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NAUTILOS

D5.3

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Nature of the deliverable		
R	Report	**X**
DEC	Websites, patents, filing, etc.	
DEM	Demonstrator	
O	Other	

Dissemination level		
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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). The project unites a substantial consortium of 21 entities spanning 11 European countries. This consortium boasts a wide range of expertise, encompassing ocean sensing and sampling instrumentation development and integration, data processing and modelling, operational oceanography, biology and ecosystem research, biogeochemistry, climate change science, water science, technological marine applications, and research infrastructure development.

NAUTILOS is poised to bridge critical gaps in marine observation and modelling, specifically targeting chemical, biological, and deep ocean physics variables. This will be achieved through the development of a novel generation of cost-effective sensors and samplers. These cutting-edge technologies will integrate within observation platforms and will be deployed in large-scale demonstrations across European seas.

The primary goal of this project is to enhance and expand the existing European marine observation tools and services. The ultimate aim is to acquire data at significantly higher spatial resolution, temporal consistency, and prolonged durations compared to what is currently available at the European scale. Moreover, the project is committed to democratizing the monitoring of the marine environment, making this valuable information accessible to a broad spectrum of users, both traditional and non-traditional alike.

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://www.nautilos-h2020.eu.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This deliverable represents the culmination of work carried out in sub-task (ST) 5.2.2, entitled “Report on integration of payloads/sensors on ASV” up to M36. It provides a comprehensive overview of the intricate process of integrating a diverse array of payloads and sensors onto the ORCA ASV platform from CEiiA and Otter ASV platform from NIVA. This platform's primary objective is to enable ocean observation and the precise monitoring of chemical, biological, and physical parameters in a challenging environment.

This report details the challenges and solutions involved in integrating the following NAUTILOS payloads and sensors:

- AQUATEC Click & Sound Recorder device including AQUATEC Passive broadband acoustic recording sensor for noise monitoring (T3.3.1) and AQUATEC Passive acoustic event recorder (T3.3.2);
- NIVA pH sensor, part of NIVA Carbonate System/ocean acidification sensor (T4.1);
- AQUATEC AQUAmodem 1000 (acoustic modem);
- NIVA Laser-Induced Fluorescence (LIF) Light Detection and Ranging (LIDAR) sensor.

The integration efforts encompassed meticulous considerations for data collection and sensor placement, and the development of bespoke solutions. This report details the challenges and solutions involved in integrating NAUTILOS sensors from NIVA and AQUATEC and communication systems with the ORCA ASV platform from CEiiA and Otter ASV platform from NIVA. It outlines the mechanical configurations and stress studies, software and hardware integrations, employed to ensure robust and reliable integration.

In summary, this report encapsulates the substantial strides made in the integration of sensors within the NAUTILOS project. These integrated systems stand as a testament to the project's commitment to pushing the boundaries of ocean exploration.

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
ASV	Autonomous Surface Vessel (or Vehicle)
EOV	Essential Ocean Variable
GNSS	Global Navigation Satellite System
IMU	Inertial measurement unit
LIF LIDAR	Laser-induced fluorescence light detection and ranging

I. INTRODUCTION

In the pursuit of advancing marine research and exploration, the NAUTILOS project has been a beacon of innovation and collaboration. At the heart of this endeavour, one of the critical tasks is the integration of payloads and sensors onto the ORCA ASV platform, a fundamental aspect of Work Package 5 (WP5). This report is dedicated to the comprehensive documentation of the integration process and the outcomes of this effort.

1. CONTEXT

The integration of payloads and sensors onto the ASV platform is critical for the realisation of NAUTILOS' mission. This task enables us to equip the ASV platform with the necessary tools and instruments to carry out its WP6 and WP7 missions effectively. It is a dynamic process that requires the adaptation of hardware, the implementation of communication systems, and the integration of a suite of specialised sensors.

2. OBJECTIVES

The primary objective of this report is to provide a detailed account of the integration of payloads and sensors onto the ASV platform, carried out under the leadership of CEiiA. This report aims to shed light on the intricate process of preparing the ASV platform to conduct unique missions vital to the project in the following WP6 controlled missions and WP7 demonstrations. Moreover, it presents the outcomes of bench testing and verification, essential steps in ensuring the platform's readiness for later field trials.

3. REPORT STRUCTURE

This report is structured to provide a comprehensive understanding of the integration process. It begins with an overview of the ASV platform. Subsequently, we delve into the integration process in greater detail, later breaking down the integration of individual payloads and sensors, with specific focus on each component. Field tests, including descriptions and results, are discussed. Finally, a summary of the key findings and outcomes.

This document serves as a valuable resource not only for the NAUTILOS project team but for the broader scientific community, providing insights into the integration of specialised equipment onto a vital marine exploration platform.

II. ASV PLATFORMS OVERVIEW

Autonomous surface vehicles (ASV) are vehicles that operate on the surface of the water without a crew. ASVs are valuable in oceanography, as they are more capable than moored or drifting weather buoys, cheaper than the equivalent weather ships and research vessels, and more flexible than commercial-ship contributions.

As ASVs achieve longer endurance, safety and adaptability it is possible to envision a new era of ocean observing. The vast versatility of ASVs allows them to operate in a large variety of missions such as oceanographic measurements (bathymetry, water monitoring, hydrographic data, structure inspection); atmosphere measurements (surface winds, air temperature and humidity, sea surface temperature, weather forecasting) and surveillance missions (coastal/port surveillance, search and rescue).

An ASV is a multipurpose unmanned vehicle for in-land, coastal and offshore applications capable of performing various missions with scientific value, namely:

- Bathymetry in lakes, rivers, reservoirs and open sea;
- Surveillance missions, for instance to prevent illegal exploitation of water environments;
- Inspection missions, for instance to inspect underwater structures such as gas pipes and dams structural integrity;
- Co-operative missions with other unmanned vehicles to diversify the data sources and fleet range;

An ASV can also take water samples in order to evaluate its composition and organisms.

1. THE ORCA ASV

The ORCA Autonomous Surface Vehicle (ASV) provided by CEiiA (Figure 1) is a multipurpose unmanned vehicle for in-land and coastal applications capable of performing various missions with scientific value. It was developed to have distinctive features, compared with the others in the market that can make our vehicle unique being one of them to be expansible in payload and configuration to adapt to different scenarios and missions, as the NAUTILOS project (maximum accepted dimensions apply, as referenced in D2.3 "Integrated ICD - Interface Control Document for partners' vehicles, platforms and infrastructure").

This modularity makes it versatile and adaptable to various scientific missions. Moreover, our vehicle incorporates an advanced collision avoidance system, enabling it to autonomously navigate and make real-time decisions to dodge obstacles or halt in the face of imminent route collisions. This technology ensures the safety of the vehicle, valuable scientific equipment, and surrounding marine environments, further enhancing its appeal to potential users.

Figure 1: ORCA ASV Platform provided by CEiiA.

By combining these distinctive features, our vehicle meets the expectations of scientific researchers, marine explorers, and clients seeking reliable and efficient solutions for their missions. Its versatility, accuracy, safety features, and integration capabilities make it a cutting-edge choice in the competitive market, catering to the evolving needs of scientific and research communities.

The dimensions of ORCA ASV are: 3400x1700x2100 mm (Figure 2). The weight can vary between 400-500 kg, it depends on the payload and respective configuration and can be carried on a light trailer. The endurance is up to one working day on full operation.

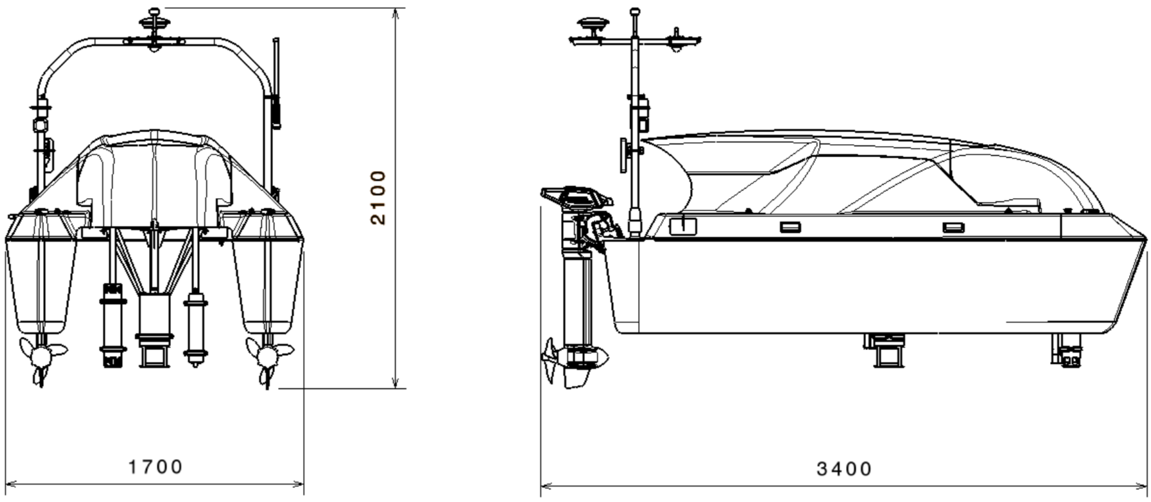


Figure 2: ORCA ASV NAUTILOS configuration dimensions.

The Otter NIVA ASV

The Otter Autonomous Surface Vehicle (ASV) provided by NIVA (Figure 3) a twin-hull vessel (2 m long, 1 m wide, 60 kg in weight), manufactured and sold by Maritime Robotics (Trondheim, Norway). Its control systems, payload sensors and two rear thrusters are powered by four 1 kWh Li-ion batteries which enables an operational range of ~20 hours (depending on speed and payload). The ASV has a high-quality IMU and dual GNSS antenna navigation and control system, which means that a mission pattern can be preprogrammed, and can be monitored and controlled over three different channels: Wifi (200 m range), 5GHz broadband radio communication (2 km range), or 4G. With a modular construction, the ASV has a central payload bay and can be easily adapted to carry additional instruments, such as the LIF LIDAR. When in operation, the ASV follows pre-programmed survey patterns and must be operated with care, as it does not have any obstacle detection/avoidance capabilities. There is, however, a forward-facing camera that provides the operator with a live video feed to monitor operations and potential collision hazards. The ASV is configured, monitored, and controlled via the manufacturer's VCS (Vehicle Control Station) software on Linux or Android.

Figure 3: Otter ASV Platform provided by NIVA.

III. ORCA ASV - PAYLOADS AND SENSORS INTEGRATION OVERVIEW

Integrating a diverse array of systems onto the platform required careful planning and execution to ensure optimal conditions for data collection, and the physical integrity of the installed sensors and other payloads, and the platform itself.

The integration process followed a structured and iterative workflow designed to systematically address each aspect of the task (Figure 4). Here's an overview of the process:

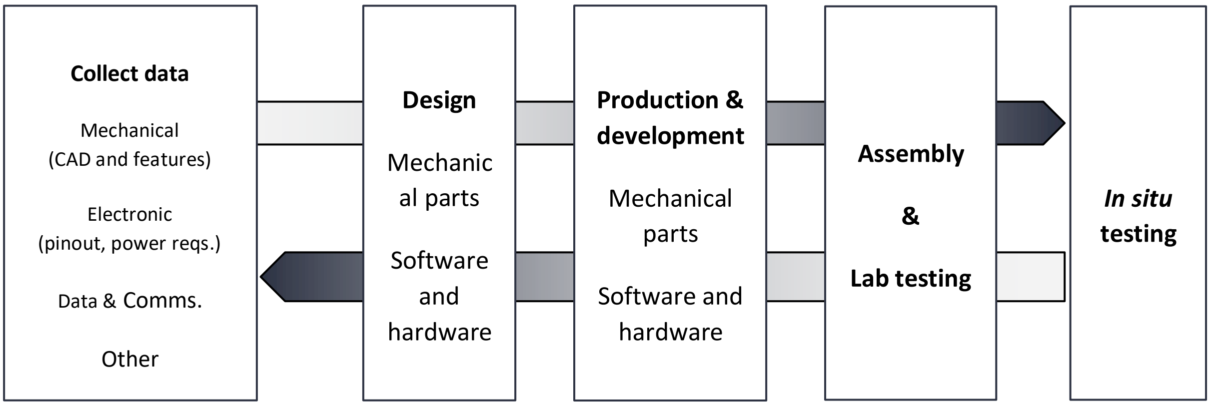


Figure 4: Schematic picture showing the Integration workflow.

1. DATA COLLECTION AND ANALYSIS

In the initial phase, we established a comprehensive understanding of the systems to be integrated. This involved gathering critical information about them, including their shapes, dimensions, power requirements, data formats and communications protocols. This crucial step allowed for a profound understanding of the unique characteristics of each sensor.

In the context of the NAUTILOS project, it's important to highlight that the development and integration of payloads operated concurrently, creating a dynamic and complex environment. This overlapping of processes posed distinct challenges, necessitating numerous iterations and adaptability.

In this highly dynamic context, continuous interaction and feedback loops were established between partners. These interactions included the exchange of preliminary designs, often in the form of Computer-Aided Design (CAD) drawings, and the creation of mock (dummy) systems. Such mock systems provided opportunities for refining and validating the integration of payloads. Moreover, the dynamic nature of the project necessitated the evolution of communication and data protocols, essential for ensuring data transfer between the integrated payloads and the platform. When necessary to proceed with mechanical integration before sensor/payload delivery this became an extremely demanding effort for CEiiA that nevertheless always succeeded thanks to the effort of all partners involved.

2. DESIGN

After the data collection and analysis phase, the subsequent step entailed the careful selection of optimal locations on the platform for the installation of sensors. This process involved consideration of factors such as the best placement and orientation of sensors to optimise data collection, minimising the potential for interference between devices, and ensuring even weight distribution. Throughout this phase, we diligently explored trade-offs and design solutions to guarantee the seamless integration of all payloads. With the installation sites determined, the focus shifted to the design of all the essential components and structures necessary to support the sensors securely. This phase was characterised by the development of custom solutions tailored to the precise installation needs of each sensor on the platform.

Throughout the design process, two essential types of documents were generated. Firstly, detailed drawings were created for every individual part involved in the solutions adopted for each sensor or component attached to the Lander. These drawings served as a crucial reference for the production phase. Additionally, a set of drawings was meticulously prepared for each assembly incorporated into the Lander. These assembly drawings provided invaluable guidance during the integration process. Some examples will be provided throughout the present deliverable.

For the link between payloads and the platform, underwater cables and bulkhead connectors were chosen or manufactured. Additionally, internal electronics were adapted to meet the power and communication requirements of the integrated payloads. The modularity of the mission management software played a pivotal role in facilitating the integration of new payloads, ensuring a streamlined and adaptable process.

The design process adhered to the highest standards to ensure the integrity and functionality of the integrated sensors. This dedication to quality underpinned the entire design process, ensuring that the integration of sensors on the platform would meet the rigorous demands of ocean exploration and research.

Again, collaboration with sensor developers played a critical role in the integration process. The proposed designs were shared and scrutinised by the developers to ensure that they aligned with the requirements and specifications of each sensor and NAUTILOS case missions: controlled scenarios (WP6) and demonstrations (WP7). This collaborative approach allowed for the refinement of the installation solutions.

3. PRODUCTION AND DEVELOPMENT

Following the approval from sensor developers, the project entered a pivotal phase where components and structures designed for sensor installation were manufactured. This tangible progression marked the transformation of design concepts into physical realities, and it encompassed not only hardware but also critical software and communication protocol development.

In addition to the physical components, a parallel effort involved the development of software and drivers required to interface with the sensors and payloads effectively. The software development process involved implementing communication protocols that were essential for gathering data from the sensors and payloads. These protocols enabled reliable data transmission and allowed for real-time data capture from the environment.

4. ASSEMBLY AND LAB TESTING AND VALIDATION

The assembly and laboratory validation phases were pivotal moments in readying the platform for its field missions. During the assembly process, every component, structure, and system was attached to the platform. This phase demanded precision to ensure that the sensors, payloads, communication, and energy equipment fit harmoniously within the platform.

In a controlled laboratory setting, a series of rigorous tests were conducted to validate the functionality and performance of the integrated systems. These tests confirmed that sensors and payloads were operating within their designated parameters and that communication systems, software, and data protocols were functioning optimally. The lab validation process served as a crucial precursor to the field tests, providing the project team with essential insights to fine-tune the system.

5. *IN SITU* TESTING AND VALIDATION

The final phase of the integration process involved rigorous *in situ* testing with the platform now housing the sensors. These tests were essential to validate the functionality, data collection capabilities, and physical integrity of the sensors in real-world conditions. Bench tests are part of WP5; however water tests will be included in WP6, in particular in D6.3 "Report on testing results of the joint operations of sensors, buoy, lander and ASV in ST6.3.1.

IV. ORCA ASV - DETAILED PAYLOADS AND SENSORS INTEGRATION

1. NAUTILOS PAYLOADS AND SENSORS

Below is a table with an overview of the systems that we integrated into the ORCA ASV provided by CEiiA (Table 1).

Table 1: NAUTILOS sensors and payload integration overview.

Payload/Sensor	Owner	Collected parameters	Mechanical Integration	Electronic Integration
pH Sensor	NIVA	pH, Temperature	Yes	Power
Click & Sound Recorder device Passive broadband acoustic recording sensor for noise monitoring; Passive acoustic event recorder	Aquatec	Audio DATA	Yes	No, Standalone
Acoustic Modem **AQUA*modem* 1000**	Aquatec	N/A	Yes	Power and Comms

2. PH SENSOR (NIVA)

a. Overview

NIVA develops, in the scope of NAUTILOS project, a carbonate system/ocean acidification sensor aiming at contributing to addressing a global environmental challenge, the impact of ocean acidification on our marine ecosystems. One of the sensors developed by NIVA and to be considered for ASV integration is the pH sensor (Figure 5Figure 5: NIVA’s pH sensor.). Monitoring pH levels with this sensor enables us to track changes in seawater acidity, a critical parameter for comprehending the health and resilience of marine ecosystems. As part of the NAUTILOS project, its integration into the ORCA ASV enhances our capacity to collect high-resolution data, advancing our understanding of ocean acidification processes and their impacts.

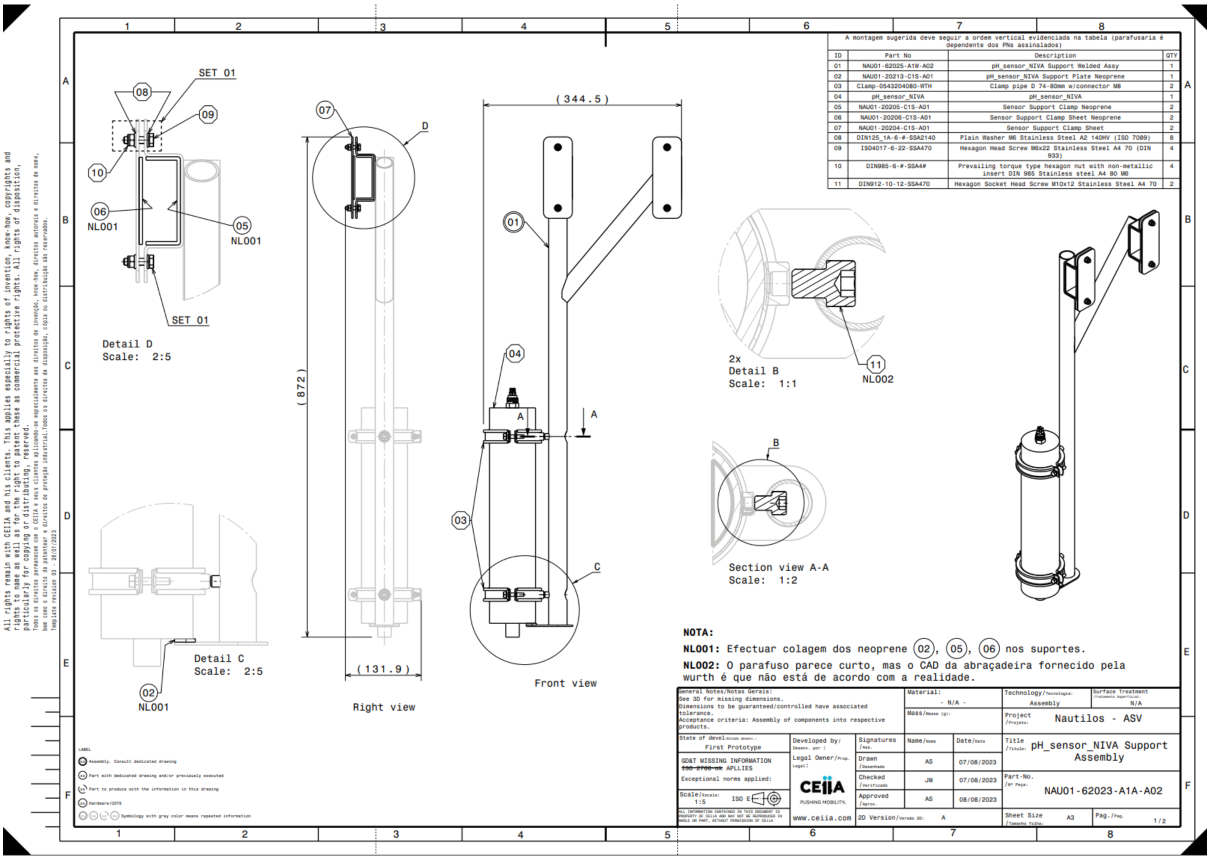
Figure 5: NIVA's pH sensor.

b. Mechanical

To integrate the pH sensor into the ASV, the CEiiA team considered corrosion prevention and equipment preservation, maintaining the fundamental approach of retrofitting the equipment without modifying the previously designed and manufactured structures.

In terms of corrosion prevention, the team chose to use stainless steel for the metallic welded support due to its exceptional performance in marine environments. The main body is a ⌀32mm stainless steel tube and the sheet-metal brackets used to secure the support to the ASV structure are crafted from 2,5mm stainless steel sheets (Figure 6). To safeguard against damage and mitigate the vibrations experienced by the vehicle during its operation, neoprene pads are utilised at the junction between the metallic brackets and the ASV structure. These pads function as a cushion, effectively preventing harm and dampening vibrations.

The equipment support is positioned at the front of the vehicle between the hulls, allowing for the submersion of the lowest part of the sensor (Figure 7). Moreover, the pH sensor is affixed to the support using easily obtainable off-the-shelf clamps. Extra clamps are delivered with the supports since these additional clamps are constructed from zinc plated steel and are susceptible to fast corrosion. All fasteners are made of stainless steel, with prevailing torque nuts specifically used to prevent unintentional loosening due to vibrations.



A montagem sugerida deve seguir a ordem vertical evidenciada na tabela (parafusaria é dependente dos PNs assinalados)

ID	Part No	Description	QTY
01	NAU01-62025-A1W-A02	pH_sensor_NIVA Support Welded Assy	1
02	NAU01-20213-C1S-A01	pH_sensor_NIVA Support Plate Neoprene	1
03	Clamp-0543204080-WTH	Clamp pipe D 74-80mm w/connector M8	2
04	pH_sensor_NIVA	pH_sensor_NIVA	1
05	NAU01-20205-C1S-A01	Sensor Support Clamp Neoprene	2
06	NAU01-20206-C1S-A01	Sensor Support Clamp Sheet Neoprene	2
07	NAU01-20204-C1S-A01	Sensor Support Clamp Sheet	2
08	DIN125_1A-6-#-SSA2140	Plain Washer M6 Stainless Steel A2 140HV (ISO 7089)	8
09	ISO4017-6-22-SSA470	Hexagon Head Screw M6x22 Stainless Steel A4 70 (DIN 933)	4
10	DIN985-6-#-SSA4#	Prevailing torque type hexagon nut with non-metallic insert DIN 985 Stainless steel A4 80 M6	4
11	DIN912-10-12-SSA470	Hexagon Socket Head Screw M10x12 Stainless Steel A4 70	2

NOTA:

NL001: Efectuar colagem dos neoprene (02), (05), (06) nos suportes.

NL002: O parafuso parece curto, mas o CAD da abraçadeira fornecido pela wurth é que não está de acordo com a realidade.

General Notes/Notas Gerais:
See 3D for missing dimensions.
Dimensions to be guaranteed/controlled have associated tolerance.
Acceptance criteria: Assembly of components into respective products.

Material: - N/A -	Mass/Massa (g):	Technology/Tecnologia: Assembly	Surface Treatment /Tratamento Superficial: N/A	
State of devel/Estado desenv.: First Prototype	Developed by/Desenv. por: Legal Owner/Prop. Legal: CEiiA PUSHING MOBILITY.	Signatures /Ass.	Name/Nome	Date/Data
GD&T MISSING INFORMATION ~~ISO 2768-mk~~ APLLIES		Drawn /Desenhado	AS	07/08/2023
Exceptional norms applied:		Checked /Verificado	JM	07/08/2023
Scale/Escala: 1:5 ISO E		Approved /Aprov.	AS	08/08/2023
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Project /Projeto: Nautilos - ASV
Title /Título: pH_sensor_NIVA Support Assembly
Part-No. /Nº Peça: NAU01-62023-A1A-A02
Sheet Size /Tamanho folha: A3
Pag./Pag. 1/2

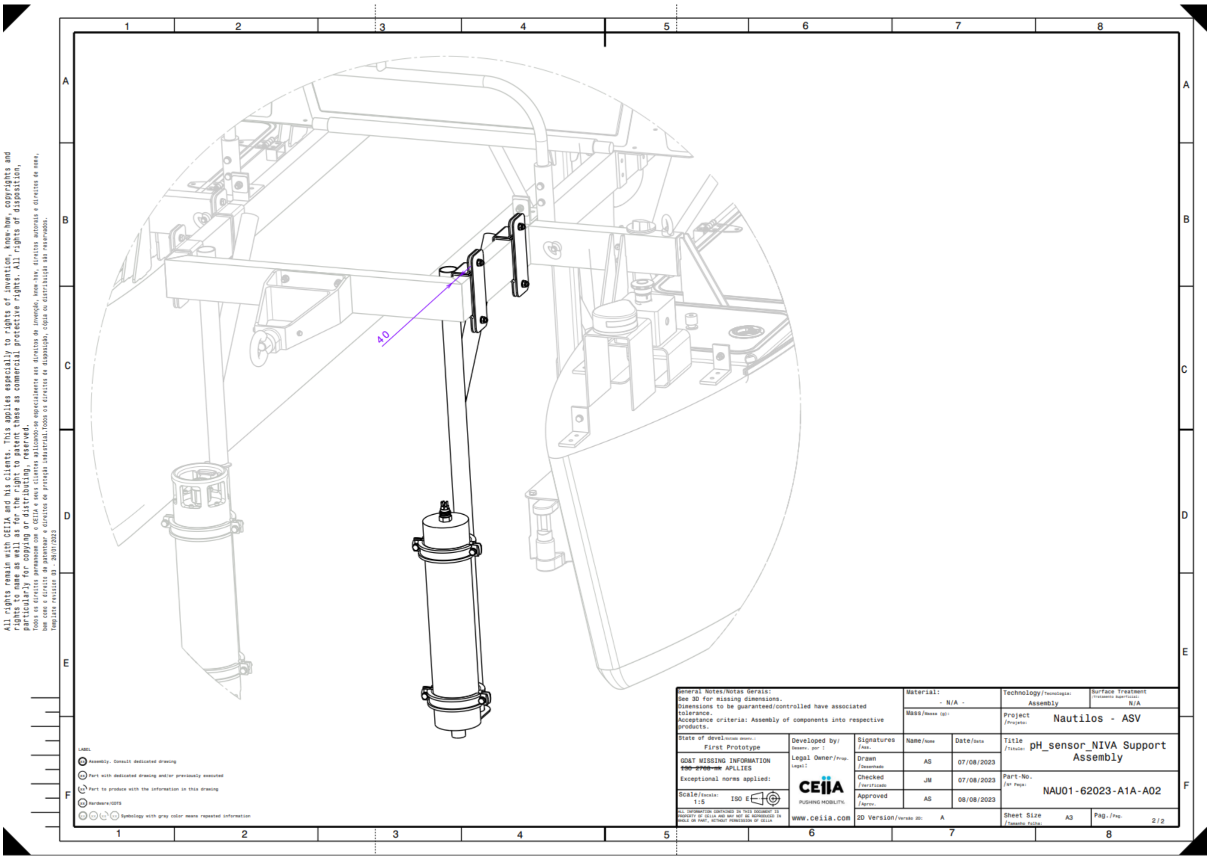

Figure 6: pH sensor mechanical integration (technical drawings).

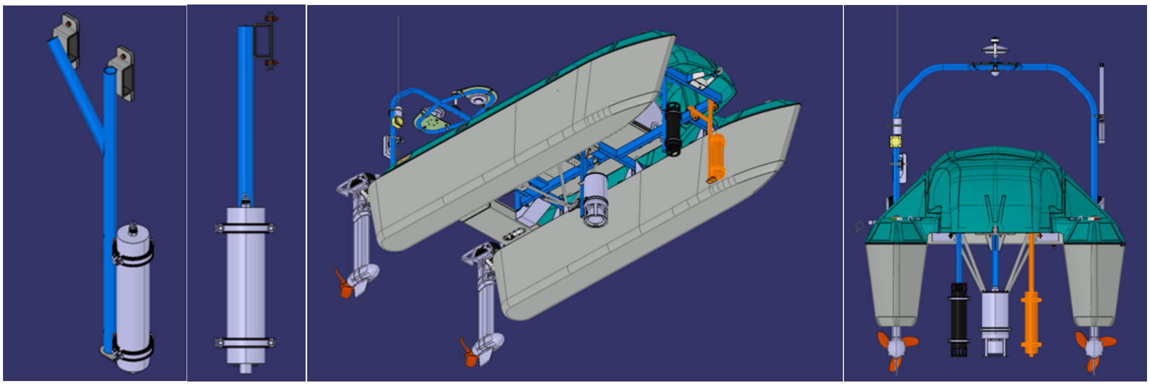

Figure 7: pH sensor mechanical integration (CAD visualization).

A structural analysis was made for this support to assure that it would bear all the loads present during all WP6 and WP7 missions (Figure 8; Figure 9).

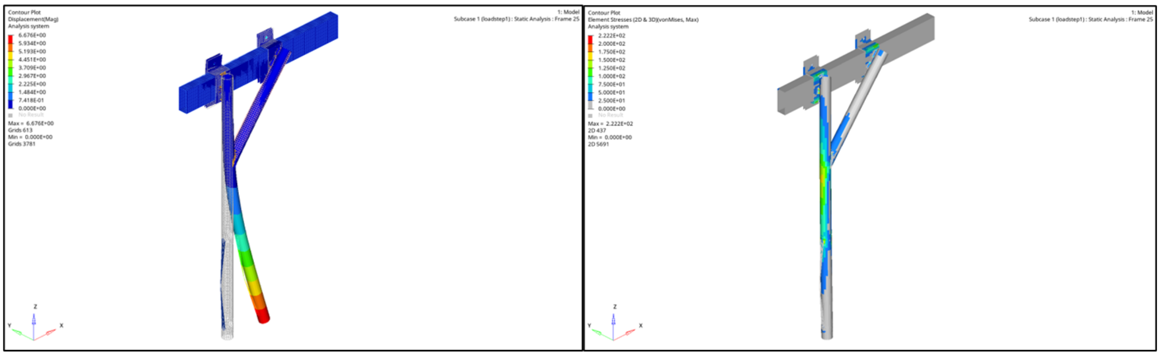

Figure 8: pH sensor mechanical integration (structural analysis).

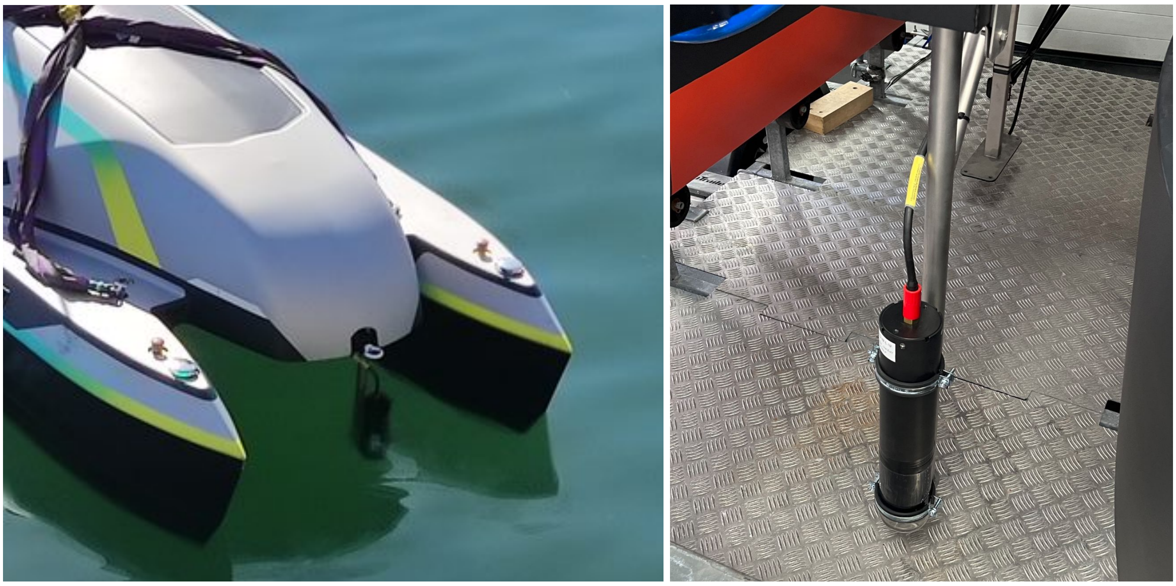

Figure 9: pH sensor mechanical integration (real images).

c. Electrical

Following the assessment of power requirements for the sensor, we leveraged the modularity of the ASV system to supply the necessary 12V power to the sensor. Furthermore, a connection was established to one of the controllable power sources, allowing for on-demand activation and deactivation. This strategic approach not only facilitated selective sampling when needed, but also prevented the accumulation of excessive data, optimizing the efficiency of the system.

d. Software

The incorporation of software elements had a substantial influence on the integration process. Following the successful electrical integration, a critical addition was made to the primary control interface for the ASV (Figure 10. Specifically, a power toggle button was implemented within this interface, enhancing the system's control and management capabilities.

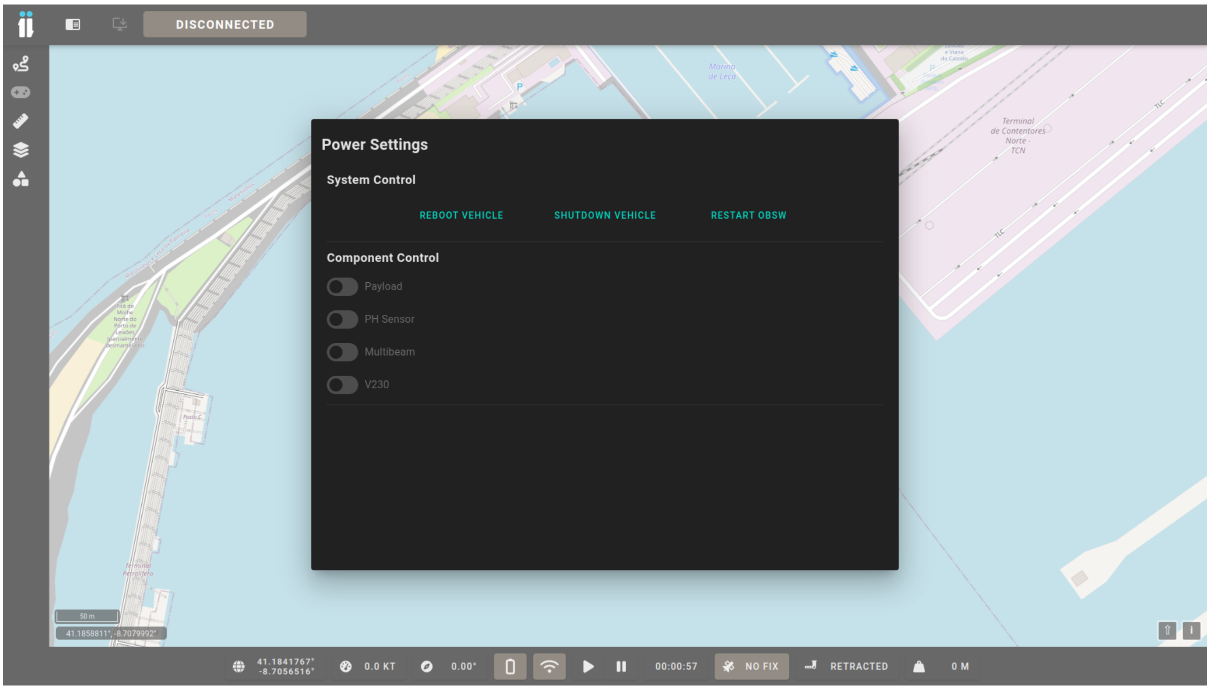

Figure 10: Doris ASV's interface vehicle and sensor control tab.

The integration process was successfully completed when the pH sensor was configured to connect to the ASV's dedicated network. This enabled direct access to the sensor's internal controller, extended data retrieval capabilities, and ensured a secure and controlled shutdown procedure, preventing data corruption.

Bench tests performed in CEiiA proved the correct pH sensor function. First dataset collected was shared with NIVA, that confirmed sensor correct function and data acquisition.

3. CLICK & SOUND RECORDER (AQUATEC)

a. Overview

Click & Sound Recorder device is a completely new technological development designated to observe echo-locating marine mammals. It is combined with a 150kHz bandwidth sound recorder that captures the full waveform of frequency-modulated whale clicks, broadband dolphin clicks and narrow-band high frequency porpoise-like clicks, as well as dolphin communication whistle sounds, which will allow for better species classification.

The Click & Sound Recorder device provided by AQUATEC (Figure 11) aggregates both NAUTILOS sensors: 1) passive broadband acoustic recording sensor for noise monitoring; 2) passive acoustic event recorder. It includes the design and development of a custom-made hydrophone with a flat frequency response over the full recording bandwidth. The design covers all aspects in terms of deployment, data uploading and post-processing with a user-friendly software.

The sensor measures 460mm in height and 98mm in diameter, the ground weight of 3.6 kg makes it easy to handle and easy to carry, while the slightly negative buoyancy of 0.79 kg ensures stability in underwater environments.

Figure 11: Click & Sound Recorder device from AQUATEC, including both NAUTILOS sensors: 1) passive broadband acoustic recording sensor for noise monitoring; 2) passive acoustic event recorder.

b. Mechanical

The integration is similar to the one on the pH sensor as both structures share most of the part numbers to facilitate the production and assembling. The Click & Sound Recorder device support was designed with the intent to withstand challenging maritime conditions and at the same time facilitate the sensor's operation.

It is also located at the front of the vehicle, between the hulls on the opposite side of the pH sensor structure to allow complete submersion of the sensor and good maintenance accessibility.

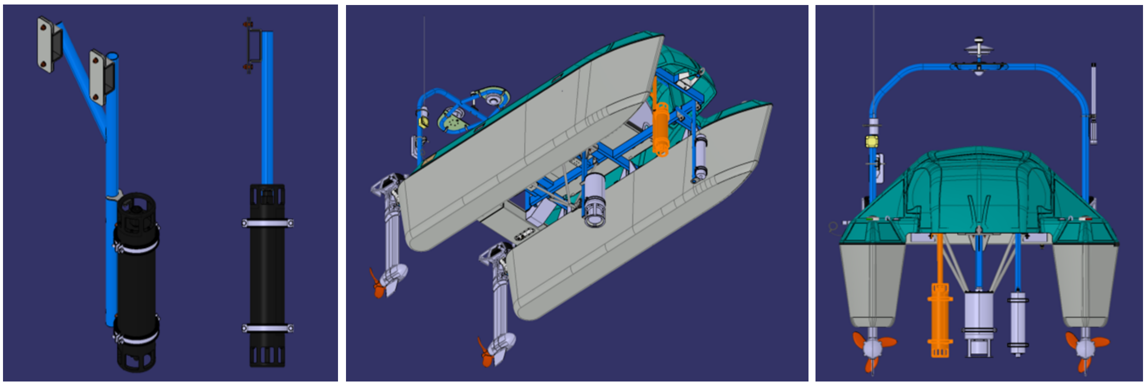

Figure 12: Click & Sound Recorder device mechanical integration (CAD visualization).

A structural analysis was made for this support to assure that it would bear all the loads present during operation during all WP6 and WP7 missions (Figure 13; Figure 14).

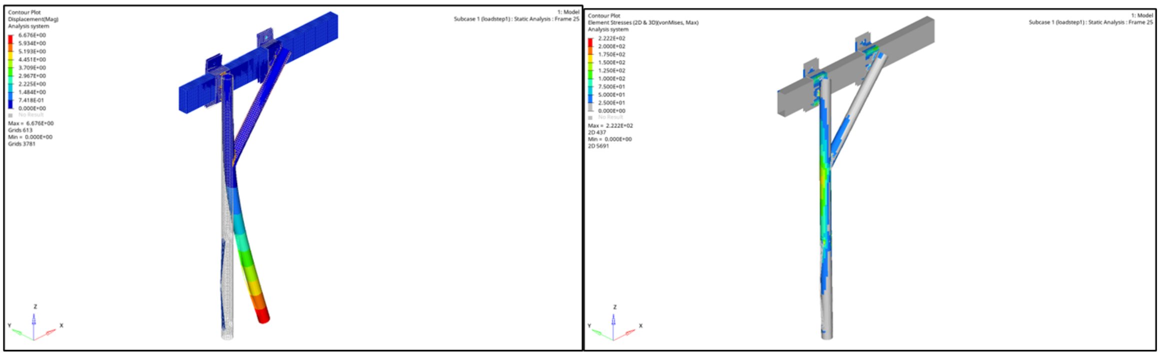

Figure 13: Click & Sound Recorder device mechanical integration (structural analysis).

Figure 14: Click & Sound Recorder device mechanical integration (real images).

c. Electrical

No electrical integration was required for this system. The internal battery of this system needs to be recharged before deployment, with a dedicated charger.

d. Software

No software integration was required for this system. AQUAtalk, a proprietary software, is used to configure the Click & Sound Recorder device before a deployment. Then, once mounted on the ASV, the system will collect data as planned.

4. AQUAMODEM 1000 (AQUATEC)

a. Overview

The AQUA*modem* 1000, developed by Aquatec, serves as a vital component in acoustic communication (Figure 15). Designed to operate at depths of up to 2000 meters, the AQUA*modem* 1000 has different power requirements depending on its operational mode. By default, when the RS232/TTL interface remains inactive, the modem conserves power by operating in its lowest-power mode, the timed/triggered state. Upon interface activity, the modem seamlessly transitions to its receiving mode. In the event that the host sends commands, including data for transmission, the modem switches to transmission mode, subsequently returning to the receiving mode as needed.

In terms of acoustic transmission, these modems operate within the 21 to 26 kHz frequency range. This frequency range empower the modems to establish communication over distances up to 2 kilometres, achieving data rates of more than 100 bps. The AQUAmodem 1000 is an essential asset for the ORCA ASV missions within the NAUTILOS project, enabling acoustic communication in the challenging deep-sea environment.

Figure 15: AQUATEC Acoustic modem.

b. Mechanical

Strategically positioned in the middle of the vehicle, between the hulls, the support structure of the AQUA*modem* sensor is attached to the ASV chassis and is supported by an already existing truss, providing resistance in the direction of movement. It was designed with the purpose of not requiring any modifications to the already produced chassis. Most of the references from this support are shared with the already existing Sonar Multibeam support having similarities in geometry and sharing the same location in the vehicle (therefore cannot be used simultaneously).

As most of the support structures described earlier, this welded assembly is entirely made of stainless steel. A rectangular tube forms the body of the structure, which accommodates 2,5mm sheet-metal pieces responsible for attaching and securing the sensor to the frame. The plate located in the middle of the structure receives and positions the sensor, and a clamp secures the sensor in the middle of the span. The interface between sheet-metal, structure, and sensor is always ensured with Neoprene sheets to prevent damage and absorb vibrations. The fasteners used to fix the sensor are provided by AQUATEC since they are made of aluminium to avoid galvanic pile. The off-the-shelf clamp is made of zinc plated steel and therefore is provided in duplicate for future replacement.

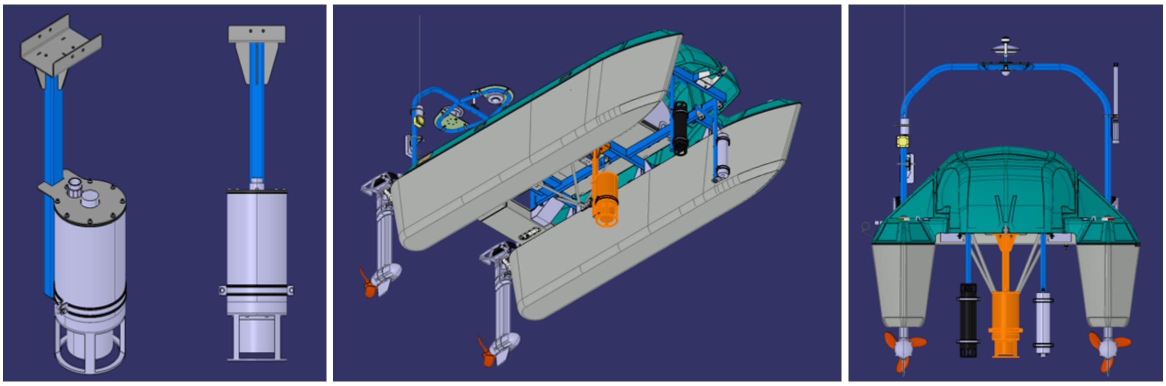

Figure 16: AQUAmodem mechanical integration (CAD visualization).

A structural analysis was made for this support to assure that it would bear all the loads present during operation during all WP6 and WP7 missions (Figure 17).

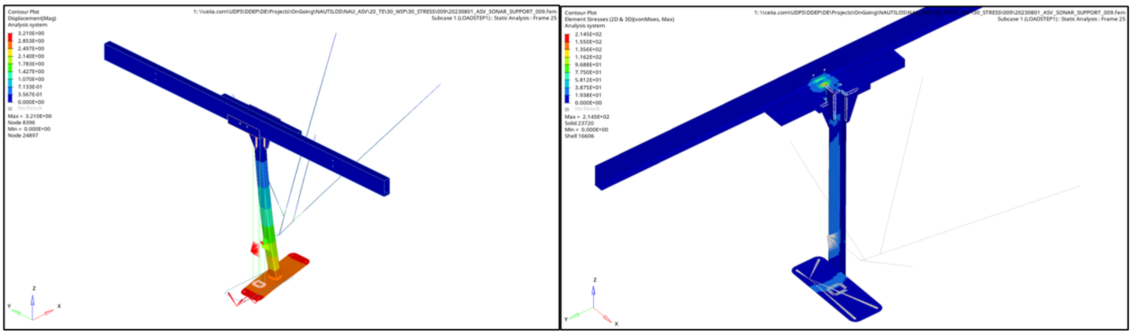

Figure 17: AQUAmodem mechanical integration (structural analysis).

c. Electrical

The AQUA*modem* 1000 depends on the ASV to provide the necessary power for its operation. Both the power and data connections were possible through a single underwater cable with "MCIL12F+DLSA-F" (To the modem Side) and "Open End" or pigtail to the ASV side.

Internally, a 24 VDC power channel was assigned to the AQUA*modem* 1000 port, this channel can supply up to 2.5 A. The channel can be controlled via software. Communication is possible via an RS-2332 interface on the onboard computer.

d. Software

As part of the integration of the AQUA*modem* 1000 with the ORCA ASV, a dedicated driver was developed for the onboard software. This driver was created in accordance with the specifications provided by AQUATEC.

Through the software we developed, we can access multiple features, such as sending telemetry, controlling the status of the mission, entering sleep mode, or waking up the Atlantis Lander.

The driver developed for the AQUA*modem* offers a versatile range of capabilities. It can instruct the modem to send and receive pings, facilitating reliable communication with other modems. The software also enables the exchange of messages between modems. Additionally, it allows for the customization of internal configurations, ensuring adaptability to specific project requirements and mission objectives.

On top of the low-level modem instructions, we defined our own message set (Table 2). This facilitates the transfer of information and commands between the operator – at the surface – and the platform.

Below is a table with the message definitions (Table 3).

Table 2: Message structure used for communication.

MSG ID	**SEQ**	**TIME**	**SYS ID**	**PAYLOAD** (Param 1 … Param N)

Table 3: Message definitions.

Message Description	Telemetry A		Telemetry B	Telemetry C	Send Command (Lander)	Jump to Task	Set Mission State	Ack
Message ID	$TELEA		$TELEB	$TELEC	$CMDLD	$JMPTK	$SETMS	$ACKCM
Sequence No	Sequence		Sequence	Sequence	Sequence	Sequence	Sequence	Sequence
Timestamp	time/date		time/date	time/date	time/date	time/date	time/date	time/date
System ID	Source ID		Source ID	Source ID	Source ID	Source ID	Source ID	Source ID
Param 1	Lat		Battery SOC		CMD	Task ID	State	ACK

								(OK/NOK)
Param 2	Lon		mission status		data 1			Sequence (ack'ed)
Param 3	Roll		vehicle status		data 2			
Param 4	Pitch				data 3			
Param 5	Yaw				data 4			
Param N					data N			

5. Other payloads - CEiiA

Other payloads, such as the multibeam sonar provided by CEiiA was considered for the WP6 controlled scenario mission whereas a habitat mission will be performed, in Crete.

I. OTTER ASV - PAYLOADS AND SENSORS INTEGRATION

1. NAUTILOS PAYLOADS AND SENSORS ON NIVA OTTER ASV

Below is a table with an overview of the systems that we integrated into the NIVA Otter ASV (Table 4).

Table 4: NAUTILOS sensors and payload integration overview.

Payload/Sensor	Owner	Collected parameters	Mechanical Integration	Electronic Integration
Low cost LIF LIDAR	NIVA	chlorophyll-a (chl-a) and colored dissolved organic matter (CDOM) concentrations	Yes	Power

2. LIF LIDAR SENSOR (NIVA)

a. Overview

NAUTILOS' Laser-Induced Fluorescence (LIF) Light Detection and Ranging (LIDAR) sensor detects fluorescent compounds like chlorophyll-a (chl-a) and colored dissolved organic matter (CDOM) in seawater. The sensor emits light UV-VIS light at 405nm (excitation) and detects fluorescent emissions of chlorophyll-a (chl-a) and colored dissolved organic matter (CDOM). The LIF LIDAR sensor can be autonomously deployed on above-water portions of observing platforms, with a detecting depth optimized at 5 meters. The LIF LIDAR is enclosed in a water-resistant enclosure measuring 35x30x25cm and weighs approximately 4 kg.

b. Mechanical integration

The LIF LIDAR will be installed and operated near the bow of the vehicle to: 1) ensure measurement of seawater is forward of the vehicle's thrusters and thus not disturbed by the ASV, and 2) positioned forward and providing some ballas at the bow of the ASV to reduce positive pitch (bow lift) during cruising (Figure 17).

Figure 18: The Otter ASV with the integration position of the LIF LIDAR represented by the red polygon.

The LIF LIDAR is mechanically integrated using a custom made 8 mm aluminium panel (Figure 18), attached to the ASV's frame, with anchors for the instrument. The instrument is attached with L brackets on the plate and facing down towards the water surface through an opening in the Otter's forward frame. The additional mass on the forward part of the Otter ASV is within the designed payload limits of the vehicle and aids in reducing bow lift when the ASV is in operation. Additionally, the small size of the LIF LIDAR presented negligible aero- and hydro-dynamic impacts.

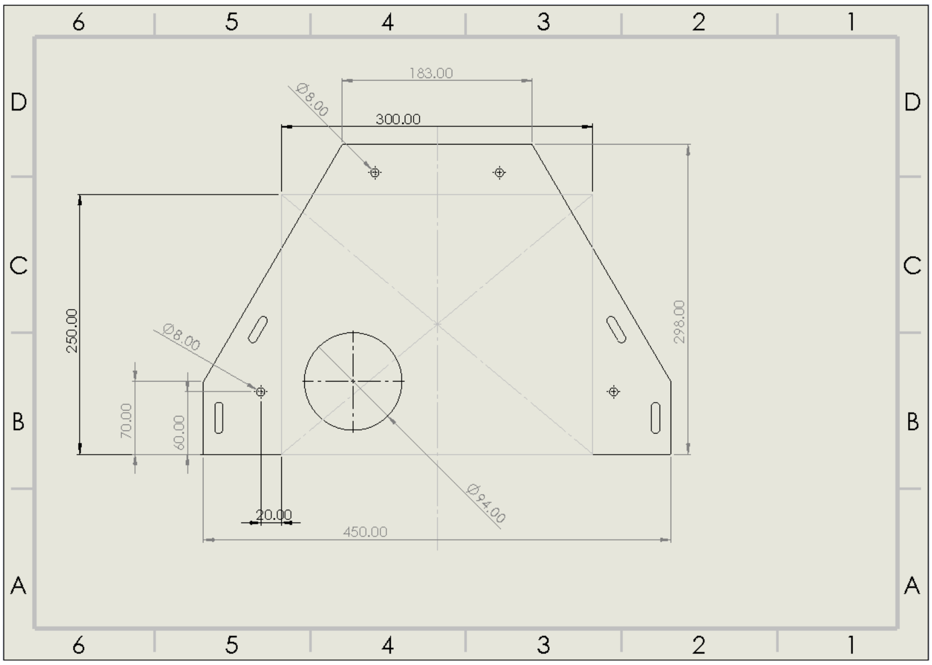

Figure 19: Drawing of the panel where the LIF LIDAR will be mechanically integrated the ASV.

c. Electrical integration

The sensor is delivered 24VDC power from the ASV batteries through a 4 pin micro circular Subconn connector on the LIF LIDAR's side and a Souriau UTS7104S connector on the ASV end.

The maximum power consumption of the LIF LIDAR system is approximately 160 W when the laser is on. Because the laser is only on for short pulses, this means the LIDAR draws 160 W for only 1 sec every 2 min, and the average power draw would be: (160 W*1 second)/2 minutes = 1.33 W. The vehicle's batteries have a combined capacity of about 4kWh. The vehicle uses about 200 W on average, so the LIF LIDAR power consumption adds only about 0.5% to the vehicle's power consumption which is low enough that it does not practically affect the ASV's operations.

d. Software

No software integration was required as the sensor operates autonomously with respect to software and data storage via a Raspberry Pi 4. The sensor receives operational commands via the Raspberry Pi 4 and logs the data internally on a micro SD memory card. Data can then be transferred after each mission after recovery of the ASV and LIF LIDAR.

V. DEVIATIONS

The integration of the sampler for Nanoplastics and Microplastics (T4.3) from SCT, developed by SCT initially for inclusion in the ORCA ASV provided by CEiiA, encountered deviations. Unfortunately, sensor development led to a device with dimensions and weight over ASV requirements in D2.3 "Integrated ICD - Interface Control Document for partners' vehicles, platforms and infrastructure". In response to these deviations, a decision was made to shift the integration of this sensor from the CEiiA ASV to the HCMR mooring line. This decision aims to fulfil the goals of NAUTILOS, with anticipated benefits, particularly because the sampler is specifically designed for stationary deep-sea deployment.

The low cost LIF LIDAR developed by NAUTILOS in task 3.2 was initially planned to be integrated and demonstrated on one of NIVA's ship of opportunity. However, due to potential safety concerns regarding the use of a high-power laser on passenger ferry that can cause irreversible eye damage, the sensor will be operated from an autonomous surface vehicle (ASV) instead. As such, the observing platform for the demonstration phase is the NIVA-owned and operated Maritime Robotics Otter.

VI. SUMMARY

As we conclude this report, D5.3 "Report on integration of payloads/sensors on ASV" within the ambit of the NAUTILOS project, we reflect on the achievements that have been realized.

The integration of an array of sensors, payloads, and cutting-edge communication systems has been meticulously detailed. The integration process, from mechanical configurations to software development, has demonstrated a resolute commitment to durability and reliability. Partners involved in the work (CEiiA, AQUATEC and NIVA) leading to this report demonstrated remarkable adaptability and a commitment to optimizing the integration process that required careful planning and execution to ensure optimal conditions for data collection, and the physical integrity of the installed sensors and other payloads, and the platform itself.

The ability to manage concurrent payload development and integration while navigating a continuously evolving landscape is a testament to the project's agility and dedication to achieving the highest standards of data collection and scientific objectives in the challenging ocean environment.

In closing, the integration of advanced systems on the ORCA ASV and Otter ASV platforms sets a new standard for ocean exploration and monitoring. This technological leap promises a brighter future for marine research and discovery, propelling the NAUTILOS project towards its goal of unveiling the secrets of the ocean.

APPENDIX 1: REFERENCES AND RELATED DOCUMENTS

ID	Reference or Related Document	Source or Link/Location
D2.3	Integrated ICD - Interface Control Document for partners' vehicles, platforms and infrastructure	**NAUTILOS Team GDrive**
D4.1	Report on the development of carbonate chemistry/ ocean acidification sensors	**NAUTILOS Team GDrive**
D3.5	Report on initial tank tests of Passive Acoustic Event Recorder	**NAUTILOS Team GDrive**
D3.4	Report on initial laboratory and tank tests of Passive Broadband Acoustic Recording Sensor	**NAUTILOS Team GDrive**