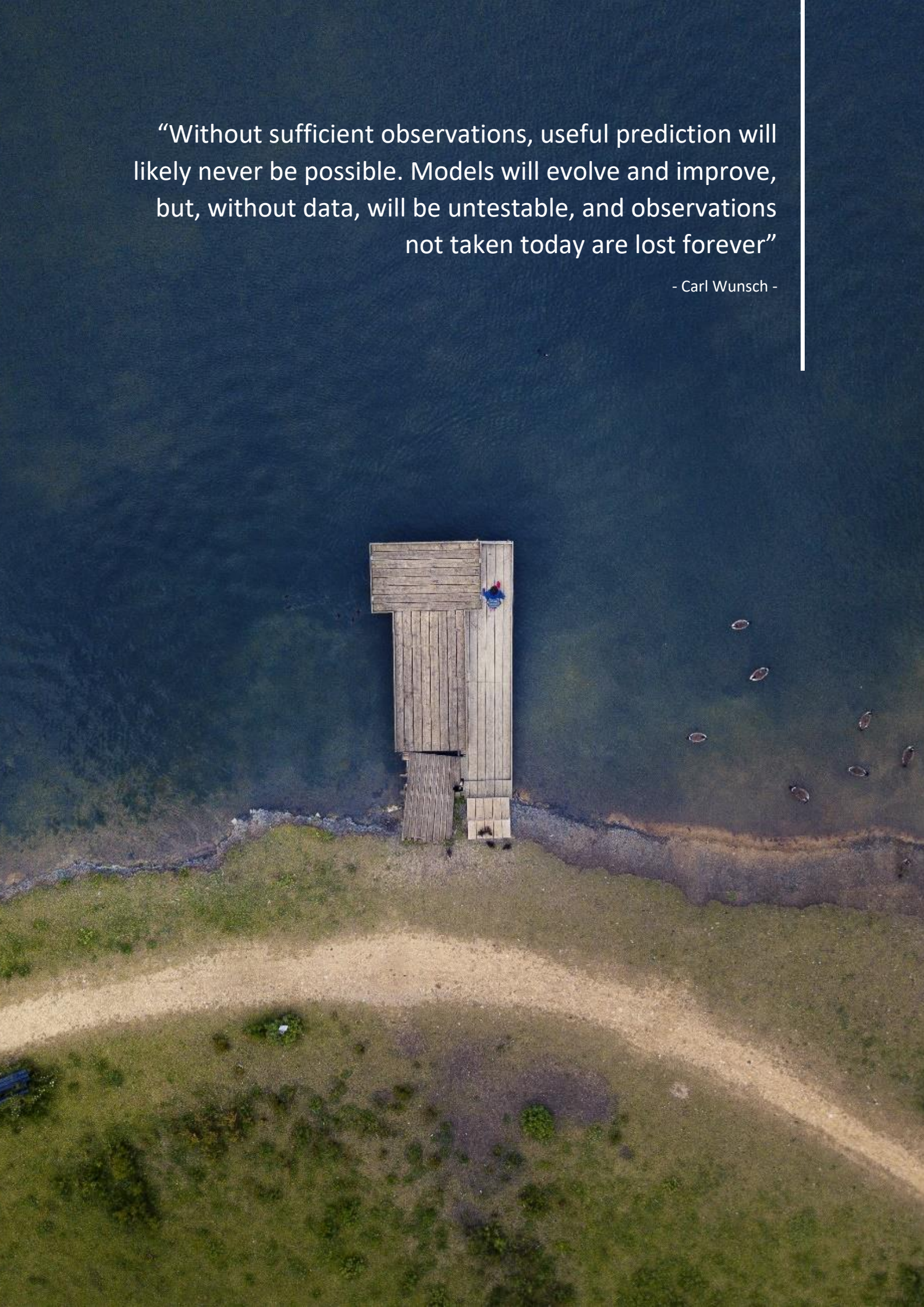
UNDERSEE:

Improved decision-making with satellite observations and forecasting of water quality changes in marine environments

“Without sufficient observations, useful prediction will likely never be possible. Models will evolve and improve, but, without data, will be untestable, and observations not taken today are lost forever”

- Carl Wunsch -



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BACKGROUND AND PROJECT OBJECTIVES

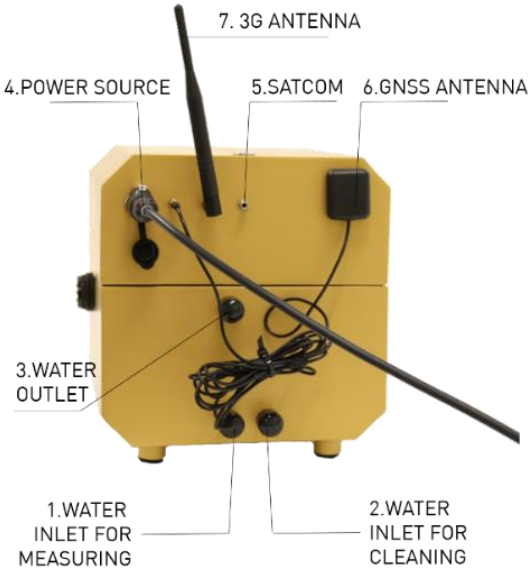
Marine environments continue to be severely under-sampled and environmental monitoring programs suffer from unsustainable funding in the long term and at the same time gathering the required ocean information can prove costly.

Traditional water monitoring technology requires high human intervention in operational aspects, especially in equipment's installation, maintenance and calibration. Water data-based customers (e.g. aquaculture producers) are mostly focused on their core activity rather than in the reliability of the data, which normally leads to low quality of data. The solution is an easy-to-use daily management tool, which are intended to supply relevant and timely information, allowing customers to take informed management decisions based on **actionable data**. Moreover, if to the standard offer of in-situ water data acquisition, we include satellite observation data and forecasting tools (from numerical models) to the same daily management tool, customer operations are enhanced due to a complete set of data and insights at different scales and temporal resolutions.

UNDERSEE is developing an end-to-end service with an integrated offering of hardware, software, installation and customer support, based on a **Connected Product-as-a-Service** model where customers subscribe for the usage of the product (subscription fee) and automated decision-making tools. This approach increases significantly the value proposition and confidence in the UNDERSEE's services and creates opportunities to build ongoing, meaningful relationships with customers based on value co-creation.

The integration of in-situ data, satellite data and numerical modelling for water quality forecasting for the upcoming days is a combination that offers not only the accuracy of in-situ measurements, but also the decision-making opportunity retrieved from the satellite observation and the forecasting models.

UNDERSEE created a compact and easy to install in-situ water data acquisition system (**UNDERSEE_water**) and a user-friendly cloud platform (**UNDERSEE_cloud**), which enables the spread of ***Ships of Opportunity*** *and* ***Precision Aquaculture*** projects in a large scale.



UNDERSEE_water device and UNDERSEE_cloud

The **UNDERSEE_water** system is **the first Portuguese 'FerryBox'** system, similar to those used in ***Ships of Opportunity*** programs. It consists in a bypass circuit of water to the boat main hydraulic system, where the flow-through equipment, including all sensors, are implemented. These 'FerryBoxes' systems are usually operated by Research Centres in the framework of funding programs. In the same way, UNDERSEE_water can be implemented in buoys or directly to aquaculture cages.

The UNDERSEE_water have the following **advantages** comparing with traditional ´Ferryboxes´: 1) Smaller and lighter; 2) Plug and Play solution, much simpler to install and operate; 3) Adaptable to boats, buoys and aquaculture cages; 4) Reduced cost compared with existing systems; 5) Lower sensor maintenance requirements.

The UNDERSEE solution is composed by the following features:

"**Data integration":** It comprehends the in-situ water data collection, its transmission in real-time to the cloud platform and their use for numerical validation. The water quality sensors monitor the **state of the water in real-time**, offering to the user its present and historical values, fluctuations, maximum and minimum. This data can also be used to validate both Earth Observation Data (EOD) products and numerical models as they always require validation from in-situ measurements to be certain about their representativity and reliability. The integration and validation of EOD and numerical

models in a simple to use tool, represents a huge competitive advantage for UNDERSEE comparing to existing commercial solutions.

"**Managing tools**": in-situ data is integrated with EOD and numerical models in the cloud platform. The integration of EOD and numerical models for water quality dynamics and forecasting as a commercial **daily management tool** is a huge step forward in the field of marine environments monitoring. This feature enables stakeholders to move from a reactive to a **preventive decision-making process** regarding possible water contaminations and threats which allows to act in advance and prevent risks. This feature enables the implementation of **risk alerts and early warnings** of possible water quality changes, for example due to excessive nutrients in the water originated from agricultural and industrial activities and urban wastewaters, or severe oxygen depletion events.

The water data provided are:

• Water temperature (important indicator of climate change; actionable data for aquaculture production);

• pH (important indicator of the extent of ocean acidification);

• Dissolved Oxygen (DO) (Indicator for the indirect effects of eutrophication; Actionable data for aquaculture production);

• Salinity/Conductivity (Changes in the distribution of salinity in the (surface) ocean are good indicators of changes in the global hydrological cycle);

• Turbidity (strongly correlated with sediment, nutrients and bacteria; indicator for the direct effects of eutrophication);

• Chlorophyll-α (phytoplankton biomass indicator; indicator for the direct effects of eutrophication);

• Oxidation/Reduction Potential (ORP is typically measured to determine the oxidizing or reducing potential of a water sample. It indicates possible contamination, especially by industrial wastewater).

SERVICE AND USERS AND CUSTOMERS

The UNDERSEE service targets are **environmental monitoring** and **aquaculture monitoring** segments.

The UNDERSEE decision-making tool is used by **environmental agencies** to improve decision-making process and to implement actions in due time and **decrease the number of water sampling campaigns**. **Aquaculture producers** can plan their daily activities for e.g. **optimise fish feeding** based on actionable data and **prevent losses** from e.g. hypoxia or algae blooms events.

Beyond the advantages of using UNDERSEE solution already mentioned, the customer relationship is enhanced due to an innovative service model approach, compared to sensors providers. UNDERSEE pricing is based on a set-up fee and an annual management fee only paid after the activation of the service (when the customer starts to receive the data). No sensor maintenance is required by the user.

Environmental Monitoring:

Customers are entities with legal responsibility to monitor the water quality of marine environments and to maintain the state of the water in good levels, and entities with marine research related activities working with satellite data and numerical models. Users are environmental agencies, Research Centres, Ports Management, Wastewater Management Companies or Municipalities which has the need to access data in a standard and easy way.

The **champion customer** profile for the environmental monitoring segment is represented by **IPMA, The Portuguese Institute for Sea and Atmosphere**. IPMA is a Governmental Institute devoted to Ocean and Atmospheric Sciences and Technologies with the mission of providing technical and scientific support to national policy definition, operating and maintaining state-owned scientific infrastructures, acquiring data, processing and maintaining the national scientific databases on its areas of competence, and of promoting and coordinating scientific research and technological development.

The feedback from IPMA regarding UNDERSEE solution is described in the following:

“Integrated ocean observation systems, combining in-situ data with satellite remote sensing observations and numerical ocean model results, are fundamental for Portugal. The Sea is one of the main vectors of national development and of major importance for sustainable smart economic growth. **The large extension of the Portuguese EEZ (Exclusive Economic Zone),** with over 1.7 million km2, with a recent increase of about 2.1 million km2 with the proposal submitted for the extension of the legal continental shelf, gives Portugal jurisdiction over about 3.8 million km2 of immersed territory. This will bring many **opportunities for the exploitation of marine resources** and an increase of sea-related economic activities, but also major challenges for the management,

monitoring and sustainable use of these marine ecosystems, which must be supported by a thorough knowledge of this entire Portuguese Sea. This knowledge will only be possible with **long-term ocean observation systems**, which will require a large operational capacity and financial effort. In this sense, the **UNDERSEE solution** makes a huge contribution to the Portuguese Sea monitoring, namely due to th**e lack of time series of environmental observations**. needed for a proper assessment of climate impacts on the entire Earth System. For example, observations that allows the prediction of anomalous growths of harmful microalgae are of great importance for public health, but also for economic sectors such as aquaculture or tourism." - A. Miguel Santos (Senior Scientist of IPMA)

Aquaculture Monitoring:

With global population expansion, the demand for high-quality protein is rising dramatically, and fish farming is gaining importance to ensure food security. Aquaculture is by result one of the fastest growing food production sectors worldwide and while environmental conditions determine the growth and health of the produced species, the fish production can also impact the surrounding environment. Therefore, there is a sea of opportunities for increasing quality and efficient aquaculture in Europe, but it can still be vulnerable to unpredicted events such as contaminants, hypoxia, eutrophication and disease, that need to be quickly detected and responded. Traditional water monitoring technology requires a **high human intervention regarding sensor operations and maintenance** which normally leads to low quality of data sets since aquaculture companies are focused on the production instead of water quality monitoring tasks. This means that aquaculture farmers still face many challenges, from reducing production costs and labour to losing stock to diseases and water contamination. To overcome these challenges, while becoming more competitive in the market, aquaculture companies begun to make operational decisions based on reliable water quality data and dynamics of the water. However, at present, aquaculture producers do not have easy access to a **daily management tool** with relevant and timely information to assist in making informed management decisions based on **actionable data**. Shellfish producers or fish-farmers can use UNDERSEE solution to prevent production losses and optimize fish feeding and growth - ***Precision Aquaculture***, as farmers will get access to predictions about dissolved oxygen for the upcoming days and early warnings via SMS or e-mail about possible algae blooms threats or severe oxygen depletion events.

To the date, UNDERSEE has achieved the following milestones:

- In the framework of MyCOAST project – Coordinated Atlantic Coastal Operational Oceanographic Observatory, the **UNDERSEE ´Ferry Box´** system is implemented in a ´Cacilheiro´ boat which navigates in a daily basis in the Tagus Estuary - Lisbon. The boat will stay collecting water quality data to our cloud platform for 18 months contract and the customer, IST -Técnico Lisboa, will use the data to validate water quality forecasting;

At left the "Cacilheiro" ferry at the shipyard and at right the UNDERSEE_water installed in the engine room.

- 10 Letters of Intent from relevant stakeholders (e.g. IPMA, UN Environment, NIVA, Shellfish producers, Fish-farmers).

- UNDERSEE received recently the information that IPMA is currently placing an order request to install 4 UNDERSEE_water units in boats, transcribed further:

"IPMA is going to adopt the UNDERSEE solution and service for environmental monitoring of Portuguese coastline under the following projects under my coordination: (i) "OBSERVA.PT-Observations on board national **commercial ships** to support the conservation of marine biodiversity in the Portuguese Seas (16-01-04-FMP-002)", funded by the UE and the Portuguese Government under the Mar2020 Programme; and (ii) "OBSERVA.FISH-Autonomous Observing Systems in **Fishing Vessels** for the Support of Marine Ecosystem Management (PTDC/CTA-AMB/31141/2017)", funded by the UE and FCT under the Portugal2020 Programme Lisboa2020 and Algarve2020" – *Letter of Intent - September 18th, 2019*.

DEMONSTRATION PROJECT

The demonstration project planned to start in the Q1 2020, to be **co-funded by ESA Business Applications** until Q3 2021, will contribute decisively to the validation of the proposed service and implementation of the already mentioned features. The starting point of the project is the ongoing implementation of the UNDERSEE_water 'FerryBox' related infrastructure in Tagus river - Lisbon.

The main objectives of the demo project are:

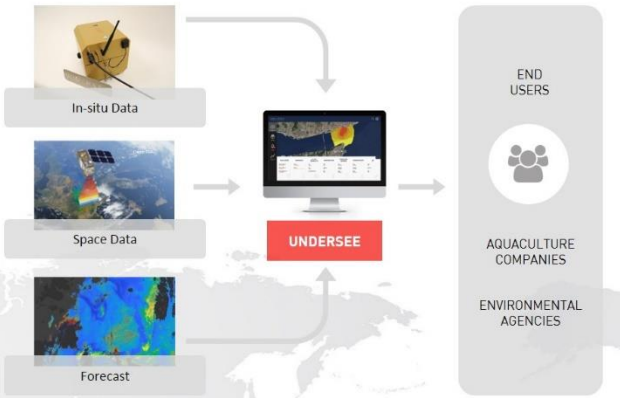
- Develop, test and implement a scalable and integrated solution for water quality monitoring in marine environments;
- Validate the accuracy of data collected from the ferry boat and from satellite imagery through **data integration**;
- Lower **maintenance** of in-situ data sensors;
- Implement an easy-to-access tool that supplies relevant and timely information, to make informed management decisions based on actionable data. **Real-time alerts** of water quality changes will be implemented as well **early warnings** of possible contaminations;
- An easy to access platform and **API**´s to validate satellite data and prediction models;
- Easy access to data with formats according the **EMODnet European Central Portal** (e.g. NetCDF4);
- **Standardisation** of data sets and implementation of an **API**´s to easily communicate with different cloud-platforms;
- Implementation of operational Copernicus forecasting tools for algae blooms;
- Implementation of operational down-scaling hydrodynamic models and predictions about water parameters for the upcoming days (e.g. Temp, DO) – which can be also applied to locations abroad (e.g. Norwegian Fjords)**;**
- Engage with potential users and customers towards new early adopters, paid and monitoring contracts.

Demonstration Projects in the field **of ESA Business Applications** are dedicated to the implementation of pre-operational demonstration services within the ESA Business Applications programme, which therefore comply with the following requirements: they are user driven (**including user involvement and contribution),** they benefit from the integrated use of one or more space assets, with clear potential to become sustainable in the post project phase.

The demonstration project will be implemented with involvement and contributions from IPMA (The Portuguese Institute for Sea and Atmosphere), INESC Coimbra (The Institute for Systems Engineering and Computers of Coimbra) , IST – Técnico Lisboa and NIVA (The Norwegian Institute for Water Research).

APPENDIX - PRODUCT / SERVICE BROCHURE

The Service



UNDERSEE

WATERWORLD SENSING FOR PERFORMANCE AND SUSTAINABILITY

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Products

#WATER

UNDERSEE #water is a small and easy-to-install device, equipped with state-of-the-art sensors technology used to collect data from water bodies at real-time. The core parameters measured are:

- Water quality:
  - Temperature;
  - pH;
  - Dissolved oxygen;
  - ORP;
  - Conductivity/Salinity;
  - Turbidity;
  - Chlorophyll-a

#CLOUD

At UNDERSEE #cloud dashboard the user will be able to get easy access to several parameters and features as the following:

- Check water parameters in real-time;
- Define alerts, faults and insights;
- Review historical data of water quality;
- View dynamic maps of water data;
- Validation and calibration of both space data and forecast models against in-situ data;
- Automated decision-making tools based on early warnings.

Environmental Monitoring

SHIPS OF OPPORTUNITY

UNDERSEE is a new generation of "ferry-boxes" technology allowing automated measurements aboard ships of opportunity.

- ✓ Plug-and-play.
- ✓ Low weight.
- ✓ Real-time water quality changes and forecasts.
- ✓ 2D maps of water quality.
- ✓ Early warnings of possible water quality changes.

Aquaculture Monitoring

PRECISION AQUACULTURE

UNDERSEE provides a scalable monitoring service that allows aquaculture companies to save their fish from sudden water quality changes without dealing with sensor maintenance.

- ✓ Plug-and-play.
- ✓ Measures in depth.
- ✓ Ability to add IoT tools (e.g. automate aerators).
- ✓ Dissolved Oxygen forecast for the upcoming days.
- ✓ Early warnings of Algae blooms and severe oxygen depletion.