1. Project Information

Proposal reference number[1]	
Project Acronym (ID)[2]	**YUCO-CTD micro-AUV**
Title of the project[3]	*Validation of an innovative easy-to-use affordable micro-AUV platform , embedding an high accuracy and resolution CTD sensor.*
Host Research Infrastructure[4]	**Marine Institute**
Starting date - End date[5]	1st February 2021 - 30th November 2021
Name of Principal Investigator[6] Home Laboratory Address E-mail address Telephone	Thomas LAMSON SEABER 31 rue des Fontaines 56100 LORIENT thomas@seaber.fr +33 (0) 972354338

2. Project objectives[7] (250 words max.)

The main objective of the Yuco-CTD micro-AUV project is to perform quantitative and georeferenced salinity and temperature profiles in coastal areas using an easy-to-use affordable fully autonomous micro-AUV platform embedding an Argo referenced, high accuracy and resolution CTD sensor.

The project's secondary objectives are the following:
- Demonstrate the accessibility, ease-of-use and reliability of this AUV technology to oceanographers such as ocean physicists, who are not necessarily trained in underwater robotics.
- Demonstrate that this micro-AUV technology is able to perform accessible, swift and reliable CTD measurements in challenging coastal environments.
- Prove that micro-AUVs embedded with CTD sensors can be used to complement the existing methodologies for CTD measurement.
- Provide a use case to show that more distributed, repeated and scientifically reliable CTD measurements can be made in coastal areas using Yuco-CTD micro-AUV.
- Demonstrate the capability of Yuco-CTD micro-AUV to perform almost vertical profiles with various "sawtooth" navigation modes in coastal waters.
- Prove the capability of Yuco-AUV to navigate accurately in unsheltered coastal area with tidal currents such as those present in Galway bay thanks to INX © navigation.
- Perform high sampling, high resolution and high accuracy temperature and salinity measurement on the Yuco micro-AUV moving platform based on CTD RBR Argo referenced sensor.
- Demonstrate the great autonomy and useability of Yuco-CTD micro-AUV platform combining AUV own performance and low-power CTD.
- Analyse variation and measurement of temperature stratification and correlate Yuco-CTD measurements with data from the SmartBay cabled observatory and glider reference platforms.

Main achievements and difficulties encountered (250 words max.)[8]

Most of the objectives were completed.

YUCO micro-AUV from SEABER was successfully deployed 3 days in a row and properly measuring during missions.

Day one and day two – 01/11/2021 & 02/11/2021 – were used to perform various types of profile patterns with the YUCO micro-AUV, next to a reference CTD cast made from the deployment vessel.

On day three 03/11/2021 one YUCO micro-AUV performed a long mission of approximately 3 hours long and about 15km distance with 2,5 knots average speed. The mission consisted in a back and forth travel from both sides of Galway Bay while performing sawtooth CTD profile all along the water column.

The YUCO micro-AUV being totally autonomous, both Marine Institute and SEABER crew had the opportunity to stay at shore during the 3 hours mission and come back to pick it up at expected end mission position and time.
At the end of the mission, YUCO was about 200m from expected recovery point. This is an estimated error of navigation of about 1%, which is better than the initial target of 2%.

The main issue encountered is the unavailability of Marine Institute Glider that didn’t allow us to perform following:
- Analyse variation and measurement of temperature stratification and correlate Yuco-CTD measurements with data from the SmartBay cabled observatory and glider reference platforms.

As deployment took place in autumn, deploying a glider in Galway Bay at this period of the year is very complex. In a way, this issue showed the interest of using micro-AUV technology in this type of complex area where other vehicles main not be that easy to deploy.

[1] Reference number assigned to the proposal by the TA-Office.

[2] User-project identifier used in the proposal.

[3] Title of the approved proposal. The length cannot exceed 255 characters

[4] Name of the installation/infrastructure accessed with this project. If more than one installations/infrastructures are used by the same project, please list them in the box.

[5] Specify starting and end date of the project (including eventual preparatory phase before the access).

[6] Fill in with the full contact of the Principal Investigator (user group leader).

[7] Write the short-term, medium and long-term objectives of the project. Use no more than 250 words.

[8] Describe briefly the main achievements obtained and possible impacts, as well as possible difficulties encountered during the execution of the project. Use no more than 250 words.

3. Dissemination of the results[9]

Analysis of the data is still in progress but it is clear that results shall be published soon especially when automated compensation algorithm of temperature convergence delay will be implemented.

Once published data will be disseminated with public access.

4. Technical and Scientific preliminary Outcomes (2 pages max.)[10]

The YUCO-CTD micro-AUV experiment took place in SmartBay area and allowed to perform a great number of autonomous missions to measure water temperature and conductivity.

Various types of patterns were tried – sawtooth, diving-screws, vertical profiling (popping-up).

Some missions happened along a CTD cast reference at some key positions, which provided a correlation information. Finally, Smart Bay fixed station provided a reference CT measure at fixed positions.

Data from the RBR Legato3 was acquired at high sample rate, 2Hz.

The great variety of performed patterns showed interesting impacts on the measurement value depending of horizontal and vertical speed of the micro-AUV. Especially, the exact depth of the thermocline base (~12.7°C) was measured at different values depending on the vertical speed of the AUV.

The RBRLegato3 used for this trial is a standard thermistor with an estimated time response of about ~1s. Therefore, depending on whether the micro-AUV is diving down or rising, and depending on its exact vertical speed, temperature measurements are shifted in depth and that must be accounted for. On the other hand, the time response of conductivity sensor is shorter but still non-zero, meaning that it must also be shifted and synchronized with temperature measurements to have an accurate correlation of both C, T and D parameters.

High repetitiveness of the measurement time shift shows that it can be easily corrected with automated algorithms. Indeed, once temperature measurement delay is corrected data comparison between YUCO-CTD micro-AUV and CTD cast seems to be well in line.

Even if data requires deeper analysis, it appeared that the less adapted pattern for such configuration is the saw-tooth where a low inclination spiral and a vertical surfacing – profiler like – showed less deviation. However, we can suppose that combining high-acquisition rate CTD and embedded algorithm can lead to very high data standard and totally comparable to a cast of a reference CTD.

Also, for such application of profile it may be interesting to consider the "high-speed" CTD version of the RBRLegato3 with 16Hz and fast response thermistor.

In general, this project led to a real proof of interest of using YUCO micro-AUV solution in coastal environment to perform CTD measurements all along the year and showed the possibility to extract scientifically exploitable data.

The great coverage in 3D at low-effort and low-cost opens the way to regular and more spatialized measurement approach for coastal monitoring.

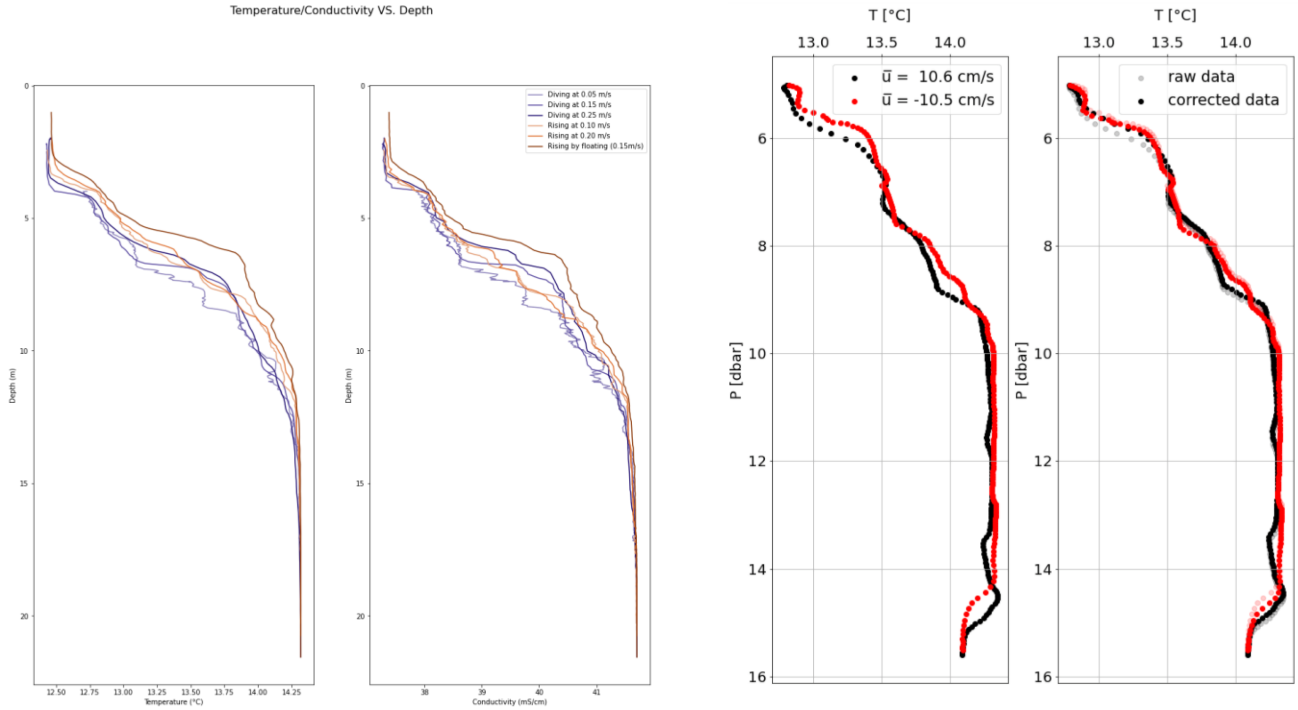

Figure 1: *CTD casts taken at various vertical speeds in the same location (total duration : ~30min).*

Left: *Orange/Brown profiles are taken by YUCO-CTD while rising up to the surface ; Purple profiles are taken while diving. Graph shows an hysteresis particularly visible at the thermocline base due to vertical speed.*

Right: *Down profile (black) and up profile (red) at 10cm/s vertically, uncorrected on the left, time-shifted on the right. Graph shows that after correction, CTD casts are very well correlated.*

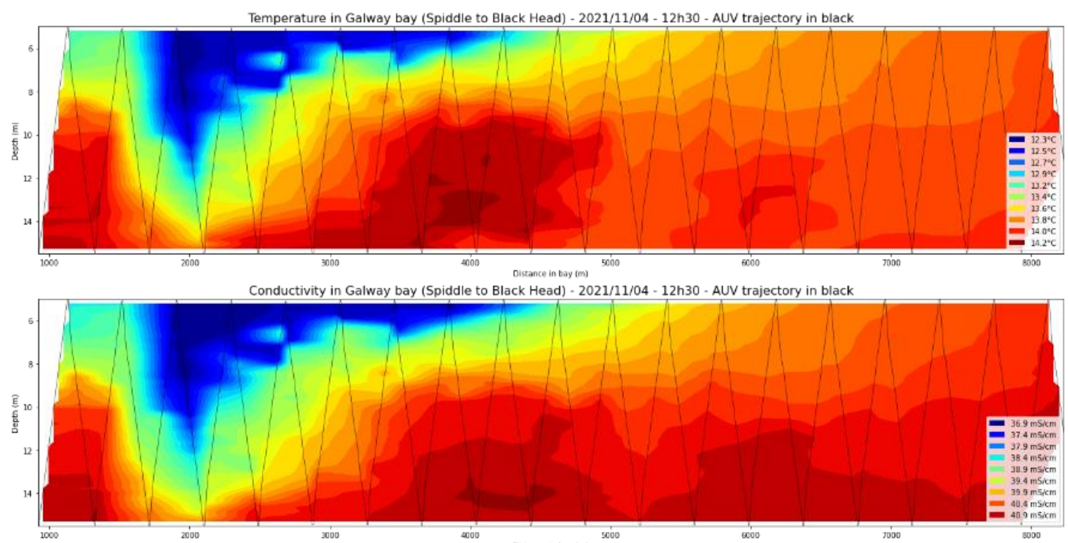

Figure 2: *Temperature transects on 03/09/2021 sawtooth pattern uncorrected*

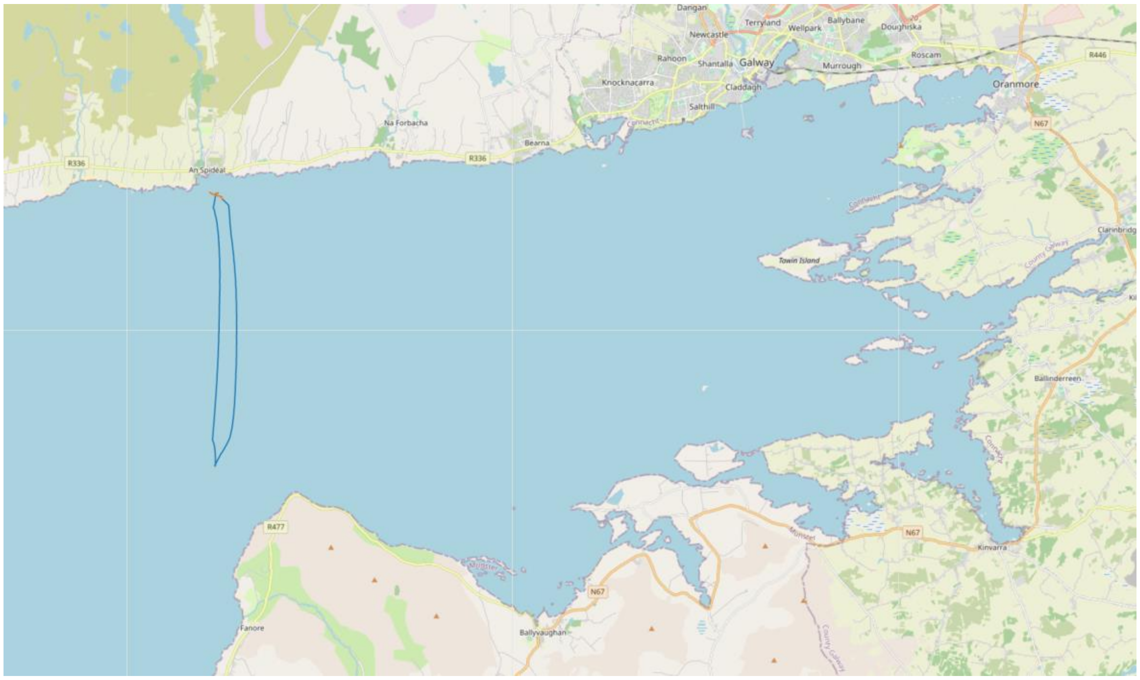

Figure 3: *2D map of travelled distance during transect on 03/09/2021*
Blue : underwater trajectory, Orange : surface trajectory (with GPS signal)

Figure 4: *2D map trajectory on 02/11/2021, where six vertical profiles were realised in a single mission.*

Blue : underwater trajectory, Orange : surface trajectory (with GPS signal)

[Location], [Date (dd/mm/yyyy)]

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Location and date

Signature of principal investigator

LORIENT, MARCH 1st, 2022

[9] Describe any plan you have to disseminate and publish the results resulting from work carried out under the Transnational Access activity in JERICO -S3: scientific articles, books - or part of them -, patents, as well as reports and communication to scientific conferences, meetings and workshops. Highlight peer-reviewed publications. Note that any publications resulting from work carried out under the JERICO -S3 TA activity must acknowledge the support of the European Commission – H2020 Framework Programme, JERICO -S3 under grant agreement No. 871153.

[10] Describe in detail results and main findings of your experiment at the present stage.