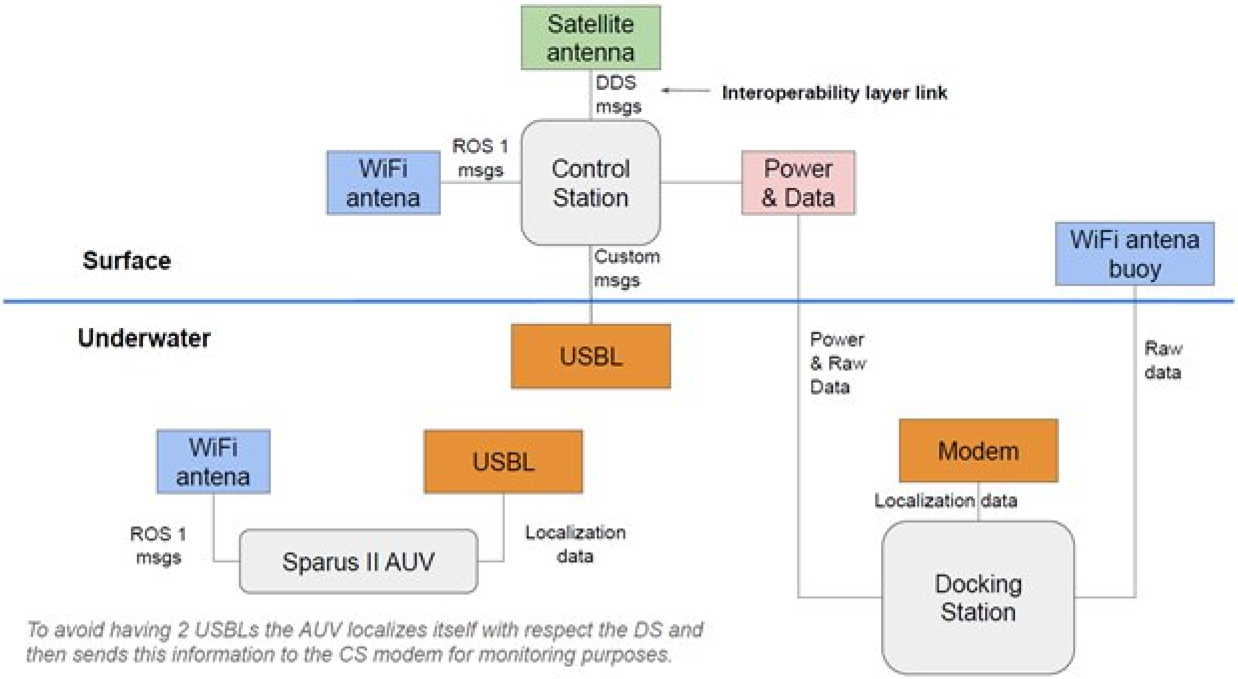


Figure 11: Communication Diagram – Sparus II and Docking Station

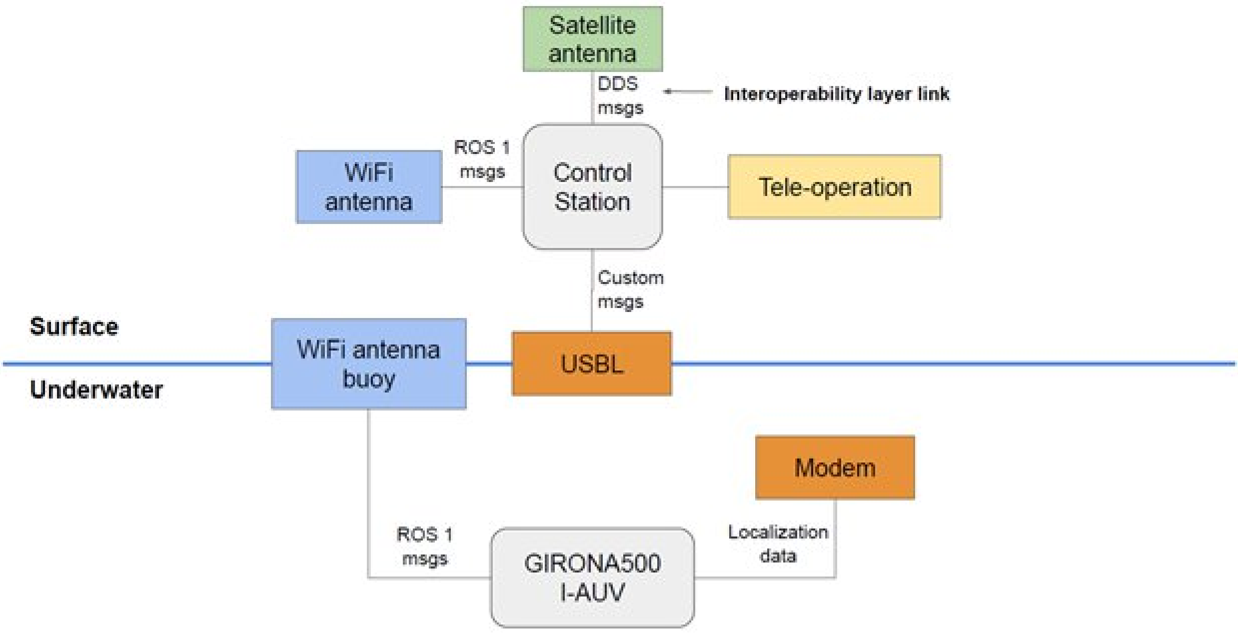


Figure 12: Communication Diagram – Girona 500

Ref	HW_Ed_1
Description	**SPARUS II acoustic communication** Acoustic communication using Blueprint modem/USBL when the AUV is

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	submerged.
Specifications	Figure 11 Communication Diagram – Sparus II and Docking Station • Blueprint SeaTrack X150 USBL/Modem beacon
Partner In Charge	UdG

Ref	HW_Ed_2
Description	**GIRONA 500 acoustic communication** Acoustic communication using Evologics S2CR18/34 USBL when the AUV is submerged.
Specifications	D1.1 - Annex Datasheet - GIRONA 500 - 5. Specifications | Communication devices | Modem System Architecture Sparus or Girona AUV 
Partner In Charge	IQUA

Ref	HW_Ee_1
Description	**SPARUS II RF Local communication** SPARUS II AUV has a WiFi antenna that allows communication with the control station when at surface.
Specifications	D1.1 - Annex Datasheet - SPARUS II - 5. Specifications | Communications devices | WiFi
Partner In Charge	UdG

Ref	HW_Ee_2
Description	**GIRONA 500 RF Local communication** Girona 500 AUV has a WiFi antenna that allows communication with the control station when at surface.
Specifications	Figure 12: Communication Diagram - Girona 500 D1.1 - Annex Datasheet - GIRONA 500 - 5. Specifications | Communications devices | WiFi

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Partner In Charge	IQUA

Ref	HW_Eh_1
Description	**SPARUS II Multi-Beam sensors** Sparus II AUV will be equipped with a Imagenex DeltaT multibeam sonar.
Specifications	Figure 10: System Architecture Sparus or Girona AUV D1.1 - Annex Datasheet - SPARUS II - 5. Specifications | Sensors | Multibeam Imagenex 837B Delta T
Partner In Charge	UdG

Ref	HW_Eh_2
Description	**GIRONA 500 Multi-Beam sensors** Girona 500 AUV will be equipped with a KONGSBERG Multibeam M3 mounted on a pan and tilt unit. It can also equip the Imagenex 837B Delta T multibeam.
Specifications	Figure 10: System Architecture Sparus or Girona AUV D1.1 - Annex Datasheet - GIRONA 500 - 5. Specifications | Sensors | Multibeam KONGSBERG Multibeam M3 Imagenex 837B Delta T
Partner In Charge	IQUA

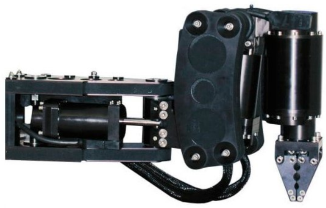
Ref	HW_Ei_1
Description	**GIRONA 500 LIDAR sensor** Girona 500 AUV will be potentially equipped with a Laser Scanner.
Specifications	D1.1 - Annex Datasheet - GIRONA 500 - 5. Specifications | Sensors | Laser scanner
Partner In Charge	UdG

Ref	HW_Ej_1
Description	**SPARUS II perception sensors** SPARUS II AUV can be equipped with the following perception sensors: - Forward Looking Sonar: Soundmetrics ARIS Explorer 3000 - Camera Proscilica GC1380 Color
Specifications	D1.1 - Annex Datasheet - SPARUS II - 5. Specifications | Sensors | Camera

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	  ARIS Explorer 3000 Prosilica GC1380
Partner In Charge	UdG

Ref	HW_Ej_2
Description	**GIRONA 500 perception sensors** Girona 500 AUV can be equipped with the following perception sensors: – FLIR Spinnaker Camera
Specifications	D1.1 - Annex Datasheet - GIRONA 500 - 5. Specifications | Sensors | Camera
Partner In Charge	IQUA

Ref	HW_Ek_1
Description	**GIRONA 500 manipulation** Girona 500 AUV will be equipped with two of the following manipulators: - BLUEPRINT REACH ALPHA 5 - BLUEPRINT REACH BRAVO 7 - ECA 5E Micro
Specifications	D1.1 - Annex Datasheet - GIRONA 500 - 5. Specifications | Actuators | Manipulator    Reach Alpha 5 Reach Bravo 7 ECA 5E Micro
Partner In Charge	UdG

5.7. Docking Station

Ref	HW_Fd_1
Description	**Docking Station Acoustic Communication** The Docking Station will have a Blueprint SeaTrack X110 Modem system that will allow communication as well as be localized by the control station and the

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

	SPARUS II AUV.
Specifications	D1.1 - Annex Datasheet - SPARUS II Docking Station - 5. Specifications | Equipment | Transponder
Partner In Charge	UdG

Ref	HW_Fe_1
Description	**Docking Station RF Connection.** Will be done by connecting the docking station to a surface buoy equipped with WiFi.
Specifications	D1.1 - Annex Datasheet - SPARUS II Docking Station - 5. Specifications | Equipment | WiFi
Partner In Charge	UdG

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

5.8. SCC

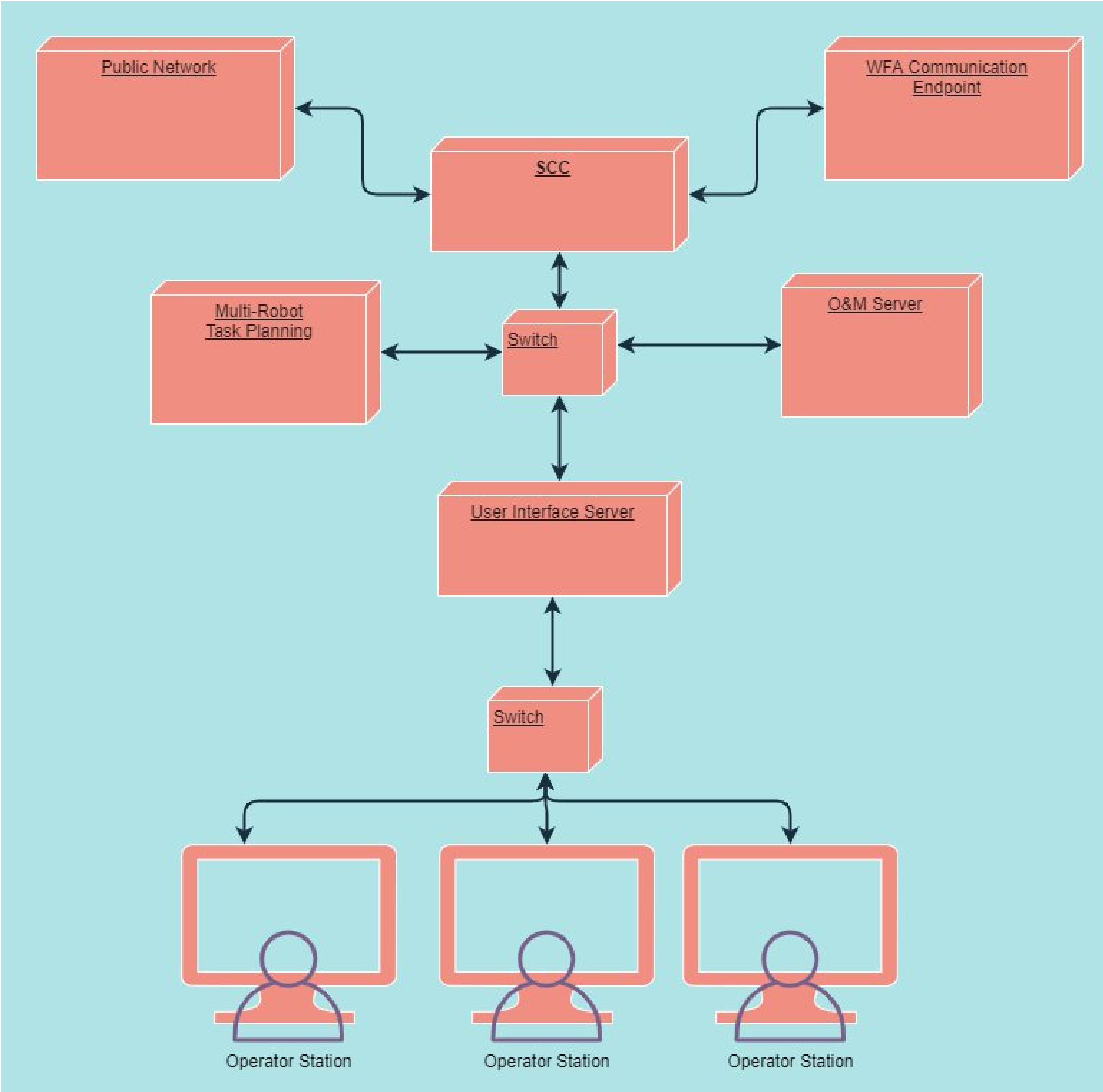


Figure 13: Onshore control centre deployment view

Ref	HW_Ga_1
Description	**SCC Satellite communication** The SCC will communicate with the satellite linked assets trough the public network and the satellite communication service provider infrastructure.
Specifications	Ethernet connection to public network
Partner In Charge	SPACEAPPS

Ref	HW_Gb_1
Description	**SCC Wired Ethernet** The computers and servers installed onshore will be connected using an Ethernet local network as described in Figure 13

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

Specifications	3 Gigabit Ethernet switches 8 port each
Partner In Charge	SPACEAPPS

Ref	HW_Gc_1
Description	**SCC Wired Optic** Given access to the windfloat line communication infrastructure, the SCC will be connected to it. The SCC will be connected to it using an Ethernet link. The connection to the WFA will be done trough a gateway computer which will separate the remote network.
Specifications	Ethernet connection
Partner In Charge	SPACEAPPS

Ref	HW_Gl_1
Description	**SCC Local Servers** The SCC components and the O&M will be deployed on the onshore facility on computing systems with enough storage and computing power to run the desired applications.
Specifications	2 Server computers 16GB RAM 2TB Storage 220VAC Power
Partner In Charge	SPACEAPPS

Ref	HW_Gl_2
Description	**SCC Operator Computers** The operators will use pc's to access the SCC user interface. Additional monitors will be available for a better view of the operation.
Specifications	3 Notebook computers 3 Monitors
Partner In Charge	SPACEAPPS, VTT

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.

6. Conclusion

In a multi-robot environment, the data exchange is an essential part. It is important that each operator can interact with the robots, to give them tasks to execute, to supervise the execution of these tasks, or to retrieve data and storing it. In order to guarantee these exchanges, the communication interfaces of each device have been described in detail with their hardware and software specifications.

Proven technologies such as satellite, WiFi, Ethernet or acoustic communication are used to adapt to different environments while guaranteeing a stable and efficient connection. This allows the robots to be connected to the SCC.

This connection between the robots and the onshore control centre is established through an interoperability layer based on a reliable communication software layer provided to UxV providers as a software library. From the SCC it is possible to ask robot from full mission execution, as area survey or exploration path to simple motion control order, as go home or keep position.

Beyond the data exchange between the different parts of the system, different hardware modules have to be interfaced. Computers, communication modules, sensors and mechanical modules that have to be established in different parts of the testbed have to be connected and D2.2 offers the plan on what is the first choice for those components and how are they going to be integrated.

This project has received funding from the European Union's Horizon 2020 research and innovation programme, under the Grant Agreement no. 871571.