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Organisation CEIIA
Department Ocean & Space

Open Access Instrumentation Roadmap

Deliverable 11.2

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DEC	Websites, patents, filing, etc.	
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NAUTILOS - New Approach to Underwater Technologies for Innovative, Low-cost Ocean observation is an H2020 project funded under the Future of Seas and Oceans Flagship Initiative, coordinated by the National Research Council of Italy (CNR, Consiglio Nazionale delle Ricerche). It brings together a group of 21 entities from 11 European countries with multidisciplinary expertise ranging from ocean instrumentation development and integration, ocean sensing and sampling instrumentation, data processing, modelling and control, operational oceanography and biology and ecosystems and biogeochemistry such, water and climate change science, technological marine applications and research infrastructures.

NAUTILOS will fill-in marine observation and modelling gaps for chemical, biological and deep ocean physics variables through the development of a new generation of cost-effective sensors and samplers, the integration of the aforementioned technologies within observing platforms and their deployment in large-scale demonstrations in European seas. The fundamental aim of the project will be to complement and expand current European observation tools and services, to obtain a collection of data at a much higher spatial resolution, temporal regularity and length than currently available at the European scale, and to further enable and democratise the monitoring of the marine environment to both traditional and non-traditional data users.

NAUTILOS is one of two projects included in the EU´s efforts to support of the European Strategy for Plastics in a Circular Economy by supporting the demonstration of new and innovative technologies to measure the Essential Ocean Variables (EOV).

More information on the project can be found at: https://www.nautilos-h2020.eu/.

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EXECUTIVE SUMMARY

This deliverable is the outcome of the work performed in Task 11.2 – "Instrumentation Roadmap. Scalability, replicability and transferability study" until M24. It presents NAUTILOS proposal for OIAR (open access instrumentation roadmap) development with a multi-step data collection methodology so that a set of reliable and updated marine instrumentation data, from industrial companies, universities and research centres, might be collected and shared in order to foster scalability, replicability and transferability of those European products, including NAUTILOS sensors and samplers. A final version of the roadmap will be released as a tool for exploitation in Power BI and included in NAUTILOS Exploitation Strategy to be delivered in M48, which will include validated data, obtained directly from oceanography stakeholders.

The roadmap builds on top of H2020 AtlantOS project and includes information from the Ocean of Tomorrow Projects (FP7) that includes Common Sense and NeXOS projects as well as information from NAUTILOS, following the general community recommendations on FAIR data. NAUTILOS OIAR will include the name of the sensor/instrument, the application area or type of technology, maturity level (TRL) and information about its ongoing or planned commercialization, as other information (e.g. Owner institution).

This deliverable also includes an update about the exploitation strategy, namely highlights future exercises to perform with all sensor developers (SWOT and BMC) to start exploring possible approaches to market with each of NAUTILOS sensor developer.

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
AtlantOS	“Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems” project
BMC	Business Model Canvas
EOV	Essential Ocean Variables
EU	European Union
EuroGOOS	European Global Ocean Observing System
FAIR	Findable, Accessible, Interoperable and Reusable
FP7	7th Framework Programme (EU Research and Innovation)
FP7-OCEAN	“The Ocean of Tomorrow” projects
HEI	Higher Education Institute
H2020	Horizon 2020 EU Research and Innovation Framework Programme
KER	Key Exploitable Result
NAUTILOS	“New Approach to Underwater Technologies for Innovative, Low-cost Ocean observation” project
OAIR	Open Access Instrumentation Roadmap
SME	Small and medium-sized enterprises
SWOT	“Strengths, Weaknesses, Opportunities, and Threats” analysis
TRL	Technology Readiness Level
WP	Work Package

I. INTRODUCTION

NAUTILOS has the strategic objective of filling in marine observation and modelling gaps for chemical, biological and deep ocean physics variables through the development of a new generation of cost-effective sensors and samplers, the integration of the aforementioned technologies within observing platforms and their deployment in large-scale demonstrations in European seas. It is led by CNR and it was successfully approved in response to the Call for Proposals: H2020-BG-2020-12 under the BG-07-2019-2020 – The Future of Seas and Oceans Flagship Initiative: Part [C] 2020 – Technologies for observations.

NAUTILOS aims at complementing and expanding current European observation tools and services, obtaining a collection of data at a much higher spatial resolution and temporal regularity and length than currently available at the European scale, and further enabling and democratizing the monitoring of the marine environment to both traditional and non-traditional data users.

So that data-users (traditional and non-traditional) have access to NAUTILOS sensors and samplers, a major effort in terms of exploitation and impact is proposed under WP11, alongside with dissemination efforts from WP10. Exploitation efforts, including property rights and valorisation strategies, guide WP11. Task 11.2 "Instrumentation Roadmap, Scalability, replicability and transferability study", aims at developing NAUTILOS OIAR, a marine instrumentation roadmap, to increase awareness of available technology for oceanography stakeholders (e.g., industry, policymakers, researchers), foster collaboration and integrated effort between stakeholders, increase exploitation potential of existing technology for observational programs and commercialization. As so, while D11.1 "NAUTILOS Exploitation strategy" **focused on global strategies and market opportunities**, D11.2 **focuses on market solutions (e.g., technology available)**. Both deliverables, together, intend to support the "road to market" of NAUTILOS instrumentation at its maximum potential, with the potential of contributing, in general, to a stronger and more complementary marine instrumentation industry in Europe.

The present deliverable is organized in four main sections:

- **Chapter I: Introduction**, provides an introduction about the work developed in WP11;
- **Chapter II: Exploitation strategy,** provides a description and an updated plan of WP11 exploitation strategy in NAUTILOS project;
- **Chapter III: Contact list,** includes the characterization of entities to be considered in NAUTILOS OIAR;
- **Chapter VI: Instrumentation data collection and access,** describes the methodology proposed to build and share NAUTILOS OIAR;
- **Chapter V: Instrumentation database** presents the first instrumentation dataset of NAUTILOS OAIR, including marine instrumentation references from European projects including NAUTILOS;
- **Chapter VI: Conclusion,** reviews the work done and summarizes future steps.

II. EXPLOITATION STRATEGY

As previously referred, T11.1 (Exploitation Strategy and Campaign) and T11.2 (Instrumentation Roadmap. Scalability, replicability and transferability study) together will foster large-scale exploitability of NAUTILOS instrumentation to be developed until M48.

In NAUTILOS, by seamlessly combining the actions of technology development, sensor testing and validation, sensor integration and demonstration, the project will streamline the business phase, from concept to prototype and further to market. As so, the project's exploitation plan, started with the Exploitation Strategy (D11.1) covers an overall view on relevant synergies and market opportunities at European and worldwide level as for example:

- Blue Growth Strategy;
- EMODnet – European Marine Observation and Data Network;
- IOC – Intergovernmental Oceanographic Commission;
- The Global Ocean Observing System (GOOS);
- OceanOPS – Joint Centre for Oceanography and Marine Meteorology in Situ Observations;
- Animal Borne Ocean Sensors (AniBOS).

While D11.1 "NAUTILOS Exploitation strategy" focused on global strategies and market opportunities, D11.2 focuses on market solutions (e.g., technology available) as NAUTILOS marine instrumentation (sensors and samplers).

Key to the exploitation success of marine instrumentation into ocean observation market is that:
1) each beneficiary is aware of possible synergies and opportunities;
2) each beneficiary knows its competitors;
3) each beneficiary understands the importance of sharing globally the instrumentation potential;
4) each beneficiary has a business model defined to start addressing the market.

All these and other relevant features will be discussed and evaluated through the SWOT (strengths, weaknesses, opportunities, and threats) analysis and BMC (Business Model Canvas; Figure 1) exercises with each instrumentation owner, in Task 11.1 in the following months.

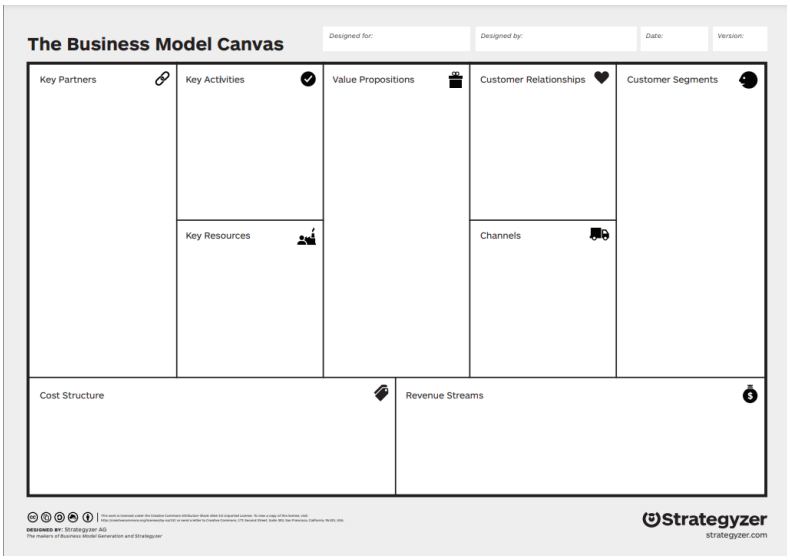


Figure 1: Business Model Canvas template[1]

While SWOT is a technique for assessing four aspects of a business (strengths, weaknesses, opportunities, and threats), the BMC is a strategic management exercise which allows developers to build their business model based on a visual chart with elements describing a product's value proposition, infrastructure, customers and finances (Figure 1). Both exercises, benefit from D11.1 and D11.2 and together will contribute to build NAUTILOS sensors and samplers exploitation plan, as well as a collective exploitation plan for all NAUTILOS marine instrumentation.

All efforts together intend to support the "road to market" of NAUTILOS instrumentation at its maximum potential. Contributions from both IOC Criteria and Guidelines on the Transfer of Marine Technology, as also the possible integration of NAUTILOS case study in Horizon Results Booster will be considered in the work to be developed during the next months.

Figure 2: Horizon results booster initiative supported by European Union[2]

[1] https://www.strategyzer.com/canvas/business-model-canvas
[2] https://www.horizonresultsbooster.eu/

III. DATA COLLECTION - CONTACT LIST

An instrumentation roadmap plays an important role for the ocean community to understand what type of technology is available and also to make strategic decisions concerning instrumentation development for global ocean observation.

Data to be collected must be reliable and updated. As such, data collection, including contact list and data collection methodologies, is a crucial part in producing the OIAR. Therefore, in T11.2 a major effort was performed into understanding the available data when discussing the best approach to produce NAUTILOS OAIR. Several questions arise:

- How many European projects and other European initiatives exist involving marine instrumentation?
- How many entities are involved in producing marine instrumentation in Europe?
- Would data collection, necessary to build OAIR, benefit from adapting AtlantOS methodology? Would be relevant to consider collecting instrumentation data for OAIR through online research? If not, which other options would exist to compile reliable and updated data?
- Could NAUTILOS innovate on the way an instrumentation roadmap is presented to oceanography stakeholders?

All questions will be answered into the following sections.

1. EUROPEAN PROJECTS & OTHER INITIATIVES

"Recognition of observation as key to the health of the oceans and sustainability of human activities on the planet has accelerated observing efforts since 2000, particularly in the upper ocean"[3]. Among some of the global efforts, Europe clearly stands out with several projects and initiatives fostering the development and demonstration of new marine instrumentation for ocean observation, either from private investment (e.g. Industry) or under public support, namely from the European Union.

NAUTILOS OIAR must build on existing information of related projects as AtlantOS and focus on instrumentation used for research of European Exclusive Economic Zones, seas and coastlines (i.e. Adriatic and Ionian Seas, Baltic Sea, Black Sea, Mediterranean, North Sea, Atlantic and Arctic Oceans and the Outermost Regions). In the scope of D11.2 it was possible to identify several initiatives to be considered as a reference for NAUTILOS OIAR which include projects funded by European Union and other initiatives involving marine instrumentation development and demonstration. Therefore, NAUTILOS OIAR intends to gather information from:

- "The Ocean of Tomorrow", including NeXOS, SCHeMA, SenseOCEAN and Common Sense projects;

[3] Visbeck, M. (2018). Ocean science research is key for a sustainable future. Nat. Commun. 9:690. doi: 10.1038/s41467-018-03158-3

- AtlantOS project;
- TechOceanS project;
- OCEANSensor project;
- Other European initiatives: EuroGOOS;
- NAUTILOS project.

An individual characterization of each initiative will be detailed in the next chapters.

1.1 "The Ocean of Tomorrow"

"The Ocean of Tomorrow" (FP7-OCEAN) includes cross-thematic calls in FP7 to implement the European strategy for marine and maritime research. "The Ocean of Tomorrow" initiative aims to foster multidisciplinary approaches and cross-fertilisation between various scientific disciplines and economic sectors on key cross-cutting marine and maritime challenges. A key feature is also the participation of business partners, in particular SMEs, in the research projects that are funded.[4]

A total of 31 projects have been selected under 'The ocean of tomorrow' initiative (2010-2013), addressing several challenges as underwater noise, marine pollution, fisheries and other topics, including also projects addressing ocean observation. In NAUTILOS OAIR, five "Ocean of Tomorrow" projects (Table 1) will be considered for data collection as they are involved in national and international research and innovation activities related to ocean observation and marine instrumentation development.

Table 1: "The Ocean of Tomorrow" projects selected to NAUTILOS OIAR

Abbreviation	Description
Common Sense | Cost-Effective Sensors, Interoperable with International Existing Ocean Observing Systems, to Meet EU Policies Requirements	COMMON SENSE project will develop cost-effective sensors, fully interoperable with existing observing systems and compatible with standard requirement such as Global Ocean Observing System (GOOS) and Global Earth Observation System of System (GEOSS). One example is the COMMON SENSE Heavy Metals sensor.
NeXOS | Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management	NeXOS project aims to develop new multifunctional sensor systems supporting for ocean monitoring and modelling of the marine environment, based on optical and passive acoustics technologies. An example are 2 optical sensors developed in the scope of the project.
SCHeMA | Integrated In-Situ Chemical MApping Probes	SCHeMA project aims at developing autonomous marine water quality observatory system deployable from various facilities. SCHeMA intends to develop miniature sensors for the detection, among others, of trace metals as mercury, cadmium, lead, arsenic and copper bioavailable metal fractions.
SenseOCEAN | Marine sensors for the 21st Century	SenseOCEAN project focus on the development of new highly integrated, multifunction, cost-effective and mass deployable in-situ marine biogeochemical sensor system, including several sensor packages for the marine and wider environmental industries. One example is the electrochemical microsensor for CO_2.

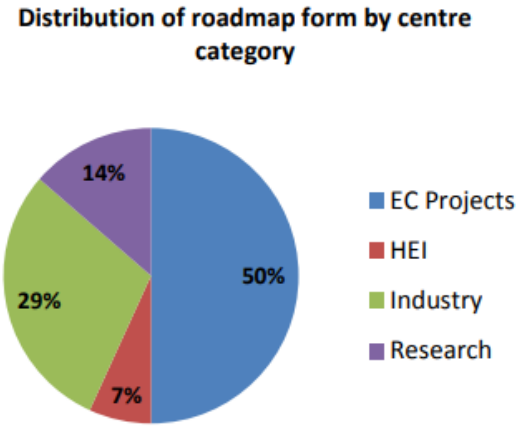
[4] The ocean of tomorrow projects (2010-2013)

1.2 AtlantOS project

AtlantOS (Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems) project, a research and innovation project funded by the European Union, proposes the integration of ocean observing activities across all disciplines for the Atlantic, considering European as well as non-European partners. By proposing integrated action, the project foster the transition from a loosely coordinated set of existing ocean observing activities to a sustainable, efficient, and fit for-purpose Integrated Atlantic Ocean Observing System (IAOOS) and contributes to blue growth by merging new information needs relevant to key sectors such as transport, tourism, fisheries, marine biotech, resource extraction and energy with existing requirements.

Stated as part of AtlantOS legacy is the aiming of facilitating free and open access to ocean data and information. With that in mind, one of AtlantOS deliverables consist in a ten-year roadmap for sensors and instrumentation, freely available[5]. A detailed analysis on methodology and data collected from AtlantOS instrumentation roadmap is essential when producing NAUTILOS OIAR. AtlantOS team used a single step method for data collection, based on a direct survey to stakeholders of relevance. Figure 3 highlights some of the characteristics of AtlantOS instrumentation roadmap as the following:

- Number of contacts to consider: survey addressed 136 entities; 12 entities replied;
- Types of entities: 50% participating in European projects, with a large representation of industry entities (29%);
- Territories: 88% of contacts are from Europe, mainly from UK and France.



Centre category	N° contacted
EC projects	66
HEI	10
Industry	42
Research	18

Centre region	N° contacted
Africa	1
Americas	12
Asia	1
Europe	121
Pacific	1

Figure 3: Description of contacts used to AtlantOS instrumentation roadmap.

[5] https://atlantos-h2020.eu/download/deliverables/6.1%20Sensors%20and%20Instrumentation%20Roadmap.pdf

AtlantOS instrumentation roadmap includes 58 different instrumentation references, including, if available, information about "sensor or instrument name", "application/target/technology", "TRL", "operational demo", "commercial release", "Links to or filename of specification/datasheet" and "Filename or link to application notes or additional" information. Replies obtained were provided by 12 entities, mainly industry entities in Europe:

- European projects: 1 entity - Common Sense Project;
- Research centres replies: 4 entities – Geomar, LOSEM University of Tuscia, National Oceanography Centre and PLOCAN;
- Industry replies: 7 entities (Flydog Solutions LLC, NKE, NORTEK, Ocean Sonics, SYSTEA, TELLabs, Vemco)

AtlantOS instrumentation roadmap is freely available[6] as a pdf file into the official project webpage.

1.3 TechOceanS project

TechOceanS[7], funded through an EU Horizon 2020 Research and Innovation grant, TechOceanS will develop nine innovative technologies in multiple underwater vehicles.

Among them the nine innovative technologies, the project aims to develop five new sensors, two imaging systems, a novel sampler and an Artificial Intelligence-driven image processing methodology, all capable of robust operations at depths beyond 2,000 metres. Sensors to be developed, focus on five different studies (nucleic acids, ecogenomic samplers, cytometry, biological sensors, and biogeochemical sensors) guided with two major goals:

- Develop new low-cost and in situ sensors for aquaculture and fisheries including relevant chemical contaminants, biotoxins and environmental.
- Develop new sensors to determine the distribution and fate of marine litter and microplastics

The technologies will capture important data that will have a significant impact in diverse areas such as ocean conservation, resource management, blue economy and policy. Technologies developed will expand knowledge of the ocean's interconnected systems and provide tangible benefits to the industries that rely on them, such as fisheries and aquaculture. The data generated will also support conservation initiatives and provide vital information to policy makers.

[6] https://atlantos-h2020.eu/download/deliverables/6.1%20Sensors%20and%20Instrumentation%20Roadmap.pdf
[7] https://techoceans.eu/overview/

1.4 OCEANSensor project

OceanSensor is a 3-year ERA-NET Cofund -MarTERA project (2018-2021), co-funded by the European Union, with 6 partners and co-ordinated by GEOMAR, located in Germany. The aim is to develop a suite of in situ marine biogeochemical sensors for remote observations in coastal and oceanic waters by combining new sensor technologies with commercially available sensors. The package will comprise of sensors for pH, pCO2 and O2 (fluorescent optodes), nitrate (UV hyperspectral), phosphate and silicate (electrochemical), and phosphate (microfluidic technology).

1.5 Other European initiatives

EuroGOOS[8] is the European component of the Global Ocean Observing System of the Intergovernmental Oceanographic Commission of UNESCO (IOC GOOS). Among several goals EuroGOOS focus on fostering cooperation thus promoting the benefits of operational oceanography. Its secretariat is located in Brussels, serving 44 members and supporting five regional systems in Europe.

It includes, in its structure, several Team Tasks. EuroGOOS Task Teams are networks of ocean observing platforms with the main goal of exchanging best practices and feed data to the EuroGOOS ROOS regional portals, EMODnet, and Copernicus Marine Service. The EuroGOOS Task Teams are 6: FerryBox, Tide Gauges, Gliders, High frequency Radar, Argo and Fixed Platforms.

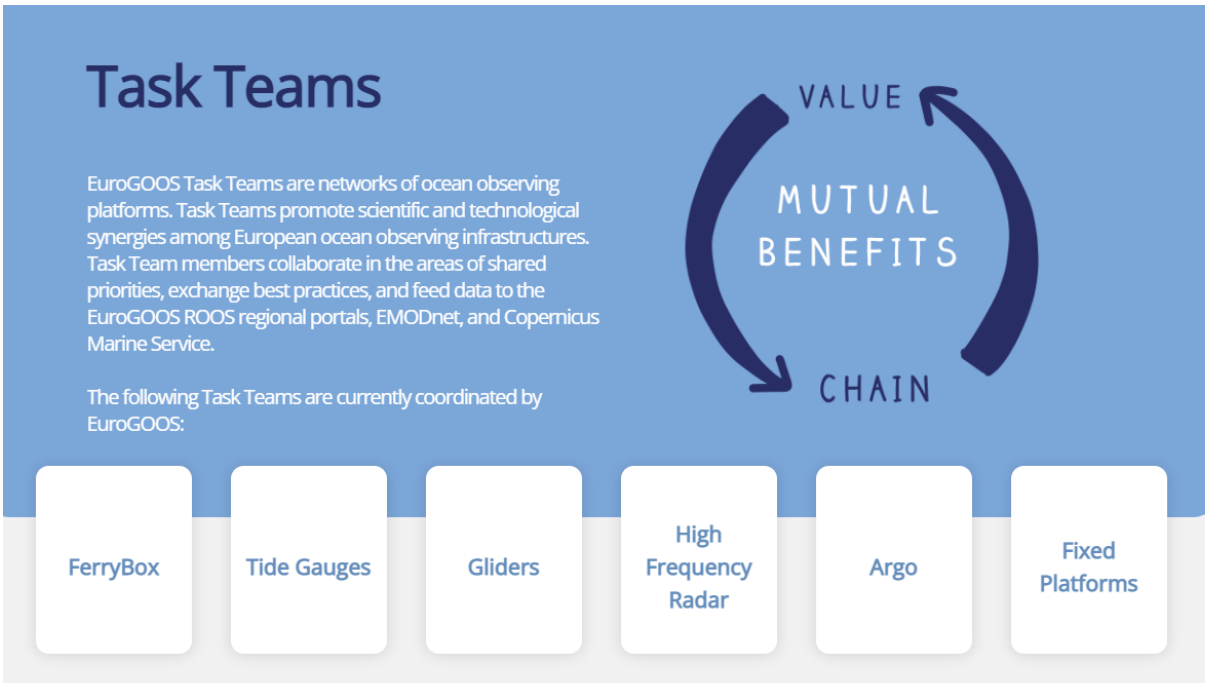


Figure 4: EuroGOOS Task Teams

[8] https://eurogoos.eu/

2 NAUTILOS OAIR CONTACT LIST

The basis of an instrumentation roadmap is data. Data to be collected must be reliable and updated. As previously referred AtlantOS project produced a contact list with 136 contacts, including European projects, industry and others. NAUTILOS OAIR contact list builds on top of AtlantOS, however it is essential to update it, as since 2016 major changes are expected mostly in terms of ongoing and expected results from European projects and other initiatives. Also AtlantOS project acknowledges that there is a possibility that not all interested parties may have been identified in the initial contact list, which can lead to a reduced representation of certain groups or organizations.

As such, in order to answer the question "How many European projects and other European initiatives exist involving marine instrumentation?", a list of entities beneficiaries from EU funding was compiled based on the list of projects and initiatives previously referred. It was possible to conclude a contact list of 74 different beneficiaries (Table 2). These entities are spread across in 19 different European countries.

Table 2: List of European projects beneficiaries included into to NAUTILOS OIAR

Institution	Country
52°North Initiative for Geospatial Open-Source Software GmbH	Germany
AARHUS UNIVERSITET	Denmark
AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	Spain
Aix Marseille University	France
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FUR POLAR-UND MEERESFORSCHUNG	Germany
Aanderaa Data Instrumentation AS	Norway
AQUA TT UETP COMPANY LIMITED BY GUARANTEE	Ireland
AQUATEC GROUP LIMITED	United Kingdom
Architecture et Conception de Systèmes Avancés	France
Carl von Ossietzky Universität Oldenburg	Germany
CEIIA – CENTRO DE ENGENHARIA E DESENVOLVIMENTO (ASSOCIACAO)	Portugal
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	France
Centro Tecnológico Naval y del Mar	Spain
CHELSEA TECHNOLOGIES LIMITED	United Kingdom
Christian Michelsen Research AS	Norway
CoLab +Atlantic	Portugal
CONSIGLIO NAZIONALE DELLE RICERCHE (CNR)	Italy
CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA – RECHERCHE ET DEVELOPPEMENT	Switzerland

CYPRUS SUBSEA CONSULTING AND SERVICE C.S.C.S. LIMITED	Cyprus
DUBLIN CITY UNIVERSITY	Ireland
ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL)	Switzerland
ECORYS Nederland BV	Netherlands
EDGELAB SRL	Italy
ERINN INNOVATION LIMITED	Ireland
ETT SPA	Italy
EVROPROJECT OOD	Bulgaria
Franatech AS	Norway
FUNDACAO EUROCEAN	Portugal
FUNDACION PRIVADA PER LA NAVEGACIO OCEANICA BARCELONA	Spain
HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE	Switzerland
HELLENIC CENTRE FOR MARINE RESEARCH	Greece
HELMHOLTZ-ZENTRUM FUR OZEANFORSCHUNG KIEL (GEOMAR)	Germany
Helmholtz-Zentrum Geesthacht Zentrum fur Material-und Kustenforschung GmbH	Germany
IDRONAUT SRL	Italy
IDRYMA TECHNOLOGIAS KAI EREVNAS	Greece
IEEE France Section	France
IMAR – INSTITUTO DO MAR	Portugal
INSTITUT FRANCAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER	France
INSTYTUT OCEANOLOGII POLSKIEJ AKADEMII NAUK	Poland
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)	France
LEITAT TECHNOLOGICAL CENTER	Spain
MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV	Germany
METROHM DROPSENS SL	Spain
NANOMATERIALES Y POLIMEROS SL	Spain
NATURAL ENVIRONMENT RESEARCH COUNCIL	United Kingdom
NKE INSTRUMENTATION SARL	France
NORSK INSTITUTT FOR VANNFORSKNING	Norway
Plataforma Oceánica de Canarias (PLOCAN)	Spain
PYRO SCIENCE GMBH	Germany
Runde Miljøsenter AS	Norway

SECRETARY OF STATE FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (CEFAS)	United Kingdom
SIMULACIONS OPTIQUES SL	Spain
SMID Technology s.r.l.	Italy
SORBONNE UNIVERSITE	France
Ss. CYRIL AND METHODIUS UNIVERSITY IN SKOPJE (FTM-UCIM)	North Macedonia
STAZIONE ZOOLOGICA ANTON DOHRN	Italy
SUBCTECH GMBH	Germany
SUOMEN YMPARISTOKESKUS	Finland
T.E. LABORATORIES LIMITED	Ireland
TECHNISCHE UNIVERSITAET GRAZ	Austria
TriOS Mess- und Datentechnik GmbH	Germany
Uni Research AS	Norway
UNISENSE AS	Denmark
UNIVERSIDADE DO ALGARVE	Portugal
UNIVERSITA DEGLI STUDI DI GENOVA	Italy
UNIVERSITA DELLA CALABRIA	Italy
UNIVERSITAET ULM	Germany
Universität Bremen	Germany
Universitat Politècnica de Catalunya	Spain
UNIVERSITE DE BORDEAUX	France
UNIVERSITE DE GENEVE (UNIGE)	Switzerland
UNIVERSITY COLLEGE CORK – NATIONAL UNIVERSITY OF IRELAND, CORK	Ireland
UNIVERSITY OF SOUTHAMPTON	United Kingdom
UNIVERZA V LJUBLJANI	Slovenia

Despite the relevance of EU strategy in fostering the development of instrumentation, it is essential to recognize the importance of other entities, as private investment in developing ocean observation instrumentation. Private investment from European companies is also an important factor for the continent's marine instrumentation capabilities. Despite strong competition from companies in other areas (e.g. USA) Europe has managed to stay relevant and is home to significant global players, such as Kongsberg, Valeport, Nortek or Sonardyne.

In NAUTILOS OAIR other types of stakeholders as industry partners are considered. In fact, when carefully analyzing AtlantOS instrumentation roadmap, private investment represents 58% of all answers received. Once private ecosystem is not supposed to be out of date as

European Projects, the following step in building the NAUTILOS OAIR contact list was to merge Table 2 with AtlantOS contact list (already containing some references).

Thus, to finish NAUTILOS OAIR contact list and be able to provide an answer to the third question "How many entities are involved in producing marine instrumentation in Europe?", it was necessary to study the private sector and identify private entities missing and to be included into NAUTILOS OAIR contact list, namely industries without participation in European projects. As in AtlantOS instrumentation roadmap results show that 88% of contacts were from Europe and 98% of answers were from Europe, in this analysis, Europe was considered as the geographical territory of reference. As such, new entities were added to the NAUTILOS OAIR contact listed, either private entities or other contacts of interest reported by some of NAUTILOS partners (Table 3).

Table 3: List of private entities added to NAUTILOS OIAR

Institution	Country
Aquaread	United Kingdom
Composite Solutions	Portugal
Endress+Hauser	Switzerland
HCTech	Spain
Kongsberg	Norway
Nortek	Norway
PreSens	Germany
Sonardyne	United Kingdom
Valeport	United Kingdom

In order to make it easier to classify and analyse data NAUTILOS OAIR classifies entities into 5 categories:

- HEI – Higher Education Institution;
- Research;
- Industry;
- Other (non-profit body or public entity or other).

The final NAUTILOS OAIR contact list is presented in Appendix 2: NAUTILOS OAIR - Contact list and summarized into Figure 5. For each entity, contact list includes geographic location and type of entity. NAUTILOS OIAR contact list includes:

- Number of entities: 185 (around 30% increase in contacts);
- Types of entities: (HEI – 39; Research – 37; Industry – 78; Other 31).

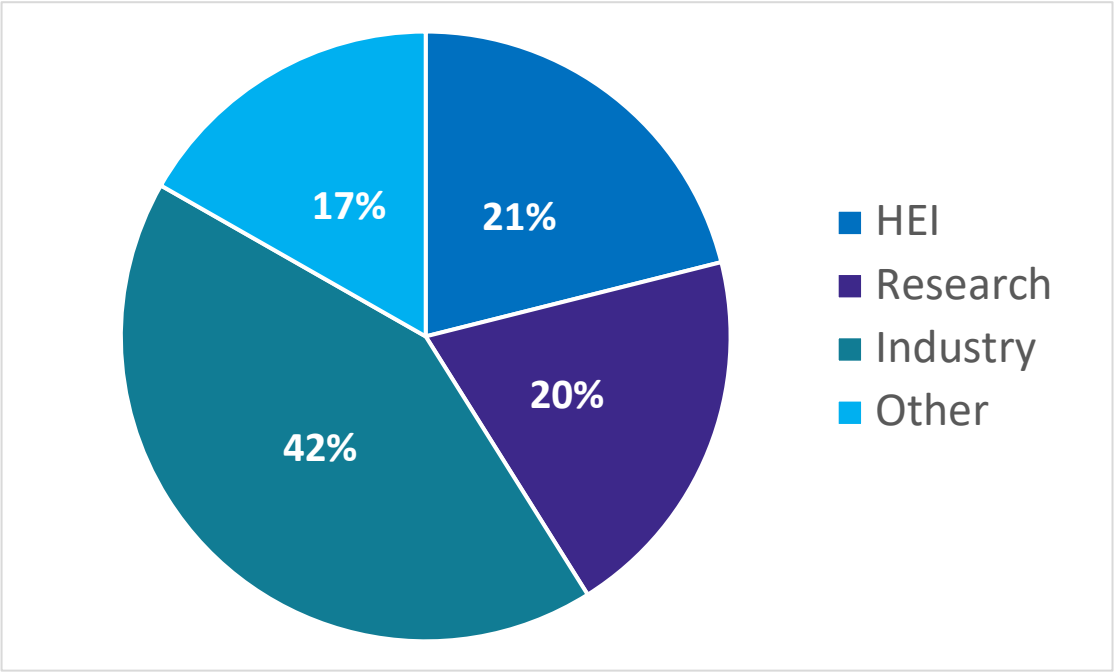


Figure 5: Description of contacts used to build Nautilos OAIR.

3 DISCUSSION

By carefully building a reliable and updated contact list, NAUTILOS offers the community a better knowledge about the ocean observation instrumentation development ecosystem. Hopefully it might be of a strategic importance when defining market approach or taking business development decisions, as by knowing and understanding our competitors, it is possible to foster a stronger and more complementary industry in Europe.

The process to build NAUTILOS OAIR contact list is intentionally detailed in this deliverable so that it can be of use for the future development of NAUTILOS OAIR, hopefully allowing the process of updating a contact list to be performed with minimum effort and always maximum accuracy while benefiting from past works. The process included four steps:

- update European project beneficiaries;
- Merge contact lists with others from previously existent and remove duplicates;
- Review industry ecosystem;
- Add other national contacts of interest with support from project partners.

Final NAUTILOS contact list can be found in Appendix 2: NAUTILOS OAIR - Contact list. Until the end of NAUTILOS project, partners would be requested to contribute to this contact list so that it keeps on growing and truly represents the ecosystem. It will be included, again, in M48.

IV. DATA COLLECTION METHODOLOGY AND ACCESS

An instrumentation roadmap plays an important role for the ocean community to understand what type of technology is available, as also to take strategic decisions concerning sensor and instrument technology development for global ocean observation.

To ensure that a database is effective in addressing goals and needs, it is important to carefully discuss data collection methodology. Additionally, the database should be easily accessible to all stakeholders who may benefit from it, and the methodology for accessing the data should be clearly defined.

Data collection methodology and access will be discussed in the following chapters.

1. DATA COLLECTION METHODOLOGY

Data collection is a crucial aspect of an instrumentation roadmap as it forms the basis of the roadmap. The data collected must be reliable and updated to ensure database accuracy and effectiveness. A comprehensive and up-to-date contact list is important for successful data collection, as well as a well-designed data collection methodology.

Data collection happens on multiple levels. The methods used to collect data vary based on the type of application. Among several, are[9]:

- automated data collection functions built into business applications, websites and mobile apps;
- sensors that collect operational data from industrial equipment, vehicles and other machinery;
- collection of data from information services providers and other external data sources;
- tracking social media, discussion forums, reviews sites, blogs and other online channels;
- surveys, questionnaires and forms, done online, in person or by phone, email or regular mail;
- focus groups and one-on-one interviews;
- direct observation of participants in a research study.

Data collection methodologies can be broadly categorized into two types: manual and technology-assisted. Manual methodologies involve collecting data through methods such as surveys, interviews, and observations, which are often carried out by human researchers. Technology-assisted methodologies, on the other hand, involve the use of technology such as web scraping, GPS tracking, and social media monitoring to collect data. Additionally, data collection can also be classified as either active or passive. Active data collection methodologies involve actively seeking out and collecting data, such as through surveys or

[9] https://www.techtarget.com/searchcio/definition/data-collection

interviews. Passive data collection methodologies involve collecting data unknowingly (Figure 6).

Figure 6: Data collection methodologies: active or knowingly; passive or unknowingly[10]

NAUTILOS team started by listing all data collection methods with interest to be considered, to find the best answer to question: "Would data collection, necessary to build OAIR, benefit from adapting AtlantOS data collection methodology? Would be relevant to consider collecting instrumentation data for OAIR through online research? If not, which other options would exist to compile reliable and updated data?". Data collection methodologies with possible application to NAUTILOS OAIR are described in Table 4.

Table 4: Data collection methodologies: examples, advantages and limitations

Method	Description, advantages and limitations
Unknowingly methods	Examples: website visits and tracking social media, discussion forums, reviews sites, blogs and other online channels. Advantages: • Low cost; • Access to global information regardless of your proximity to their locations; • Ease of conducting research, via online; Limitations: Data unreliability: outdated information might be available

[10] https://www.techtarget.com/searchcio/definition/data-collection

Knowingly methods	Example 1: surveys to stakeholders done online, by e-mail. Advantages: • Low cost • Access to global information regardless of your proximity to their locations • Reliable data collected directly from the source • Ease of conducting research, via online; Limitations: • Requests may be lost among the myriad of emails people receive on a daily basis Data unreliability: with no moderator or administrator to answer clarifying questions, some responses may be questionable
	Example 2: using focus groups and one-on-one interviews Advantages: • Updated and detailed information Limitations: • Time and cost consuming

In AtlantOS project data collection was obtained through a single step and active data collection methodology, using online surveys to stakeholders sent by e-mail. Unfortunately, results show that from 136 entities contacted only 12 of them replied, unfortunately showing a low engagement from stakeholders.

Considering AtlantOS experience, NAUTILOS OAIR considers a data collection methodology in two steps, one passive and other active, therefore adapting AtlantOS data collection methodology:

- First step: through collecting, unknowingly, data using website visits and tracking social media, discussion forums and other online channels, mainly for European projects whereas most of the information available online is reliable;

- Second step: through a direct survey to stakeholders sent by e-mail, but also shared in NAUTILOS and NAUTILOS partners social media. The questionnaire (Annex A) will allow to collect detailed and updated information about application area or type of technology, maturity level (TRL), depth of operation, EOV covered, ongoing or planned commercialization and owner entity. If necessary, the questionnaire may be made in languages other than English.

By increasing the complexity of data collection, NAUTILOS aims to increase the representation of instrumentation developed in European projects and to reduce lack of information due to survey nonresponse. Also, it allows to build on top of AtlantOS database without losing data. Due to the effort in terms of cost and time, focus group or one-to-one meeting are not planned as part of NAUTILOS OAIR methodology, even though they might happen if requested.

As a key pillar of the instrumentation roadmap is to have a broad stakeholders engagement, in NAUTILOS from oceanographic community, including but not restricted to research centres, research institutes and industrial companies, survey rewards mechanisms will also be implemented and discussed in the following months. Some of the rewards mechanisms to be implemented are:

- Keep stakeholders informed about the availability of this roadmap, by e-mail, where key information will be displayed as current TRL, planned commercialization, among others, about marine instrumentation;
- Availability to showcase their products and contacts to a large and oriented audience;
- Possibly to engage stakeholders into NAUTILOS public activities, as brokerage event(s).

4 NAUTILOS OAIR OPEN ACCESS & POWER BI

AtlantOS and NAUTILOS instrumentation database should should be easily accessible to anyone who needs it and should be made available in an open access format. The goal of open access is to make knowledge more widely available and to increase the impact of research by allowing more people to access and use it.

While discussing the best approach to share NAUTILOS OAIR, a major question arises: Could NAUTILOS innovate on the way an instrumentation roadmap is presented to oceanography stakeholders?

AtlantOS is publicly available as a pdf file. NAUTILOS OIAR is presented in this deliverable and in M48, also in pdf file. However, an innovative way in sharing NAUTILOS OAIR will also be available, using Power BI (Figure 7).

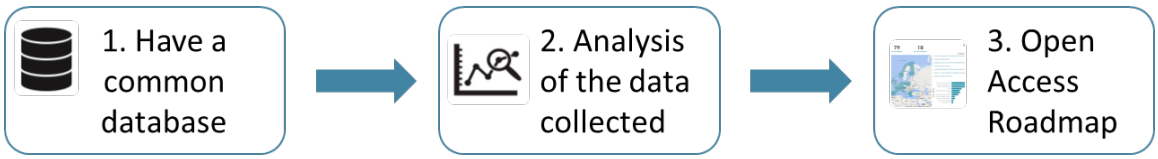


Figure 7: Methodology to develop the open access instrumentation roadmap

Power BI may be one of the most aptly named tools ever developed by Microsoft, giving analysts and developers a powerful business intelligence and analytics playground. Using Power BI, the processes of data discovery, data modelling, data visualization and sharing are made elegantly simple using a single product. It allows users to connect to various data sources, such as databases, and create interactive visualizations, reports, and dashboards. NAUTILOS OAIR in Power BI will be available in NAUTILOS website, allowing users to easily explore and analyse data (Figure 8 and Figure 9).

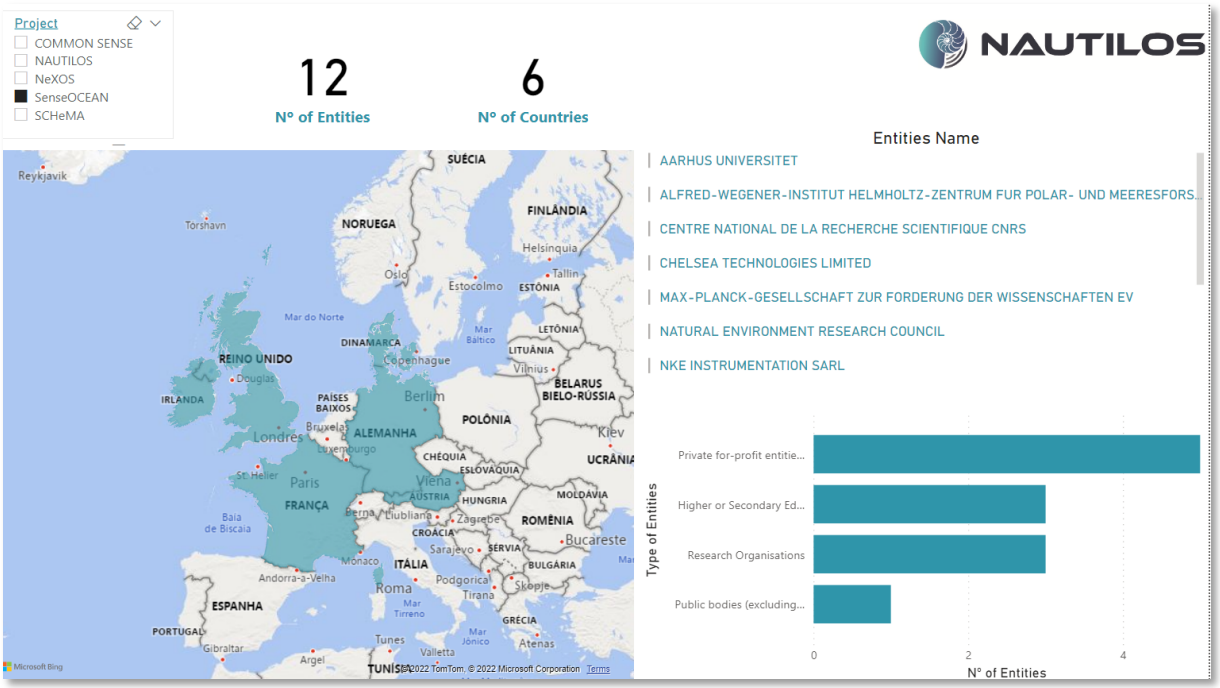


Figure 8: NAUTILOS OAIR in Power BI – SenseOCEAN project contact list

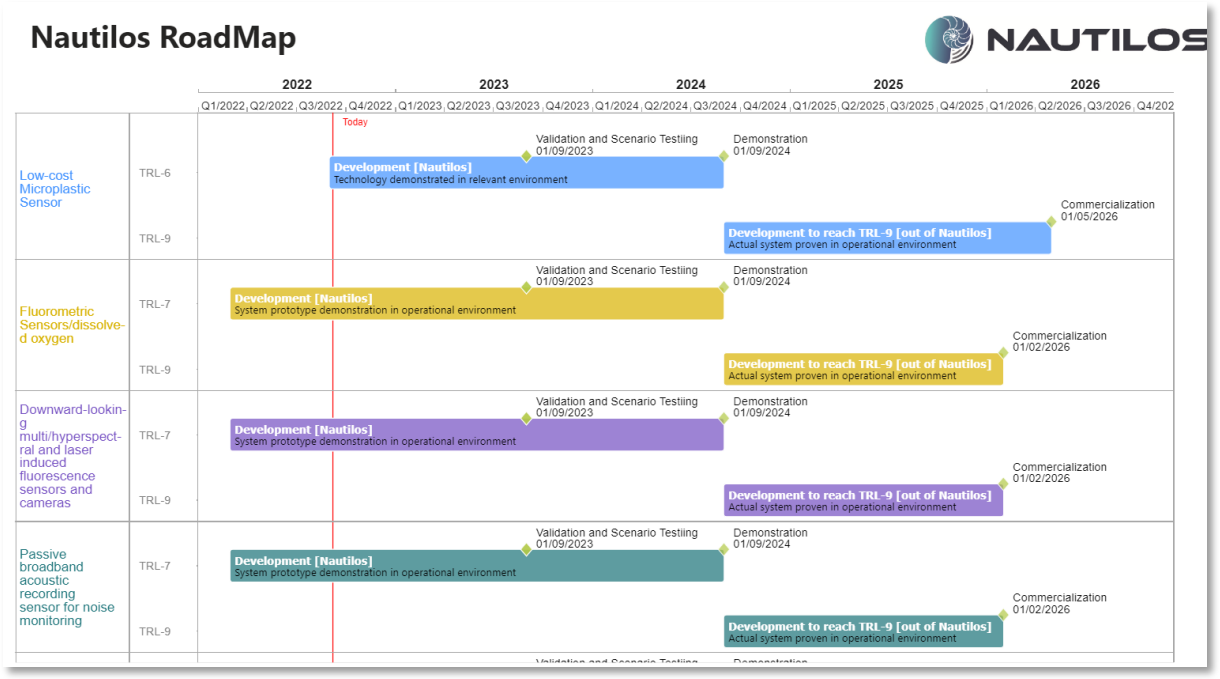


Figure 9: NAUTILOS OAIR in Power BI - NAUTILOS sensors timeline based on TRL

V. DATA COLLECTION – MARINE INSTRUMENTATION

NAUTILOS OAIR data collection methodology is divided into two steps, one passive and other active, as previously referred. Also, NAUTILOS OAIR builds on top of AtlantOS instrumentation roadmap that includes 58 different marine instrumentation references. In AtlantOS instrumentation roadmap, software solutions and web/mobile apps were not included. Hence, in NAUTILOS OAIR we will keep the focus on hardware solutions.

D11.2 presents results from the first step of NAUTILOS OAIR, where data was collected by passive or unknowingly methodology, using website visits and tracking social media, discussion forums and other online channels. Through this process it was possible to identify 44 new references to marine instrumentation developed in the scope of European projects including NAUTILOS project, not previously included into AtlantOS instrumentation roadmap, representing an increase of about 40% in marine instrumentation references.

Passive data collection methods have a limitation: data available is commonly outdated. Thus, active data collection step will be essential to collect detailed information using the questionnaire (Annex A), as for example marine instrumentation references namely maturity level (TRL), depth of operation, EOV covered, ongoing or planned commercialization and owner entity.

1. MARINE INSTRUMENTATION DATA FROM NAUTILOS PROJECT

NAUTILOS brings together a group of 21 entities from 11 European countries with multidisciplinary expertise to fill in existing marine observation and modelling gaps through the development of a new generation of cost-effective sensors and samplers for physical (salinity, temperature), chemical (inorganic carbon, nutrients, oxygen), and biological (phytoplankton, zooplankton, marine mammals) essential ocean variables, in addition to micro-/nano-plastics, to improve our understanding of environmental change and anthropogenic impacts related to aquaculture, fisheries, and marine litter. Nevertheless, the focus on instrumentation development (hardware solutions), we are not reducing the importance of other KERs (e.g., as software) when working in ocean observation domain. In fact, NAUTILOS KERs include several types of outputs from policies to sensors - software solutions or web/mobile apps will be provided (e.g. the NIR Scanner, a citizen science application) and data modelling products as well.

From those 44 new instruments (not previously included into AtlantOS instrumentation roadmap), 13 of them are sensors and samplers developed in NAUTILOS project. Table 5 includes information NAUTILOS instrumentation: name, technology maturity and depth of operation.

The method for estimating the maturity of technologies is defined as TRL (Technological Readiness Level; Figure 10).

Figure 10: TRL schematic representation[11]

TRL enables consistent and uniform discussions of technical maturity across different types of technology and are based on a scale from 1 to 9 with 9 being the most mature technology.[12] Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified[13]:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

NAUTILOS instrumentation is low to mid-TRL levels (starting from TRL 3 – experimental proof of concept) and the NAUTILOS goal is to develop them further to reach at least prototype stage (TRL 7) by the end of the project (except for microplastic sensor with maximum of TRL6 as it is the first ever in-situ microplastic sensor). This would include proven prototypes for fluorometric sensors (TRL 7-8), downward-looking multi/hyperspectral and laser induced fluorescence sensors and cameras (TRL 7), passive broadband acoustic recording sensor for noise monitoring (TRL7), passive acoustic event recorder (TRL7), active acoustic profiling sensor (TRL7), sampler for phytoplankton and other suspended matter (TRL8), carbonate system/ocean acidification sensors (TRL9), silicate electrochemical sensor (TRL8), sampler for nano-plastics and micro-plastics (TRL9), low-cost micro-plastic sensor (TRL6), deep ocean CTD (TRL7), deep ocean low-level radioactivity sensor (TRL7) (Table 5).

Once NAUTILOS goal is to improve ocean observation, depth of operation is of major importance. Instruments will operate from shallow coastal waters to open and deep-sea sites, providing complete datasets for studying the marine ecosystem functions and advanced data

[11] https://medium.com/prime-movers-lab/tools-for-technology-evaluation-trls-11daec23689
[12] https://web.archive.org/web/20171011071816/https://www.innovation.cc/discussion-papers/22_2_3_heder_nasa-to-eu-trl-scale.pdf
[13] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

products and tools. In NAUTILOS, 10 sensing and sampling technologies within NAUTILOS will be developed for deep sea environments (below 200 m), where 5 of those will have the capability to go below 2000m (Table 5).

Table 5: Starting and ending TRL for NAUTILOS 13 sensors and samplers

Marine Technologies Demonstrated in NAUTILOS	Starting TRL	Expected TRL achieved in the scope of NAUTILOS project				Depth of Operation (m)
		TRL6	TRL7	TRL8	TRL9	
Fluorometric Sensors/dissolved oxygen	3					250
Dissolved Oxygen and Fluorescence Sensors	5					600
Downward-looking multi/hyperspectral and laser induced fluorescence sensors and cameras	4					Subaerial
Passive broadband acoustic recording sensor for noise monitoring	4					1000
Passive acoustic event recorder (porpoise & dolphin clicks for abundance estimation)	5					300
Active Acoustic Profiling Sensor	5					1000[14]
Sampler for phytoplankton and other suspended matter	3					5500
Carbonate system/ocean acidification sensors	5					<100
Silicate Electrochemical Sensor	5					2000
Sampler for Nanoplastics and Microplastics	7					600
Low-cost Microplastic Sensor	3					0[15]
Deep Ocean CTD	4					2000
Deep ocean low-level radioactivity sensor	4					5000

Besides sensor name, TRL and depth of operation, NAUTILOS OIAR will collect information about ongoing or planned commercialization and EOV covered.

While, ongoing or planned commercialization, it is a topic under discussion in the following months, thus to be updated into the NAUTILOS OAIR to be updated until M48, EOV was a starting point in building NAUTILOS application. NAUTILOS will cover 14 Biology and Ecosystem and Biogeochemical EOVs (inorganic carbon, stable carbon isotopes, dissolved oxygen, inorganic macronutrients, suspended particulates, ocean colour, ocean sound, phytoplankton biomass and diversity, zooplankton biomass and diversity, marine turtles,

[14] With an option to go to 6000 m
[15] With an option to go to 600 m

birds, mammals, abundance and distribution, live coral, sea grass cover, microbe biomass and diversity (emerging) and invertebrate abundance and distribution (emerging), 2 DOOS specific EOVs (litter including microplastics, seafloor sponge habitat cover) and 9 MSFD Descriptors (D1, D3, D4, D5, D6, D7, D9, D10, D11) by the sensors and samplers as identified in Figure 7.

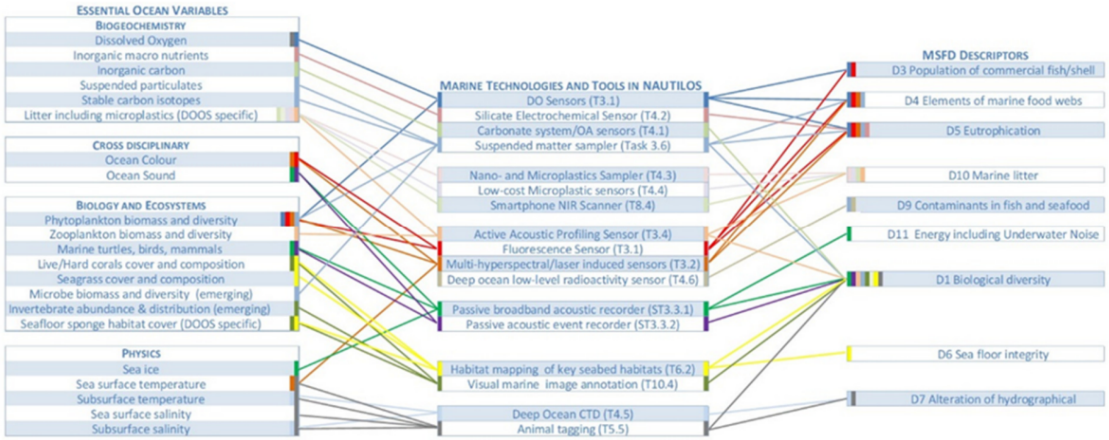


Figure 11: Environmental variables as covered by NAUTILOS instrumentation

2. MARINE INSTRUMENTATION DATA FROM OTHER EUROPEAN PROJECTS

From the 44 new instruments (not previously included into AtlantOS instrumentation roadmap), 31 new instruments, are reported as developed or under development in the scope of other European projects. Those results are described in Table 6.

Table 6: List of instrumentation compiled during instrumentation roadmap online survey

Project	Sensor name
NeXOS	A1 Acoustic Sensor
NeXOS	A2 Acoustic Array
NeXOS	O1 MatrixFlu
NeXOS	O1 MiniFluo
NeXOS	O2 OscarG2
NeXOS	O2 Hyperspectral Absorption Sensor
NeXOS	O3 Cbon2
NeXOS	O3 Cbon3
NeXOS	EAF-STPO2
NeXOS	EAF-STPFluo
SCHeMA	Carbon Cycle Sensing Module
SCHeMA	Trace Metal Sensing Module

SCHeMA	Nutrients Sensors Module
SCHeMA	Algae Sensing Module
SenseOCEAN	ANESIS: Autonomous Nutrient Electrochemical Sensor In Situ
SenseOCEAN	Multiparameter optical sensor – UV fluorescence applications
SenseOCEAN	Multiparameter optical sensor – Chlorophyll fluorescence
SenseOCEAN	Optodes for marine measurements
SenseOCEAN	Electrochemical microsensor – CO2
SenseOCEAN	Electrochemical microsensor – N2O
SenseOCEAN	Lab on chip chemical sensors
COMMON SENSE	Common Sense MISS (Mini-Seawater Sampling) System
COMMON SENSE	Common Sense pH/CO2 sensors
COMMON SENSE	Common Sense Temperature sensor
COMMON SENSE	Common Sense Heavy Metals Sensor
OCEANsensor	Miniaturized in-situ calibration system for Trace-Oxygen, pH and pCO2 optodes
OCEANsensor	TriOS UV nitrate sensor
OCEANsensor	SeaGuardII instrument
CEiiA	towed/mounted animal tagging
CNRS	Glue-on animal tagging

3. DISCUSSION

Passive data collection methods have several advantages, as they are cost-effective and low-time consuming, but above all in NAUTILOS OAIR it provides a rich source of data, that could be not registered due to absence in replying to a questionnaire. Nevertheless, it is common for passive data collection methods, such as literature reviews and searches of publicly available information, to present outdated or incomplete data. This is because these methods rely on information that has already been published or made publicly available and may not include the most recent developments or proprietary information.

In fact, NAUTILOS OIAR results show a significant increase in the number of marine instrumentation references, compared to the AtlantOS instrumentation roadmap. In additional to 58 references from AtlantOS, NAUTILOS OAIR includes 13 new technologies from NAUTILOS and 31 new instrumentation references from other European projects, for a total of almost 100 references for marine instrumentation.

However, it was possible to confirm the absence of relevant data as information on the current TRL and planned commercialization of these instruments. This data will be requested to stakeholders during the second phase of data collection

Additionally, it was possible, when assessing all aforementioned projects, to identify 33 different testing platforms that were considered for the questionnaire (Appendix 4: NAUTILOS OAIR – Questionnaire).

NAUTILOS OIAR can be found in Appendix 3: NAUTILOS OAIR – Instrumentation database. It will be updated until M48 with information retrieved from stakeholders' answers to questionnaire or other contribute from NAUTILOS project so that it keeps on growing and truly represents the ecosystem. It will be included, again, in M48, to be available for all.

VI. CONCLUSION

NAUTILOS OIAR is a multinational marine instrumentation roadmap, collecting information about available technologies for oceanography stakeholders (e.g., industry, policymakers, researchers). It builds on existing information of related projects as AtlantOS with a focus on marine instrumentation related to European entities (in AtlantOS, instrumentation roadmap results show that 88% of contacts were from Europe and 98% of answers were from Europe).

As a key pillar of the instrumentation roadmap is to have a broad stakeholder's engagement, in NAUTILOS, to maximize the impact of NAUTILOS OAIR, a close attention to the contact list made it possible to increase the number of contacts from 136 to 185, thus trying to avoid AtlantOS concern of a reduced representation of certain groups or organizations. Therefore, rewards mechanisms will be implemented to encourage stakeholders to share their instrumentation data and use NAUTILOS OAIR as a strategic tool. The goal is to foster a stronger and more complementary industry in Europe by understanding competitors.

NAUTILOS OAIR data collection methodology includes two steps: passive and active. By increasing the complexity of data collection, when compared to AtlantOS, NAUTILOS aims to increase the representation of instrumentation developed in European projects, to reduce lack of information due to survey nonresponse and to build on top of AtlantOS database without losing data. NAUTILOS OAIR includes 58 references from AtlantOS project, 13 from NAUTILOS and 31 new instruments found when assessing European projects. Altogether, it includes more than 100 references for instrumentation (Appendix 3: NAUTILOS OAIR – Instrumentation database). The second step of NAUTILOS OAIR is an online survey, which is expected to increase the representation of instrumentation and collect detailed and updated information about the current TRL and planned commercialization. All information will be delivered as part of the final exploitation strategy of NAUTILOS in M48.

The data collected by NAUTILOS OAIR system will be organized and made available in open access format, in PDF format and using Power BI. This will allow for easy access to the data for all interested parties, and users will be able to interact with various data sources and create interactive visualizations, reports and dashboards.

APPENDIX 1: REFERENCES AND RELATED DOCUMENTS

ID	Reference or Related Document	Source or Link/Location
1	Grant Agreement	*https://cloud.nautilos-h2020.eu/index.php/f/30*
2	D11.1 - NAUTILOS Exploitation Strategy - Initial Version	*https://cloud.nautilos-h2020.eu/index.php/f/2706*
3	D2.1 - A review and prospectus of the mandate for marine environmental monitoring systems – technology challenges and opportunities	*https://cloud.nautilos-h2020.eu/index.php/f/3344*
4	Sensors and Instrumentation Roadmap, from AtlantOS project	*https://atlantos-h2020.eu/download/deliverables/6.1%20Sensors%20and%20Instrumentation%20Roadmap.pdf*
5	Roadmap Advanced Instrumentation	*https://hollandhightech.nl/_asset/_public/Innovatie/Technologieen/z_pdf_roadmaps/Roadmap-Advanced-Instrumentation_v25112020-FINAL-update-2020.pdf*
6	Visbeck, M. (2018). Ocean science research is key for a sustainable future. Nat. Commun. 9:690. doi: 10.1038/s41467-018-03158-3	n.a.
7	The Ocean of Tomorrow Projects (2010-2013) - Joint Research Forces to Meet Challenges in Ocean Management. 2014. European Commission.	*https://op.europa.eu/en/publication-detail/-/publication/85b05ee8-7f0b-49ae-80ba-0bbb811de915*
8	Microsoft Power BI Quick Start Guide : Bring Your Data to Life Through Data Modeling, Visualization, Digital Storytelling, and More, 2nd Edition by Mitchell Pearson, Devin Knight, Bradley Schacht and Erin Ostrowsky (2020, Trade Paperback).	n.a.
9	IOC criteria and guidelines on the transfer of marine technology	*https://unesdoc.unesco.org/ark:/48223/pf0000139193*

APPENDIX 2: NAUTILOS OAIR - CONTACT LIST

Institution	Country	Entity type
TECHNISCHE UNIVERSITAET GRAZ	Austria	HEI
EIG Eumetnet	Belgium	Other
European Global Ocean Observing System (EUROGOOS)	Belgium	Research
VLIZ	Belgium	Research
Ministério da Ciência, TecNologia e INovação (MCTI)	Brazil	Other
EVROPROJECT OOD	Bulgaria	Industry
Dalhousie University	Canada	HEI
MEOPAR Incorporated	Canada	Industry
Ocean Sonics	Canada	Industry
RBR	Canada	Industry
Satlantic	Canada	Industry
Vemco	Canada	Industry
Bruncin	Croatia	Industry
Danmarks Meteorologiske Institut	Denmark	Other
Danmarks Tekniske Universitet (DTU)	Denmark	HEI
International Council for the Exploration of the Sea (ICES)	Denmark	Other
Konsortium Deutsche Meeresforschung e.V. (KDM)	Denmark	Other
AARHUS UNIVERSITET	Denmark	HEI
UNISENSE AS	Denmark	Industry
Flydog Solutions LLC	Estonia	Industry
Havstovan	Faroe Islands	Other
SUOMEN YMPARISTOKESKUS	Finland	Other
ACRI-ST	France	Industry
Collecte Localisation Satellites (CLS)	France	Industry
Hydroptic	France	Industry
Ifremer	France	Research
Institut de Recherche pour le Dévelop., Lab. d'Etudes en Géoph. Et Océanog. Spatiales (IRD)	France	Research
Institute of Electrical and Electronics Engineers Inc (IEEE)	France	Other
Mercator Ocean	France	Other
Meteo France	France	Other
United Nations Educational, Scientific and Cultural Organization - UNESCO IOC	France	Other
Universite Pierre et Marie Curie (UPMC)	France	HEI

Villefranche Oceanographic Laboratory (LOV)	France	Research
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	France	Other
Institut Français de Recherche pour l'Exploitation de la Mer	France	Other
Aix Marseille University	France	HEI
Architecture et Conception de Systèmes Avancés	France	Industry
NKE Instrumentation	France	Industry
IEEE France Section	France	Other
UNIVERSITE DE BORDEAUX	France	HEI
CONTROS Systems & Solutions GmbH	Germany	Industry
Develogic GmbH	Germany	Industry
Geomar	Germany	Research
RIBOCON GMBH	Germany	Industry
Universitaet Bremen (MARUM)	Germany	HEI
DEUTSCHES FORSCHUNGSZENTRUM FUR KUNSTLICHE INTELLIGENZ GMBH	Germany	Research
Universität Bremen	Germany	HEI
52°North Initiative for Geospatial Open Source Software GmbH	Germany	Other
Carl von Ossietzky Universität Oldenburg	Germany	HEI
TriOS MEss- und Datentechnik GmbH	Germany	Industry
Helmholtz-Zentrum Geesthacht Zentrum fur Material-und Kustenforschung GmbH	Germany	Research
UNIVERSITAET ULM	Germany	HEI
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FUR POLAR- UND MEERESFORSCHUNG	Germany	Research
MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV	Germany	Research
PYRO SCIENCE GMBH	Germany	Industry
SUBCTECH GMBH	Germany	Industry
PreSens	Germany	Industry
HELLENIC CENTRE FOR MARINE RESEARCH	Greece	Other
Star Oddi	Iceland	Industry
T.E. LABORATORIES LIMITED	Ireland	Industry
AQUA TT UETP COMPANY LIMITED BY GUARANTEE	Ireland	Industry
DUBLIN CITY UNIVERSITY	Ireland	HEI
UNIVERSITY COLLEGE CORK - NATIONAL UNIVERSITY OF IRELAND, CORK	Ireland	HEI
Alma Mater Studiorum-Universita di Bologna (UNIBO)	Italy	HEI

Centro Euro Mediterraneo sui Cambiamenti Climatici S.c.a r.l. (CMCC)	Italy	Other
CLU Srl	Italy	Industry
ETT S.p.A. - Electronic TechNology Team	Italy	Industry
LOSEM University of Tuscia	Italy	HEI
Systea	Italy	Industry
EDGELAB SRL	Italy	Industry
UNIVERSITA DELLA CALABRIA	Italy	HEI
SMID Technology s.r.l.	Italy	Industry
IDRONAUT SRL	Italy	Industry
UNIVERSITA DEGLI STUDI DI GENOVA	Italy	HEI
CONSIGLIO NAZIONALE DELLE RICERCHE (CNR)	Italy	Research
Ko-Ichi Nakamura	Japan	Research
MARIS B.V.	Netherlands	Industry
Stichting Koninklijk Nederlands Instituut Voor Zeeonderzoek (NIOZ)	Netherlands	Research
ECORYS Nederland BV	Netherlands	Industry
Ss. CYRIL AND METHODIUS UNIVERSITY IN SKOPJE (FTM-UCIM)	North Macedonia	HEI
IMR	Norway	Research
Norsk Institutt for Vannforskning (NIVA)	Norway	Research
University Bergen Norway (UIB)	Norway	Research
Christian Michelsen Research AS	Norway	Research
Runde Miljøsenter AS	Norway	Industry
Franatech AS	Norway	Industry
Uni Research AS	Norway	Research
Kongsberg	Norway	Industry
Nortek	Norway	Industry
Institute of Oceanology Polish Academy of Sciences (IO PAS)	Poland	Other
Interdisciplinary Centre for Marine and Environmental Research (CIIMAR)	Portugal	Other
Universidade do Porto (UPORTO)	Portugal	HEI
Universidade do Algarve (UALG)	Portugal	HEI
University of the Azores (IMAR)	Portugal	HEI
UNIVERSIDADE DO ALGARVE	Portugal	HEI
CEIIA - CENTRO DE ENGENHARIA E DESENVOLVIMENTO (ASSOCIACAO)	Portugal	Research
CoLab +Atlantic	Portugal	Research

FUNDACAO EUROCEAN	Portugal	Other
IMAR - INSTITUTO DO MAR	Portugal	Research
Composite Solutions	Portugal	Industry
Daithi O'Murchu Marine Research Station Ltd.	Republic of Ireland	Research
DCU	Republic of Ireland	Research
Marine Institute	Republic of Ireland	Research
TelLab	Republic of Ireland	Industry
Marlin-Yug Ltd.	Russia	Industry
SAMS	Scotland	Research
UNIVERZA V LJUBLJANI	Slovenia	Other
Council for Scientific and Industrial Research (CSIR)	South Africa	Research
Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC)	Spain	Research
Albatros marine tech	Spain	Industry
Instituto Español de Oceanografía (IEO)	Spain	Other
Plataforma Oceánica de Canarias (PLOCAN)	Spain	Other
Universitat Politècnica de Catalunya	Spain	HEI
Centro Tecnológico Naval y del Mar	Spain	Research
NANOMATERIALES Y POLIMEROS SL	Spain	Industry
LEITAT TECHNOLOGICAL CENTER	Spain	Research
METROHM DROPSENS SL	Spain	Industry
FUNDACION PRIVADA PER LA NAVEGACIO OCEANICA BARCELONA	Spain	Other
SIMULACIONS OPTIQUES SL	Spain	Industry
Hercules Control	Spain	Industry
HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE	Switzerland	HEI
CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT	Switzerland	Research
UNIVERSITE DE GENEVE (UNIGE)	Switzerland	HEI
ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL)	Switzerland	HEI
Endress+Hauser	Switzerland	Industry
Aquaread	United Kingdom	Industry
Aquatec	United Kingdom	Industry
Atlas Electroniks	United Kingdom	Industry
Babcock	United Kingdom	Industry
Bae Systems	United Kingdom	Industry
BAS	United Kingdom	Research
Blue Lobster Ltd	United Kingdom	Industry

BMT Defence	United Kingdom	Industry
Boeing	United Kingdom	Industry
Bristol University	United Kingdom	HEI
CEFAS	United Kingdom	Research
Chelsea Technologies Group	United Kingdom	Industry
Cranfield technology uni	United Kingdom	HEI
DE&S	United Kingdom	Industry
DSTL	United Kingdom	Industry
European Centre for Medium-Range Weather Forecasts (ECMWF)	United Kingdom	Other
Fraser Nash	United Kingdom	Industry
Lockheed Martin	United Kingdom	Industry
MBA	United Kingdom	Research
Met Office	United Kingdom	Other
NATURAL ENVIRONMENT RESEARCH COUNCIL	United Kingdom	Other
OSIL	United Kingdom	Industry
Oxford University	United Kingdom	HEI
Planet Ocean	United Kingdom	Industry
PML	United Kingdom	Research
Qinetiq	United Kingdom	Industry
RN	United Kingdom	Industry
Robert Gordon Institute	United Kingdom	HEI
Rolls Royce	United Kingdom	Industry
RS Aqua Ltd	United Kingdom	Industry
SAHFOS	United Kingdom	Research
SEA Ltd	United Kingdom	Industry
Seascape Consultants Ltd (EMODNET Secretariat)	United Kingdom	Industry
SECRETARY OF STATE FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (CEFAS)	United Kingdom	Other
Sonardyne	United Kingdom	Industry
STS defence	United Kingdom	Industry
Thalis	United Kingdom	Industry
UEA	United Kingdom	HEI
UK Hydrographic Office	United Kingdom	Industry
Ultra Electronics	United Kingdom	Industry
University of Bangor	United Kingdom	HEI
University of Cambridge	United Kingdom	HEI

University of Exeter	United Kingdom	HEI
University of Hull	United Kingdom	HEI
University of Liverpool	United Kingdom	HEI
University of Plymouth	United Kingdom	HEI
University of Southampton	United Kingdom	HEI
Valeport	United Kingdom	Industry
Los Gatos, Batelle	USA	Industry
National Oceanic and Atmospheric Administration	USA	Other
Seabird Scientific	USA	Industry
Teledyne	USA	Industry
WetLabs	USA	Industry
Woods Hole Oceanographic Institution	USA	Research
Xylem	USA	Industry
Universidade de Aveiro	Portugal	HEI
Inova-Ria - Association of Companies for an Innovation Network in Aveiro	Portugal	Other
Fórum Oceano	Portugal	Other

APPENDIX 3: NAUTILOS OAIR – INSTRUMENTATION DATABASE

Project	Sensor name
NAUTILOS	Fluorometric Sensors/dissolved oxygen
NAUTILOS	Dissolved Oxygen and Fluorescence Sensors
NAUTILOS	Downward-looking multi/hyperspectral and laser induced fluorescence sensors and cameras
NAUTILOS	Passive broadband acoustic recording sensor for noise monitoring
NAUTILOS	Passive acoustic event recorder (porpoise & dolphin clicks for abundance estimation)
NAUTILOS	Active Acoustic Profiling Sensor
NAUTILOS	Sampler for phytoplankton and other suspended matter
NAUTILOS	Carbonate system/ocean acidification sensors
NAUTILOS	Silicate Electrochemical Sensor
NAUTILOS	Sampler for Nanoplastics and Microplastics
NAUTILOS	Low-cost Microplastic Sensor
NAUTILOS	Deep Ocean CTD
NAUTILOS	Deep ocean low-level radioactivity sensor
NeXOS	A1 Acoustic Sensor
NeXOS	A2 Acoustic Array
NeXOS	O1 MatrixFlu
NeXOS	O1 MiniFluo
NeXOS	O2 OscarG2
NeXOS	O2 Hyperspectral Absorption Sensor
NeXOS	O3 Cbon2
NeXOS	O3 Cbon3
NeXOS	EAF-STPO2
NeXOS	EAF-STPFluo
SCHeMA	Carbon Cycle Sensing Module
SCHeMA	Trace Metal Sensing Module
SCHeMA	Nutrients Sensors Module
SCHeMA	Algae Sensing Module
SenseOCEAN	ANESIS: Autonomous Nutrient Electrochemical Sensor In Situ
SenseOCEAN	Multiparameter optical sensor – UV flurescence applications
SenseOCEAN	Multiparameter optical sensor – Chlorophyll flouorescence

SenseOCEAN	Optodes for marine measurements
SenseOCEAN	Electrochemical microsensor – CO2
SenseOCEAN	Electrochemical microsensor – N2O
SenseOCEAN	Lab on chip chemical sensors
OCEANsensor	Miniaturized in-situ calibration system for Trace-Oxygen, pH and pCO2 optodes
OCEANsensor	TriOS UV nitrate sensor
OCEANsensor	SeaGuardII instrument
CEiiA	towed/mounted animal tagging
CNRS	Glue-on animal tagging
COMMON SENSE	Common Sense MISS (Mini-Seawater Sampling) System
COMMON SENSE	Common Sense pH/CO2 sensors
COMMON SENSE	Common Sense Temperature sensor
COMMON SENSE	Common Sense Heavy Metals Sensor
Common Sense Project	Cefas Noise Sensor (pre production prototype)*
Common Sense Project	SSU (Smart Sensor Unit)*
Common Sense Project	MK2 pCO2 Analyser (water)*
Common Sense Project	MK3 pCO2 Analyser (air)*
Common Sense Project	OceanPack AUMS*
Common Sense Project	OceanPack Subsea*
Common Sense Project	Microplastic sensor*
Common Sense Project	Nutrient Sensor*
Flydog Solutions LLC	Profiler buoy 'Mona'*
Flydog Solutions LLC	Submersed profiler 'Salla'*
Geomar	HydroFIA TA*
Geomar	HydroFlash O2*
Geomar	HydroFlash CO2*
LOSEM University of Tuscia	TFLaP*
LOSEM University of Tuscia	Spectra (derived from TFLaP)*
National Oceanography Centre	Chemical Sensors: Nitrite
National Oceanography Centre	Chemical Sensors: Phosphate
National Oceanography Centre	Chemical Sensors: Ammonia
National Oceanography Centre	Chemical Sensors: Silicate
National Oceanography Centre	Chemical Sensors: DON
National Oceanography Centre	Chemical Sensors: DOP

National Oceanography Centre	Chemical Sensors: pH
National Oceanography Centre	Chemical Sensors: TA
National Oceanography Centre	Chemical Sensors: DIC
National Oceanography Centre	Chemical Sensors: Fe
National Oceanography Centre	Chemical Sensors: Mn
National Oceanography Centre	Chemical Sensors: O2
National Oceanography Centre	Chemical Sensors: pCO2
National Oceanography Centre	Chemical Sensors: CH4
National Oceanography Centre	Chemical Sensors: Hydrocarbons
National Oceanography Centre	Chemical Sensors: Aptamer sensors
National Oceanography Centre	Biology Sensors: Cytometer
National Oceanography Centre	Physical Sensors: T,C
NKE	SST & SSS sensor*
NORTEK	Signature55 *
NORTEK	Signature250*
NORTEK	Signature500*
NORTEK	Signature1000*
NORTEK	Nortek DVL*
Ocean Sonics	icListen Smart Hydrophone*
Ocean Sonics	icListen RB9-ETH*
Ocean Sonics	Digitial hydrohone array

APPENDIX 4: NAUTILOS OAIR – QUESTIONNAIRE

Please fill in one form per sensor or instrument.

This form is part of deliverable **D11.2 Open Access Instrumentation Roadmap of NAUTILOS project** which intends to outline a marine instrumentation roadmap of available technology for oceanography stakeholders, it will be a ten-year open access roadmap for marine instrumentation presenting information from industrial companies, universities and research centers including the name of the sensor/ instrument, the application area or type of technology, maturity level (TRL) and information about its ongoing or planned commercialization.

More information on the project can be found at: https://www.nautilos-h2020.eu/.

Name of the sensor or instrument that was developed:

Sensor description:

[Brief description of the sensor or instrument goal; up to characters no spaces]

Link for more information:

[datasheet; website; other relevant information, sensor ID]

Did this sensor was developed or/and validated or/and demonstrated in any of these projects?

- ☐ NAUTILOS
- ☐ NeXOS
- ☐ SCHeMA
- ☐ SenseOCEAN
- ☐ Common Sense
- ☐ OCEANSensor
- ☐ Other:
  - *[Description]*
- ☐ None (sensor is/was developed outside of the scope of anyproject)

Essential ocean variables (EOVs) covered by this sensor:

1. Physics
   - ☐ Sea state
   - ☐ Ocean surface stress
   - ☐ Sea ice
   - ☐ Sea surface height
   - ☐ Sea surface temperature
   - ☐ Subsurface temperature
   - ☐ Surface currents
   - ☐ Subsurface currents
   - ☐ Sea surface salinity
   - ☐ Subsurface salinity
   - ☐ Ocean surface heat flux

2. Biochemistry

- ☐ Oxygen
- ☐ Nutrients
- ☐ Inorganic carbon
- ☐ Transient tracers
- ☐ Particulate matter
- ☐ Nitrus oxide
- ☐ Stable carbon isotopes
- ☐ Dissolved organic carbon

3. Biology and Ecosystems:
   - ☐ Phytoplankton biomass and diversity
   - ☐ Zooplankton biomass and diversity
   - ☐ Fish abundance and distribution
   - ☐ Marine turtles, birds, mammals abundance and distribution
   - ☐ Hard coral cover and composition
   - ☐ Seagrass cover and composition
   - ☐ Macroalgal canopy cover and composition
   - ☐ Mangrove cover and composition
   - ☐ Microbe biomass and diversity (*emerging)
   - ☐ Invertebrate abundance and distribution (*emerging)

4. Cross-disciplinary (including human impact):
   - ☐ Ocean colour
   - ☐ Marine debris (*emerging)
   - ☐ Ocean sound

5. Other variables covered:
   - ☐ DO
   - ☐ Chlorophyll
   - ☐ Laser induced chlorophyll-a fluorescence
   - ☐ Marine mammal sound detection
   - ☐ Suspended particle concentration / distribution
   - ☐ pH
   - ☐ pCO2
   - ☐ CO3
   - ☐ Silicate concentration (Si)
   - ☐ Concentrated suspended matter samples
   - ☐ Characterisation of microplastics
   - ☐ Conductivity
   - ☐ Marine radioactivity
   - ☐ Plastics
   - ☐ Others
     - *[Description]*

Application/ commercial purpose:

- ☐ Aquaculture Observing Systems
- ☐ Fisheries
- ☐ Fishermen deploying static nets
- ☐ Detection & mapping of marine mammals
- ☐ Study of sea ice dynamics

- ☐ Detection & localization of seismic events
- ☐ Monitoring of acoustic impact of different human activities
- ☐ Detect possible drifts
- ☐ Detect evidence of volcanoes, hydrothermal vents, and other deep-sea features that cause changes to the physical and chemical properties of seawater
- ☐ Oceanic plastic pollution
- ☐ Phytoplankton detection
- ☐ Sea surface temperature
- ☐ Others:
    - *[Description]*

Depht of operation (in meters):

Platforms that can be integrated:

- ☐ Abalone tank
- ☐ AdriFOOS
- ☐ Argo Float
- ☐ ASV
- ☐ AUVs
- ☐ Deep Gliders
- ☐ Ferries
- ☐ FerryBox
- ☐ Fixed platforms
- ☐ Fixed stations
- ☐ Floating buoy
- ☐ Floating pontoons
- ☐ Glider
- ☐ Harbor Station
- ☐ Lander
- ☐ Mobile platforms
- ☐ Motorboat
- ☐ Profiling CTDs
- ☐ Profiling float
- ☐ Racing Yacht
- ☐ RV
- ☐ Ship
- ☐ Steel frame on pontoon
- ☐ Submersible housing
- ☐ Surface Gliders
- ☐ Towed vehicles
- ☐ UAV
- ☐ Undersea mooring
- ☐ UUV
- ☐ Vessel
- ☐ Wave Gliders
- ☐ Others
    - *[Description]*

Current TRL:

- ☐ TRL 1 - basic principles observed
    - Yes

- No
- When
  - *[Date]*

☐ TRL 2 - technology concept formulated
- Yes
- No
- When
  - *[Date]*

☐ TRL 3 - experimental proof of concept
- Yes
- No
- When
  - *[Date]*

☐ TRL 4 - technology validated in lab
- Yes
- No
- When
  - *[Date]*

☐ TRL 5 technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- Yes
- No
- When
  - *[Date]*

☐ TRL 6 - technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- Yes
- No
- When
  - *[Date]*

☐ TRL 7 - system prototype demonstration in operational environment
- Yes
- No
- When
  - *[Date]*

☐ TRL 8 - system complete and qualified
- Yes
- No
- When
  - *[Date]*

☐ TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)
- Yes
- No
- When
  - *[Date]*

Upload a picture of the sensor:

Already commercially available:

- ☐ Yes
  - Available online?
    - Yes
    - No
    - Which institution sells this sensor?
      - *[website and contact point to be made available in NAUTILOS OAIR]*
- ☐ No
  - Expected to be in:
    - *[Date]*
  - *Not expected*

Which institution owns sensor IPR?
[institution name; contact point]

Information about the person filling the questionnaire:

- Contact Person:
- Contact Person e-mail:
- Institution Name:
- Institution website:

Please fill in one form per sensor or instrument.