COMMERCIAL APPLICATIONS OF SPACE-ENABLED ROBOTICS: MARITIME AND MARINE USE-CASES

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1. INTRODUCTION

This document lists the use cases to be used as part of the *Maritime and Marine* thematic area of the 'Commercial Applications of Space-Enabled Robotics' thematic call for proposals.

The use cases presented result from the cooperation between the European Space Agency (ESA) and key stakeholders in the maritime sector. It aims to support the study and demonstration of services enabled by robotics and satellite technologies that are uniquely positioned to solve issues in the maritime sector.

When writing the initial proposal (APQ/Outline proposal), the applicant will make clear what use case(s) their solution will address.

2. MARITIME & MARINE USE CASES

ESA and key stakeholders have identified the below focus areas and use-cases within which space-enabled robotics may add value. Prospective bidders to this thematic call for proposals are invited to submit proposals addressing the below use-cases, or to submit alternative ideas within the overarching theme based on their own preference.

2.1. Fórum Oceano

Fórum Oceano is the managing body of Portugal's Blue Economy Cluster, certified and recognised by the Ministry of Economy and the Sea. It is a non-profit organisation whose mission is to promote and enhance the economy of the sea in Portugal, supporting the sustainable development of the maritime sector in Portugal, promoting innovation, entrepreneurship and cooperation between entities in the sector. To this end, it develops various initiatives and projects aimed at strengthening the competitiveness of companies and institutions operating in the maritime economy.

The main activities of Fórum Oceano include promoting research and development of new technologies, facilitating access to finance and investment, and supporting the internationalisation of companies and institutions in the sector. Fórum Oceano has more than

150 members from different sectors, bringing together companies, associations and institutions in the sector and playing a key role in promoting the country's maritime economy.

Presented below are a series of use-cases related to how space-enabled robotics can transform maritime operations, making it more efficient, safer, and environmentally responsible. The integration of satellite technology with robotics provides a powerful means of better understanding and managing the complexities of the maritime domain.

2.1.1. Remote Acoustic Modelling for Noise Pollution Mitigation in the Oceans

Anthropogenic noise poses a critical threat to marine ecosystems, making underwater acoustics an essential tool for maritime environmental assessments. The soundscape has been chosen as one of the descriptors of the EU Marine Strategy Framework Directive to characterise the health of the European coastal areas. However, tracking such noise in real-time and enforcing associated regulations presents significant challenges. This includes access to reliable real-time noise maps, the tracking of the noise that could be mitigated and the costs related to both activities.

New methods that can autonomously monitor and evaluate the users of the sea in real-time and assess their impact (and potential impact), allowing for proactive flagging of non-compliance are therefore needed. By integrating satellite imagery with Automatic Identification System (AIS) data, it becomes more feasible to identify sources of excessive marine noise, evaluate the related activities and determine the expected noise emissions of the sources. The expected emitted sound pressure levels could then be propagated in the area of interest, using satellite data as supporting inputs for the noise propagation modelling. In the event of excessive noise, this system could trigger alarms, to autonomously instigate local surveillance and warnings to the noise emitter to enforce local regulations.

2.1.2. Automated Detection of Noise Sources in the Oceans

Underwater surveillance is essential for multiple applications such as security, protection of critical offshore infrastructures, and maritime conservation. Visual methods using cameras offer limited range due to the poor visibility in marine environments, whereas acoustic technologies allow to reach a much wider monitoring area.

Currently, hydrophone technologies capable of long-term and real-time underwater acoustic surveillance are limited and extremely expensive. Instead, an affordable, reliable (i.e. validated with different data sources), autonomous (i.e. with access to power and real-time communications for data sharing) solution is required. Coupling the acoustic data with state-of-the-art AI detection algorithms and high-resolution satellite imagery could enable the identification and validation of noise sources more effectively. Such a system would enhance early detection of potential threats, improving the protection of both marine ecosystems and critical maritime infrastructure.

2.1.3. Enhance Real-Time Oceanographic Data Collection and Forecasting

In regions like the dynamic coastal zones near the Nazaré Canyon, autonomous underwater vehicles (AUVs), gliders, and autonomous surface vehicles (ASVs) are deployed to gather critical data such as temperature, salinity, and ocean currents. These areas exhibit high temporal and spatial variability, challenging traditional data collection and leading to uncertainties in satellite observations.

Integrated with satellite products, autonomous marine systems bridge this gap by providing real-time, high-resolution data rapidly assimilated into ocean models, such as those stored in repositories like EMODNET. [1] This approach reduces model uncertainty and improves forecasting accuracy, enabling optimised vehicle routes that target high-priority regions. For example, these platforms validate satellite-derived data in near-real-time by measuring oceanic variables and then feeding this data back into predictive models, forming a feedback loop that enhances both future satellite products and model predictions. This integration of robotics and satellite cross-validation can significantly improve our understanding of coastal ocean processes, benefiting scientific research, environmental monitoring, and naval operation.

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[1] Home | European Marine Observation and Data Network (EMODnet) (europa.eu)

2.1.4. Critical Infrastructure Monitoring

Autonomous underwater vehicles (AUVs) equipped with sonar systems can map the seafloor, creating detailed charts for navigation and resource exploration. Satellite data is able to help identify target areas and optimise survey routes, of particular interest due to revived interest in exploring ocean resources and inspection and maintenance in the offshore energy domain.

Autonomous systems can also offer added value in inspection of underwater infrastructure such as pipelines, cables, and offshore platforms. Satellite imagery may aid in planning and executing these inspections efficiently.

2.1.5. Border Security

Space-enabled robotics can assist in monitoring and securing maritime borders. Drones equipped with sensors provide a means to carry out real-time surveillance, track suspicious activities and detect illegal fishing.

In-situ autonomous systems can inspect and secure port facilities, including monitoring cargo and detecting potential security threats. Satellite imagery may help coordinate these efforts and identify areas of concern.

2.1.6. Disaster management

Space-enabled robotics can assess damage to coastal infrastructure and marine environments after disasters such as hurricanes or tsunamis. Satellites provide wide-area imagery, while drones and AUVs can perform detailed on-site inspections. Also, satellites may facilitate the coordination of emergency response efforts, ensuring that robotic systems are deployed effectively to assist with disaster relief.

2.1.7. Search and Rescue Operations

Space-enabled robotics can use satellite imagery and data to locate missing vessels or individuals at sea. Drones and autonomous underwater vehicles (AUVs) can be dispatched and navigated based on real-time satellite coordinates and environmental conditions. Also, satellites may provide critical communication links for coordinating rescue missions, allowing for better tracking and managing rescue operations.

2.1.8. Marine Pollution Management

Recent advances in remote sensing technologies show promise for detecting floating marine debris and mapping microplastics globally. Current methods, like inspecting fish stomachs or filtering water samples, offer limited understanding of microplastics' distribution and impact in bodies of water. Improved means of detecting and mapping microplastics and marine debris are needed, potentially aided by satellite data and autonomous robotic systems (aerial and/or water surface). Use of hyperspectral and other satellite data may offer an avenue towards this end.

Moreover, marine oil spills cause severe damage to marine life and ecosystems, with incidents frequently occurring during petroleum exploration, production, and transport. Notable spills include the Deepwater Horizon disaster (2010), which released over a significant tonnage of crude oil into the Gulf of Mexico, the Jakob Maersk spill (1975) and Prestige spill (2002) in the NW Iberian Peninsula, both significant environmental disasters. Immediate response typically involves physical and chemical methods to control oil spread, but these do not aid in ecological restoration. Bioremediation using oil-degrading microorganisms offers an eco-friendly solution, utilising diverse microbial consortia to fully decompose petroleum hydrocarbons. Satellite-based solutions alongside in-situ surveys (such as via Unmanned Aerial Vehicles) can enable an early detection and mitigation of the problem in an efficient manner.

2.1.9. Marine Resources Management

Marine resource management involves the sustainable and effective use of ocean and coastal resources to balance ecological health, economic benefits, and social well-being. It encompasses a wide range of activities and strategies aimed at preserving marine environments while enabling their use for human purposes. Autonomous systems can assist in monitoring fishing activities and enforcing regulations to ensure sustainable practices. Satellite data may complement by tracking fishing fleets and their activities.

Robotic and autonomous systems equipped with advanced sensors can explore and analyse marine resources, such as mineral deposits, with satellite-based guidance aiding in the identification of potential resource-rich areas.

2.1.10. Port Air Quality and Marine Pollution Monitoring

In the scope of emerging stringent European regulations on pollution and Green Deal requirements, there is an increased need for monitoring of port water quality and atmospheric measurements. Combined use of satellite data with in-situ measurements is expected to improve the evaluation of the deployment of transformative environmental monitoring and management services. This covering broader parameters across water (oil spills, plastics, exotic species) and air quality (COx, SOx, NOx, PM10, PM2.5) monitoring than traditional solutions. This data should be available under normal operating conditions as well as under extreme weather events, enabling evaluation of climate change impacts.

2.1.11. Marine Traffic Management

Space-based navigation systems help manage and track fleets of autonomous ships and drones. Although these have not been fully implemented, autonomous ships are expected to become a reality in the near future. These systems will ensure accurate positioning and collision avoidance, critical for improving maritime traffic management as these systems become operational. Satellite data can also assist in optimising shipping routes for autonomous vessels, considering factors like weather conditions and ocean currents.

2.1.12. Environmental and Oceanographic Weather Forecast

Space-based observations combined with robotic sensors can enhance oceanographic research, providing data on ocean currents, temperatures, and other critical parameters. Robotics and satellite data may help monitor and analyse the impacts of climate change on marine environments, including sea level rise, ice melt, and shifting marine ecosystems. Moreover, biochemical monitoring of the ocean can be improved with in-situ systems such as floating or moored ocean observatories, combined with data gathered from satellites.