# iFADO Case Study:

## AUTONAUT FOR EXTREME ENVIRONMENTS

## A partnership of Autonaut with iFADO project

*Figure 1: Autonaut Picture*

## Deployment and route plan

*Delayed start.*

The intention was to launch in late May / early June. Due to Covid 19 affecting supplies and resources the launch was delayed to 4th August. This had a significant effect on the battery charging that was possible with the PV panels alone, and therefor on the route plan as it developed.

*Diplomatic consents*

Collecting data in the EEZ of other nations requires diplomatic consent, applied for through the UK Foreign and Commonwealth Office (FCO) and normally taking six months. The Extension timing made it unlikely this could be achieved before July. In the event diplomatic consents for Iceland and the Faroes were secured, but with conditions. Later the FCO were helpful in quickly securing Irish consent, allowing the project to collect data and route south through Irish waters.

*Mid-Atlantic OSNAP array*

As it became apparent that heading north from Rockall on the Ellett Line was not likely to be productive consideration was given to heading west from Rockall to the mid-Atlantic ridge where there is an extensive OSNAP array of moored sensors owned by various countries, led by the US. SAMS and NOC are members of OSNAP. The US OSNAP lead was contacted, and she distributed to US partners our offer to collect and share surface data from over the moored arrays, for comparison. At the time of launch the route plan was to go to approximately point ‘E’ on the chart below, and return to Oban.

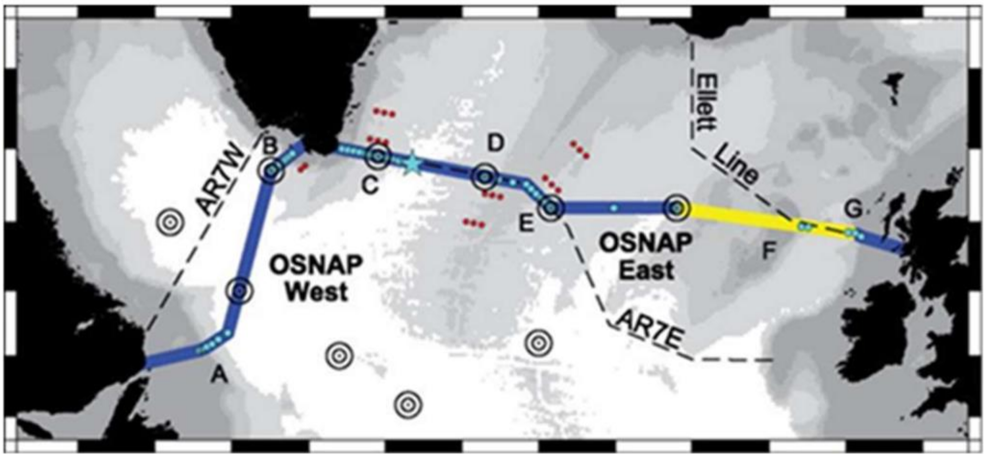


*Figure 2: The OSNAP array*

### Partner responses

Responses from European partners were helpful, including the Irish Marine Institute, the Galway Mayo Institute of Technology, CEFAS, iFADO and the UK Met Office.

### Sensor fit

The sensor fit was agreed with SAMS to match the data that could be compared with those from moored arrays and deployed gliders. Sensors were loaned by manufacturers. These were Nortek Signature500 Acoustic Doppler Current Profiler (ADCP); Xylem Aanderaa Motus wave sensor; Seiche micro passive acoustic monitor (uPAM). The University of East Anglia, which partnered in the original EE project, and went on to purchase an AutoNaut specially adapted to deploy a Kongsberg SeaGlider to the Southern Ocean, loaned their Seabird conductivity, temperature and depth (CTD) sensor: later UEA loaned the power generation controller (PGC) from their AutoNaut Caravela. In addition, AutoNaut provided an AirMar weather station, and a replacement. iFADO have provided support and data review throughout. We are very grateful for the support of all these partners in providing the equipment, and their assistance in analysing the data gathered.

SAMS, the Irish MI and GMIT all had plans to deploy underwater gliders in the area, and to service moored arrays deploying PAM and other sensors.

### Gliders and moored arrays

The concept was to gather surface data at the same time and location as these facilities, to allow data comparison. In the event the gliders were not deployed.

- Depart Oban 4th August. All systems working
- Exit Firth of Lorn. Intermittent failure of PV3. Cycle sensors to manage power.
- Proceed to Stanton Bank and hold station to recharge batteries.
- Hourglass transects over Stanton Bank with PAM
- Hourglass transects over S1 with PAM
- Transect between EB1E and EB1W with ADCP. Curtailed by lack of hotel power. Decision to head S.
- Pass M4 Met Office buoy. No sensors on, to save power.
- Recovery to Blacksod in NW Ireland to change out Power Generation
- Controller and AirMar. Download data. Reinforce foils.
- Relaunch and make way to M6 Met Office buoy.
- ADCP transect over shelf break enroute to M6.
- M6 Box of transects 3.5 nm around with wave sensor.
- ZigZag route down shelf break (provided by SAMS) intermittent sensor use ADCP and PAM due to lack of power.
- Progress from Porcupine Bank towards PAP-SO aborted with batteries at 0%. Pickup by tug. Batteries recharged on deck on track back to Ireland.
- Due to import/export difficulties decision not to land in SW Ireland, but to relaunch at M3 and route back to Cornwall.

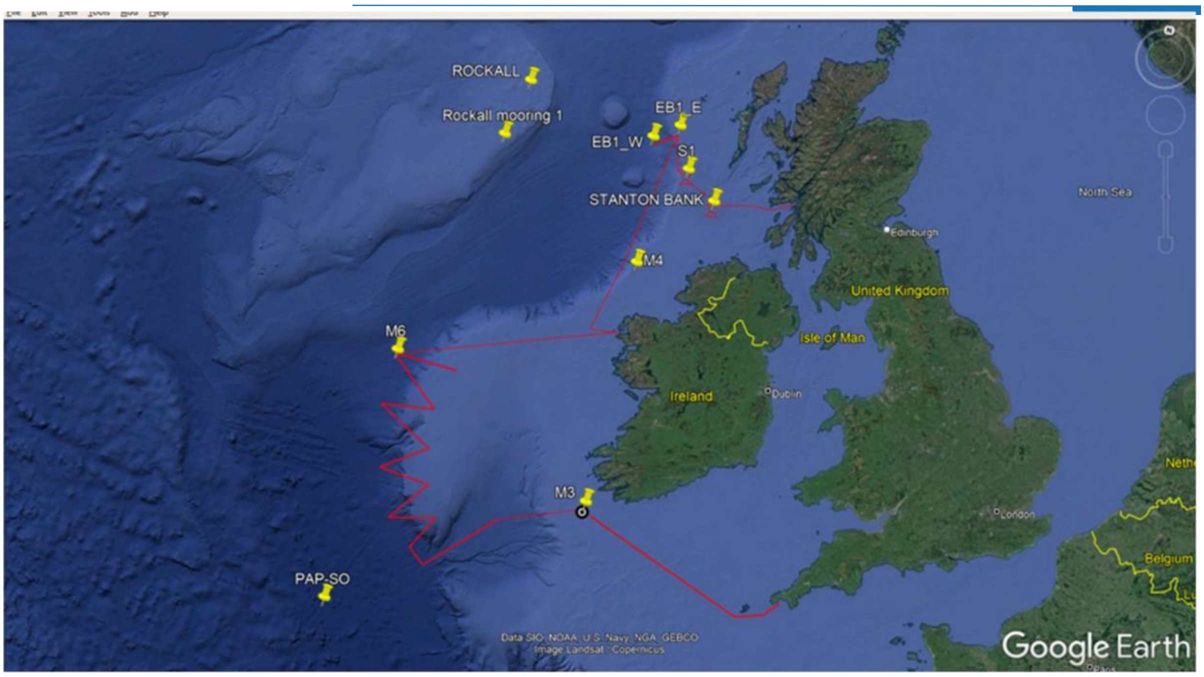


*Figure 3: Simplified route map*

- PAM transects in Celtic Sea.
- Route west and south of Isles of Scilly and shipping separation lanes. Wait out Storm Arwen off Mount's Bay. Recovery to Penzance.
- NOTE: a large part of this 4,000 nm voyage was spent in holding positions, and drifting, with all sensors switched off while the PV panels recharged the batteries. This was due to the late launch meaning that at the end of the mission the sun was never reaching above 15 degrees over the horizon.

## Data

### *PAM*

Data analysed by Seiche, SAMS, and GMIT. Initial findings included numerous cetacean identifications. Possible first acoustic detection of Kogia (pygmy sperm whale) in UK waters. Poster for conference presentation at Annex A.

### *ADCP*

Data analysed by Nortek and SAMS.

### *CTD*

Satisfactory, used as part of ADCP analysis

### *WAVE*

Motus data analysed by Aanderaa, and Dr Ajit Pillai of UoE as fellowship support.

### *WEATHER*

Two AirMar weather stations 'drowned' possibly due to being mounted on low bridge. Possibly an old spec of AirMar. No useful data, but largely used for piloting info.

## Verification and validation

The technology developments made in Phase 1 to be validated and verified in this extension were:

### *The robustness of the USV*

Robustness included testing hull, struts, foils, as well as internal and external fixings and fittings, and choice of materials. All of these were modified as a result of the research undertaken at UEA's sea-ice chamber and other work, including destructive drop testing and ice impact trials.

Result:

- The USV was recovered to Penzance after 115 days at sea in good working order.
- One foil was broken when the USV was recovered

to a tug in 4.5m waves off SW Ireland. This was repaired on board the tug with through bolted backing plates.

- The mounting for EchoMax radar transponder was reinforced at Blacksod.

### *Anti-icing coating*

In Phase 1 some 25 COTS waxes and hydrophobic coatings were tested. One product was selected. This was then exposed in the open environment ashore for 1 year. For this Extension one PV panel was treated.

Result:

- The hydrophobic coating was working well on recovery.

### *Ice-detection and avoidance*

Following the successful detection of a block of ice in waves off Plymouth UK in Phase 1, this aspect of the project continued into this Extension. Results showed the best image was obtained using an IR camera. It was then necessary to obtain IR video of small ice in Arctic waters, to confirm the contrast remained adequate.

Result:

- With some difficulty video was secured, and a machine learning programme is being trained. This will continue after the Extension completes. The aim is then to apply detected ice targets to the USV's existing anti-collision system, or to a new platform control system when developed.

### *Energy harvesting*

In Phase 1 the University of Exeter Energy Harvesting Department researched and built a prototype pendulum energy harvester. This was sea trialled in the final stage of Phase 1. No power was produced, probably due to the load / resistance being too high. Therefore, the pendulum harvester was not installed in this Extension. The intention was to replace this power source with a fuel cell, or a bespoke packaging of new D cell Li batteries. The Bramble fuel cell tested in the final month of Phase 1 had overheated in benchtop trials. Due to Covid we had insufficient resources to design, test and install the proposed D cell pack.

Result:

- The Extension highlighted the need to develop additional sources of power for high latitude deployments, and even UK latitude deployments in winter. This lack of power was accentuated by the problems encountered in getting charge from the PV panels into the new Li batteries.
- We have researched options, and this will be continued after completion. These include:
  - A new kind of Li-seawater battery being developed by PolyPlus in the US, where it is identified as 'of national significance' for defence. Potentially this has the highest energy density of the battery and fuel cell options.
  - A low-profile vertical axis wind generator.
  - A shelved collaboration with SAFT to develop bespoke D cell battery packs

Reconfiguring the pendulum harvester produced by UoE. The concept is to mount the device as high as possible, and in the bow of the USV to maximise movement. This will allow the pendulum length to be almost doubled, and for all the mass to be located at the bottom.

Power take off is being reconfigured to charge capacitors, with a soft-start load. Testing will take place after the Extension.

- Some design work has gone into using heat differences aboard the USV.
- Other TRL 1 harvesting options, such as plankton, piezo and triboelectric technologies remain on the watch list, as does generating power from the foil action.


*Figure 4 AutoNaut 'Oban' on display at Robotics for a Safer World, Bristol 29th March 2022*

## Conclusions and future steps

Taking the initial three-year project and this extension together this has resulted in:

1. A greatly improved USV with rudder system, struts and foils now capable of long endurance, and all parts suitable for high latitude extreme environment use.

2. Work will continue on providing adequate hotel power, preferably through energy harvesting, but possibly also a fuel cell or battery system.

3. Work will continue detecting small ice in waves and collision avoidance.

4. Ongoing analysis of data gathered with a view to publication in peer reviewed journals, as well as general media releases.

5. The low 'bridge' installed instead of the usual sprung mast was not a success. The idea had been to minimise the risk of mast breakage in very rough Southern Ocean seas. However, the bridge shaded the PV panels in low light, and the low mounting reduced the range of antenna, AIS, radar transponder, and nav light. A short mast will work well.

6. A useful lesson for pilots was the ability to let the vessel take up a course relative to the wind while recharging batteries, so saving the power required for steering.

7. Ongoing promotion of AutoNaut into the offshore wind industry, with a baseline PAM survey in summer 2022. (We have done excellent baseline surveys for previous customers such as BP but cannot publish their data).

8. Ongoing project development with CEFAS for fish survey and Met Offices particularly in provision of wave data. Potentially this provides them with a zero-carbon option for gathering met forecasting data from the open ocean.

9. Ongoing project development with NOC, iFADO, OSNAP and other science institutes, making full use of AutoNaut's zero carbon ability to operate in the open ocean without the need for a supporting mothership.