PROJECT FINAL REPORT

Grant Agreement number: 614102

Project Acronym: NeXOS

Project Title: "Next generation, cost-effective, compact, multifunctional web enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management"

Date of latest version of Annex I against which the assessment will be made:

Periodic report: 3rd

Period covered: From 37th month (October 2016) to 48th month (September 2017)

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COOPERATION	NeXOS - Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management, is funded by the European Commission's 7th Framework Programme - Grant Agreement Nº 614102

1. FINAL PUBLISHABLE SUMMARY REPORT

1.1. An executive summary

Ocean processes are of biological, geological, chemical or physical nature, occurring at micro- to kilometre scales, from less than seconds to centuries, turning the understanding and the sustainable management of the ocean into a multi-scale and multi-disciplinary effort. The European FP7 project NeXOS addresses the challenges above by answering to the key environmental descriptors identified by the European Marine Strategy Framework Directive (MSFD) with a set of new generation multifunctional, compact, interoperable and Web enabled optical and acoustical sensor systems as well as sensors for fisheries management.

Cost-efficiency is improved through specific innovations of broad spectrum, robust, complementary measurement technologies that can be hosted by existing in-situ observing systems, including mobile platforms (drifters, gliders, vessels) and fixed platforms (buoys, moorings, seafloor stations, cabled observatories).

These sensor systems have been designed, built, tested and validated in a number of platforms using scenarios that are demonstrations of applications for long-term implementation.

In this report, the context and the specific objectives of the NeXOS project are presented, followed by a description of the main scientific and technical results obtained for each objective. The outcomes of the project range from specific innovations, such as Optical, Passive acoustic and EAF sensors, to transversal innovations such as sensor and data interoperability and an antifouling system. Finally, the potential impacts of the project's results are discussed.

The outcomes of NeXOS are expected to have a wide influence in different fields. The design specifications and developed technological solutions provide a base for the reduction of costs and increase in the spatial and time resolution of marine observations, through the use of cost-effective methods and technologies. The applied system engineering methodology, which follows a traceable path from user and market requirements to validation and demonstration of the new sensors may serve as guidelines and example for future projects. The NeXOS project, through the development of several new sensor technologies of high technology readiness levels, also significantly contributed to the benefit of European SMEs involved in the oceanic engineering sector.

1.2. A summary description of project context and objectives

Oceans regulate the Earth's climate and are integral to all known sources of life. Ocean processes are of biological, geological, chemical or physical nature, occurring at micro- to kilometre scales, from less than seconds to centuries, turning the understanding and the sustainable management of the ocean into a multi-scale and multi-disciplinary effort. Collection of in-situ observation of a volume that covers over 70% of the planet is also inherently challenging and remains generally difficult and costly in time and resources, with yet and so far, a rather unsatisfactory result, in particular with respect to space-time resolution. Most chemical sampling methods are still experimental and expeditionary, i.e. based on costly laboratory analysis and field campaigns. These can also only harvest data for a limited time-space window, resulting in the problem of insufficient sampling resolution with potential, spectral aliasing. At the other end of observation strategies, real-time or near real-time permanent ocean observatories need to be more cost-effective and pervasive. As was highlighted in the ESONET project, reducing the frequency of sensor maintenance and implementing a remote management of sensors are important targets for cost-reduction. Following this trend, new sensor system transducers are also needed, which can measure several parameters with enhanced reliability.

European marine policy makers stated in the “Ostend Declaration” of 2010 that the major challenge is now to support the development of a truly integrated and sustainably funded European Ocean Observing System (EOOS) to monitor key ocean processes. This would form the European component of the Global Ocean Observing System (GOOS), and would continuously monitor the European seas from near-coastal to open ocean, and surface waters to seafloor. Fixed and mobile observing platforms would be used to offer real-time, or near real-time, open and standard downstream services to the public and private sectors. To achieve this, more long-term measurements of key parameters are required, but the costs and unreliability of ocean sensors remain a major problem.

The general priority for all observing systems, monitoring strategies and sensor technologies is therefore to create mechanisms and technologies such that data has greater societal and scientific value, and the overall life cycle cost of sensors and observing systems is reduced. This will be achieved by innovations in data accessibility, reliability, interoperability and multifunctionality for the key ocean variables.

The general objective of NeXOS is to develop new cost-effective, innovative and compact integrated multifunctional sensor systems (ocean optics, ocean passive acoustics, Ecosystem Approach to Fisheries (EAF) sensor system), which can be deployed from mobile and fixed ocean observing platforms, as well as to develop downstream services for GOOS, Good Environmental Status (GES) and the Common Fisheries Policy (CFP). This will be achieved through the following specific objectives:

- To develop a new, compact and cost-efficient multifunctional sensor system for optical measurement of several parameters, including contaminants such as hydrocarbons and other components of the carbon cycle. This sensor will contribute to the monitoring requirements of the MSFD on Good Environmental Status, as it relates to hazardous substances and environmental parameters.
- To develop a new cost-efficient compact and integrated sensor system for passive acoustic measurements. Development focused on the pre and post processing of acoustic information and improved transducer integration, reducing size and cost while increasing functionality in one integrated acoustics sensor system. Embedded processing is reconfigurable, allowing the monitoring of related MSFD/GES descriptors 1 (Biodiversity) and 11 (Underwater Noise).
- To develop a new low-cost sensor system for an ecosystem approach to fisheries management. providing measurement of stock-relevant parameters, including fluorescence (proxy of chlorophyll-a) and oxygen, in addition to the currently measured physical parameters (T, S, Depth). The development built upon the RECOPESCA system and will support the Common Fisheries Policy and MSFD for Good Environmental Status by including new biogeochemical parameters of interest to EAF.
- To develop and integrate a miniaturised smart sensor interface common to all new NeXOS sensor systems. This interoperable standard interface is reconfigurable in order to respond to sensor specificities and monitoring strategies and allows to connect to the majority of ocean observing platforms. The reconfiguration capacity allows the interface to be tailored to fulfil the power, communication and maintenance needs of a range of sensors for a variety of disciplines.

- To develop and apply innovative sensor antifouling technologies, which are the main limiting factor of sensor reliability, and to develop and test improvements based on cost-efficiency, power-efficiency and economic viability. The technology addresses the reliability requirements of current sensor systems, and improves cost-efficiency by the reduction of high-cost maintenance needs of observing systems.
- To develop a common toolset for web-enabled and reconfigurable downstream services, for European marine databases and data facilitators, from Seadatanet to IOC services such as GOOS, and the GEOSS. These services facilitate publication of data in a standard format to global ocean observing initiatives and ocean modelling portals such as MyOcean, in agreement with the INSPIRE directive and the GEOSS guidelines.
- To assess and optimise the economic feasibility and viability of the new sensor developments including the manufacturing phase, in the context of large scale industrial production and accounting for the operational phase of the life cycle of the sensors, addressing the position of European SMEs and industry players vis-à-vis their competitors.
- To demonstrate new developments in real operational scenarios collaborating with pre-defined scientific and oceanographic missions, observatory maintenance, industrial sea operations (e.g. Oil&Gas) and fisheries fleet operations.
- To work with producer and user communities to upgrade requirements and provide a system that allows easier transition to manufacturing and operations, bridging the gaps between science, industry and government.
- To manage and coordinate the specific aims described above, and contribute to dissemination and outreach, to communicate the results and innovations of NeXOS to the European and Global Ocean Community. Working with – and across – communities of users, operators and producers of sensor systems.

1.3. A description of the main S&T results/foregrounds

The NeXOS Project developed several innovative sensor technologies to increase the temporal and spatial resolution of the monitoring of the marine environment. Results of the Project offer significant advantages over existing systems, not only from the perspective of performance, but also from the capability to be easily integrated into a wide variety of platforms. To increase the reliability of optical sensors in particular, a new antifouling system has been developed to work with the sensors. These sensor systems have been designed, built, tested and validated for specific technologies and monitoring strategies. They feature enhanced interoperability features through open standards, such as the OGC-PUCK plug and play capability, data interfacing and transmission protocols (OGC-SWE sensor web enablement that addresses the flow of information from sensor to user).

The main scientific and technical results of NeXOS go beyond just sensors to systems that simultaneously address multiple objectives and applications of increasing importance. The new methods also notably have potential to reduce costs due to their capacity to be multifunctional (single sensor systems addressing several phenomena), be deployed on a large majority of ocean monitoring systems from surface to the seafloor, and, be operated for long periods with less maintenance needs. They can address a number of the important challenges that have been indicated as impacts in the following chapter.

Thus, NeXOS takes a perspective of both sensors and sensor systems with significant advantages over existing observing capabilities via the implementation of innovations such as multiplatform integration, greater reliability through better antifouling management and greater sensor and data interoperability through use of OGC standards.

The main project's results are reported with more detail in the following sections.

1.3.1 New sensor systems for passive acoustic measurements

In marine applications, although regulations are now in place for underwater noise (MSFD Descriptor 11), marine acoustic sensors and acoustic data processing remain costly. This is due to acquisition and transmission costs and the need for experts at several stages of the process, from sensor operation to data processing. A European task group on underwater noise was formed and proposed the establishment of a set of underwater noise observations as a monitoring solution to GES Descriptor 11/Underwater Noise, as well as noise indicators. In addition to monitoring noise, new sensors and platforms can provide cost-efficient information for the assessment of marine mammal populations. Other applications include the detection of fish reproduction areas, the non-lethal mitigation of catch depredation by whales in fisheries activities, detection of Green-House Gas (GHG) seeps from pipelines and deep sea carbon storage, gasification of methane clathrates estimation of rainfall, detection of low-frequency seismic events, ice-cracking, ocean basin thermometry and tomography and acoustic communication. The existing ocean passive acoustic sensor systems generally face the following technical shortcomings: (1) Current passive acoustic sensors are not able to perform measurement of sound level extremes (very low and very high), e.g. of 50 to 180dB re. 1µPa; (2) the lack of onboard processing overloads the communication links if near real time data is desired; and (3) Acoustic system power requirements currently limit the long time continuous use on mobile battery operated platforms such as gliders.

To address these challenges, NeXOS produced new sensor systems called A1 and A2, which have the following characteristics: the analog front-end is designed to reduce input noise level and the signal is digitized by low-noise converters, which results in the ability to measure below Sea State Zero and very high sound pressure levels. The digital sensors, if used in array configuration, were designed to allow simultaneous sampling so they can be used for accurate phase measurement and source localization. Embedded pre-processing of data supports low bandwidth communication links. Use of reliable low-cost, low-power components and technologies have been implemented for deployment on open-ocean low-power platforms. Compactness was also prioritised for integration on mobile platforms like profilers and gliders. The new NeXOS sensor systems have two configurations. A1 is a compact, low power multifunctional passive acoustics sensor system (a.k.a smart digital hydrophone), enabling on-platform measurement and characterization of underwater noise and several soundscape sources, aimed for platforms with autonomy and/or limited communication capability. The A2 sensor builds on A1s upgraded with Ethernet communication capability and is a compact multifunctional passive acoustics array, enabling real-time waveform streaming for the measurement of underwater noise and soundscapes, and providing directional information.

1.3.2 New sensor systems for optical measurements

The project has developed three types optical sensors systems: O1 sensors are based on the use of fluorescence, O2 on absorption, and O3 on Carbon sensing.

O1s are new compact, low-power multifunctional optical sensor systems based on multi-wavelength fluorescent technology. Their aim is to provide detailed information on both water constituents and other relevant contaminants that are optically active in different spectral regions. Fluorescence information from laboratory measurements is done via excitation-emission-matrix (EEM) spectroscopy. However, this has disadvantages including extensive sample preparation, long measurement times and delays that may entail changes in the sample. All these issues can be addressed and avoided by in-situ measurements. In NeXOS, three different fluorescence sensor types have been constructed. Two of them, the MatrixFlu-UV and the MatrixFlu-VIS are based on a similar system design with different inner optical designs and complementary capabilities. Both use different combinations of three or four narrow band excitation and emission wavelengths. The third O1 system, the MiniFluo consists of two separated single channel fluorescence detectors within a single housing. It detects two distinct parameters in the water column, precisely dedicated to wavelength combination of fluorescence signals from hydrocarbons in the water.

O2 is represented by two devices for continuous flow-through measurements of water absorption coefficients: the OSCAR-G2 and the Hyperspectral Absorption Sensor. Both take advantage of the use of an integrating cavity, since this avoids errors introduced by light scattering on particles present in the sample and it increases the sensitivity of the measurements. From the hyperspectral (2 nm resolution) absorption coefficient data, which is the primary output of the sensors, phytoplankton-related information can be derived. Certain coefficients can be used as optical proxies for important bulk parameters like chlorophyll-a and total suspended matter (TSM), which are a quantitative measure of phytoplankton in the water. Furthermore, the shape of the spectrum can be evaluated with respect to taxonomical information, since it is determined by the presence of accessory pigments, which are often specific for certain types of phytoplankton. This phytoplankton identification is done by comparison of the measured spectrum to a database of spectra with known phytoplankton compositions. The algorithms for this approach have also been developed in the course of the project. Of the two instruments, the OSCAR-G2 is the more compact, submersible, and commercially available instrument manufactured by the project partner TriOS. It can be operated in flow-through mode both as bench-top instrument or connected to a profiling measurement or sampling system. The HyAbS is a prototype of the Helmholtz-Zentrum Geesthacht (HZG) of a completely automated absorption sensor dedicated for long-term usage as benchtop instrument in locations with no restrictions regarding power consumption. In the HyAbS, the complete measurement protocol can be customized by the user and carried out automatically.

The O3 carbon sensor is used for monitoring the calcium carbonate saturation state with enough accuracy to provide trends of threats to some marine organisms and their role in the ecosystem. This is observing some of the ecosystem impacts of ocean acidification. Fully understanding the carbonate system demands not only measuring temperature and salinity, but also knowledge of at least two of four measurable carbonate chemistry parameters: pH; dissolved inorganic carbon (DIC) which is the sum of all inorganic carbon sources (carbon dioxide (CO2), carbonic acid (H2CO3), bicarbonate ions (HCO3-) and carbonate ions (CO3--) in solution); total alkalinity (TA, the buffering capacity of seawater); and pCO2. If two of these parameters are known, then the calcium carbonate saturation state can be estimated. Two versions of the O3 have been developed, Cbon2 and Cbon3. Cbon2 is the system produced for combined pH and pCO2 analysis, both for mobile platforms and ferries. The Automated Flow-through Embedded Spectrophotometry (AFtES) unit is based on a miniaturized flow-through arrangement. Absorbance detection is supervised by a Debian based, versatile ARM architecture with custom electronics for signal conditioning, acquisition and controlling electromechanical parts. Water line is derived from the main water loop and is in parallel with the CO2 extraction branch. The light source is based on commercial LEDs controlled by custom electronics and D/A converters that accurately set light levels. In the Cbon2-fb version for ferries, pCO2 is measured by extraction from liquid phase in a continuous flow, followed by detection in the gas phase by a novel, selective, solid electrolyte sensor. The sensor needs high temperature to operate and provide enough current to be detected, resulting in limiting the application where continuously powered systems can operate, as onboard ships of opportunity. The system measures chemical-physical parameters of seawater. The Cbon3, available only for ferrybox applications, is basically a Cbon2-fb coupled with a total alkalinity analyser based on flow injection analysis. The procedure is an alternative to the standard operating procedure, where a titration of the sample with HCl in a cell occurs and a pH electrode is essential to determine the amount of hydrogen ions needed to balance the excess of anions of the sample. Here, the electrode is replaced with a dye suited for the pH range during the analysis and pH is measured spectrophotometrically. The whole system takes 5 minutes to carry out a single alkalinity measurement, 30 seconds for a pH analysis and 1 second for pCO2. Precision is down to 3 µmol/kgSW, yet at present accuracy is not at the level of analytical laboratory systems. Nevertheless, the possibility of measuring three quantities provides an outstanding advantage to refine calculations and apply correction factors. The O3 systems are web-enabled using the OGC PUCK and Sensor Web Enablement (SWE) standard protocols. The settings and sampling strategy of the systems can be modified remotely, according to weather conditions and power availability. For the SailBuoy application, data transfer is achieved by compact, low data flow satellite communication and data are visible real-time by a NeXOS client application. These ensembles implement, for the first time, novel solutions for providing researchers with monitoring ocean surface CO2 system with unprecedented resolution in time and space with high reliability and maintenance/attendance costs negligible compared to those needed for running conventional systems.

1.3.3 New sensor systems for Ecosystem Approach to Fisheries (EAF)

The EAF multi-functional sensor system builds upon the RECOPESCA concept and technologies by adding new observations relevant to fisheries management. The challenge in NeXOS was to develop cost efficient sensors that do not require any efforts by the fishermen and thus are self-powered and autonomous. Also, the sensors must be tough enough to be placed on commercial fishing gear. The existing RECOPESCA measures pressure, temperature, salinity and turbidity. It includes a hauler counter, specifically based on the ship weighting scale. A data concentrator is used to store and transmit the data to a shore management centre in near-real-time. For the EAF application, NeXOS created two additional sensors, one for oxygen and the other for fluorescence, which is a proxy for chlorophyll. These have application for both fish population assessments and as Essential Ocean Variables for the operational oceanographic community. To achieve low cost, existing sensor components were evaluated and inexpensive components offering adequate accuracy were selected.

The OEM transducer selected for the oxygen measures (gas or dissolved oxygen in liquids) is the Pico2 by Pyro Science Company. The module utilizes a measuring principle based on red light excitation and lifetime detection in the near infrared using unique luminescent oxygen indicators (REDFLASH technology). The measuring principle is based on the quenching of the REDFLASH indicator luminescence caused by collision between oxygen molecules and the REDFLASH indicators immobilized on the sensor tip of surface. The REDFLASH indicators are excitable with red light (more precisely: orange-red at a wavelength of 610-630 nm) and show an oxygen-dependent luminescence in the near infrared (NIR, 760-790 nm). The measuring principle is based on a sinusoidally modulated red excitation light. This results in a phase-shifted sinusoidally modulated emission in the NIR. The "Piccolo2" (a.k.a by the manufacturer and hereafter Pico2) measures this phase shift. The phase shift is then converted into oxygen units based on the Stern-Vollmer-Theory. The OEM transducer selected as fluorometer is made by Turner Designs. It is a single-channel, mini-fluorometer designed for monitoring fluorophores in water, as for example chlorophyll a. It is designed to be integrated into a multi- parameter system from which it receives power and delivers a voltage output proportional to fluorescence to the system data logger. The excitation wavelength is 460 nm and the emission wavelength is 620 – 715 nm. This OEM transducer provides a wide measurement dynamic range of 0.03 to 500 µg. L-1 for Chlorophyll a that can be scaled down by user-selectable gain. Voltage output can be correlated to concentration values by calibrating with a standard of known concentration. Both sensors have been integrated in the RECOPESCA system and the housing contains the electronic board and the battery, able to power the sensors for several months (variable, depending on environmental conditions) without batteries replacement.

1.3.4 Smart sensor interface common to all new NeXOS sensor systems

The Smart Electronic Interface for Sensor Interoperability (SEISI) consists of a multifunctional interface for several types of sensors and instruments, and it is responsible for data communication between them. The purpose of SEISI is to ensure that the sensors and actuators developed/deployed in NeXOS can be integrated in an interoperable manner so that it is available for further adaptations. As a result, a framework has been defined which comprises the following components: Analog transducer, or array of analog transducers requiring an analog front-end, a digital conversion as part of the hardware interface, and software interface (SEISI). A digitised transducer or array of digitised transducers (i.e. that include an Analog to Digital converter), sharing a common hardware and software interface. A distributed sensor (e.g. sensor network) under an existing control and communication layer, where data is located in repositories and only a Standard Software Interface (SSI) is required.

1.3.5 Innovative sensor antifouling technologies

Oceans environmental monitoring and seafloor exploitation need in situ sensors and optical devices (cameras, lights) in various locations and on various carriers in order to initiate and to calibrate environmental models or to operate underwater industrial process supervision. To be economically operational, these systems must be equipped with a biofouling protection dedicated to the sensors and optical devices used in situ and, generally, coastal monitoring system must be able to run without maintenance for 3 months in order for the system to be economically acceptable. For deep-sea observatories, ESONET, the European network of excellence for deep-sea observatories, defines maintenance interval recommendation from 12 up to 36 months. For optical sensors, NeXOS has developed a very efficient biofouling protection that is based on the coating of the optical window by a "transparent" conductive layer. This robust transparent conductive layer is polarised in order to generate a very low quantity of hypochlorous acid on the whole surface of the optical port. This technic offers a high level of robustness (no moving parts), a high level of protection efficiency (the whole optical window is protected) and consumes very low energy. It has the advantage to be an active technique that then can be turned ON and OFF in order to arrange free biocide generation period. This specific biofouling protection technic has been coupled to an ALVIM Srl biofilm sensor in order to apply the active biofouling protection only when fouling pressure is indeed sensed by the biofilm sensor. This allows to optimized at it's maximum the efficiency in term of energy needed and in term of biocide free period to allow proper measurements or usage of the optical device.

1.3.6 Common toolset for web-enabled and reconfigurable downstream services

NeXOS sensors have been developed compliant with the Open Geospatial Consortiums Sensor Web Enablement framework, avoiding proprietary protocols and non-standard architectures. With the objective of being deployed in a wide variety of observation platforms (gliders, buoys, cabled observatories, etc) each one with its own software and hardware layers and communications protocols, a standardized mechanism to remotely manage and configure these sensors was required, regardless of the hosting observation platform.

The Sensor Web Enablement Bridge (SWE Bridge) 'bridges' the gap between sensor systems and observation platforms. The bridge is an self-configurable acquisition software meant to be deployed on any kind of observation platforms, fixed or mobile, the main objective of which is to provide plug & work capabilities to any instrument, whether it is SWE-compliant or not. This software component, which acts as a cross-platform universal driver, configures itself from a SensorML description file. This SensorML file is a key piece of the architecture, as it contains both sensor metadata and the sensor's acquisition parameters for the acquisition software. Any Ethernet or serial sensor can be used with the SWE Bridge as it only needs a SensorML description file containing the sensor's description and acquisition configuration. The SOS Proxy is a software component, which acts as an intermediary between the acquisition platform and the SOS server. It injects the SWE Bridge output files containing observations to the SOS database. Additionally, it can also send requests to download a new SensorML description files, which can modify the current mission of the observation platform. The Sensor Observation Service Server is the software component that registers both sensor metadata and sensor data. Using a web client, it is possible to visualize both sensor data and metadata stored in the SOS database. Through the web client it is also possible to modify the existing SensorML description file for a specific instrument, modifying acquisition parameters such as sampling rate, post-measurement processing, etc. The Remote Configuration Service is a SOS-based approach to provide a new SensorML description file to the observation platforms. This file contains the new acquisition configuration parameters, which the SWE Bridge decodes and uses in the acquisition process. These new description files are written into the sensor's OGC-PUCK payload. Thus, the whole chain, from the sensor to the SOS Server, is aware of the current configuration. To determine if there is a new configuration file the SOS Proxy periodically sends requests to the SOS Server. If a new configuration file is available it is downloaded and sent to the SWE Bridge, which will be configured accordingly. Using this approach, the observation platform does not need to implement a server to accept tasking requests, which is an advantage in front of other protocols, reducing time of integration/operation and therefore costs.

1.4. The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results

- **<u>Provide a large increase in the temporal and geographic coverage from in-situ marine sensors to enhance the European contribution to Global Monitoring of the Oceans</u>**
    - The deployment of NeXOS multifunctional sensor systems enhance data production capabilities and the quality control necessary for reliable routine measurements.

Miniaturisation and standard interfacing further facilitate their use across different platforms, including floats, gliders, vessels of opportunity and fixed observing systems.
    - With their multifunctionality and multiplatform compatibility, NeXOS sensors increase the number of parameters that can be collected by the platforms currently used and increase measurement capability for new platforms.
    - New interfacing capabilities allow for real-time data to be collected without the need for a specialist.
    - Standard data and metadata descriptions make it possible to understand and easily integrate all the data collected by the new sensors.
- **Increase availability of standardised in-situ data that is suitable for integration within key marine observation, modelling and monitoring systems and reduce ocean modelling uncertainty**
    - NeXOS helps to resolve this by providing and validating sensors with defined accuracy and data quality that can be deployed on multiple platforms (due to small size, low power demand, low price).
    - The use of standard formats and protocols also allows the data to be more easily archived, and so improve accessibility for the user community.
- **Reduce cost of data collection system in support of fisheries management**
    - The combination of the new low-cost EAF sensors developed in NeXOS, with RECOPESCA as a cost-efficient observing system (fishing vessels equipped with low-cost and reliable sensors), contribute to further reduce the cost of the data collection system.
- **Advance competitiveness for European Industry's & particularly SME's within the Marine sensing sector**
    - NeXOS outcomes such as lowering the costs benefit SME players since it reduces the risk profile associated with investments. Increased sensor placements lead to an increased manufacturing capacity. NeXOS also contributed to the connection between scientific research and industry, giving further advantage to European SME competitiveness.
    - The NeXOS project provided added value to the European marine sensor industry, by addressing the industrialisation strategies required to realise the European economic added value from innovations.
- **Enable better cooperation between key sectors (Manufacturing Industry, ICT, Maritime Industry, Marine Science, Fisheries etc.)**
    - Through the research tasks as well as the dissemination plan, intensive exchange between stakeholders across various user sectors has taken place, ensuring requirements from all marine sectors are properly taken into account.
- **Support implementation of European Maritime Policies (MSFD, CFP, IMP, etc.)**
    - Thanks to the new developments, existing and emergent economic activities in the sea can better comply with the Good Environmental Status defined in the Marine Strategy Framework Directive (MSFD).
    - The Common Fisheries Policy can now be supported by new ecosystem-relevant data coming from fishing vessels, used as platforms of opportunity.
    - NeXOS worked towards a Common Information Sharing Environment (CISE) for the EU's maritime domain, in line with EMODNET, SEADATANET, My Ocean/Copernicus and GEO related initiatives.
    - The increase in the ocean monitoring capabilities will contribute to the areas targeted by the Blue Growth strategy, such as the sustainability of coastal tourism, ocean renewable energy, aquaculture and marine mineral resources.

- **<u>Promote new discoveries leading to better understanding of the seas.</u>**
  - The new sensors support improved understanding by making new observations of key variables, not possible or difficult to acquire with existing autonomous systems. The potential for new discoveries are further increased by the possibility to install the sensors on a variety of fixed and mobile platforms.

In order to make sure that all the achievements of the project were disseminated and available to the public, NeXOS was represented on several international conferences by oral and/or poster presentations and scientific papers were produced, for a total of about 219 dissemination and outreach actions. Moreover, posters, roll-up, flyers and brochures illustrating the project and its progress were regularly updated and distributed at conferences and meetings. Several technical webinars were published to inform about technical progress of the project.
The NeXOS public website was regularly updated and provides detailed information about the project, news and events, and links to the deliverables and further information material such as the final project video. Details about the project were also distributed in face-to-face discussions during surveys needed for the economic aspects of developments. With all these dissemination activities NeXOS reached out not only confined scientific communities but also the wider public, developers and policy-makers.

1.5. The address of the project public website, if applicable as well as relevant contact details.

Official website: http://www.nexosproject.eu

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Figure 1: Project and partner's logos

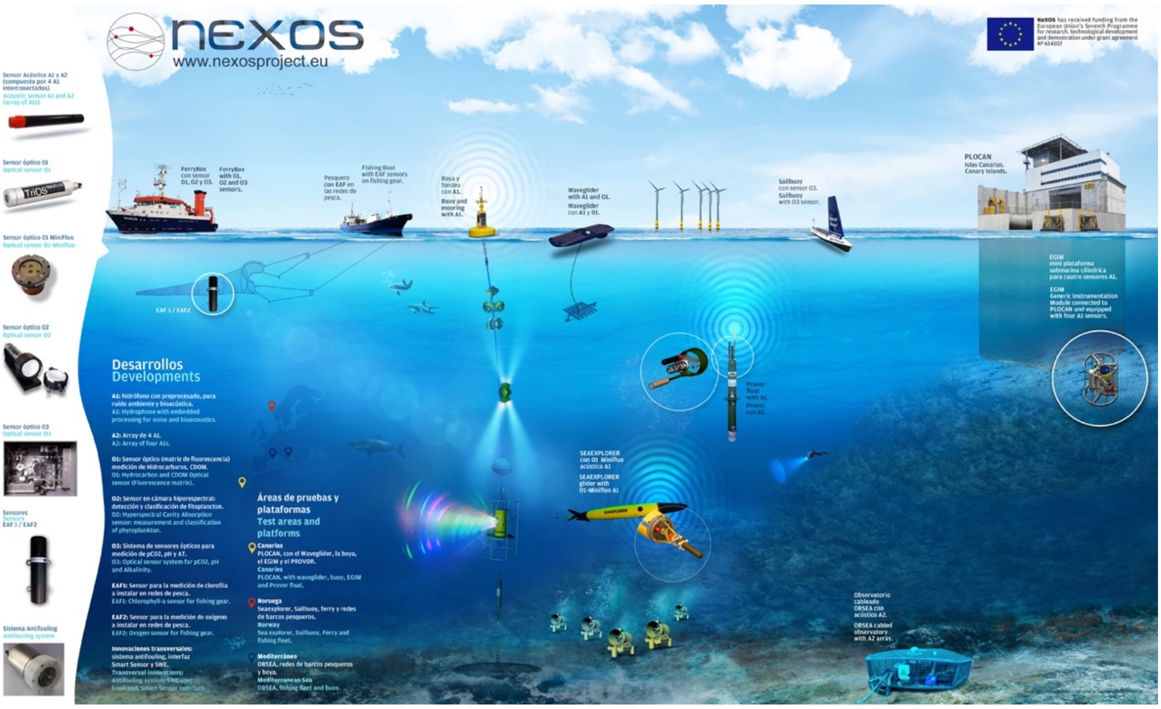

Figure 2: NeXOS oceanscape

Figure 3: NeXOS developments

Project video	address
Full version	https://ieeetv.ieee.org/ieeetv-specials/nexos-observations-supporting-ocean-sustainability
Short formal version	https://ieeetv.ieee.org/ieeetv-specials/nexos-observations-supporting-ocean-sustainability-formal-version
Short version general public	https://ieeetv.ieee.org/ieeetv-specials/nexos-observations-supporting-ocean-sustainability-short-version

Table 1: NeXOS video address