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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

The objective of Task 5.5 is to report the integration of a silicate sensor into a new generation of profiling float CTS5, to demonstrate functionality in end-user specific environments according to Interface Protocol outputs from Task 2.3. A focus on balanced energy, power consumption, hardware and software packages has been done.

This report presents the qualification of the silicate electrochemical sensor in laboratory and local field testing sites for validation. A strong step of calibration and validation in the field has been carried out. A first field was not conclusive, and the silicate sensor needed repair. The latter test introduced a delay in the agenda and a new campaign has been planned for M36. This deliverable is intended to be conclusive on the integration of the silicate sensor on a profiling float. The integration on a float continued beyond month 36 after validating the performance of the sensor in the Thau lagoon in Mediterranean Sea. Our objectives are to evaluate and validate the performance of the silicate sensor (repeatability of calibration and testing protocol…) and test several measurement frequencies before launching the phase of demonstration on a profiling float. Indeed, this step is essential because we have observed some strange phenomena on the oxidation of molybdenum during the cycle of measurement in simulated real environment. This latter could be longer in the first measurements, which are implying an increase of data files sizes. The Square Wave Voltammetry (SWV) method implemented to determine the concentration of silicate in field has shown some promising results.

A reliability of the embedded signal processing was launched to avoid post-processing of the data after in situ deployment. We have developed new tools to post-process data recorded by the silicate sensor.

A series of testing integration with successively more sophisticated simulators has been done in parallel and reported. This step enables us to model the effects of adding a new silicate version with an algorithm for calculation to the platform and its interaction with the platform hardware and software prior to deployments.

Final integration of the silicate sensor on a CTS5 profiling float was completed in early 2024 ahead of the demonstration launch in the Mediterranean Sea in June 2024.

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
SWV	Square Wave Voltammetry
EOV	Essential Ocean Variable
SBD	Short Burst Data
RUDICS	Router-based Unrestricted Digital Interworking Connectivity Solution
GUI	Graphical User Interface
SD	Secure Digital
LGC	Laboratoire de Génie Chimique

I. INTRODUCTION

1. PLATFORM DESCRIPTION

1.1. Profiling float

The platform used to integrate a new version of silicate sensor is a profiling float (CTS5) produced by the company Nke Instrumentation. This new generation of float is suitable for a large range of “Bio-Argo” applications. CTS5 is an autonomous multisensors profiling float, self-ballasted and supporting high payload. The CTS5 float is per default equipped with a standard payload including a Seabird SBE41CP probe. This can carry a full suite of other sensors including pH, dissolved oxygen, downwelling irradiance, particle backscattering, nitrate, chlorophyll fluorescence and others. By measuring the different EOVs (Temperature, Salinity, Pressure, Dissolved Oxygen, Silicate), we will assess the level of quality seawaters in open ocean. To validate the performance of the silicate sensor, the number of sensors on the platform has been limited to the need of the NAUTILOS project.

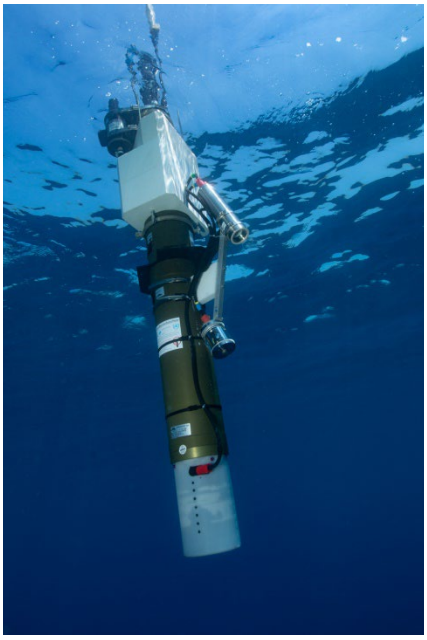


Figure 1: Autonomous multisensors profiling float (PROVOR CTS5)

The CTS5 float is based on its self-ballasting features and has an important volume variation capacity. Its mission consists of a repeating cycle of descent, submerged drift, ascent, and data transmission (Figure 2). It can be deployed from any vessel at low speed and in a wide range of density gradients. The float dynamically controls its buoyancy with a hydraulic system. This latter adjusts the density of the float causing it to descend, ascend or hover at a constant depth in the ocean. The user selects the depth at which the float drifts between descent and ascent profiles. After the submerged drift portion of a cycle, the float proceeds to the depth at which the ascending profile is to begin and collects measurements of physico and biogeochemical parameters depending on sensors mounted. The float records data into its internal memory. After each ascent, the float transmits data to the satellites of the Iridium system.

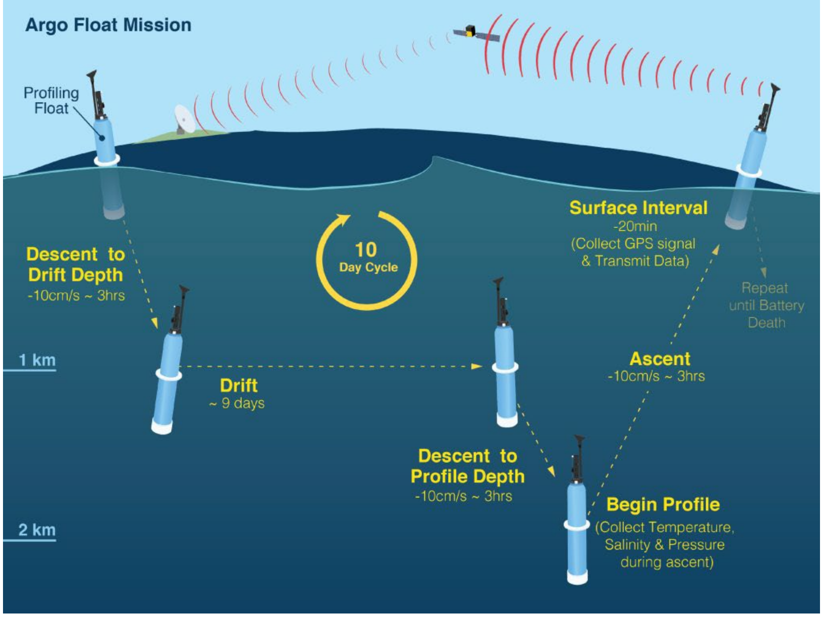


Figure 2: Argo Float Mission

1.2. Technical specifications

The CTS5 float is equipped with RUDICS which is two-way Iridium communication. Its weight is about 21.6 kg, and the float stands approximately 1.5 m high with a buoyancy system that will allow it to profile to 2000 m anywhere in the open ocean. Its battery life is estimated to 4.5 years when run on a standard Argo 10-day mission.
Technical specifications of the profiling float are detailed in the table.

Table 1: Technical specifications of the float

Seabird Electronics SBE 41 CP **Salinity** Range 0 to 40 PSU Initial accuracy ± 0.003 PSU Observed drift < 0.01 PSU / 5 years **Temperature** Range - 5°C to 35 °C Initial accuracy ± 0.0002°C Observed drift < 0.002°C / 5 years **Pressure** Range 0 dbar to 2100 dbar Initial accuracy ± 2.4 dbar Drift < 5 dbar / 5 years
Float Dimensions Overall Length 225 cm with antenna Hull Length 170 cm

Hull ϕ17.3 cm Max. ϕ35 cm damping collar) Weight 40 kg*(depending on configuration)
Operating conditions Max. operating depth 2000 dbar Operating temperature -2°C to 35°C Operating life 4.5 years at sea Power supply Lithium cells
Storage conditions Temperature -20°C to +50°C Maximum storage time before use 1 year Real time clock saved by separate battery

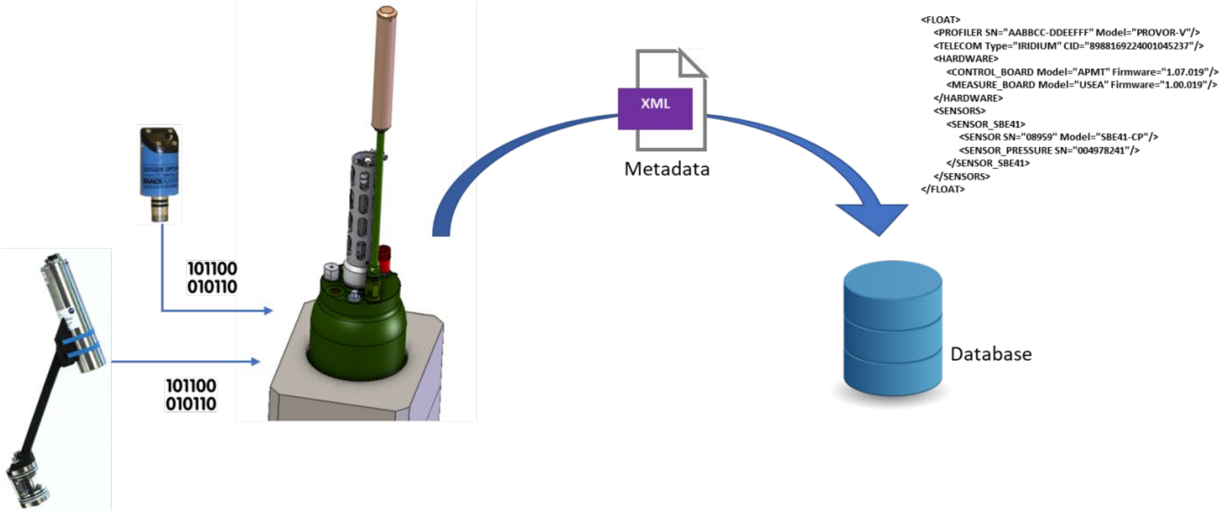
Data are recorded at a high sampling resolution down to 1 sec.

1.3. Data Management and communication protocol

The data management system implemented on the profiling float collects temperature, pressure, salinity, and silicate data and communicates to a communication board dedicated to transfer data files over satellite to an Iridium Provider Server.

How does the CTS5 float operate?
Once the float reaches the surface, it will synchronize its internal clock with GPS. Sensor's data are acquired during the ascent and are stored on a non-volatile memory inside the communication board of the float.
It is possible that when the profiling float fitted with the silicate sensor is deployed, we will have to modify the measurement acquisition procedure. The measurement cycle / equilibration of silicate takes a bit longer in situ. Silicates are non-electroactive species meaning they cannot be detected directly by electrochemical methods. The measurement acquisition procedure is the following: after 10 minutes of complexation with molybdates at acidic pH, the silicomolybdic complex formed is detected on gold working electrode with classical electrochemical techniques. Once deployed and depending on the depths reached, we will schedule silicate measurements during the parking phase at depth.

Furthermore, the CST5 float has the possibility to offer metadata traceability as shown in Figure 3. This platform can generate and transmit a metadata file with ancillary data together with the sensor data for a better identification. This metadata includes float identification, serial numbers, and sensor's metadata.



```
<FLOAT>
  <PROFILER SN="AABBCC-DDEEFFF" Model="PROVOR-V"/>
  <TELECOM Type="IRIDIUM" CID="8988169224001045237"/>
  <HARDWARE>
    <CONTROL_BOARD Model="APMT" Firmware="1.07.019"/>
    <MEASURE_BOARD Model="USEA" Firmware="1.00.019"/>
  </HARDWARE>
  <SENSORS>
    <SENSOR_SBE41>
      <SENSOR SN="08959" Model="SBE41-CP"/>
      <SENSOR_PRESSURE SN="004978241"/>
    </SENSOR_SBE41>
  </SENSORS>
</FLOAT>
```

Figure 3: Metadata traceability

To communicate with sensors, the profiling float is equipped with functionalities and integration facilities. A software embedded on the Navigation board (APMT) used on the CST5 profiling float enables a flexible sampling strategy to optimise the resolution and volume of data. An Exchange Multi-Application Protocol (EMAP) has been implemented directly in the embedded software of the profiling float and is used between the silicate sensor and the internal navigation board.

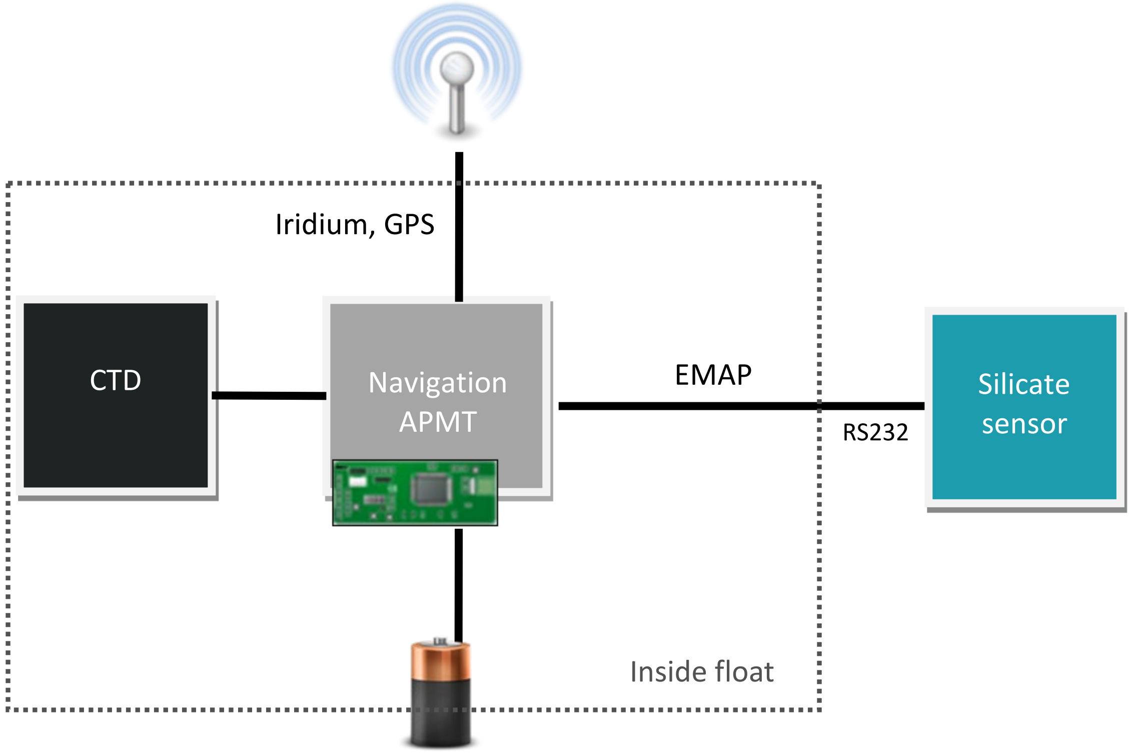


Figure 4: Protocol communication

During the surface phase, the internal navigation board works as follows: the float interrogates the navigation board the list of data files acquired by silicate sensor in format CSV and downloads it into its memory as described in Figure 5.

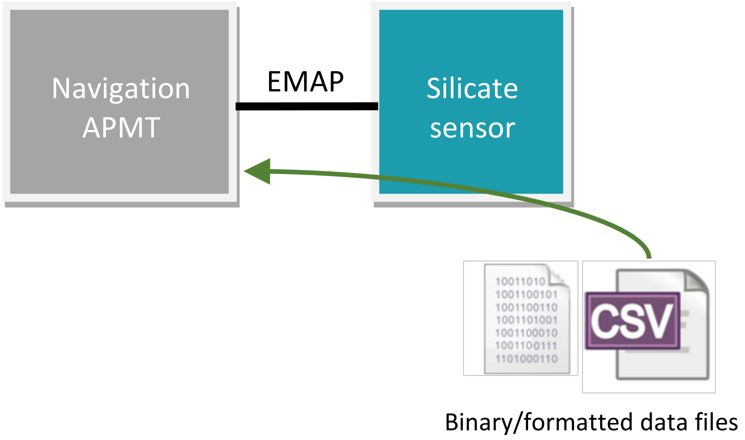


Figure 5: Downloading sensor's data files

In the case where a configuration file in format XML is deposited from the IRIDIUM RUDICS server, the float can upload it to the navigation’s board. After each communication process, a synchronization with the internal clock is performed.

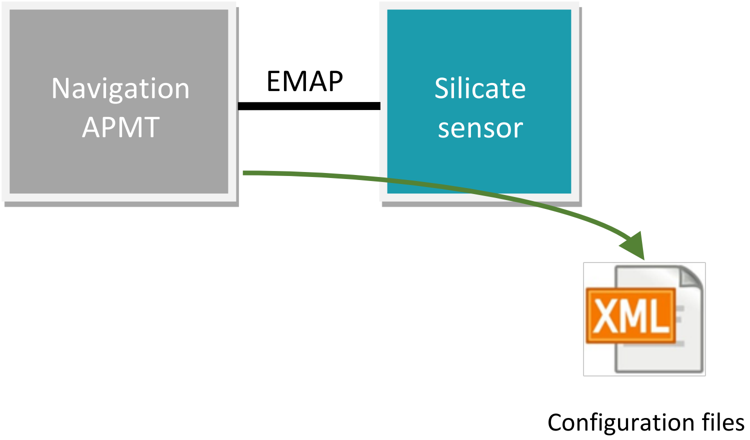
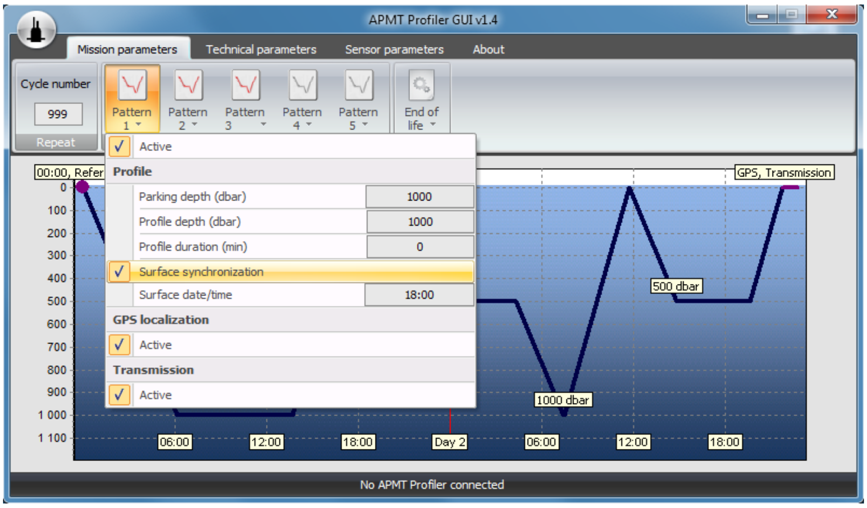


Figure 6: Uploading sensor's configuration files

1.4. CTS5 Interface GUI

Two user interfaces are available to communicate with the CTS5 float. The operator can use either a Bluetooth link to program a mission or check the parameters of float or use a Graphical User Interface as shown in Figure 1Figure 7.



Cycle number: 999

☑ Active

Profile

Parking depth (dbar)	1000
Profile depth (dbar)	1000
Profile duration (min)	0
☑ Surface synchronization	
Surface date/time	18:00

GPS localization

☑ Active

Transmission

☑ Active

No APMT Profiler connected

Figure 7: Graphical User Interface (GUI)

This graphic configuration tool (Figure 7) has been developed to configure, diagnose, and simulate the behaviour of CTS5 float during a mission. We can set/change navigation and standard sensor settings, estimate data size recorded per profile and lifetime expectancy, check, or modify the configuration, establish a diagnosis of the float and generate a new remote command file to change the mission.

2. INSTRUMENT DESCRIPTION

2.1. Silicate electrochemical sensor

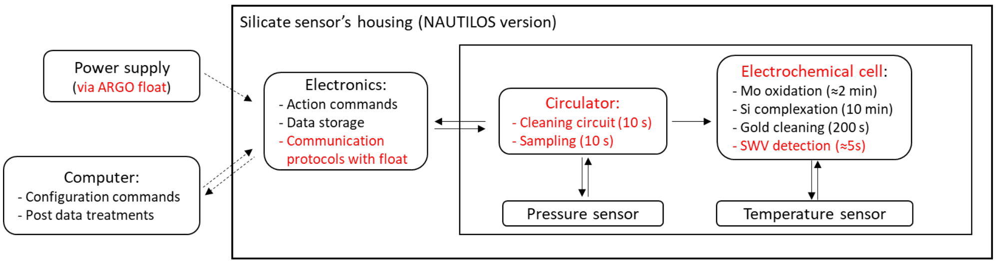
Electrochemical silicate sensor (new optimized design) presented on Figure 8 is an anodized aluminium cylinder of 9 cm diameter and 25 cm long with a weight of 2.2 kg. The housing has been validated up to 100 bars (1000 m depth). The device is also equipped with pressure and temperature sensors. Pressure is measured when the water is sampling while temperature is monitored during the electrochemical detection. The sensor is equipped with a SUBCONN waterproof connector (6 contacts, micro-circular) to communicate with the platform and to be powered by this latter. The silicate electrochemical sensor is described in detail in the deliverable 4.2.

Figure 8: NAUTILOS version of Silicate Electrochemical sensor

The NAUTILOS version was globally redesigned by integrating a water circulator that fills the measurement chamber and facilitates the cleaning of the cell detection between two samplings.

2.2. Technical specifications

The new silicate sensor developed in the NAUTILOS project requires 12V power provided by the platform. This current consumption is approximately about ~40 mA. This version is compliant with profiling floats deployments after significantly decreasing the measurement time to less than 15 minutes. All achievements shown in red are synthetized in the scheme (Figure 9).



Total = 13 min → Compatible with profiling floats deployment

Figure 9: All achievements on the silicate electrochemical sensor

2.3. Communication interface and protocol

The silicate sensor is connected to the profiling float via a waterproof SUBCONN cable. Both the sensor and the platform are fitted with a waterproof SUBCONN connector (6 contacts, micro-circular). The communication protocol is via an RS232 serial port. On the float side, the SUBCONN connector is mounted directly on the float body near the bladder, as shown in the Figure 10.

Figure 10: Subconn connector on the float side

The pinout connections of the silicate sensor and how to communicate with it are indicated below:

Table 2: Pinout connection of the silicate electrochemical sensor

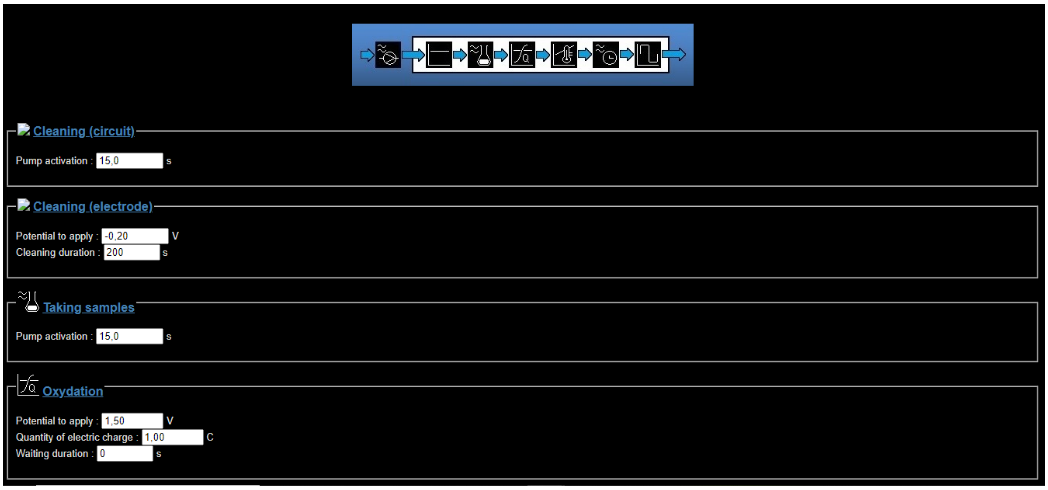
Subconn 8 contacts	Color	Description	Reference
Pin 1	Black	12 Volts	Power + 12 V
Pin 2	White	GND	GND Power
Pin 3	Red	Tx	Pin 3 Sub-d 9pts
Pin 4	Green	Rx	Pin 2 Sub-d 9pts
Pin 5	Orange	GND	Pin 5 Sub-d 9pts
Pin 6	Blue	Pushbutton (PB)	1 Pole of PB
Pin 7	White/Black	LED	LED pole +
Pin 8	Red/Black	LED	LED pole -
Wiring Pushbutton			
1 pole --> to Pin 6 of the Subconn connector (Blue cable) 2 pole --> to GND via Pin 2 of the Subconn connector (white cable)			

There are two ways to configure the silicate sensor via software. The first consists of directly using a PPP connection and on an FTP server to modify or replace the configuration file. The second consists of a real time link by sending commands for the parameters to modify by a Terminal Network (Telnet). A description is detailed in the deliverable 4.2.

2.4. Silicate Interface GUI

A web server has been developed for the needs of the silicate sensor and allows for support of sensor configuration in the form of HTML pages. Also, the sensor is configured without the need for special software. A simple web browser can be used to perform this operation.

The pages can be used to configure the sensor, calibrate it and start measurement cycles. An example of an HTML page is shown on Figure 11.



Cleaning (circuit)
Pump activation : 15,0 s

Cleaning (electrode)
Potential to apply : -0,20 V
Cleaning duration : 200 s

Taking samples
Pump activation : 15,0 s

Oxydation
Potential to apply : 1,50 V
Quantity of electric charge : 1,00 C
Waiting duration : 0 s

Figure 11: Silicate interface GUI to set sensor parameters

All these pages are embedded in the sensor and can be accessed via the sensor's IP address 192.168.1.20. The most common browsers can be used to access html pages: Internet Explorer, Firefox, Chrome. However, depending on the browser version, certain functions may or may not be active. The recommended browser is Chrome version X.

II. OVERVIEW OF THE INTEGRATION AND VALIDATION

This part is dedicated to the integration of the silicate sensor on a profiling float. We will look at software, hardware, mechanical and electronic implementation.

1. SOFTWARE INTEGRATION

The software implemented on the acquisition board used on the CST5 profiling float enables a flexible sampling strategy to optimise the resolution and volume of data. The EMAP protocol has been implemented directly in the embedded software of the profiling float. Data are logged to an internal SD card, using EMAP to a navigation board developed by Nke Instrumentation (Figure 12). The communication layer is based on a master/slave exchange. It is assumed that the EMAP board is the master.

When deployed, the navigation board periodically asks the silicate sensor for data download (collected and stored by the sensor’s board), configuration update and date/time synchronisation (with EMAP’s GPS).

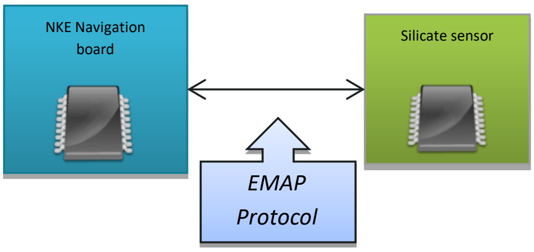


Figure 12: Protocol communication between sensor and platform

In fact, the sensor board should be ready for each time the communication process is started. The communication layer is based on a file management system. All data from sensors are transferred as files. The file content can be text or binary. We have defined the silicate data as follows:

1. The sensor by its name and address (hexadecimal format)
2. The date/time of file creation (yymmdd_hhmmss format)
3. Type by the file extension

For example :

4. “silicatexxxx_150216_171600.csv” for Silicate sensor’s data in text format

Configuration files are included in the data file or are independent such as: “silicatexxxx_150216_171600.xml”.

When the sensor configuration is updated, the files name will be named by “silicatexxxx.xml”.
Frames are based on an ASCII format with separated fields with start/stop header and a frame control.

2. MECHANICAL INTEGRATION

A first step consists of modelling the integration of the silicate sensor and platform in 3D (Figure 13). The aim is to model the mechanical integration of the silicate sensor on a profiling float using a software drawing. This enable us to define the best possible architecture without disturbing the float's equilibrium once it is in the water. The integration of a new sensor has required a new buoyancy balance.

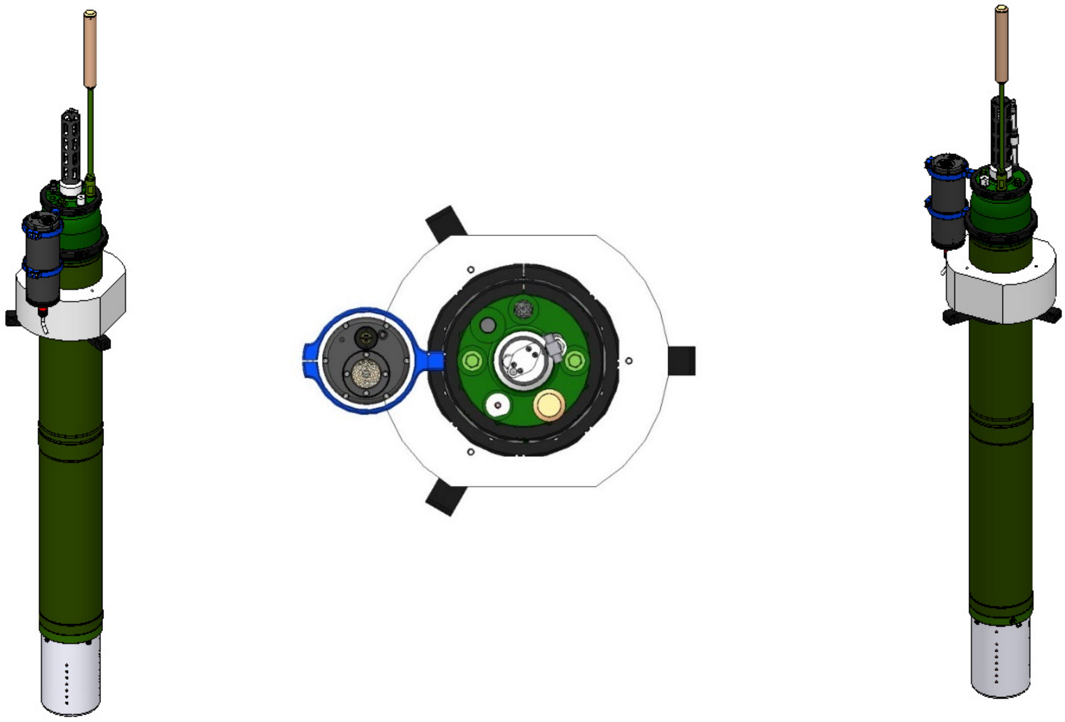


Figure 13: Mechanical integration of the silicate sensor on a PROVOR float from three different angles

We studied different solutions for installing the silicate sensor on the float. It is important to consider the tilt of the float as it moves through the water and when it leaves the water to transmit data to the satellite. The integration of the silicate sensor is relatively negligible on the float as its apparent weight is almost zero in the water.

We decided to position the sensor at the base of the float, which gives an angle of inclination of the float close to 0° with respect to the vertical axis. This solution is shown in Figure 14.

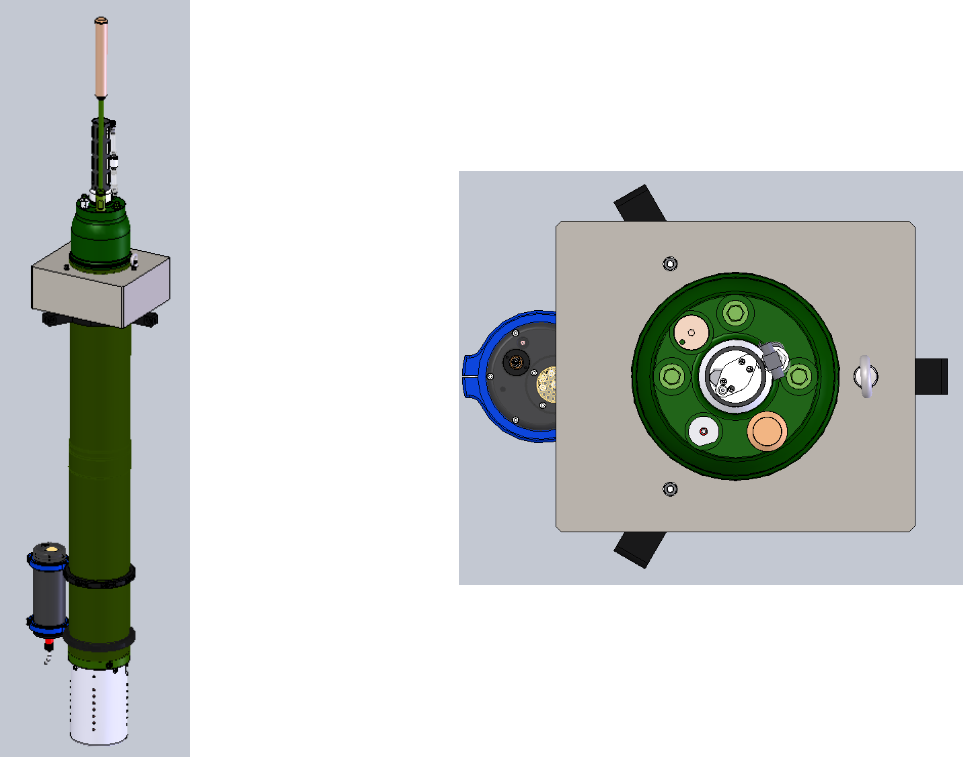


Figure 14: Other mechanical integration of the silicate sensor on a float

To integrate the silicate sensor on a platform, buoyancy calculations were carried out. The float is an autonomous platform equipped with an external ballast visible under the white hull in figure 13 or 14 and an internal bladder (not visible here). This float operates on the principle of Archimedes' buoyancy. The float is considered as a constant mass, and only a transfer of oil between the internal and external ballast (equivalent to a volume of fluid displaced) allows the buoyancy to vary. At the surface, the external ballast tank is full and the internal bladder empty. The buoyancy of the float is at its maximum at this stage and the float floats (buoyancy is positive). Once the external ballast is empty, the principle is reversed. The buoyancy decreases and becomes negative. The float is denser than the water, so it sinks.

We therefore carried out buoyancy calculations by determining both the center of mass Zg and Zv, the barycenter of the volume of water displaced (the float's center of buoyancy) to guarantee its stability and to examine its inclination.

The table below shows our calculations of the center of mass of the float, the total volume of fluid displaced and the center of buoyancy in the case of empty ballast (table 3) and full ballast (table 4). The total mass m of the float is expressed in grams. It can vary according to the geometric tolerances of the parts that make up the float. Here, the mass of the float fitted with the silicate sensor varies between 43600.2 g and 44051.0g. The total volume of fluid displaced is expressed in cm^3.

Table 3: Calculation of the centre of mass of the float, the total volume of fluid displaced and the centre of buoyancy in the case of empty ballast

Total mass m (g)	Mass center Z_g (mm)	Total Volume of displaced water with ballast (cm^3)	Upward buoyant force Z_v (mm)
43890.5	558.3	41838.6	683.7
44051.0	557.5	41980.0	684.0
43600.2	559.1	41780.3	683.1

Table 4: Calculation of the centre of mass of the float, the total volume of fluid displaced and the centre of buoyancy in the case of full ballast

Total mass (g)	Mass center Z_g (mm)	Total Volume of displaced fluid with ballast (cm^3)	Upward buoyant force Z_v (mm)
43890.5	490.6	44838.6	627.4
44051.0	490.0	44980.0	627.9
43600.2	490.9	44780.3	626.8

In the integration study of the silicate sensor on a float, we are also studying the influence of density on Archimedes' buoyancy force, expressed in Newtons, depending on whether the external ballast is full (maximum buoyancy) or empty (minimum buoyancy).

Table 5: Calculation of Archimedean buoyant force with ballast empty as a function of water density between 1000 and 1038 kg/m^3

Water Density kg/m^3	Min Archimedean buoyant force (N) with m = 43890.5 g	Median Archimedean buoyant force (N) with m = 44051.0 g	Max Archimedean buoyant force (N) with m = 43600.2 g
1000	-2051.9	-2071.0	-1820.0
1012	-1549.8	-1567.2	-1318.6
1020	-1215.1	-1231.4	-984.3
1025	-1005.9	-1021.5	-775.4
1027	-922.3	-937.5	-691.9
1027.6	897.2	-912.3	-666.8
1030	-796.7	-811.6	-566.5
1031	-754.9	-769.6	-524.8
1032	-713.1	-727.6	-483.0
1035	-587.5	-601.7	-357.6
1038	-462.0	-475.7	-232.3

Table 6: Calculation of Archimedean buoyant force with full ballast as a function of water density between 1000 and 1038 kg/m³

Density kg/m³	Min Archimedean buoyant force (N) with m = 43890.5 g	Median Archimedean buoyant force (N) with m = 44051.0 g	Max Archimedean buoyant force (N) with m = 43600.2 g
1000	948	929.0	1180.0
1012	1486	1468.8	1717.4
1020	1845	1828.6	2075.7
1024	2024	2008.5	2254.8
1025	2069	2053.5	2299.6
1027	2159	2143.5	2389.1
1028	2204	2188.5	2433.9
1030	2293	2278.4	2523.5
1031	2338	2323.4	2568.2
1032	2383	2368.4	2613.0
1035	2517	2503.3	2747.4
1038	2652	2638.3	2881.7

Once the silicate sensor has been integrated and the stability/fluidity of the float has been studied, the float must be weighted down with lead in Ifremer's water pool. The direction of the lead contributes to the stability of the float and will be checked. The angle of inclination will be measured in the Ifremer pool before the demonstration in the Mediterranean Sea.

3. ELECTRONIC AND HARDWARE INTEGRATION

The silicate sensor is connected to the profiling float via a 6-point socket and a waterproof SUBCONN cable. The baseplate is connected to the float's measurement board, which controls the silicate sensor by interrogating it. A MCIL6F to MCIL6M cable is used between the float and the silicate sensor.

To communicate with the platform, the link between the two boards is limited to a serial link. The communication layer uses a 2-wire serial link. Table 7 describes the power supply and serial link characteristics.

Table 7: Power supply and serial link

Power supply	Range
Voltage	+9,6 to +16VDC
Consumption	1 A (max.)
Serial link	**Value**
Interface	RS232
Baud rate	57600
Data bits	8
Parity	None
Stop bits	1
Handshake	None

Another, more flexible alternative solution for managing float-mounted sensors is currently being developed by nke. This consists of implementing an intermediate board that will act as a junction between the profiling float's APMT board and the silicate sensor. The board currently being developed will enable new functions to be added to the management of the silicate sensor by the profiling float. If the results are conclusive, they will be displayed in deliverable 7.5 - Report on the demonstration of silicate sensor on ARGO float in the Mediterranean Sea.

III. RESULTS AND DISCUSSIONS

1. DESCRIPTION OF LABORATORY AND FIELD TESTS

To characterise and calibrate the silicate sensor, we worked under controlled laboratory conditions in a 40L tank using silicate standard solutions and Certified Reference Material (CRM). The results of calibration are described in the deliverable 6.2.

To evaluate the endurance of the silicate sensor in a real environment (the Mediterranean Sea), we have mounted the silicate sensor on a platform like a bathysond (Figure 15). The sensor is powered via an external battery. All silicate data are logged to an internal SB card. The platform was deployed in the Thau Lagoon and fixed to a pontoon. In parallel, samples were collected periodically on the site for comparison with colorimetric reference instruments in laboratory.

Figure 15: A silicate sensor (autonomous version) mounted on a rosette for field validation

We use a specific test bench to reproduce the complete measurement chain between sensor and platform including the silicate sensor and the navigation board.

2. LABORATORY TESTS

A full simulation chain allows validating the integration of new product and getting a better understanding of the float. We developed new capabilities for the mission flexibility. Since a float follows marine currents and may encounter different density gradients, it is important to model its future missions to better understand its behaviour. This also enables us to define the number of missions to be carried out over a few days, at what depths, the number of data sets acquired, the size of the files obtained, etc.

Metadata file is generated by the float itself; it comes with a graphical interface where the mission can be tested in advance to check the validity of the choices and get an energy budget estimation. Acquisition can be made at 1 Hz and all data points are time stamped.

We have simulated a mission of float with the silicate sensor introduced in the chain of measurements (Figure 16). We have tested the good reception of data recorded by silicate sensors.

This test bench enables to model the effects of adding the sensor(s) to the platform and its interaction with the platform hardware and software prior to deployments. We have simulated the behavior of the float and tested different missions at different depth.

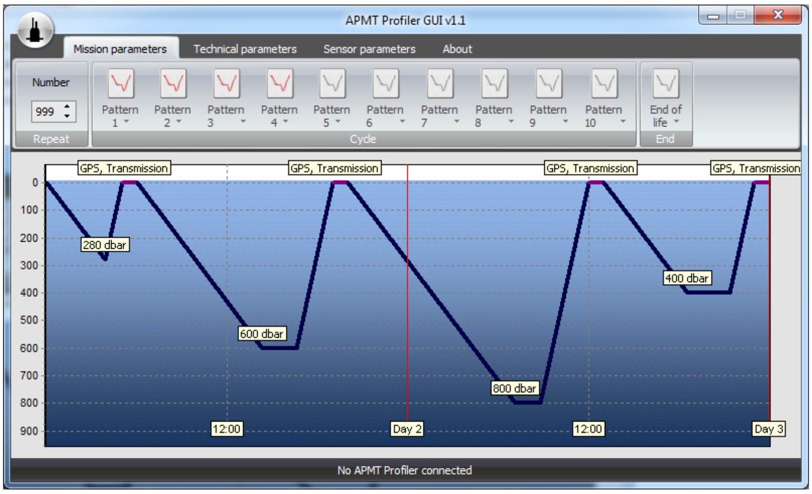


Figure 16: Simulated mission of float on a test bench

Other achievements from 5.5 have been performed to avoid post-processing of the data after in situ deployment. We have developed new tools with our LEGOS partner to post-process data recorded by the silicate sensor.

3. FIELD TESTS

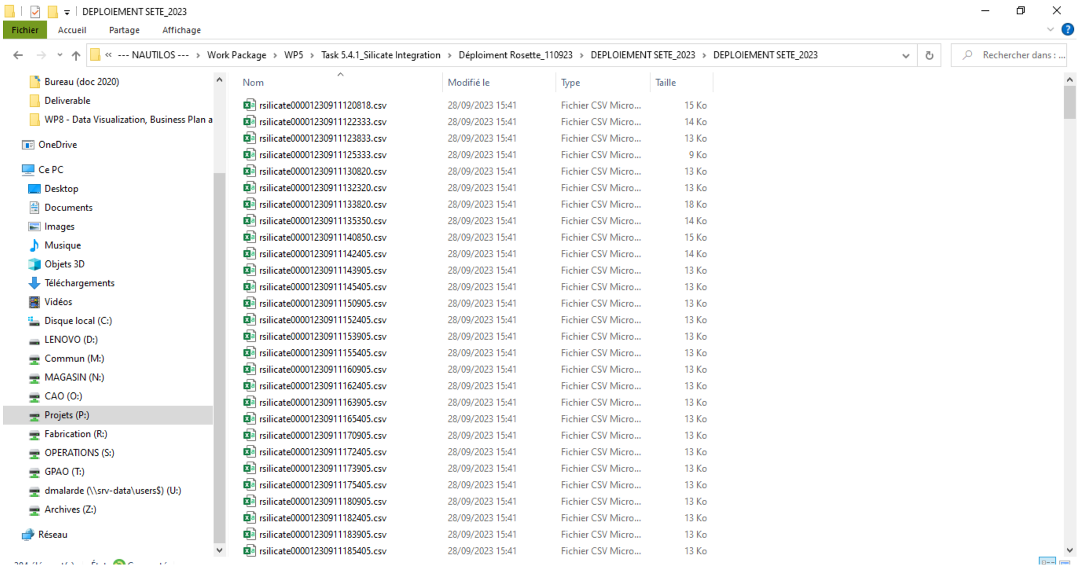
Before integrating the silicate sensor on a new-generation CTS5 profiler, we wanted to deploy the sensor on a site in the Mediterranean Sea and evaluate its performance by setting it up at different acquisition frequencies. The sensor is mounted on a rosette and can operate autonomously via an external power supply. The objectives included to make comparisons between silicate measurements and values obtained from on-site sampling, to validate the sensor's entire acquisition chain (frequency of measurements, size of files transmitted, etc.), and finally to check that the sensor performs well in a real environment (pump priming, sending of respected commands) (Figure 17).

Figure 17: Development of an unexpected chemical reaction on the surface of the detection cell damaging the silicate sensor after a few days of field validation

The silicate sensor was previously repaired at nke after an initial campaign during which it was damaged following an electronic problem which generated a chemical reaction on the detection cell preventing the oxidation of the molybdenum from operating correctly. A biofouling was also observed on the mechanical body during the campaign. The sensor was tested in an aquarium filled with seawater to check the square wave voltammetry and verify the timing of molybdenum oxidation. The sensor was then sent to the LGC for calibration. The sensor's various electrodes were prepared according to a strict protocol. The sensor was calibrated using silicate concentration solutions. The calibration was checked using CRMs. The sensor underwent two series of calibrations to assess the repeatability of the measurements over time. Once calibrated, the sensor was installed in its autonomous version on a pontoon in the Thau lagoon in the Mediterranean Sea (Figure 18).

Figure 18: Marine Station of Sete - Etang de Thau

The sensor was programmed to run continuously between 11/09/2023 to 21/09/2023. So normally it should make one measurement every 15 minutes. In parallel, sampling, and colorimetric analysis are take samples every 30 minutes. After this first series of measurements, the frequency measurement is set off again for one measurement every 60 minutes. SQW data are logged to an internal SB card.
This campaign gave good results in terms of size recorded files, number of SQW measurements at different measurement frequencies. We have recorded a lot of data files at different measurement frequencies as shown in Figure 19. These trials showed that the frequency of measurements could not be under 15 minutes. This frequency can generate some defaults on the cycle of measurements.



Nom	Modifié le	Type	Taille
rsilicate0001230911120818.csv	28/09/2023 15:41	Fichier CSV Micro...	15 Ko
rsilicate0001230911122333.csv	28/09/2023 15:41	Fichier CSV Micro...	14 Ko
rsilicate0001230911123833.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911125333.csv	28/09/2023 15:41	Fichier CSV Micro...	9 Ko
rsilicate0001230911130820.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911132320.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911133820.csv	28/09/2023 15:41	Fichier CSV Micro...	18 Ko
rsilicate0001230911135350.csv	28/09/2023 15:41	Fichier CSV Micro...	14 Ko
rsilicate0001230911140850.csv	28/09/2023 15:41	Fichier CSV Micro...	15 Ko
rsilicate0001230911142405.csv	28/09/2023 15:41	Fichier CSV Micro...	14 Ko
rsilicate0001230911143905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911145405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911150905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911152405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911153905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911155405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
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rsilicate0001230911163905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
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rsilicate0001230911170905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911172405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911173905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911175405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911180905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911182405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911183905.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko
rsilicate0001230911185405.csv	28/09/2023 15:41	Fichier CSV Micro...	13 Ko

Figure 19: Data recorder and sent by silicate sensor

The field silicate sensor analysis results will not be described in this deliverable.

4. FINAL INTEGRATION OF SILICATE ON A CTS5 FLOAT

The final integration of the silicate sensor on a new-generation CTS5 was carried out at Nke. All the silicate sensor's energy management, communication management and satellite data transmission functions between the silicate sensor and the platform were verified. The system performed buoyancy tests in Nke's freshwater column. Data reception tests were carried out on the Nke server. The next step will be to carry out profiles at a depth of 20 m in Ifremer's water tank to perform buoyancy tests in real seawater, study its behavior and adjust its buoyancy to transmit the data correctly and have the float antenna sufficiently out of the water. The system will then be sent to Villefranche-Sur-Mer in June for deployment in the Mediterranean to carry out profiles at depths of up to 1,000 m.

Figure 20: Final integration of silicate sensor on a CTS5 float

IV. SUMMARY

In this task, we integrated the silicate electrochemical sensor in a real environment to evaluate its endurance after a few days of deployment. Trials seem to be given successful results and a series of silicate recorded at different frequencies. The post-treatment is being progressed.

We designed a new integration of a silicate sensor on a profiling float. We tested the silicate sensor on an environment simulator of the profiling float before the final integration and demonstration planned in 2024. The test bench enables us to model the effects of adding the new electrochemical sensor to the platform and its interaction with the platform hardware and software prior to deployment. We have tested the EMAP communication and checked the good transmission of data through the platform. This step is not totally completed and will be finalized at the beginning of next year.

The final integration of the silicate sensor on a profiling float is completed. The next step will be to demonstrate the silicate sensor on a profiling float in the Mediterranean Sea (WP7.4).

We consider the integration part of the silicate sensor on a platform to have reached a TRL level of 6.

V. APPENDIX 1: REFERENCES AND RELATED DOCUMENTS

ID	Reference or Related Document	Source or Link/Location
1	D4.2 Report on the development and laboratory validation of silicate electrochemical sensor.pdf	https://cloud.nautilos-h2020.eu/index.php
2	D6.2 Report on results and methodology of calibration / validation experiments performed in T6.2.pdf	https://cloud.nautilos-h2020.eu/index.php