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Executive Summary

This document intends to give the background information to define the test plan in the demonstrators of the EU-SCORES project. This report provides a brief overview on the available tools and technologies for O&M and environmental monitoring, with focus on aerial and underwater robotic tools, and with a brief explanation of the Portuguese and Belgium test sites in the project. The document also presents the available robotic assets and operational support and test facilities for the project and describes the planned monitoring activities with these robotic tools to be performed in both demonstrators.



1. Introduction

Operations and maintenance (O&M) have to be performed for the full operational life of offshore energy platforms, with a non-negligible budget devoted only to maintenance and operations actions. The EU and the sustainable/green energy sector have ambitious aims for cost-reduction to make green energies more attractive and more cost-efficient. As an example, considering the current technology base, O&M costs can account for up to 30 % of the total cost of energy for offshore wind power [1]. A substantial contribution to cost reduction must therefore come through improved and new solutions and technologies.

The offshore marine environment is characterized by harsh conditions. Project developers of offshore energy parks have to cope with many logistical and safety issues and also the environmental assessment that developers of wind/ solar energy projects on land do not, or at least not to the same extent. The use of robotics based solutions in a common framework where aerial and underwater systems can be launched and recovered from surface vessels (also possibly autonomous) together with the emergence of systems that enable the persistent deployment of autonomous robots (docking stations for battery recharging and high speed data exchange, ubiquitous wide band communications, among others), will greatly reduce the logistics associated with offshore inspection and maintenance activities, with a direct economic impact. Moreover, these robotics assets can simultaneously monitor marine environment and fauna through a set of sensors that can be installed in the fleet. The EUSCORES project will contribute to a seamless progression of robotic based solutions for offshore infrastructures inspection and maintenance and their integration into the environmental monitoring activities associated with the offshore energy park operations.

This document will present a brief description of the current state-of-the-art on robotic systems for O&M operations and environmental monitoring (Section 2) and further briefly introduce the demonstrator test sites (Section 3), the available robotic assets (Section 4) and the plan of activities of the robotic tools in the context of the EU-SCORES demonstrators. (Section 5).



2. Robotics tools in O&M and env. monitoring

The O&M and environmental monitoring activities associated with offshore wind, wave, and solar systems are suitable to utilize autonomous or semi-autonomous robots. These robots, which can be of an aerial or subaquatic type, allow optimizing the costs and the duration of the inspection and surveillance tasks, such as the search for faulty system elements, detection of cracks and physical defects on the system structures, and the characterization of the surrounding environment and wildlife.

This chapter focuses on discussing the applicability of robotic tools in O&M and environmental monitoring of wind, wave, and solar systems, describing some related work done in this area and considering solutions related to both aerial and underwater robots.

2.1 Aerial robotics tools

Unmanned aerial vehicles (UAVs) are a powerful tool in the inspection of wind, wave, and solar parks, being able to carry sensors such as visual cameras, thermal cameras, and light detection and ranging (LiDAR) sensors, that can be used to collect large quantities of data, detect faults and map the system from above.

The usage of UAVs in the inspection of wind turbines has been widely studied and documented. In particular, the usage of cameras to identify cracks in the tower and the blades of the turbine is a very common implementation for inspection using UAVs [2-6]. Similarly, thermal imagery has also been used for detection of delamination, impacts, and cracks on the turbines' surface [7-9].

Additionally, some other UAV wind turbine inspection techniques have been studied, such as the usage of ultrasonic sensors for detection of cracks on the rotor blades [10] and the usage of acoustic sensors for detection of rotatory devices faults [11,12].

In the case of the inspection of solar parks, the data collected using UAVs can be used for the detection of low voltage, panel failures, cracks, and occlusions of light. In [13], Rosende et al. proposed a remote UAV fleet management system for maintenance, inspection, surveillance, and security in solar power plants. The system included the capability of using visual and thermal cameras onboard the UAVs for detecting the presence and behaviour of pedestrians and vehicles that may enter the plant site and interfere with its operation and for representing the complete solar park. The usage of UAVs in this system allowed for the remote inspection of approximately 35 square meters of solar panels per second, or about 5 minutes per hectare, and the thermal images obtained during the UAV flight



were used in a convolutional neural network (CNN) that allowed to identify each panel individually in a stitched thermal image of the entirety of the solar plant.

In particular, the usage of thermal cameras onboard UAVs has been widely studied for inspection of solar plants, in the context of preventive and corrective maintenance. The thermal images of solar panels, collected during their normal operation during daytime and sometimes paired with visual data, are suitable for the detection of panel failures, low voltage, cracks on the panels, and occlusions of light, such as weeds and shadows, as it was demonstrated in [14-17].

Additionally, some studies have investigated the possibility of using electroluminescence images, which are normally collected at night, using the solar cells as light emitters under a forward bias current, to detect panel failures in solar plants [18-20].

UAVs can also be a valuable tool for registering the effect of the offshore energy parks on the surrounding environment, being used to observe and identify marine species in the proximities of the structures. One of the main applications in this subject is the usage of onboard cameras to detect the effects on the presence of marine mammals that can be periodically seen at the water surface, such as cetacean species.

The usage of UAVs for the observation and identification of cetaceans has been documented through projects such as the one in [21], where the images collected by UAVs are used in a convolutional neural network to accurately identify whale species and length, and the finFindR project [22], where residual convolutional neural networks were used to identify individuals of the bottlenose dolphin species through identification and quantification of dorsal fin characteristics.

2.2 Underwater robotics tools

The usage of underwater robots in energy conversion offshore parks allows for efficiently executing inspection tasks related to the O&M of the various system elements. Both remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) can carry sensors, such as sound navigation and ranging (SONAR), LiDAR, camera, and water properties sensor systems, which can be used to collect data about the state of the structures and components, and their impact on the surrounding environment.

Rémouit et al. [23] have studied both the technical challenges and the potential time and costs saved when using ROVs instead of divers in the underwater operations associated with the deployment and monitoring of WECs. These studies have concluded that the usage of ROVs in large WEC deployments increases the efficiency of these tasks and minimizes the costs of the operations



and the time spent, while it also prevents the decrease in diver safety associated with increased depths and operation time.

As for the impact of the wave energy converters structures on the surrounding environment, Polagye et al. [24-26] have documented the development of an AUV for environmental monitoring of a tidal turbine site. The AUV carried a stereo-optical camera system with strobe illumination to monitor interactions between animals and the turbine and an array of smart hydrophones for localizing marine mammals.

Additionally, there are many examples of the development of ROVs/AUVs suited for the execution of other underwater inspection tasks, such as the FlatFish [27], Dagon [28], Marlin [29], and Girona 500 [30] systems. INESC TEC's own TriMARES [31] is also an example of an hybrid AUV/ROV developed with focus on inspection tasks, more specifically the inspection and periodic monitoring of large dam reservoirs.

Moreover, the INESC TEC robotics and autonomous systems team has been involved in various underwater inspection and monitoring projects. In this context, the development of the TURTLE hybrid lander platform resulted in a robotic tool that allows long-term deep-sea bottom observation and profiling efficiently, using mainly acoustic sensors [32]. The ¡VAMOS! project is another example of the application of robotic tools in underwater operations, where a positioning, navigation, and awareness (PNA) system was proposed for the re-opening of mining operations in inland flooded open-pit mines with autonomous and remotely operated vehicles. The project proposed the combined usage of mining machines (MV), launch and recovery vessels (LARV), and support and survey autonomous/remote operated underwater vehicles (AUV/HROV) for an environmentally and economically viable mining technique [33]. In the context of the ¡VAMOS! project, the EVA hybrid ROV/AUV was developed, in order to support the operation of the underwater mining machines. The EVA platform can operate both in tele-operated and fully-autonomous modes and is equipped with laser based structured light systems with smart digital cameras, a multibeam profiler/imaging sonar and a CODA Octopus Echoscope 3D acoustic camera, allowing to perform bathymetry surveys, obtain precise 3D environment data, and provide localized inspection and external views of the environment to an operator [34].

Regarding the usage of robotic tools for monitoring underwater environments, the Monterey Bay Aquarium Research Institute (MBARI) has been relying on ROV and AUV systems for research of marine species and environmental conditions for over 30 years [35]. In particular, the Dorado class modular AUVs have been used in chlorophyll peak capture, upwelling front detection and capture, location of hydrothermal chimneys, and repeat bathymetric surveys [36].

Additionally, AUVs have also been used in other environmental monitoring related tasks, such as the detection and tracking of underwater plumes, namely hydrothermal vent plumes, oil spills, and harmful algal blooms [37], and the



monitoring of marine species, of which the work done in [38] is an example, where an AUV was used to evaluate depth limits, types of limits, and bottom coverage descriptors for assessing the good ecological status of the *P. oceanica* seagrass species, as well as providing in-situ images, bathymetry of the area, and water quality measurements.



3. Demonstrators

3.1 Solar PV demonstrator - Belgium

The Solar PV demonstrator (WP3) will be implemented offshore the Belgian orth ea coast at the Blue Accelerator (BA) test site close to the Oostende harbour.



Figure 1 – Blue Accerelator Test Site

At this site there is a permanent offshore structure (monopile with container on top) close to the planned experimental offshore floating PV (FPV) arrangement which will be deployed.





Figure 1 – Blue Accelerator Test Site, support structure [image from BA, <https://www.blueaccelerator.be/>]

The floating pv project will consist of 600 floaters providing 3000 kWp. It will comprise a 240x80m of footprint (the inner rectangle in the following figure) and with a safety area of 300x100m.





Figure 3 – FPV deployment at Blue Accelerator [image courtesy Oceans of Energy]

The Blue Accelerator is managed by POM West-Vlaanderen, and Oceans of Energy will be the technology partner responsible for delivering, operating and decommissioning of the FPV system.

The water in this area is shallow with an average depth below 10m. An energy export cable (shown in Fig.3 as a blue line) will provide connection to shore.

Due to the close proximity with the harbour and shore, and the nearby BA structure the aerial robots can either be deployed from a support boat or from the existing structure.

The low water depth does not pose any additional technical requirement for the operation of underwater robots apart from the possibly high influence of waves and potentially reduced visibility (limiting the usage of high precision structured laser light systems for object inspection).

A full year of FPV operation is foreseen for 2024, being the period planned for the execution of robotic field missions (see Section 5).

The existing BA structure is also useful for supporting field missions, allowing for remote access to assets in the area. For the foreseen underwater robotics tests, with hybrid ROV/AUVs, docking system and sensor modules, it is expected to use local boat support with light restrictions (this will be defined on a particular mission basis in cooperation with our partners BA and Oceans of Energy).



3.2 Wave energy demonstrator - Portugal

The Wave energy demonstrator (WP4) will be implemented at the Aguçadoura test site in Portuguese waters.

The Aguçadoura test site is located at the northwestern coast of Portugal (northwest of Póvoa de Varzim). It has an 3.2 km² ocean area.

It has an average depth between 40 and 50m. In the western shore of Portugal it has an average wind speed of 6.8m/s and average wave energy of 32.2 kW/m.



Figure 4 – Aguçadoura Test Site





Figure 5 – Electrical grid connection substation and support station at Aguçadoura site

The site is managed by a consortium led by INESC TEC together with WAVEC and EDP.

In this demonstrator site, CorePower will deploy 4 WECs and a collector hub.

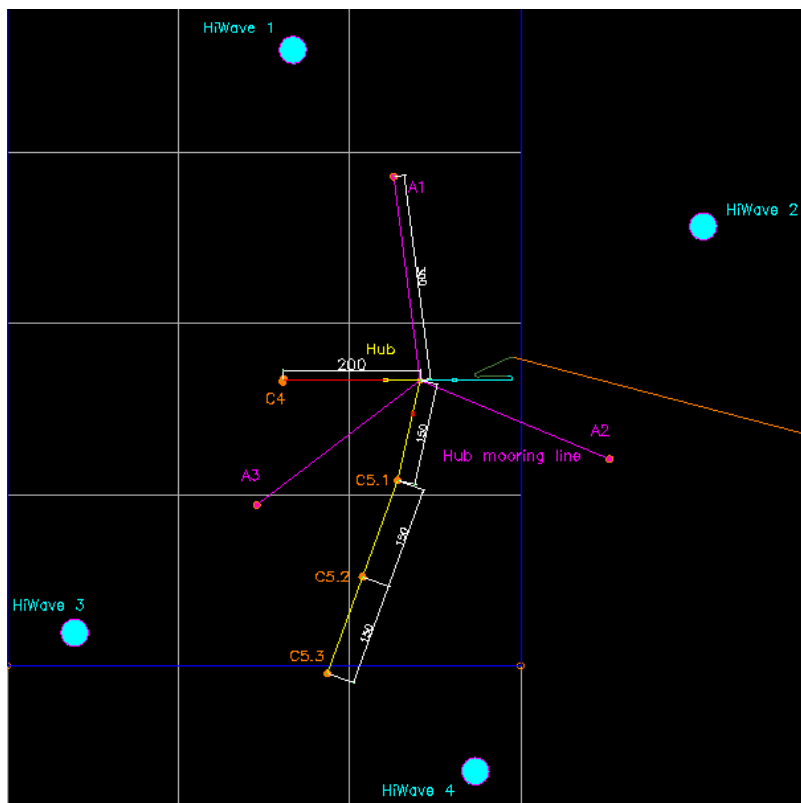


Figure 6 – Map diagram of the WECs (C4, C5.1, C5.2, C5.3 and hub) [Courtesy Corepower]



Each WEC device will be anchored to the sea bottom at an approximate depth of 44m and has an above water part of the floating structure and the underwater structure.

The distance to shore is approx. 5.5km (roughly the same to the nearest harbour).

Export cable laid by CPO in May 2022 will provide connection to the shore station and connection to the power grid. A jumper cable will be connected to the static cable in the subsea junction box with underwater connector.

Given the distance from shore operations with rotary wing UAVs such as the existing STORK and GRIFO systems will have to be performed from local surface support. MAR Profundo ship will be in this case an excellent platform for deployment and recovery of these systems.

For the underwater operations with IRIS or other light robotic systems the Episea boat can be used or the R/V Mar Profundo vessel. For deployment of the TURTLE system it is expected to use R/V Mar Profundo.

The expected underwater structures to be inspected (see section 5) are the WECs underwater structure, WEC moorings, the collector underwater hub structure, mooring lines, the dynamic and jumper cables , underwater connectors and the transport cable layed down on the seabed (it will be partially buried).

The operating depth does not pose any restriction for operation to the INESC TEC robots operations.

The relatively close distance to Porto and Leixões harbour (base of INESC TEC ships) and to INESC TEC labs, allows for the ease of field testing with the INESC TEC robotic tools.



4. Robotic assets

4.1 Aerial robots

STORK autonomous aerial vehicle

STORK is a medium sized custom developed hexacopter autonomous aerial vehicle. It is capable of autonomous flight with high precision navigation. The customized geometry of the UAV provides the ability to integrate in the front side a pan&tilt equipped with thermographic and a high-resolution visual camera and also a LiDAR system for 3D reconstruction and obstacle detection and avoidance. The vehicle provides a payload capacity of 3 kg with an endurance of ~30 minutes. The vehicle is equipped with a custom made autopilot with Real-Time Kinematic GNSS centimeter-level precision and an high accuracy IMU.



Figure 7 – STORK UAV

It has already been used in multiple infrastructure inspection missions namely on wind turbine inspection.



The vehicle main characteristics are:

Table 1 – STORK UAV features description

Size open (DxH):	1060 x 570 mm
Size close (DxH):	670 x 570 mm
Motors:	6 x DJI E2000 Pro
Weight (with batteries):	9.3 kg
Batteries:	22.2 V - 22000 mAh
Flight time:	20 - 25 min
Payload:	3 Kg
GNSS:	Ublox NEO-M8T e ComNav
Autopilot:	Custom Designed Autopilot
IMU:	STIM300
Cameras:	Pointgrey Grasshopper3
IR Camera:	Teledyne Dalsa Calibir DXM640
LiDAR:	Velodyne VLP-16* (mounted only for 3D reconstruction missions)
CPU:	Odroid XU3

Grifo-X autonomous aerial vehicle

GRIFO-X is a large sized custom developed hexacopter autonomous aerial vehicle. It is capable of autonomous flight with high precision navigation. The vehicle provides a payload capacity of 25 kg with an endurance of more than 30 minutes and a modular approach to allow the integration of new sensors such as hyperspectral cameras. The vehicle is equipped with a custom-made autopilot with Real-Time Kinematic GNSS centimeter-level precision and an high accuracy IMU.





Figure 8 – Grifo-X UAV

Table 2 – FRIFO-X UAV features description

Size open (DxH):	1522 x 1590 mm
Size close (DxH):	858 x 998 mm
Motors:	6 x DJI E2000 Pro
Weight (with batteries):	25 kg
Batteries:	6 x 22.2 V - 22000 mAh
Flight time:	40 - 45 min
Payload:	25 Kg
GNSS:	Unicore UB482 dual antenna
Autopilot:	Custom Designed Autopilot
IMU:	STIM300
Cameras:	Teledyne Dalsa Genie Nano GiE
IR Camera:	Teledyne Dalsa Calibir DXM640
LIDAR:	Velodyne VLP-16* (mounted only for 3D reconstruction missions)
Hyperspectral Cameras (additional):	Specim FX10e and HySpex Mjolnir S-620
CPU:	i7-6822EQ with 16 GB of RAM DDR4

4.2 Underwater robots and sensors



IRIS – Hybrid ROV/ AUV

IRIS is a small hybrid ROV/AUV that can be operated either in ROV mode with a light optical fibre umbilical or in full autonomous AUV mode.

It can be deployed from a small boat and it is equipped with autonomous navigation and full 6DOF motion control. With profiling, and imaging sonar and a dual camera system It can be used to obtain 3D environment information and imaging of underwater scenario.



Figure 9 – IRIS AUV

Table 3 – IRIS ROV/AUV features description

Dimensions:	0.8 x 0.6 x 0.4 m
Motors:	8 Thrusters (5kgf trust)
Weight:	27 kg
Depth (max):	150m
Motion control	6 DOF motion control
Imaging sonar	Mechanical scanning sonar imaging (Tritech DST)
Profiling Sonar	Multibeam sonar (Imagenex DeltaT)
GNSS:	Dual GNSS antenna
DVL	WaterLinked DVL50
Gen. purpose actuator	Light general purpose gripper
Battery	550 Wh NMC pressure tolerant battery
Mission autonomy :	5 hr (depending on operation conditions)
Cameras	Front and back camera (Full HD)



EVA – Hybrid ROV/AUV

EVA is medium size hybrid ROV/AUV capable of operating either in ROV mode with and optical fibre tether or in full autonomous AUV mode.

It has a high precision navigation system with more than 8h of mission endurance and is equipped with an extensive set of sensors including a full 3D acoustic camera, imaging sonars and profiling multibeam sonars. In addition it has multiple cameras and structured laser light systems capable of obtaining millimeter resolution 3D scans of the underwater environment.



Figure 10 - EVA AUV

Table 4 – EVA ROV/AUV features description

Dimensions:	1.2x0.8x06 m
Motors:	12 thrusters
Weight:	150 kg
Depth (max):	1000m
Motion Control:	6 DOF motion control
GNSS:	Dual antenna RTK GNSS
IMU:	Tactical grade INS navigation system
Acoustic navigation/comms:	Evologics USBL/modem (S2C R 18/34)
Operation modes:	Autonomous navigation and locomotion
Profiling/imaging sonar:	Multibeam sonar (Kongsberg M3)
3D sonar camera:	3D multibeam acoustic camera (Octopus Echoscope)
DVL:	Nortek 1MHz



On board processing	On board computer for vehicle navigation, data processing and logging
SLS	High precision 3D structured Laser Light System
Cameras	Multiple 3.2 MPx cameras
Bateries	3750 Wh LiFePo Pressure tolerant batteries
Mission autonomy	8 hr (depending on operation conditions)

TURTLE – Robotic autonomous lander

TURTLE is a Robotic Deep Sea Autonomous lander. It is a system that combines a seabed lander system with high efficiency (variable buoyancy) vertical ascent and descent and autonomous locomotion capabilities. It is capable of permanence for extended periods of time in the seabed and of autonomous relocation capabilities (operating like and AUV). With a high payload capacity it can be used as movable seabed observation node or to provide support (navigation or energy recharging) to operations of other underwater robots.



Figure 1111 – TURTLE Robotic lander

Table 5 – TURTLE features description

Dimensions:	1.4x1.4x1.2m
Motors:	8 Custom developed thrusters (15 kgf each)
Weight:	600 kg
Depth (max):	1000m
Payload:	100Kg



VBS	Hidraulic variable buoyancy system (50Kg)
Batteries:	30 KWh NMC pressure tolerant batteries
GNSS	Two antenna RTK GNSS receiver
DVL	RDI Tasman DVL
Operation modes	Autonomous navigation and locomotion
On board computer	On board computer for vehicle navigation, data processing and logging
Acoustic navigation/comms	Evologics USBL/modem (S2C R 18/34)
Mission autonomy	Variable (2 months in current configuration)

EGIM sensor package

The EGIM module is an EMSO EGIM assembly module with integrated data logger that can be used either as a conventional lander in standalone mode (bottom image) or to be deployed and integrated in a TURTLE robotic lander (top image)

The system has an onboard battery allowing for continuous operation of more than 2 months.



Figure 12– EGIM sensor module (top: attached to TURTLE, bottom: standalone)



The EGIM sensor module possesses a set of sensors detailed below:

Table 6 – EGIM features description

Sensors:	Hydrophone (iCListen)
	Acoustic Doppler Current Profiler (Teledyne RDI Monitor)
	Water turbidity (Wetlabs) CTD (Seabird SBE37)
	CO2 (AMT)
	Precision pressure sensor (Tsunami RBR Quartz3)
	Dissolved oxygen (Aandreaa)
	Data Logger
Batteries	Multiple 1.5 kWh NMC pressure tolerant batteries
Autonomy	Multiple months (depending on number of batteries)

These sensors that are also used in other EGIM modules of multiple EMSO observatory nodes all around Europe allow for the collection of comprehensive environmental information data that can be easily compared with information collected from multiple sites.

4.3 Operational support and test facilities

INESC TEC has access to a set of sea operation support assets namely the Episea boat and R/V Mar Profundo ship and also installations in Leixões harbour. These assets are useful of the realization of robotic missions at sea in the Portuguese coast and in particular with the Portuguese demonstrator of WP4.

In addition, the robotics lab has a 10x6x5m test tank and hyperbaric chambers for pressure testing of components up to 7000m of water depth (in this case not relevant for the EU-SCORES scenarios).





Figure 13 – Robotics lab water test tank

The EPISEA is a 7m long rib boat with a 250 HP motor and capable of operating in the northern Portuguese coast (and the Aguçadoura site in particular). It can be used for support of aerial robot operations or to support small underwater robot operations such as to support the field trials with IRIS AUV.



Figure 14 – EPISEA operations support boat

The Mar Profundo research vessel is a 19m long catamaran capable of extended operation at sea with missions of up to 4 days without land support, with a set of facilities such as on board lab space, winches and cranes. It has the following mission-related characteristics

- A-Frame (2 x 2 x 2 m³ max load dimensions)



- Winch (1500 kg; 1000 m cable)
- Crane (1 ton at 7 m)
- 3000 kg payload (including passengers and their equipment)
- Moonpool with equipment towing arm (suitable for mounting, e.g., multibeam sonars)
- Two (2) hydraulic platforms for equipment deployment and recovery (max 300 kg)
- Capable of 24 h full-operation (propulsion and hydraulics excluded) in silent conditions.
- Technology validation and benchmarking in controlled condition tests (test tank, controlled sea area)



Figure 15 – Mar Profundo research ship



5. Robot monitoring plan

The robotics monitoring activities for O&M and environmental monitoring to be developed in conjunction with the demonstrators of WP3 and WP4 are developed in the context of T5.4 addressing the usage of new robotic tools in large scale multi-source offshore large scale offshore energy parks.

These activities have as primary objectives to:

- Demonstrate capabilities / validate specific robotic tool applications
- Assess operational costs and procedures in a real scenario
- Evaluate efficiency and costs
- Contribute to define operations/use cases of robotic tools in O&M and env. monitoring for offshore (multi-source) energy parks
- Test and validate EU-SCORES specific new technological developments (in robotic tools)

Types of tests and missions:

- Technology validation and benchmarking in controlled condition tests (test tank, controlled sea area)
- Field mission tests at demonstration scenarios for data collection
- Field mission tests and demonstrations in the operational scenario for technology validation and benchmarking.

The first set of tests and missions correspond to validation and technology development tests that occur in a controlled environment ranging from test tank at the lab to open sea in controlled conditions.

The second type of missions correspond to data collection missions where the main purpose is to collect useful sensor data for technology assessment and possible developments. Examples of this are initial bathymetry logs or aerial imagery for technical developments such as the automated detection of cetaceans.

The third type of missions correspond to the field experimentation of the robotic tools for specific O&M and env. monitoring tasks in order to benchmark and validate their use or the validate technical developments performed in EU-SCORES.



The set of robotics activities in the demonstrators will address the environmental monitoring tasks, O&M procedures namely inspection tasks and the demonstration of the technologies in integrated missions.

The following set of activities are foreseen:

For the O&M related activities the main usage of robotic tools (aerial and underwater robots in different modes of operation) will address:

Aerial inspection of FPVs – Visible spectrum, thermographic (and potentially hyperspectral) imagery of FPVs will be used. In addition, LIDAR 3D data can be used to provide a 3D detailed model of above surface.

Aerial inspection of WECs- UAV imaging (visible. IR) will be used to provide information of the above water part of the WECs.

Underwater inspection of underside FPV – Underwater robots equipped with imaging sensors and sonars will provide the inspection of the underwater part of FPVs allowing for the detection of structural faults or marine growth.

Underwater inspection of FPV mooring and cable – Underwater robots will be used to provide the inspection of the mooring system and the dynamic cable.

Underwater inspection of WEC - The underwater robotic tools will collect imagery, sonar and SLS profiling data of the underwater part of the WEC hull and structure.

Underwater inspection of WEC mooring and cable – Vision and sonar data will be collected for the mooring of the WECs and the power cable. This inspection tasks will collect relevant information on the morphology of the systems and their state.

For the environmental monitoring related activities are foreseen:



Aerial detection of cetaceans- An analysis of the possible usage of UAV systems as possible sources of information retrieval and image processing to provide automatic detection of cetaceans will be performed.

Visual information assessment of underwater ecosystem – Underwater robots will be used (in all modes: ROV, AUV and seabed robotic lander) to gather visual information of the ecosystem.

Sea morphology dynamic assessment- Robotic tools will be used to provide detailed local bathymetry models (from onboard sonar data) in order to access possible seabed morphology changes of the different installations.

Water parameter measurements – Water parameter and environmental data collection will be performed both with free flying AUVs and seabed landers (both fixed and robotic ones)

Acoustic monitoring – Underwater environment noise measurement with robotic tools namely landers (TURTLE and fixed landers)

In addition, the following activities are planned:

Demonstration of underwater robotic docking in the FPV demonstration scenario – This activity will demonstrate the underwater docking of an AUV in the BE demonstrator, validating a crucial technological step in the resident robotics concept.

Demonstration of resident underwater robots with TURTLE and AUVs - This activity will demonstrate in the Portuguese scenario (due to cost reasons) the concept of underwater resident robotics with a TURTLE robotic lander system acting as AUV base for docking, allowing for the operation of the AUV in the area and providing a docking system for AUV recharging and data transfer.



Floating offshore PV robotics test plan

According with the previously described activities addressing the FPVs and also in the context of environmental monitoring tasks a set of robotic missions are foreseen in the course of the project.

Two main global missions are planned for the operation in the WP3 demonstrator. These will combine the operation of aerial robots and underwater robots. Due to the additional costs of operating in the Belgium site (transport and personnel displacement) and according with the available budget allocation each of this field tests has an expected duration of around one week.

The aggregation of the aerial and underwater data collection activities will allow for higher efficiency and reducing of costs.

The first mission will occur in the beginning of the demonstrator operation phase. Here multiple sources of information will be collected (aerial and underwater imagery, sonar data, water parameter data and robot operation information) and will allow for an initial evaluation of tools and techniques in the WP3 scenario and also will contribute to specific developments.

A second robotics mission in the end of the operation period will allows for a more thorough gathering of data and for a demonstration of the developed concepts and tools in WP3, both for O&M and environmental monitoring purposes.

These missions do not preclude occasional site visits or other data gathering event that can be deemed necessary during the project.

Local operations support will require a small support boat.

It is expected that in conjunction with the operation of one of the INESC TEC UAVS, that at least a hybrid ROV/AUV will be deployed along with a docking system.

The exact timing of the planned missions will depend on the actual demonstration implementation, technological developments and weather conditions and will determined with the relevant partners accordingly.

Due to the cost limitations to tests in the WP3 scenario the use of a small mock-up FPV scenario in controlled conditions in Portugal is foreseen where preliminary trials can occur more frequently and thus serve as pre-validation of solutions before missions in the Belgium site.

he deployment of a EGIM module fixed lander is also foreseen for environmental data collection for extended period (more than the one week of robotic operation), since it can be deployed in one of the missions and afterwards locally retrieved by partners at the site without significant extra costs.



5.2 Wave energy converters robotics test plan

The robot test and field missions in the Portuguese demonstrator (WP4) will occur in accordance with the defined activities, both for O&M inspection tasks in WECs and for environmental monitoring.

In contrast to the Belgium site, with the ease of access to the Portuguese site (since INESC TEC labs are located in Porto) and due to the available support boats Episea and R/V Mar Profundo the relative cost of robot operation and deployment is significantly lower. In addition, the INESC TEC robotics team has extensive experience of operating both aerial and underwater robots in the sea environment.

In view of this multiple missions will be performed throughout the demonstrator operation.

These multiple missions will comprise the collection of data for technological developments (such as above water visual data from WECs or underwater collected data), as well as logging of operational data useful for the defining and analysis of possible robotic solutions for large scale parks in the context of task 5.4.

It is foreseen also that in the end of demonstrator operation period a one to two weeks mission will be performed to validate and demonstrate all the technological developments and the concept of operation.

The task of cetacean observation with aerial robots will be primarily demonstrated in the PT site. For this preliminary data gathering flights will be performed and will also be coordinated with the environmental monitoring plan in execution and with our partners in Portugal (Corepower and WAVEC).

The tests of the TURTLE robotic lander system and its operation will also mainly be performed in the Portuguese site. The availability of R/V Mar Profundo plays here a relevant role as the support ship to deploy and retrieve the system.

In addition to multiple missions for inspection tasks (both above and underwater), a local bathymetry map will be produced during the operation allowing for the potential detection of sea morphology changes.

Underwater environmental monitoring data will also be collected with fixed EGIM deployments, TURTLE deployments (for varied periods of time) and other underwater robots.

The exact timing and duration of each test will be defined according with the technological development requirements and will be planned in cooperation with the partners and operations at the field,



It is planned that during the demonstrator operation (and starting already in 2022, extending for 2023 and 2024) between 20 to 30 days in total of robotic missions supported by Mar Profundo to be executed.

The timing and duration of tests will also be subject to the weather conditions that can be very adverse in the northern Portuguese shore (mainly during the winter).

It is foreseen that most of the different tests and trials will occur in the Spring and Summer periods and that both aerial and underwater robotics tests will occur in these periods.



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