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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 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: <http://nautilus-h2020.eu/>.

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EXECUTIVE SUMMARY

This report highlights the efforts made during the WP7 activities, which focused on advancing the technology readiness levels (TRLs) of the NAUTILOS sensors. It summarises these efforts comprehensively in order to draw conclusions about procedures and possible improvements that could contribute to advancing the maturity of marine scientific instrumentation technology.

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
ACT	Alliance for Coastal Technologies
ASVs	Autonomous Surface Vessels
Chl- <i>a</i>	Chlorophyll -a
COTS	Commercial Off-the-Shelf
CTD	Conductivity Temperature Depth
DO	Dissolved Oxygen
EC	European Commission
EU	European Union
H2020	HORIZON 2020
IR	Infrared

¹ <http://www.oceanobs09.net/proceedings/cwp/Brasseur-OceanObs09.cwp.10.pdf>

LIF-LIDAR	Laser-Induced Fluorescence Light Detection and Ranging
NASA	National Aeronautics and Space Administration.
NCP	National Contact Point
NSF	National Science Foundation's
OOI	Ocean Observatories Initiative
PAS	Passive Acoustic Sensor
pCO ₂	Partial pressure of Carbon dioxide
pH	Potential of Hydrogen
QA/QC	Quality assurance/Quality control
R/V	Research Vessel
TRL	Technology Readiness Level
UAVs	Underwater Autonomous Vessels

I. INTRODUCTION

Technological innovation plays a vital role in advancing both scientific research and industrial applications. As technologies progress, they move through various stages of development — from early ideas to fully operational solutions. To track this progression, the Technology Readiness Level (TRL) scale is used. Ranging from basic concept to market-ready product TRL offers a standardised way to measure how mature a technology is. This scale helps researchers, developers, and policymakers understand how close a technology is to practical use and large-scale deployment.

II. TRL DEFINITION

- 1. BACKGROUND

The TRL scale² was originally defined by U.S. National Aeronautics and Space Administration (NASA) as “a type of measurement system used to assess the maturity level of a particular technology.” TRL scale is a parameter that evaluates the maturity of a technology according to a series of indicators ranging from 1 (the basic principles are documented) to 9 (the technology is released, and industrial production is started). The TRL scale was introduced in EU-funded projects in 2012 and is currently the point of reference for determining the development or maturity of a research product and its readiness for market uptake and potential investments (Fig 1). Also, the TRL enables applicants and reviewers to align with the expectations of the EC in the context of the evaluation of proposals and project results. As an example, Research and Innovation Actions typically cover projects starting at TRL 2-3 and reaching TRL 5-6, while the Innovation Actions cover projects that start at TRL 4-5 and end at TRL 6-8. TRL is also useful to define what steps should be taken in order to bring the research result to the next level.

²<https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/>

Technology Readiness Levels

Where the specific call/topic conditions require a Technology Readiness Level (TRL), the following definitions apply, unless otherwise specified:

- TRL 1 — Basic principles observed
- TRL 2 — Technology concept formulated
- TRL 3 — Experimental proof of concept
- TRL 4 — Technology validated in a lab
- TRL 5 — Technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 — Technology demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 — System prototype demonstration in an operational environment
- TRL 8 — System complete and qualified
- TRL 9 — Actual system proven in an operational environment (competitive manufacturing in the case of key enabling technologies, or in space)

Figure 1. The TRL scale for EU-funded projects (from the General Annexe n. 13 of the Horizon Europe Work Programme 2023-2025³).

● 2. TRL DEFINITION

Since the TRL of the H2020 project is self-declared, it is important to adopt a TRL definition and scale that is applicable to a specific sector. Especially because the transition between TRLs can be somewhat elusive if just applying the general Annex definition. The transitions between levels, especially mid-range (TRL 4 to TRL 6), often involve subjective judgment (Fig 2).

Different industries interpret TRLs differently — e.g., a TRL 6 in healthcare might not be equivalent to a TRL 6 in aerospace or environmental monitoring products. Moreover, the type and extent of evidence required to justify higher TRLs—such as laboratory validation, pilot testing, or field demonstrations—vary greatly between sectors. A demonstration for a software solution involves different procedures and timeframes compared to a hardware component, which typically must undergo testing under realistic operating conditions.

³https://www.google.com/url?q=https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2023-2024/wp-13-general-annexes_horizon-2023-2024_en.pdf&sa=D&source=docs&ust=1753444430240109&usg=AOvVaw3kEygX8G3Kn8lrTOPpl8TR

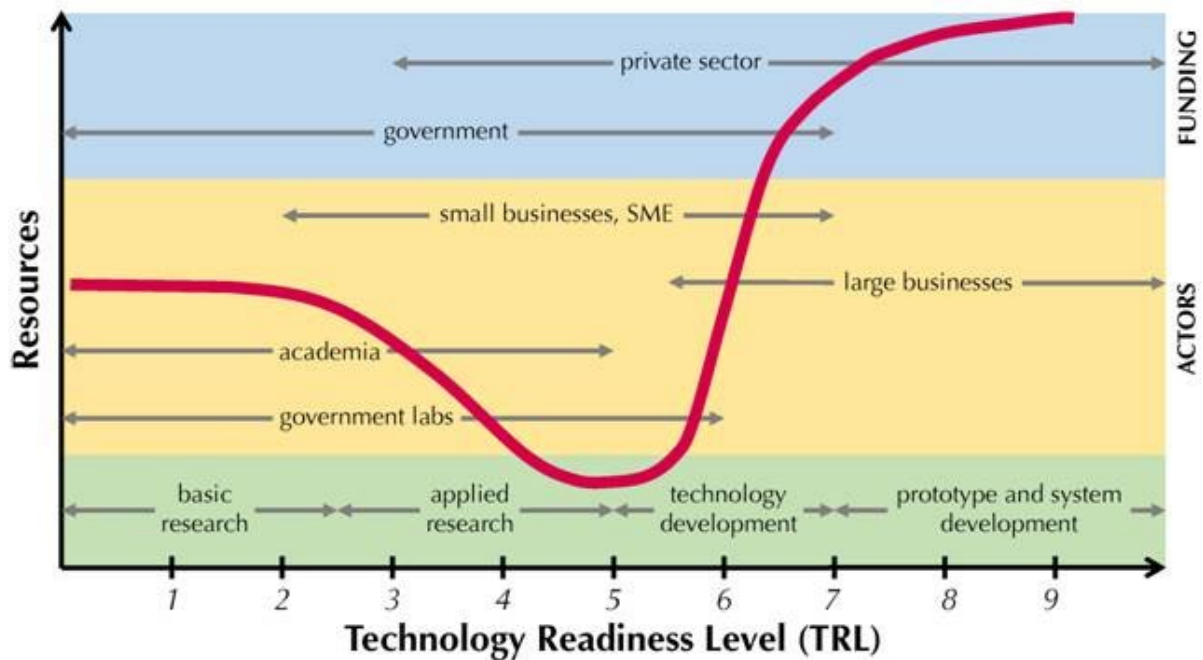


Figure 2. Availability of resources for new product development at various TRLs, highlighting the “Valley of Death” where support often drops off⁴. The “Valley of Death” refers to the critical gap between early-stage innovation and market-ready products, where many technologies fail due to a lack of support. Bridging this gap is a key focus of EU policy programs like Horizon 2020, aiming to accelerate the transition from research to commercial application.

The TRL definition adopted by the NAUTILOS project to characterise the technology maturity status after each development/testing step originates from the H2020 Bridge2HE project⁵. The Bridge2HE project worked on the integration of the National Contact Points (NCP) system into a coherent framework for Horizon Europe. It also provided a library of tools and services for participants, such as the TRL self-assessment tool (horizoneuropencpportal.eu/store/trl-assessment) focused on Research and Innovation Actions corresponding to a TRL starting level of 3.

● TRL ADOPTION

This tool guides the definition of TRL based on the type of solutions to be developed, categorised into 5 possible types of outputs:

- 1) A product that is manufactured
- 2) An industrial process
- 3) A software
- 4) A medical device

⁴<https://www.rehva.eu/rehva-journal/chapter/using-building-simulation-for-moving-innovations-across-the-valley-of-death>

⁵<https://cordis.europa.eu/project/id/101005071>

5) A drug

So, in the case of NAUTILOS, being a project that develops marine monitoring technologies and products, the choice is #1 (manufactured products), corresponding to the TRL definitions presented in the table below.

Table 1. The TRL scale for a product that is manufactured.

TRL 3	Analytical studies on separate elements of the technology. Laboratory based trials that show the feasibility of the predictions.
TRL 4	Basic technological components integrated together to show that they work together. At this point, durability is not yet important
TRL 5	Basic technological components integrated within realistic context under a fully controlled environment in or outside the lab.
TRL 6	A functional version of the product working in a realistic environment, able to draw conclusions on the technical and operational capabilities of the product.
TRL 7	A manufacturable version of the product working in an environment which addresses all the operational requirements for the product.
TRL 8	Product in its final form working in full mode under expected conditions and periods.
TRL 9	Product in its final form under full commercial deployment.

III. TRL ADVANCEMENT STRATEGY

The NAUTILOS project has been organised as a series of successive steps, each one paving the way for the next one in terms of technology maturity. In this chain of events WP2 guided the development providing specifications for marine instrumentation followed by WP3 and WP4 focused on the actual development of the sensors. Next steps performed in parallel for time effectiveness were the integration of sensors in platforms/systems during WP5 and the laboratory and control environment testing and validation in WP6. The final technical step of the project were the demonstrations in realistic conditions carried out in WP7.

The main objective of the calibration and validation tests performed during WP6 was to assess measurement accuracy under realistic/relevant conditions and ranges and to ensure the instruments' reliability for the demonstration requirements of WP7. Links with WP5 were also considered for certain sensors to verify performance when integrated into observing platforms. A key aim of WP6 was to improve the technical readiness level, enhancing the likelihood of successful in situ demonstrations. The tests were conducted across multiple laboratories and experimental sites in a harmonised manner to ensure consistency. Experiments focused on sensor performance and data validation, using reference equipment and materials. New experimental setups accounted for external factors such as temperature and salinity. Post-data compensation methods were tested, and new validation protocols were developed. These efforts were critical both for achieving the required data quality and for assessing the TRL of the sensors and samplers after the development in WPs 3 and 4.

During WP7, the NAUTILOS sensors were demonstrated across multiple regions using a variety of oceanographic platforms and configurations. The strategy behind these demonstrations was to test the sensors in diverse and representative marine environments, ensuring their performance under different operational conditions. This included deployments on platforms such as autonomous vehicles, fixed observatories, commercial and research vessels and marine animals as sensor carriers.

In addition to the EU/BRIDGE2HE TRL, that guided the technical work and reporting for the demonstrations of the project, NAUTILOS also considered:

- a) the TRL definitions applicable to the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI) core sensors (Fig.3).

OOI TRL	Description
1. Proof of Concept / Development	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. The application is speculative and there is no proof or detailed analysis to support the assumption. Includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology.
2. Research: Prototype	The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated or relevant environment. Prototype instrument packages have been used to collect data in research studies of technology or environmental parameter.
3. Research: Proven	Technology has not been commercialized, but is clearly beyond prototype stage. Multiple instrument packages have been fabricated and deployed for extended periods under expected environmental conditions. Publications exist which demonstrate scientific utility of data.
4. Commercial	Technology has been proven to work in its final form and under expected environmental conditions. Instruments are in commercial production with appropriate supporting materials (replacement parts, operations manual, etc.)
5. Operational	Actual application of commercial or research-proven technology in its final form and under sustained operational conditions. Independent, third-party evaluation or application that demonstrates reliable long-term field operations.

Figure 3. The OOI TRL scale for marine instrumentation technologies (source: Brasseur et al. 2010⁶).

The OOI TRL scale⁷, developed by the ocean observation scientific community as end users of marine sensors, extends beyond the conventional TRL 9 — which signifies commercialisation. It serves as a comprehensive guide for advancing sensors toward full operational capability, with the goal of integration into cutting-edge marine research infrastructures. This scale provides detailed criteria for assessing technology maturity, specifically tailored to oceanographic instrumentation.

- b) The approach used for the ocean instrumentation validation from the Alliance for Coastal Technologies (ACT)⁸.

ACT conducts two types of technology evaluations: Verifications and Demonstrations. Verifications are thorough assessments of commercially available technologies to confirm they meet the manufacturer's performance claims and provide reliable data for stakeholders. This involves a detailed 25-step process, including consensus-based test protocols, laboratory and field testing, and strict QA/QC procedures, typically carried out at four to six ACT partner sites. In contrast, Demonstrations focus on pre-commercial or emerging technologies, aiming to showcase their potential, raise awareness, and support further development. These are less formal, involve fewer steps, and are usually conducted at two to three partner sites, depending on stakeholder needs.

⁶ <http://www.oceanobs09.net/proceedings/cwp/Brasseur-OceanObs09.cwp.10.pdf>

⁷ www.oceanobs09.net/proceedings/cwp/Brasseur-OceanObs09.cwp.10.pdf

⁸ www.act-us.info

The primary objective of WP7 was to validate the in situ functionality, robustness, and data quality of selected sensors. Additionally, it evaluated ease of integration and operational flexibility. Each demonstration was strategically chosen to address distinct end-user requirements and application scenarios. These tests provided valuable, application-driven feedback on system readiness, contributing to the refinement and contextual relevance of TRL assessments within the ocean observing domain. The flow chart of the NAUTILOS technical WPs, the interactions in terms of TRL and the dependencies between them are presented in Figure 4.

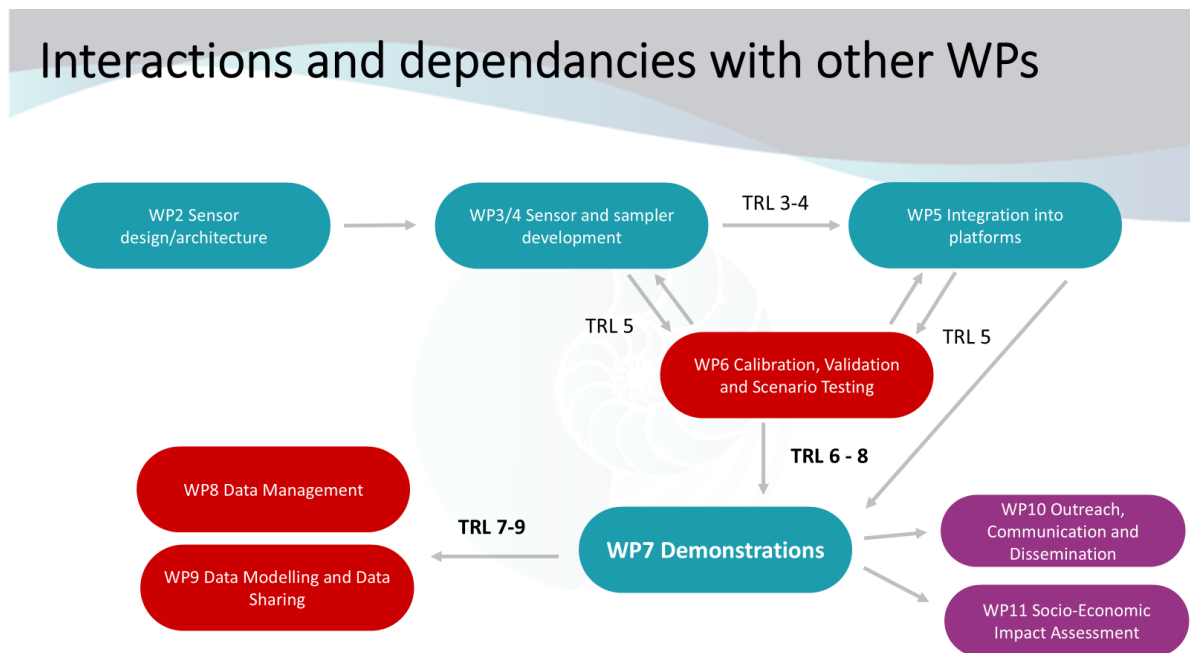


Figure 4. NAUTILOS technical WPs flow chart and dependencies.

The demonstration of sensors in WP7 was organised into five distinct tasks, each aligned with the type of sensor technology and the corresponding testing platforms and infrastructures available. This structure allowed for focused fit to purpose validation under relevant environmental and operational conditions. The tasks and activities carried out were as follows:

Task 7.1: Fisheries and Aquaculture Observing Systems

The ST7.1.1 demonstrations on Fisheries Observing Systems, involving the DO and Chl-*a* prototypes developed by NKE in ST3.1.2, were carried out, from summer 2023 to winter 2025, in the Adriatic Sea and the Bay of Biscay, by CNR-IRBIM and Ifremer, respectively. The sensors were installed on fishing gear (bottom trawler and pots) and were supported by the WiHub devices enabling data transfer. The DO and Chl-*a* sensors reached TRL 9 and 7 respectively. In ST7.1.2, two different approaches were demonstrated, based on the locality of the phenomena in two sites in Norway and Greece, focusing on providing useful information to support sustainable aquaculture management. In Norway, the DO and Chl-*a* prototypes developed in ST3.1.2 and pH and pCO₂ sensors developed in ST4.1 were deployed in May–June 2025 at an aquaculture fish farm in Herdlefjord, 25 km northwest of Bergen, Norway. In Greece, this sub-task aimed to evaluate the performance of low-cost infrared (IR) sensor data collected aboard the HCMR R/V *Philia* as part of efforts to enhance coastal marine monitoring for sustainable aquaculture. The IR sensor data, collected during a month-long survey in September–October 2024, demonstrated good agreement with *in situ* CTD measurements, confirming the operational reliability of the sensor. The use of the NAUTILOS sensor in this subtask contributed to the evaluation of TRLs reported for other demonstrations. Subtask 7.1.3 involved demonstrating the Passive Acoustic Sensor to evaluate its effectiveness in detecting and identifying marine mammals in their natural habitats. The sensor was tested in different environments (i.e. in Sweden in the Kolmården Wildlife Park dolphinarium and in the open sea in the Lysekil area, and the Pelagos Sanctuary near Portofino, Italy) and reached TRL7.

Task 7.2: Demonstration on platforms of opportunity

Downward-looking sensors for ocean platforms and aerial drones were tested in coastal Norway using UAVs and ASVs, and results compared to Ferrybox data. UAV-mounted cameras and ASV-mounted LIF-LIDAR systems reached TRL 7. Further testing under diverse environmental conditions is recommended. A new low-cost infrared temperature sensor was validated aboard a research vessel in the North Aegean, Ionian Sea, and nearby Greek coastal waters, using CTDs for reference. The sensor reached TRL 7, with several technical improvements needed before progressing to TRL 9. The phytoplankton and suspended matter sampler was tested with the Ferrybox system in Norway. Calibrated for Chl-*a* and eDNA, demonstrations showed comparable eDNA concentrations between automated and manual sampling. The sampler achieved TRL 8. Further long-term testing and integration with event detection algorithms are planned. The microplastic sampler reached TRL 7 after successful demonstrations in coastal Norway. However, the full microplastic detection system (sampler + detector + Ferrybox) and the detector alone remain at TRL 3–4 and have not yet been field-tested. A Commercial Off-the-Shelf (COTS) low-cost pH sensor) was tested in the Baltic Sea for over a year as part of a carbonate system. As the sensing element itself was already a commercial one (TRL 9) for various industrial and production process applications , the TRL to be achieved in the context of NAUTILOS project referred to its usability for operational oceanographic observations. Compared to a high-end spectrophotometric sensor and buffer solutions, it showed a consistent offset, mainly due to calibration limitations. While unsuitable for climate-level precision, it is viable for weather-scale and operational monitoring, reaching TRL 7.

Task 7.3: Demonstrations on Augmented Observing Systems

The underwater radioactivity sensor was successfully deployed on a cabled observatory in Germany and research vessels in Greece, proving its robustness under high-pressure and chemically dynamic deep-sea conditions, achieving TRL 7. Similarly, the SuNaMiPS sampler demonstrated autonomous microplastic sampling during a three-month deployment in the Cretan Sea, showing reliable operation, minimal biofouling, and consistent data recovery, confirming its suitability for long-term observatory integration and a TRL of 7. The active acoustic sensor was tested using the ATLANTIS lander in a coastal environment, with synchronised acoustic and visual data confirming fish detection and sensor functionality at TRL 6. Parallel efforts to validate the UL-FE deep ocean CTD revealed issues related to corrosion and an offshore malfunction resulting in a TRL of 6. Additional demonstrations in Italy focused on the AQUATEC Passive Acoustic Sensor (PAS) and HESSO DO fluorimeter across buoy and AUV platforms. The PAS captured underwater noise data in Calabria but experienced technical issues in Liguria, while the fluorimeter showed stable data collection in both stand-alone and AUV-mounted configurations, confirming their readiness at TRL 7.

Task 7.4: Demonstration on ARGO platform

The ST7.4 demonstrations on ARGO floats, featuring the silicate prototype developed by NKE and CNRS-LGC (ST4.2), were conducted in May 2025 following initial validation in IFREMER's seawater pool. The sensor was installed on an ARGO float to assess its performance and reliability at depths over 500 m. Despite some technical challenges — leading to maintenance and operational recommendations — the sensor showed strong stability and resilience, reaching TRL 8. Near real-time data transmission to an FTP server was achieved, with real-time transfer to central repositories still in progress. Further development is needed for a peak recognition tool to deliver silicate concentrations ($\mu\text{mol/L}$), and additional pressurised environment testing is required to validate transmission stages.

Task 7.5: Animal-borne instruments

During T7.5, demonstration activities were performed by CNRS, IMAR, and CEiiA, with significant progress in the deployment of two types of animal tagging instrumentation, performance validation, and data acquisition. CNRS successfully conducted five additional deployments at Kerguelen Island, recovering 9 out of 10 CTD-Oxy SRDL tags and transmitting 979 validated CTD-Oxy profiles in near-real time, despite some reliability issues later resolved through collaboration with SMRU. Delayed mode data are being validated for distribution via the MEOP/ANIBOS portal, supporting the declared TRL 8. CNRS also tested innovative sensor integration, including a micro-sonar and light sensor tag for bioluminescence and trophic level studies, recovering full datasets from three seals, while a miniaturized camera prototype is ready for at-sea testing. IMAR, with CEiiA, advanced the development of MAANTA NAUTILOS, overcoming engineering and calibration challenges, and performing experimental hyperbaric tests and data validation. From 2024, 35 deployments were completed across the Atlantic, Pacific, and Indian Oceans, including 23 animal-borne missions, all successfully recovered—some from distances over 130 nautical miles—demonstrating operational ability at depths beyond 1200 m. Deployment durations ranged from minutes to nearly 12 days, with continuous data acquisition prioritized. Tagging included all target species and two additional ones (whale sharks and shortfin mako sharks), and international expeditions expanded the geographical scope to Colombia and Indonesia. The data confirmed expected oxygen stratification and supported the MAANTA NAUTILOS system’s TRL 8 status.

IV. RESULTS

In a joint effort between WP7 and WP9, the drafting of the TRL data summary was performed and included in D9.7 – KPI Assessment 2, and it is used here as the basis for the present analysis, with a focus on providing information concerning the overall TRL advancement during WP7. The technical details and the demonstration results for each sensor are reported in the other deliverables of WP7. Figure 5 illustrates the Technology Readiness Level (TRL) progression of the NAUTILOS sensors and instrumentation. It highlights the initial TRL, the target TRL specified in the Description of Action (DoA), the TRL achieved following the completion of WP6, and the final TRL reached after the demonstration activities conducted in WP7. Figure 6 presents a pie chart summarising the number of sensors at each TRL level following the completion of WP7.

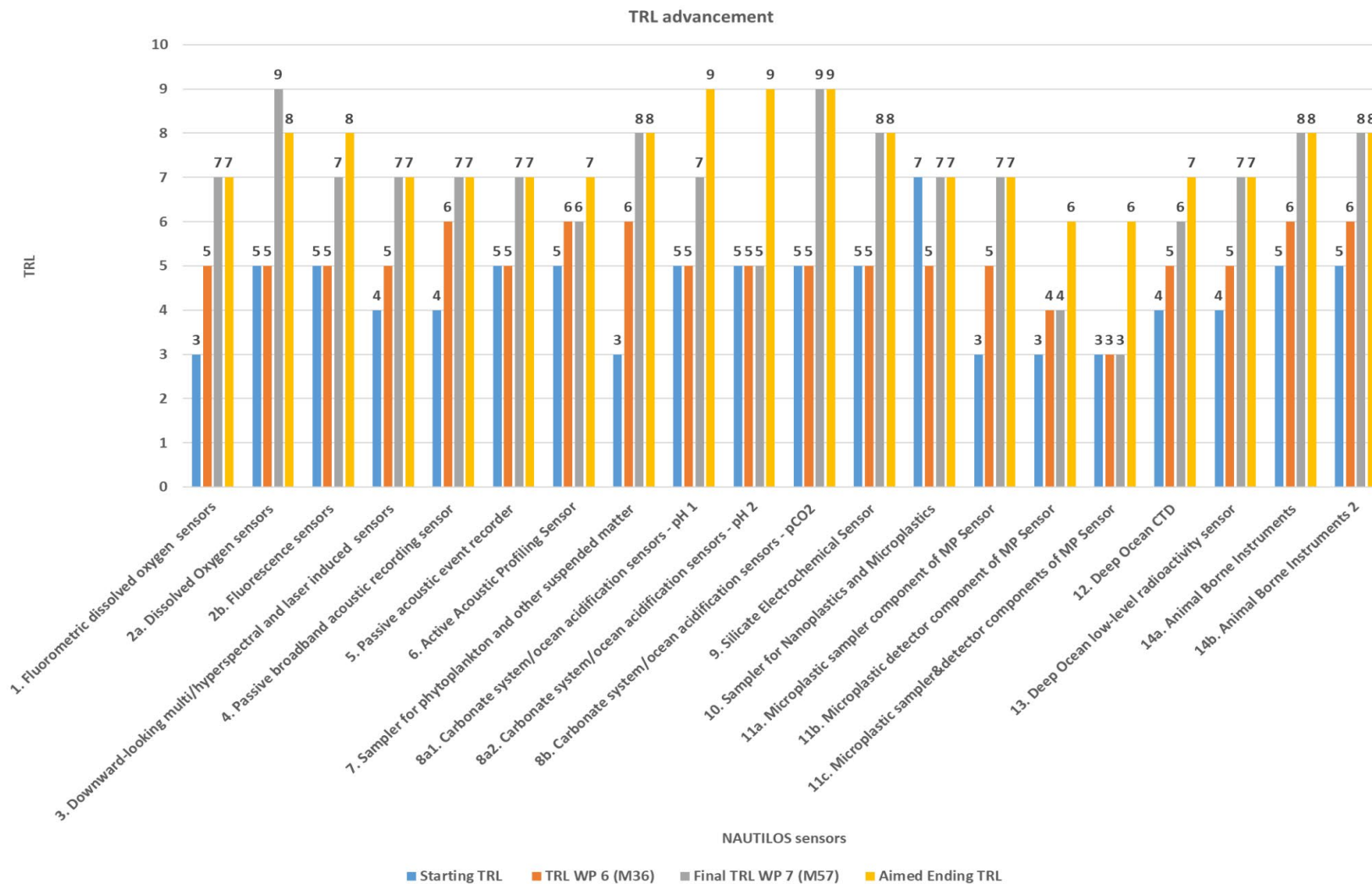


Figure 5. Technology Readiness Level progression of the NAUTILOS sensors and instrumentation.

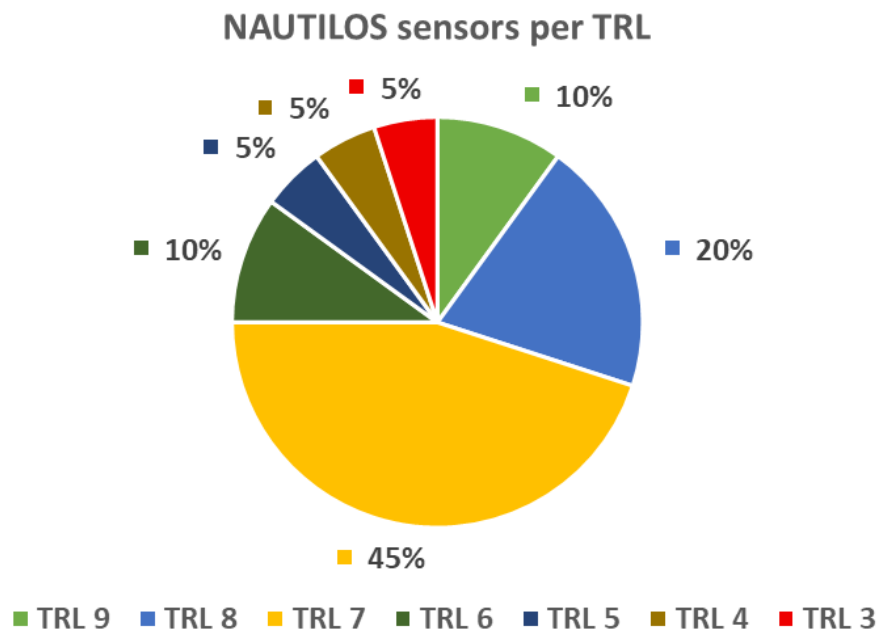


Figure 6. NAUTILOS sensors per TRL.

The majority of sensors—15 in total, representing 75%—achieved a TRL of 7 or higher, with two reaching TRL 9. At project month 36 (M36), these 15 sensors were at TRL 5–6. Most of them participated in both the laboratory validation activities conducted under Tasks 6.1 and 6.2, as well as in the controlled-condition coastal site testing of WP6. Additionally, during WP7, these sensors were deployed in parallel with other platforms or data sources to support *in situ* validation. In Figures 7 to 11, sensors for each TRL class are presented.

- TRL 9

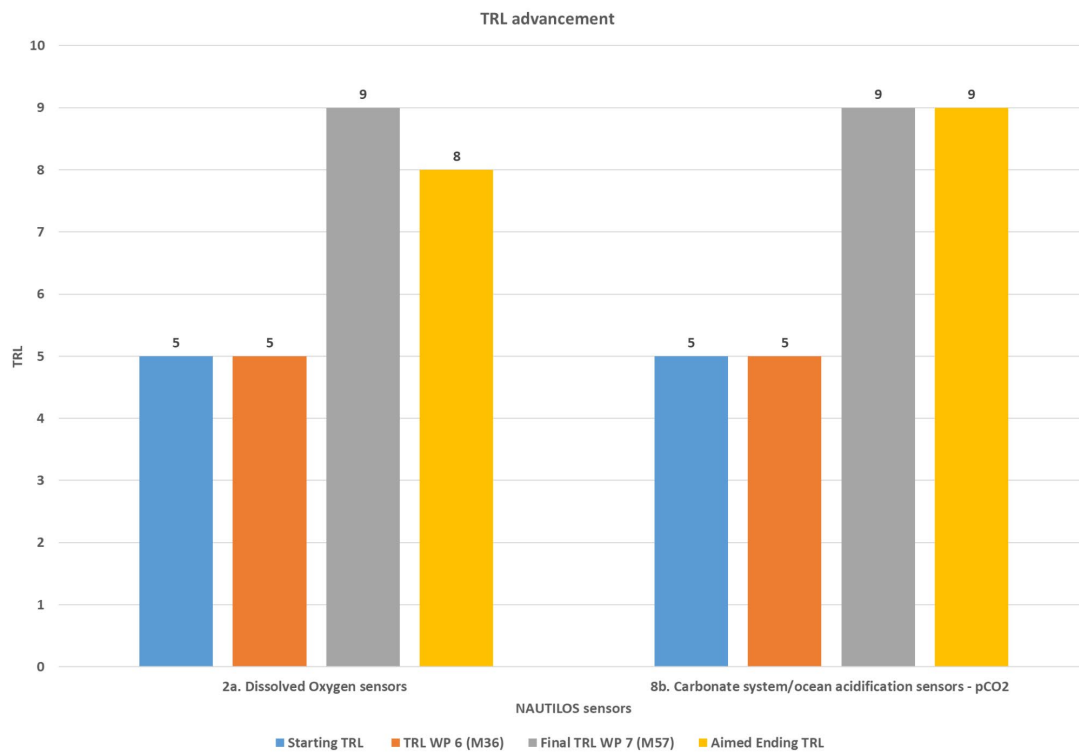


Figure 7. NAUTILOS sensors at TRL 9.

Two sensors advanced to TRL 9. Both of them were used in more than one configuration in several sites operated by research partners. The TRL finally declared for the dissolved oxygen sensor exceeded the initial expectations.

- TRL 8

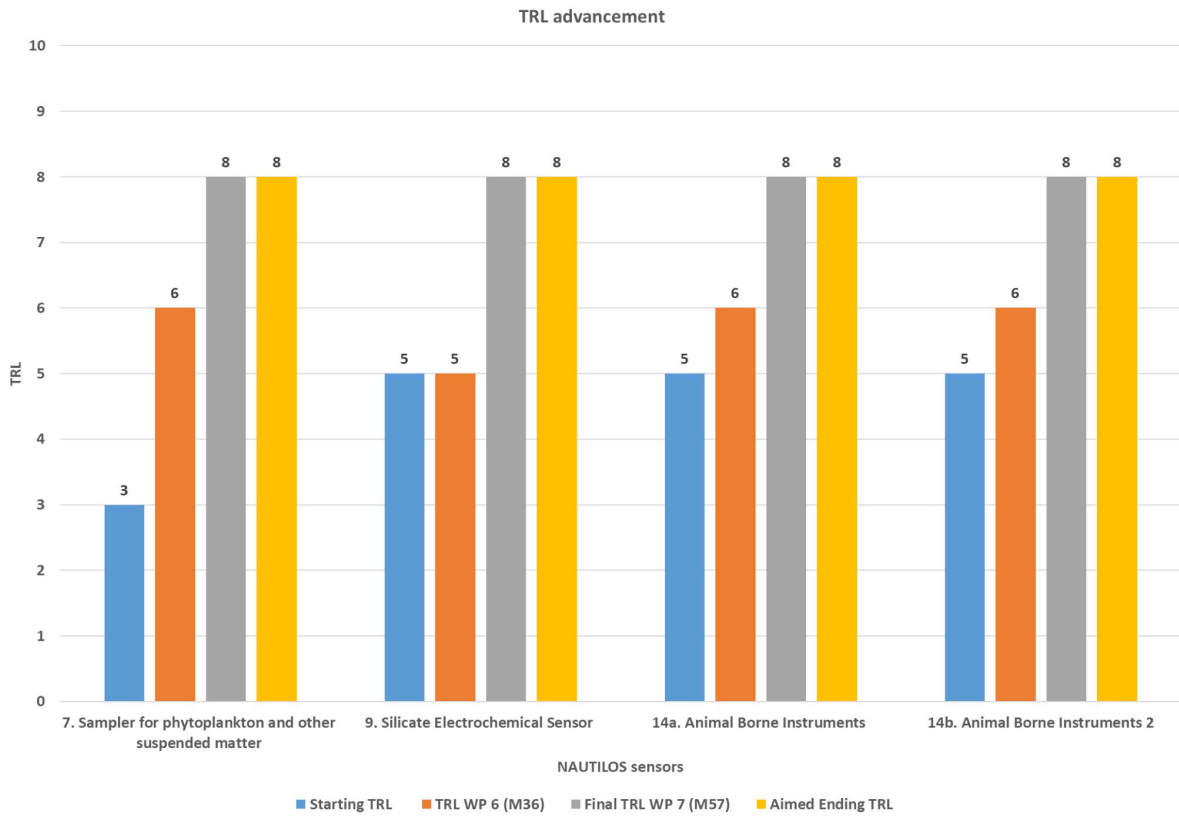


Figure 8. NAUTILOS sensors at TRL 8.

The four sensors with final TRL 8 were used in more than one demonstration during the project because the duration of these field experiments ranged from hours to days.

- TRL 7

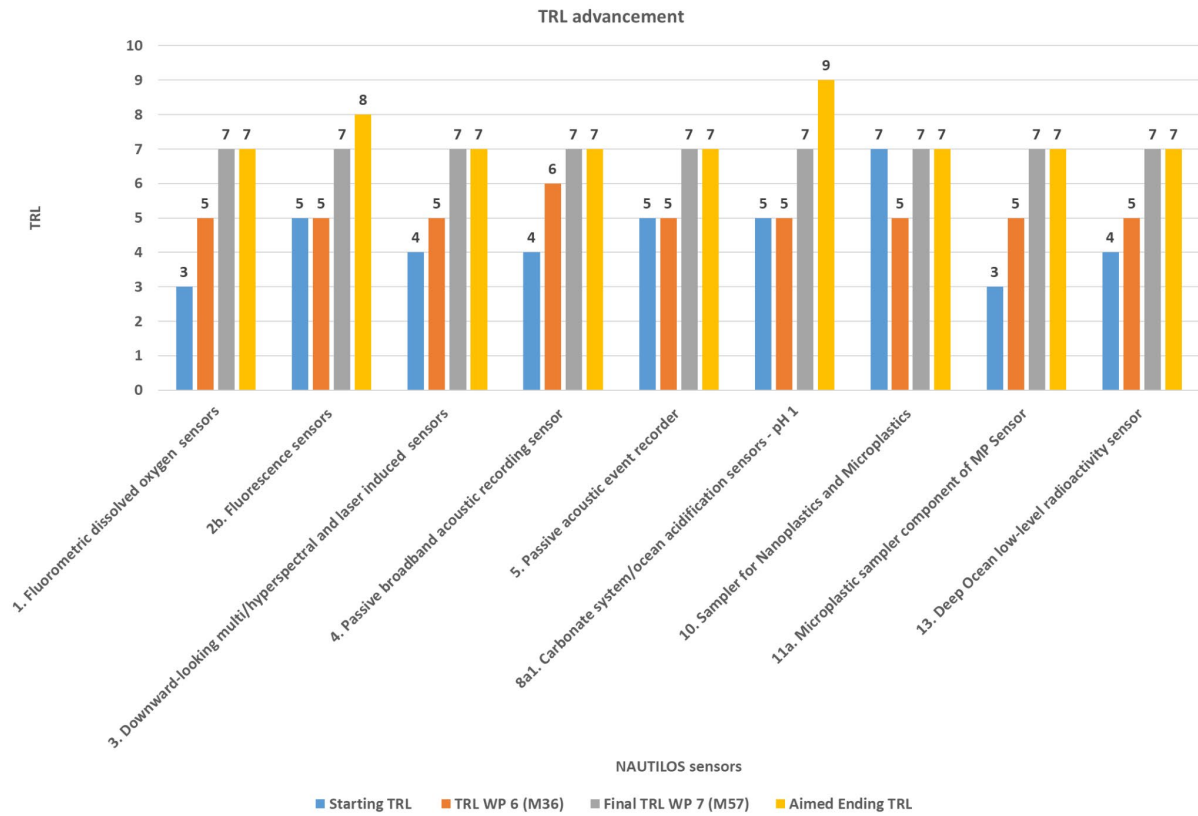


Figure 9. NAUTILOS sensors at TRL 7.

The majority of sensors reached TRL 7 that was the initial declared target according to the DoA. Also one of the fluorescence (2b) and of the pH (8a1) sensors, for which the initial target turned out to be too optimistic, reached TRL7. The deliverables of WP7 report on the improvements needed for each one of them to be able to advance to a higher TRL.

- TRL 6

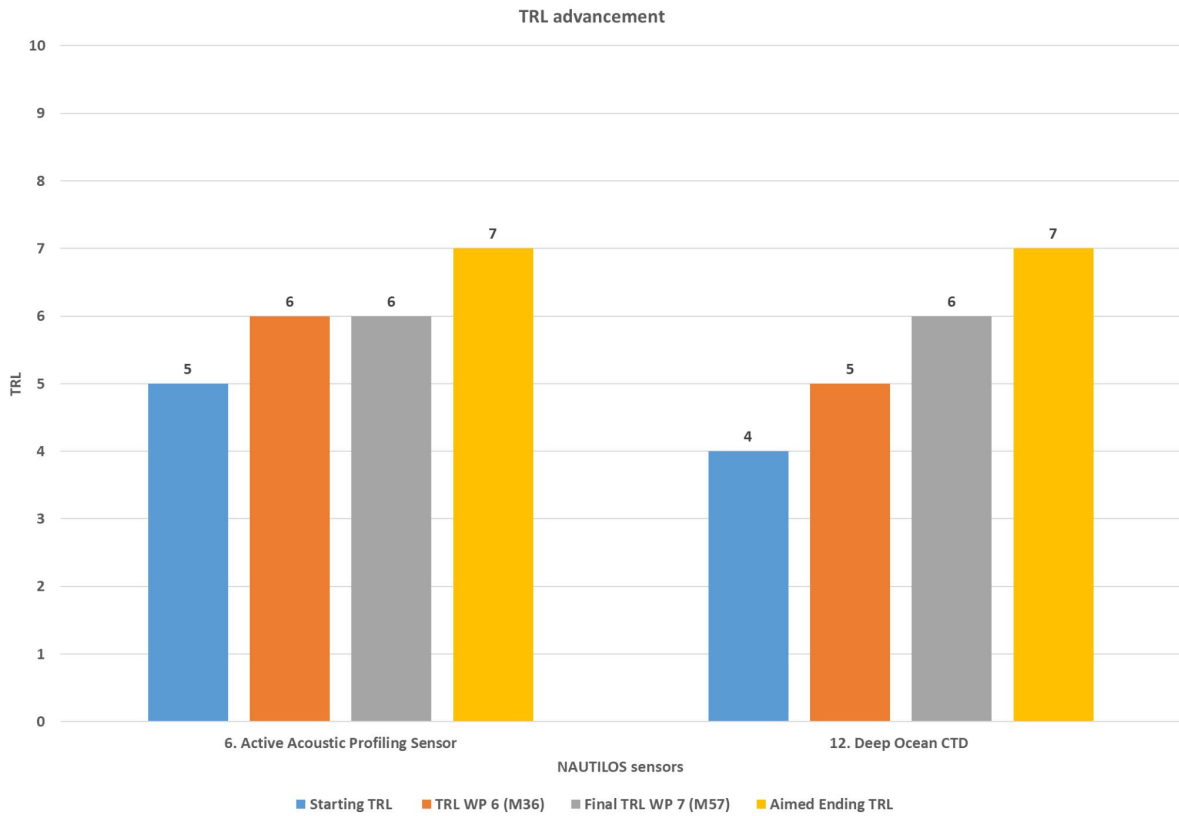


Figure 10. NAUTILOS sensors at TRL 6.

Two sensors reached TRL 6 being both integrated in a lander platform. There were several tests during the WP7 activities improving the sensor performance, but technical failure did not permit achieving a higher TRL.

- TRL < 6

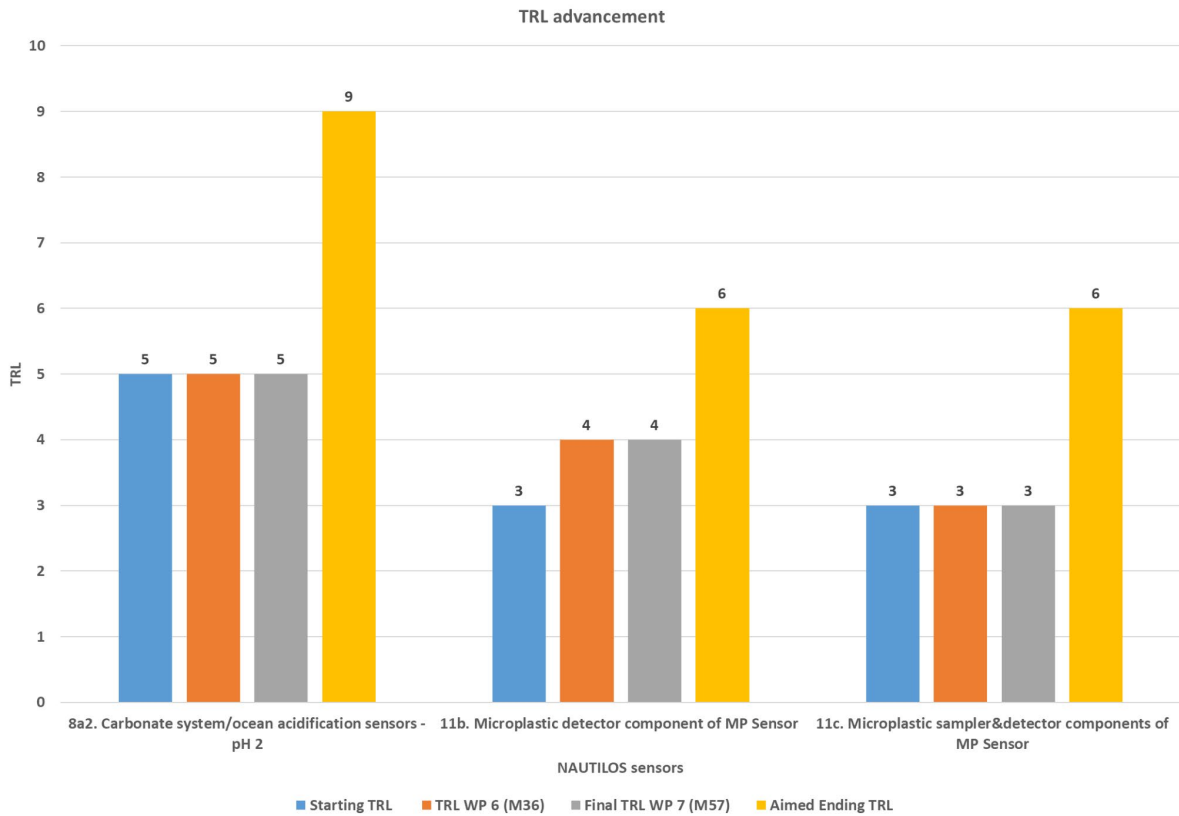


Figure 11. NAUTILOS below TRL 6.

Three sensors failed TRL 6 and did not evolve from their initial TRL. These were the sensing components of the microplastic sensor and one of the two pH sensors. It has been proven that both of these technologies are unsuited to operating in a marine environment.

V. SUMMARY AND CONCLUSIONS

In this chapter, the conclusions drawn for the TRL development are summarized. Best Practices for future developments of oceanographic equipment are recommended based on NAUTILOS experiences and lessons learnt.

Advancing a technology along the TRL scale is a complex and resource-intensive process that demands more than just technical innovation. It requires the synergistic collaboration of interdisciplinary expertise, access to specialised infrastructure, and the involvement of experienced partners across research, development, testing and demonstrating phases.

- *Best practice #1: Involve both scientists and technology manufacturers in the early stages of design.*

A critical component of this process is the role played by scientific infrastructures—especially calibration laboratories and coastal testing facilities. These infrastructures provide controlled environments where sensors and instruments can be evaluated against reference standards. Such controlled assessments are essential for verifying measurement accuracy, ensuring repeatability, and establishing baseline performance before technologies are exposed to field conditions.

- *Best practice #2: Make use of already existing research infrastructures like laboratories and coastal marine observatories as evaluators and testing fields for technology.*

Beyond the laboratory, demonstration sites operated by scientific partners, observatories, and marine research institutions serve as essential platforms for realistic validation. These environments allow for testing under dynamic and often unpredictable conditions, providing insights that cannot be replicated in controlled settings. They also enable feedback from broader scientific communities, end-users, and operational teams—adding practical perspectives that help align the technology with real-world needs.

- *Best practice #3: Build demonstration scenarios based on already existing scientific activities to expand apart from the technical criteria of the testing.*

Reaching the higher TRL levels (TRL 7 to TRL 9)—where a technology is demonstrated in an operational environment and is ready for market uptake—can be particularly time-consuming and demanding. This phase typically requires extended deployments, long-term performance monitoring, and in some cases, re-engineering based on field performance.

- *Best practice #4: Build realistic scenarios for duration and location including risk assessments and alternative planning of activities*

It is important to recognise that TRL advancement is not always linear. A technology that has reached TRL 5 in the laboratory, for example, might regress to TRL 4 when it fails to perform under field or deployment scenarios. Such setbacks are common and should be viewed as part of the natural iteration cycle required to build robustness and operational reliability.

- *Best practice #5: Build demonstrations taking into account that some procedures and tests must be repeated.*

This challenge is especially pronounced in the marine domain, where advancing from TRL 7 to TRL 8 entails long-term exposure to harsh environmental forcing. Technologies must endure physical forcing such as pressure, wave energy, currents, in a corrosive environment with salinity and chemical compounds present. Furthermore, biological activity leading to fouling—can radically degrade performance over time. Also, the parameter being measured can significantly influence vulnerability. For instance, optical or chemical sensors may be affected by biofouling faster than physical sensors like temperature or pressure probes.

- *Best practice #6: Marine instrumentation needs robust design and dedicated antifouling techniques. This should be considered in the original design of the technology.*

In such cases, extended in situ validation—often across different regions and deployment types—is required to fully evaluate reliability, maintainability, and interoperability with existing observing platforms. These efforts are not only essential for achieving a credible TRL assessment but also for increasing confidence among end-users, stakeholders, and potential adopters of the technology.

- *Best practice #7: More than one prototype of a technology should be available for cross-platform validation in several sites with different environmental conditions.*

As a conclusion, it is advised that EU marine technology initiatives and projects would greatly benefit from a coordinated effort dedicated to the validation and testing of marine technologies. Establishing harmonised procedures and standardised methodologies—along with independent testing carried out by a partnership of research institutions, resource managers, and private sector companies—could significantly enhance the credibility and comparability of results across the sector. Such a collaborative approach would not only help advance the TRL of emerging innovations, but also foster greater trust among end users and stakeholders. Ultimately, this would add substantial value to the European marine technology community by accelerating technology adoption, supporting policy development, and strengthening Europe’s position in the global blue economy.

APPENDIX 1: REFERENCES AND RELATED DOCUMENTS

ID	Reference or Related Document	Source or Link/Location
1	D6.1: Report on results and methodology of calibration/validation experiments performed in T6.1	NAUTILOS Drive
2	D6.2: Report on results and methodology of calibration/validation experiments performed in T6.2	NAUTILOS Drive
3	D6.3: Report on testing results of the joint operations of sensors, buoy, lander and ASV in ST6.3.1	NAUTILOS Drive
4	D6.4: Report on the testing results of the joint operations of sensors, buoy and AUV in ST6.3.2	NAUTILOS Drive
5	D6.5: Report on the testing results of the joint operations of sensors and UAV in ST6.3.3	NAUTILOS Drive
6	D7.1: Fisheries and Aquaculture Observing Systems demonstration mid-term report	NAUTILOS Drive
7	D7.2: Fisheries and Aquaculture Observing Systems demonstration final report	NAUTILOS Drive
8	D7.3: Platforms of Opportunity and Ferryboxes demonstration final report	NAUTILOS Drive
9	D7.4: Augmented Observing Systems demonstrations final report	NAUTILOS Drive
10	D7.5: Report on the demonstration of silicate sensor on ARGO float in the Mediterranean Sea	NAUTILOS Drive
11	D7.6: Report on Animal Borne Instruments demonstrations	NAUTILOS Drive