atlantis The Atlantic Testing Platform for Maritime Robotics

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Forward-looking report identifying the future opportunities and barriers to technology

INESC TEC

Actions

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Disclaimer

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List of acronyms

ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
CTV	Crew Transfer Vessel
IMO	International Maritime Organization
IMR	Inspection, Maintenance, Repair
O&M	Operations and Maintenance
OW	Offshore Wind
ROV	Remotely Operated Vehicle
SCC	Supervisory Control Centre
SME	Small and Medium Enterprises
TQ	Technology Qualification
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
WFA	WindFloat Atlantic

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1. Introduction

This document is entitled "Forward-looking report identifying the future opportunities and barriers to technology" and it is developed as part of the ATLANTIS project that received funding from the European Union's Horizon 2020 Research and Innovation program under the Grant Agreement number 871571.

1.1. Scope and aim of the report

This report details the outcome of Task 6.6 - Long-term Technology Roadmap of the ATLANTIS Solutions. More precisely, it deals with the challenges and barriers to the uptake of robotic technologies in the offshore wind sector and presents what the project envisions as the potential measures to overcome these challenges and barriers, centred on the ATLANTIS Test Centre.

The aim of this report is to provide a guide to the use and monetisation of the ATLANTIS Test Centre, in a way that impacts all relevant stakeholders, particularly in the promotion of the use of robotic technologies in offshore environments. Central to this is not only the proper identification of all relevant stakeholder groups, but also the description of the Test Centre capabilities and services, as they are a central piece for this goal.

1.2. Report outline

The remainder of this report is structured as follows:

- Section 2 briefly presents the current challenges and barriers to the adoption of robotic technology, both in a widespread manned and in the offshore wind sector in particular.
- Section 3 presents the details of the ATLANTIS Test Centre, in terms of capabilities, infrastructures and services, as it represents a central piece in the promotion of robotic technologies.
- Section 4 presents a roadmap that can be used to improve adherence to robotic technologies in the offshore wind (OW) sector. In particular it identifies the relevant stakeholders, discusses how to tackle the dissemination of the Test Centre, presents its business model, along with example service costs, and provides information on the certification process devised for the Test Centre.

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2. Barriers to the adoption of the technology

The use of robotic technologies for the inspection, maintenance, and repair (IMR) of offshore infrastructures has several potential benefits, including the reduction of Operation and Maintenance (O&M) costs, increase of operational windows, reduced downtime, improved worker safety, the scalability and replicability of the operations, among others.

However, the use of existing robotic technologies in offshore O&M in general, and offshore wind in particular, is still very limited. There are significant challenges that need to be addressed to allow an increase in the adherence of end-users and asset owners to these technologies. In this section we discuss some of the largest challenges that limit the uptake of robotic technologies.

2.1. Legal challenges

From the presented above, it is clear that the use of robotic platforms can bring economical and safety benefits. However, the deployment of robotic solutions in real offshore environments, in any recurring way, requires the compliance of these technologies with legal and regulatory requirements in place, which can limit the widespread deployment of these solutions.

Given the accelerated rate of developments in robotics, as well as the novelty applying robotic solutions to offshore IMR operations, there are a lot of unclear aspects regarding the regulations applicable to these solutions. While the use of remotely operated vehicles (ROVs) in inspection operations is already somewhat widespread, and as such there is clearer regulation for its use, other platforms, such as unmanned aerial vehicles (UAVs), unmanned or autonomous surface vehicles (ASVs) and autonomous underwater vehicles (AUVs) are subject to more generic regulations, that can be confusing and limit their operationality. For example, given that most regulation for vessels have been drafted with a crew in mind, they might not be directly applicable to unmanned surface vessels as these lack a crew, by definition. From a legal standpoint this can have different interpretations, including the ASV not conforming to regulations and therefore being illegal [1]. Similar examples can be found for the remaining types of platforms.

Additional challenges can arise from the use of cooperative systems operating in different domains (e.g., UAV taking off from an ASV). The development of these types of solutions is already underway, with a significant number of scientific developments related to taking-off and landing on moving platforms and docking of underwater vehicles into surface vehicles. However, the crossing of environments can lead to confusion on which regulation standards are to be followed.

The issues presented above exemplify some of the regulation and legislation challenges that need to be tackled to allow robotic technologies to be a viable solution to offshore IMR operations. However, the tackling of these challenges is further complicated by the fast pace at which robotic technology is advancing, that cannot be accompanied by changes in legislation.

2.2. Level of trust in robotic technologies

While the capabilities of existing and new robotic technologies have been improving rapidly, their testing and validation are severely limited, with the vast majority not being tested and demonstrated in any kind of realistic environment. Consequently, the level of trust instilled in end-users and asset owners by these technologies is not significant enough to motivate their uptake in current IMR practices.

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As this concern naturally stems from the lack of safe testing environments that emulate realistic conditions, tackling it can be particularly challenging. Moreover, end-users are not keen of providing access to real environments, without some degree of guarantee that the use and testing of the technology will not lead to damages to existing assets. This is particularly significant in offshore scenarios, where the environmental conditions tend to be mode adverse compared to onshore environments. While demonstrations of the operational capabilities of the technologies can be made offshore, without the use of dedicated infrastructures, this is not enough to ascertain their safety to be used in IMR operations.

In addition to this, the lack of a recognised and transversal metric that quantifies not only the benefit of the use of robotic technologies over traditional methodologies, but also their operational safety, means that the use of these technologies must be assessed case-by-case. This can require a significant amount of resources by end-users, reducing the motivation to uptake robotic technologies for their operations.

2.3. Technological Challenges

In addition to the presented above, and while capabilities of robotic systems and technologies have been subject to great advances, there are still some technical challenges that require tackling to foster their widespread adoption in IMR operations.

One of the most common challenges in terms of robotic capabilities for offshore operation is the development of reliable perception systems and capabilities. This is particularly the case for underwater systems, where visibility decreases significantly with depth. For the case of UAV's, the limitations are related to weight, given the already limited endurance of existing systems, and to the limitations a heavy payload can impose in their manoeuvrability.

The capability of systems performing long-term operations, or even having a system deployed on site permanently is appealing, in terms of resources and operations efficiency, as having systems capable of operating at the site without human-presence can be a major factor in the reduction of operation costs. However, existing systems tend to have limited operation times, and are not able to perform long operations without interruptions (e.g., inspection of multiple assets sequentially). As such, developing methods to have a robotic platform to be present on site for long periods of time, allowing it to recharge itself, can be highly beneficial.

One other aspect of robotic solutions that require further development is related to the autonomy of these systems. Autonomous capabilities can have significant impact in the outcomes of IMR operations, as they remove cognitive load from the operator during the inspection, allowing a focus on the outcomes of the operation. However, the development of fully autonomous systems requires them to be able to deal with unexpected circumstances, which can require advance decision-making algorithms.

While the above are just a few representative examples, they illustrate the need for technological advancements to fully realise robotic technologies as a viable solution to offshore O&M.

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3. The ATLANTIS Test Centre

To provide some guidance to tackling the challenges presented, and as a result, contribute to the uptake of robotic technologies in IMR operation of the offshore wind sector, ATLANTIS has developed a testing facility – **the ATLANTIS Test Centre** – focused on providing appropriate testing and validation of new robotic technologies.

The purpose of the Test Centre is to fill the gap in terms of testing that exists between laboratory testing and validation and real offshore environments, allowing new technologies to be tested in realistic but controlled environments, and leading to increased impact of the validation of robotic technologies, all with the objective of promoting the adoption of these technologies by the OW sector. To achieve this objective, the testing, validation, and demonstration activities taking place in the Test Centre are expected to:

- Contribute to the increased end-user trust in robotic technology;
- Motivate changes in the existing legal and regulatory framework that constrict the use of these technologies;
- Incentivise robotic developments.

In this way, the ATLANTIS Test Centre will become a central piece to develop and take to market robotic technology for offshore IMR, through safe demonstrations of these technologies operating in real environments (**Error! Reference source not found.**). Given the objectives and capabilities of the Test Centre, it has the potential to affect the complete robotics and wind energy value chain. The Test Centre can cater to universities and research centres, technology developers, service providers and end-users.

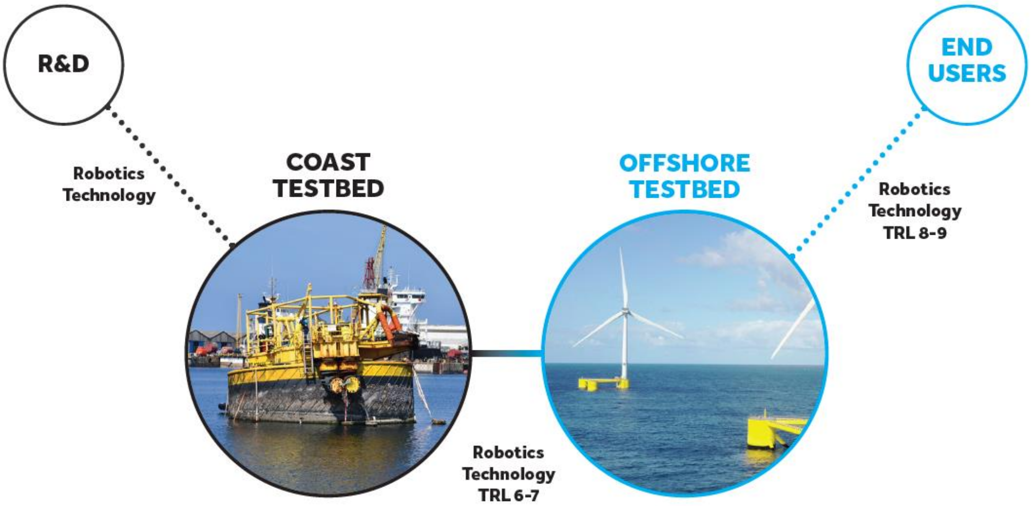

Figure 3-1 - High level road map concept

The ATLANTIS Test Centre is a pilot infrastructure that is geared towards the testing and demonstration of robotic technology, directed to offshore O&M. The Test Centre is capable of encompassing technologies at various levels of technology readiness level (TRL), to support and incentivise the development process. While mostly directed to technologies targeting the offshore wind sector, developments related to other applications of maritime robotics can be tested and demonstrated at the Test Centre, with the final aim of demonstrating, in a certifiable manned, the viability of robotic solutions for maritime applications.

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The Test Centre is composed by two testbeds, Coastal Testbed and Offshore Testbed, and a Supervisory Control Centre (Figure 3-2). While the Coastal Testbed is focused on the de-risking of robotic technologies with lower TRL, the Offshore Testbed consists of dedicated positions within a commercial wind farm, the WindFloat Atlantic (WFA)[1], that will be reserved for demonstrating robotic technologies in a real environment (higher TRL).

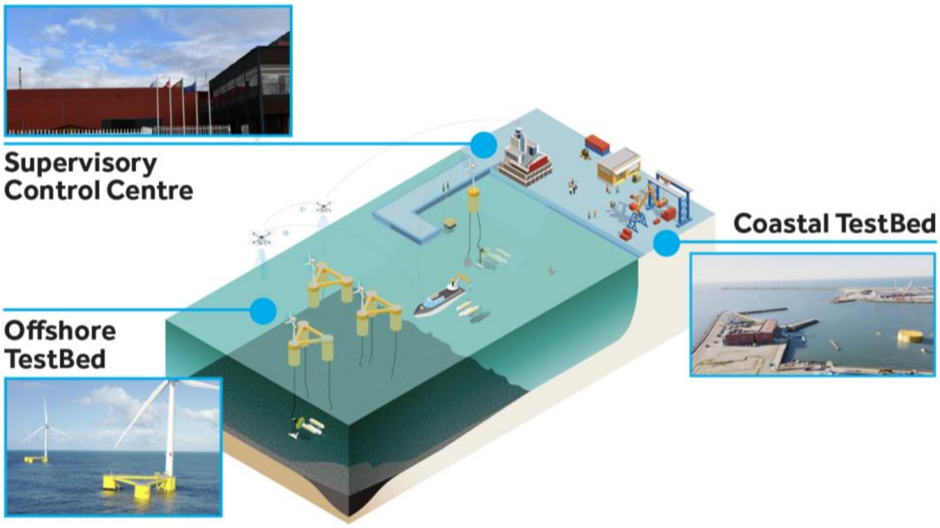

Figure 3-2 - Conceptual image of the ATLANTIS Test Centre

3.1. Coastal Testbed

The Coastal testbed of the ATLANTIS Test centre is equipped with a floating structure, that simulates an offshore floating structure of an offshore floating wind turbine. The floating structure installed is a decommissioned Catenary Anchor Leg Mooring (CALM) buoy, that provided support to the loading and discharging of liquid product cargo to/from tankers, near onshore or production fields [2].

Figure 3-3 - Floating Structure installed on the Coastal Testbed of the ATLANTIS Test Centre

1 https://www.edp.com/en/innovation/windfloat

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Figure 3-3 shows the floating structure, named DURIUS, as installed in the Coastal Testbed of the ATLANTIS Test Centre, in Viana do Castelo. The buoy has a diameter of 16 meters, and a height of 6 meters. The floating station is anchored in exit of Lima river using three mooring chains. In the current installation of the buoy in the Test Centre, four meters of the structure is submerged and two meters above the water. top of the buoy, with access to the top of the floating structure enabled through two ladders, placed almost diametrically opposed in the buoy. Power and network connection is available on the buoy, being provided from shore by an underwater cable. All these elements (access stairs, mooring chains, anodes, and power cable), as well as the floating structure itself, can be used as subject for the testing and validation of robotic technologies for offshore inspection.

3.2. Offshore Testbed

The Offshore Testbed is composed by the real offshore wind farm WindFloat Atlantic, containing three floating offshore wind turbines. These turbines are located between 10 and 20 kilometres of shore from Viana do Castelo. Water depths in the WindFloat wind park area range from 40 to 100 meters.

As a real environment, the infrastructures available for the demonstration of robotic technologies include all components that require inspection in a fully functional offshore wind turbine. These include:

- Wind turbine blades and tower
- Transition Piece
- Mooring lines
- Anchors
- Array cables
- Export cables.

For demonstrations related to the blades and tower or requiring close proximity to work on the floating structure, the wind turbine is required to be stopped. Additionally, the access to the offshore wind park is restricted. As such, permission for the tests as well as confirmation for potential testing dates need to be obtained from the wind park owners (Ocean Winds and WindPlus). For this reason, after the completion of the project, the Test Centre will aim to establish an agreement with Ocean Winds and WindPlus to facilitate the process of obtaining accessing rights to the offshore wind park for the users testing their technologies, and minimize the impact of testing and demonstration activities in the normal operation of the turbines.

Specific training and valid medical certification are required for all team members performing the demonstrations to access the area of the WindFloat Atlantic. The level of required training depends on the demonstrations being performed, but the Sea Survival training and OEUK (old OGUK) medical certification are a minimum requirement. Access to the Offshore Testbed is performed through a vessel departing from Viana do Castelo.

3.3. Supporting Infrastructures

Beyond the floating structure and respective working area, the Coastal Testbed of the ATLANTIS Test Centre has access to a set of supporting amenities and infrastructures that facilitate the realisation of the tests and validations.

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Infrastructures

As the Test Centre is installed in close proximity of the premises of the Clube de Vela of Viana do Castelo, support of the activities in the Coastal Testbed is performed through existing infrastructures of the Clube the Vela. One of the most relevant supporting infrastructures to the testing in the Coastal Testbed is the crane that allows easy deployment and recovery of the robotic vehicles into and from the water. Additionally, there is also access to a dock and support vessels (with skipper if necessary) to monitor from the water, if needed.

Supervisory Control Centre

In addition to the physical infrastructures available, a Supervisory Control Centre (SCC), with a direct line of sight to the floating structure (Figure 3-4), has been implemented in the premises of the Clube de Vela. The SCC will allow for the planning, monitoring and control of the operations from shore.

Figure 3-4 - ATLANTIS Test Centre Coastal Testbed and related infrastructures

The SCC has a connection network with both the Coastal Testbed floating structure and offshore Testbed (through a mobile network box), to allow for remote planning, monitoring and control of operations. All robotic vehicles performing validations or demonstrations are required to connect to the ATLANTIS Test Centre SCC, through the installation of an interoperability layer that facilitates their integration into the SCC.

In the SCC, multiple stations are available running the client used for the planning and monitoring of operations. Additionally, a small work area is available for more software intensive work.

Mar Profundo Vessel

To perform the transfer between Viana do Castelo and the Offshore Testbed, the ATLANTIS Test Centre makes use of the vessel Mar Profundo, that is part of the TEC4Sea project (see Figure 3-5). Mar Profundo is a catamaran type vessel, with a maximum capacity of 12 passengers, including the 3-member crew. It is equipped with all required amenities to deploy robotic vehicles offshore (crane, A-frame, lifts for water access, support boat), as well as a communication link to the SCC (monitoring of operations).

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Figure 3-5 - Mar Profundo Vessel

3.4. Services & Supported Testing

As stated above, the ATLANTIS Test Centre is targeting the complete value-chain of robotics for offshore wind. As such, the services provided are directed to the needs of each of the different stakeholders. Examples of these services include:

- **Universities and Research Centres:** Field testing, technology validation, research, and development projects;
- **Technology Companies:** Technology validation and demonstration, data collection, certification of technology;
- **Service providers:** Validation and demonstration of new methodologies, assessment and de-risking of solutions, training, and certification of personnel;
- **End-users:** De-risking of technology, training of personnel, knowledge sharing and collaborations;

While offshore operations are strongly limited by weather conditions, i.e. operations are only possible during summer and early fall, testing and validation activities at the Coastal Testbed are possible year-round. All of the services provided by the Test Centre include support in terms of logistics, methodology refinement and operations.

In terms of testing and validation, the ATLANTIS Test Centre is ready to support activities directly related with the scenarios of the ATLANTIS Project. Included in these are:

- ***Scenario 1 - Inspection of blades and tower***
    - Visual inspection and reconstruction using aerial vehicles
- ***Scenario 2: Inspection, maintenance, and repair (IMR) of the transition piece or the floating structure***
    - Visual inspection and reconstruction of the floating structure (above water level)
    - Visual/Acoustic inspection and reconstruction of the floating structure (underwater)
    - Cathodic protection testing
    - Underwater cleaning of the floating structure
- ***Scenario 3: Repair of underwater floating wind turbine cables protection systems***

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    - Visual/Acoustic inspection and reconstruction of underwater cables
- ***Scenario 4: Underwater monitoring over extended time periods***
    - Deployment of charging and/or docking stations
    - Visual/Acoustic underwater surveys
- ***Scenario 5: Underwater close-range inspection of foundations***
    - Visual/Acoustic inspection of mooring lines
    - Visual/Acoustic inspection of anchor points
    - Cleaning of mooring lines
- ***Scenario 6: Underwater monitoring of scour protection interventions***
    - Bathymetric inspection of seabed
- ***Scenario 7: O&M operations supported by crewless vessels***
    - Unmanned solutions for deployment of robotic solutions (e.g., USV transporting and deploying ROV/AUV)
    - Remote control stations
- ***Scenario 8: Optimization of robotic-based operations***
    - AI tools for scheduling inspection and maintenance operations
    - Predictive tools for maintenance operations

The activities presented in the list above represent the more streamline and well-defined tests that can be performed in the ATLANTS Test Centre (either Coastal or Offshore Testbeds). However, given the resources and conditions available at the Test Centre (see previous sections), it is possible to perform a multitude of additional tests. In these situations, as the tests will not fit into the standard test list, the details need to be discussed and agreed between Test Centre coordinators and potential users.

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4. Roadmap to the adoption of the technology

With the ATLANTS Test Centre as a central piece, the ATLANTIS project has devised a roadmap as a way of providing a clear path and timeline for new robotic technologies and IMR methodologies to be accepted and deployed by end-users at a faster pace. The aim of this roadmap is to define and promote a set of conditions, that by leveraging a unique testing environment will allow the tackling of the most relevant challenges to the adoption of robotic technologies for maritime applications in general, but with a special focus on the OW sector. Figure 4-1 presents the proposed roadmap, that by utilizing the project results can foster developments and accelerate the adoption of robotic technologies.

Figure 4-1 - Roadmap to the adoption of robotic technologies for Offshore IMR, based on the capabilites and resources of the ATLANTIS Test Centre

On a short-term the project will perform testing campaigns offshore, that combined with previous Coastal testing campaign will demonstrate the full capacities and benefits of the ATLANTIS Test Centre. These results will be the basis for the initial Test Centre dissemination, that together with the stakeholder ecosystem developed in the project, will aim to attract future users.

On a medium-term, it is expected that the services provided by the Test Centre, coupled with its increasing visibility, will promote further developments of the robotic capabilities required for offshore operation, as well as increase the confidence level of end-users and asset owners to utilize robotic technologies in their operations, through the devised certification process provided by the Test Centre. As a direct outcome of this, it is expected that IMR activities will increasingly change from fully human-based to a more hybrid set-up, where while there is still human presence offshore, it is reduced, and dangerous operations are performed with the support of robotic technologies.

On the long-term, it is expected that the trend in reducing human presence offshore will continue, allowing the transition to fully remote operations, that are monitored from shore. Coupled with increased developments and confidence in the area of autonomy of operations, it is expected that the deployment of autonomous solutions will slowly grow, eventually only requiring the monitoring of the operations from shore, where the operator has only high-level control of the operation.

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4.1. Identification of Stakeholders and Potential Users

For the development of a roadmap to promote the uptake of maritime robotic technology, particularly related to OW IMR operations, centred on the ATLANTIS Test Centre, the identification of the stakeholders and potential users that will be serviced by the Test Centre is essential. As such, this section is focused on their identification, as it will strongly influence not only the service portfolio of the Test Centre, but also its marketing/dissemination strategies and business model.

Robotic Technology Developers and **Service Providers** are one of the more easily identifiable stakeholders for a testing facility for robotics. In terms of technology developers, given the focus and capabilities of the Test Centre related to the OW sector, the most relevant of these are companies involved in the development and manufacturing of robotic systems specifically designed for offshore inspection and maintenance, that can benefit from access to the full range of the Test Centre's facilities and expertise to validate and refine their technologies. However, while technology developers related to other areas of maritime robotics might only take advantage of a subset of available Test Centre’s resources and facilities, they are still an important potential user base. Service providers present a similar profile, as stakeholders. Organizations specializing in offshore wind farm maintenance and inspection services can leverage the Test Centre to assess and validate the performance of their existing robotic systems or explore new technologies to enhance their service offerings.

One other very relevant set of stakeholders are **Offshore Wind Farm Owners and Operators**. These companies have a vested interest in ensuring the efficiency, safety, and reliability of their inspection and maintenance activities. As such, they can utilize the Test Centre to evaluate, test and de-risk robotic solutions before implementing them in their operations. To allow this assessment to be as streamlined as possible, the involvement of **Certification and Accreditation Bodies** is highly relevant. Organizations responsible for certifying and accrediting technologies and services can collaborate with the Test Centre to establish testing protocols and validate the performance and safety of robotic inspection technologies, allowing the standard to move from self-certification to a recognised standard.

To fully promote the adoption and roll-out of robotic technology, the involvement of **Policy-Makers** and **Regulatory Bodies** is extremely important. While presenting slightly different focuses, the involvement of these type of stakeholders can have a strong impact. On one side, government bodies and policymakers involved in the development of regulations, incentives, and policies for the offshore wind industry can collaborate with the Test Centre to gain insights into the capabilities and potential impact of robotic technologies. On the other side, companies, and bodies responsible for setting regulations, standards, and guidelines related to offshore wind farm inspections can collaborate with the Test Centre to evaluate the compliance of robotic systems and contribute to the development of industry best practices.

As one of the major selling points of the Test Centre is its controlled but realistic environment (particularly in the Coastal Testbed), it represents a very attractive environment to foster new developments and identify technological needs. As such **Research Institutions and Universities** focused on maritime robotics, offshore engineering, and renewable energy can utilize the Test Centre's resources for research, development, and testing of new robotic technologies and methodologies.

The uptake of robotic technologies as alternative to human-based operations imposes a significant shift in the qualification requirements of the related workforce. As such, **Training Providers**, that offer training programs, courses, and certifications related to robotics and offshore wind can collaborate with the Test

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Centre to develop specialized training modules and offer hands-on practical experience to their students and facilitate the transition.

4.2. Dissemination of the Test Centre & Services

To allow the creation of a costumer/user base for the Test Centre, its successful dissemination is essential. As such, this section is focused on providing a base for the Test Centre the dissemination strategy, based on work completed in the project.

As part of the ATLANTIS project, the Test Centre has established links with existing and relevant robotics communities, such as RIMA Network and SPRINT Robotics. Additionally, through multiple events that included seminars, conferences, exhibitions and workshops, the project has extensively disseminated the Test Centre, with the objective of creating links with potential users of the Test Centre. Additionally, the results of the associated with the Test Centre have been disseminated through social media platforms, such as LinkedIn.

However, while the links established through the project will be leveraged to gain maximum visibility not only to the Test Centre, but also to users that have successfully demonstrated their technology/methodology, disseminating the results, and user's testimonials, a clear and dedicated dissemination strategy will be required for promote the Test Centre, and its advantages. This is not only aimed at increasing the visibility of the Test Centre and its users, but also the visibility of the robotic technologies tested, to increase the Test Centre user base and further foster their widespread adoption.

The development of the dissemination and marketing strategy is strongly based on the identified stakeholders and users of the Test Centre. From this list, key messages and services will be identified for each of the stakeholders' groups in order to allow a directed strategy and avoid the dissemination of excessive and/or irrelevant information to each of the groups. The messages devised will start by leverage **project's activities and results** to demonstrate and highlight the **Test Centre's impact** and will be frequently updated as new testing and validation operations take place.

In addition to these, the Test Centre will also work in developing and sharing compelling case studies that highlight successful applications of robotics in offshore inspection and maintenance. These will include quantitative and qualitative data showcasing the benefits achieved, such as cost savings, increased efficiency, and improved safety, as well as testimonials from satisfied clients and partners to validate the Test Centre's capabilities and credibility.

The messages devised will be shared with the stakeholder groups and potential users recurring to various tools and opportunities, including:

- *Test Centre Website:* an informative and user-friendly website will be created to provide detailed information about the Test Centre's services, facilities, and expertise.
- *Social Media:* By making use of social media platforms (e.g., Twitter, LinkedIn), the Test Centre will publish posts, whitepapers, and research articles that address key industry challenges, technological advancements, and case studies, as well as Test Centre Results, events, and success stories
- *Industry Events and Conferences:* The Test Centre will leverage links established in the project to participate in relevant industry conferences, exhibitions, and trade shows to showcase the Test Centre's capabilities. Additionally, it will also organize and host workshops, seminars, and technical sessions to present research findings, best practices, and emerging trends.

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- *Media and Press Relations:* The Test centre will aim to develop relationships with relevant industry media outlets, journalists, all while working internally to issue press releases to announce significant Test Centre results, milestones, partnerships, and notable projects.

Beyond the above presented, the Test Centre will work on forging e strategic partnerships with industry associations, research institutions, and technology providers to amplify the Test Centre's reach. These will include collaboration in research projects, knowledge exchange initiatives, and technology demonstration programs.

To ensure the successful dissemination and marketing of the Test Centre, and its services, the presented strategy will be subject to regular assessments and improvement. For this purpose, key performance indicators (KPI), such as number of successful tests, website visits, events attended, press releases, social media followers, etc., will be assessed in conjunction with feedback form users and industry partners. This will allow the identification of the areas of the dissemination strategy that require improvement.

4.3. Business model and examples

To fully realise the potential impact of the Test Centre, in the promotion of the adoption of robotic technology, a clear business model is required. In this section we provide details on the business model for the ATLANTIS Test Centre beyond the project, as well as example costs for different common user profiles.

4.3.1. Business Model

Value Proposition

The ATLANTIS Test Centre, as an essential element of the roadmap to the adoption of robotic technology in offshore IMR, provides a facility for the testing, validation, and demonstration of maritime robotic technologies, particularly focused on the offshore wind sector. As a result, it enables users to evaluate the performance, reliability, and efficiency of the robotic solutions, providing both a safe/controlled near-real environment and a real offshore environment. Beyond the environment, the Test Centre is able to provide access not only to the required infrastructures for the testing, but also to a support and technical team experienced in deploying and operating robotic solutions offshore, which can contribute to the acceleration of the developments and deployment of robotic technology in this environment. Additionally, given the ecosystem centred around the Test Centre, it is able to facilitate collaboration and knowledge-sharing among stakeholders to drive innovation and best practices.

Customer Segments:

With regards to users/customers of the Test Centre, they can be grouped in different groups, based on their size and area of intervention:

- *Start-ups and SMEs:* Smaller companies, developing innovative technologies for offshore wind energy who require testing and validation services to bring their products to market.
- *Technology providers and Developers:* Larger companies, that develop and commercialise robotic solutions, requiring opportunities to test and validate their products during the development stage and demonstrate them in real environments, once ready for commercialisation.

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- *Universities and Research Centres:* Institutions conducting research and development in the field of maritime robotics and/or offshore wind energy, providing them with testing facilities, technical support, and opportunities for collaboration.
- *O&M Service Providers:* Companies that require testing, certification, and optimization services for their equipment and systems.
- *Offshore Wind Farm Owners:* Companies that own offshore assets and require either training of personnel or the de-risking of their operations using new robotic solutions.

Key Activities:

The main activity related to the operation of the Test Centre is the operation of robotic technologies for their **testing, validation, and demonstration**, as it is central to the majority of the services provided to the Test Centre. This can include comprehensive testing and validation services to assess the performance and reliability of technologies, components, and systems (related to offshore wind energy), demonstration of commercial technology by companies to interested third parties, among others.

One other relevant activity of the Test Centre is **providing expert technical support**, including but not limited to guidance in the preparation of the operations, support troubleshooting during testing and validation operations, training in the offshore deployment of robotic platforms, connect users with relevant stakeholders, and data analysis.

Lastly, the centre will also organise networking and training activities, such as open days, conferences, workshops, and seminars to foster knowledge exchange and facilitate collaborations.

Key Resources:

The most relevant resources accessible to users of the Test Centre have been described in Section 3 of this document. These include:

- Floating structure installed at the Coastal Testbed, containing the relevant elements for inspection;
- Outside working and storage areas;
- Access ramps and crane for deployment of robotic technology;
- Control room for the planning and monitoring of the operations;
- Support vessels to monitor operations and access the Offshore Testbed;
- Access to skilled personnel in deploying and testing robotic systems.

Revenue Streams:

The revenue of the ATLANTIS Test Centre is strongly associated with the services provided:

- *Testing of Technologies:* Given the condition and infrastructures available at the Test Centre, different tiers of testing are available, based on the needs of the users. The rates of each of the tiers will change based on elements such as domain of the tested technology, number of days of testing, required work and storage area, technical support required, and Testbed being used (Coastal only or both).
- *Equipment Rental:* The test centre will have available a set of robotic platforms and/or sensors that can be used for the testing of new algorithms or methodologies. Equipment rental rates can vary depending on the type of equipment and the duration of the rental.

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- *Certification Services:* An important element to building trust over robotic solution is their certification in terms of performance, reliability, and safety of equipment. The test Centre will have available different certification tiers, with rates varying rates based on tier and scope of the certification process.
- *Training Programs:* The use of robotic technologies in challenging environments such as offshore, requires qualified personnel. As such, the Test Centre will develop and offer training programs and workshops to enhance the technical skills and expertise of stakeholders in the use of robotic platforms. The training programs will differ based on the technology being considered (UAV, ASV, AUV or ROV), and have different tiers, based on course duration and previous exiting knowledge from participants.

Key Partnerships:

To take full advantage of the Test Centre capabilities, as well as map any relevant improvements and additions that can be made to extend the range of services, partnerships with relevant stakeholders will be made. These will include **offshore wind farm owners**, to gain access to data from real operating conditions and constantly assess and understand their needs, allowing the development of scenarios that will match; **service providers** and **technology developers**, to showcase existing and under development solutions, as well as ensure the Test Centre can meet the operational requirements for these solutions; and research institutions and universities, leverage their expertise, access cutting-edge research and expand the potential areas of application the Test Centre can cater to.

Key Metrics:

An important element of any business plan it's the assessment of its success, to allow constant refinement and improvement. For this purpose, the Test Centre will use of KPIs that will include:

- Number of testing and validation projects conducted;
- Customer satisfaction and feedback;
- Partnerships and collaborations established;
- Revenue generated from provided services;
- Success stories of robotic technologies implemented in the offshore wind industry.

Cost Structure:

Fully understanding the costs associated with the operation of the Test Centre is essential to ensure not only that the services are appropriately priced, but also that there is enough revenue to maintain and improve the Test Centre and its facilities. In general, the cost associated with any business can be divided into fixed, variable, and administrative costs. In addition to this, given the business model provided for the Test Centre, research and development costs, as well as a contingency budget should also be considered. Table 4-1 below presents a breakdown of the costs encapsuled in each of the presented categories.

Cost Type	Description
Fixed	• Facility Rental • Software licences
Variable	• Floating Structure Maintenance • Offshore Support Vessel • Coastal Support Vessel

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	• Crane Services • Technical Staff • Marketing and promotion • Utilities
Administrative	• Insurance • Offshore Training and Medical certifications • Management Staff
Research and Development	• Development of new services • Improvement of the testing facilities
Contingency	• Equipment failures • CTV rental

Table 4-1 - Cost breakdown for the operation of the ATLANTIS Test Centre

4.3.2. Examples of testing services costs

While the Test Centre will have access to different revenue streams, it is indisputable that central to most of them is the execution of tenting operations. As such, and to provide a baseline for all of the services that require testing of technology, three different testing scenarios are presented below, along with their associated final cost.

Scenario description	Operation details & required support	Estimated Cost
SME intending to test a new ROV technology at a lower TRL (4/5)	• Testing performed only at the Coastal Testbed • Technical personnel required to support the operation: 2 • Crane Services and Support Vessel • Storage area • Minimum testing duration 1 day.	700 €/day
Technology developer intending to validate an AUV at a close to market stage (TRL 7/8)	• Testing performed both at the Coastal and Offshore Testbed • Technical personnel required to support the operation: 3 • Crane Services and Support Vessel • Support vessel to Offshore Testbed • Storage area • Minimum testing duration 2 days (1 Coastal + 1 Offshore)	7200 €/day
Service provider intending to demonstrate a new UAV inspection methodology	• Testing performed both at the Coastal and Offshore Testbed • Technical personnel required to support the operation: 3 • Support vessel to Offshore Testbed • Storage area • Minimum testing duration 2 days (1 Coastal + 1 Offshore)	6900 €/day

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Table 4-2 - Estimated Costs for example operations per day

4.4. Quality Assurance and Certification of Technology

An extremely important element to promote the adoption of robotic technologies for offshore IMR by end-users is assessing and ensuring the quality of the testing, as well as the certification of the tested technology (in case of successful testing and demonstration). This process is of extreme importance, as self-certification does not provide end-users with a sufficient level of trust in the technologies to allow its deployment in place of traditional and verified methodologies. This gap can be tackled through the involvement of classification societies, that are able to devise a certification that can be recognised by third parties and end-users, guaranteeing the safety and reliability of the technology.

For this purpose, ATLANTIS is devising systematic testing procedures, that consider not only the robotic system's characteristics and testing objectives (defined by the Test Centre users or end-users), but also the task and associated performance indicators, to ensure the testing results are up to the highest standards. The final aim of this process is the certification of the demonstrated technology or methodology, while also ensuring all certified technology is aligned with existing safety regulations and is a viable alternative to traditional methodologies, performance-wise.

Two different stages of certification are being considered for this process, **Approval in principle** and **Technology Qualification**, that are strongly connected to the current TRL of the robotic technology being tested, and by consequence how far it went in the testing process (Coastal only or Offshore). Regardless of the certification level required, the process follows the same streps. However, for the Technology Qualification, the involvement of external parties (such as the owners of the WFA) is required.

For the purpose of the certification, we consider the following definitions:

- **Novel Technology:** Technology that is not proven, i.e., there is no documented track record for a defined application. This implies that the definition of novel technology encompasses the application of both a proven technology in a new environment and an unproven technology in a known environment.
- **Fitness for Service:** A novel technology is considered fit for service when the supporting evidence demonstrates that the technology fulfils all the requirements of functionality, safety, reliability, availability, and maintainability defined in the qualification basis.

As a systematic process, the certification process follows the following steps:

1. *Definition of Qualification Basis*

The purpose of the qualification basis is, in the possible absence of fully relevant codes and procedures, to define the objectives of the novel technology, the fulfilment of which are to be proved through the certification process. The qualification basis will be used as the input for the certification process, through the establishment of criteria that are to be shared by the assessing party and technology owner. It should include a description of the technology, operational conditions and limits, functional requirements, and Safety, reliability, availability, and maintainability criteria.

2. *Technology Assessment*

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The purpose of the Technology Assessment is to divide the technology into manageable elements, assess the elements that involve aspects of novel technology and identify the key challenges and uncertainties. The Technology Assessment should include the following issues:

- Division of the technology into manageable elements (i.e., subsystems and components, processes or operations, manufacturing, installation etc.);
- Assessment of the technology elements with respect to novelty;
- Identification of the main challenges and uncertainties related to the novel technology aspects.

3. *Selection of Qualification Methods*

The objective of this step is to select methods that adequately address the key issues of the technology subject to qualification. Such methods will likely consist of a proper combination of engineering analyses and test programs, aimed at increasing the confidence level in the novel technology and reducing the uncertainties. The selected qualification methods will become mandatory for the certification process.

A risk assessment of the novel technology is to be conducted according to the techniques dealt with in the applicable standards. 'Risk' in this context is related to the events that may affect the fitness for service of the novel technology, with the proper attention to the interfaces with the proven technology.

4. *Data collection (analysis and testing)*

The objective of this phase is to collect the results of the selected qualification activities.

Supporting evidence of the design, construction, operations, and maintenance of the novel technology in its lifetime is to be provided. Means of catering for confidentiality issues are to be agreed up front among the stakeholders.

The typical documentation, as far as applicable, to be provided at this stage includes:

- Design criteria
- Applicable normative framework
- Detail drawings
- Technical specification
- Manufacturing and installation
- Material specifications and certificates
- Operating manuals
- Test and maintenance procedures
- Engineering analyses
- Risk assessment reports.

5. *Functionality assessment.*

The objective of this phase is to obtain confirmation that the functional requirements and the safety, reliability, availability, and maintainability criteria are fulfilled, by providing evidence of the results of the relevant certification activities. At this stage, the testing of the technology is performed, and assessed based on the previously defined criteria.

The final result of the certification process is an official statement, supported by appropriate documentation, of fitness for service consistent with the qualification basis. The statement may be in the form of a certificate, class notation or other equivalent document which is issued following the evaluation

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of the supporting evidence (drawings, technical reports, applicable rules, and standards etc.), the survey for construction, installation, and commissioning. The statement will confirm that the novel technology meets the specified requirements for its intended service.

4.5. Collaborations and Funding Opportunities

The exploitation of the ATLANTIS Test Centre, with all of its associated services, is a key process in promoting the uptake of robotic technologies. However, the services provided by the Test Centre are focused on the testing and validation of third-party technology, and in this way promote developments in maritime robotic technology. As such, by actively seeking partnerships, engaging with industry stakeholders, and securing funding, the Test Centre can not only finance the developments of owned robotic platforms, but also expand the Test Centre to account for different scenarios of the OW sector, as well as other application fields of maritime robotics.

As part of the business model devised for the ATLANTIS Test Centre, close collaborations between the Test Centre and Ocean Winds, owners of multiple offshore assets, as well as other end-users, such as ENGIE and EDPR, are considered with the objective of presenting the Test Centre as an essential element to the robotization of IMR activities and collecting updated information on the needs of the OW sector. In a similar fashion, collaborations with local stakeholders, such as local shipyards and authorities (e.g., captaincy, port authorities), ensures access to resources and areas of operation essential to the operation and growth of the Test Centre. Additionally, links with regulating bodies, such as the International Maritime Organization (IMO), and classification societies, such as RINA, allow the development of certification processes for the technologies and methods tested and validated at the Test Centre. However, while extremely relevant, these collaborations are ultimately focused on providing adequate testing facilities and stakeholder ecosystem to potential Test Centre costumers.

As an additional way of fostering collaborations, the Test Centre can also be used as a focal point in establishing new partnerships/consortiums with the purpose of securing funding for research and development projects. These can leverage the testing condition of the Test Centre to foster new developments in the robotic systems available, as well as the development of new platforms. The funding opportunities considered include:

- National funding agencies;
- Funding of European projects;
- Industry partnerships to develop new technologies.

Additionally, given the capabilities of the Test Centre, the collaborations established with the aim of acquiring funding can go beyond the OW sector, by fostering developments applicable to multiple industry sectors. Particular examples of this include areas such as security of ports and harbours, biologic inspection of sea life and seabed, among others. These areas require the establishing of partnerships with entities or fields not directly related to maritime robotics, but that can regardless benefit from their developments.

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5. References

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