

## Underwater glider custom payload for long-term radioactivity measurements

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**Abstract** – The RAMONES project addresses rising concerns about marine radioactivity through innovative instruments, incorporating autonomous underwater gliders equipped with custom payload for long-term and continuous radioactivity measurements. Hardware modifications involve integrating a radioactivity sensor, a USBL/modem for precise positioning and navigation, and a single-board processing unit for logging and control. Payload data and glider are controlled using the ROS framework, which incorporates adaptive planning and decision algorithms, enabling real-time mission re-planning underwater. Chip-scale atomic clocks allow for minimizing USBL energy consumption through a new silent interrogation scheme. Successful initial field tests in a lake verified glider dynamics and acoustic communication, paving the way for open-sea trials.

**Keywords** – underwater glider, radioactivity monitoring, acoustic communications and positioning

### I. BACKGROUND

Global increase in anthropogenic activities, coupled with natural processes, such in hydrothermal vents, has led to a rising concern regarding the levels of radioactivity in marine environments. Monitoring radioactivity in the sea is crucial for understanding the distribution and sources, and accurate measurements provide essential data for assessing the impact of radioactivity levels, evaluating the effectiveness of regulatory measures, and guiding decision-making processes. Additionally, continuous monitoring aids in the identification of potential hotspots, allowing for prompt intervention to mitigate environmental and public health risks.

To this end, RAMONES, an EU H2020 FET Proactive Project, aims to offer new instruments and techniques to perform continuous and in situ measurements of natural and artificial radioactivity in the marine environment. Along with the new instruments, RAMONES engage autonomous underwater gliders (AUGs) that have been customized for long-term wide-area radioactivity reconnaissance and monitoring.

### II. UNDERWATER GLIDER MODIFICATIONS

AUGs are well known for their extended missions lasting weeks to month due to their energy-efficient design. However, to keep these advantages, payload integration has to follow low energy, volume and weight designs. One of the tasks for RAMONES was to integrate a radioactivity sensor, an USBL/modem for accurate positioning and navigation, as well as, a processing unit for logging and control (Fig. 1). Adaptive planning and decision algorithms allow near real-time mission re-planning while underwater

and position updates from the surface allow for precise navigation even in confined environments, such as underwater volcanoes with active hydrothermal vents.

Radioactivity measurement payload. The main radioactivity sensor is based on a small-factor gamma spectrometer with a 4 cm<sup>3</sup> CZT crystal. The stand-alone instrument is protected from the elements with a 600 m depth rated hard anodized aluminum 6082-T6 pressure tolerant housing. Data and power provided via USB with one underwater connector. A ROS wrapper driver has been developed that allows data storing and parameters initialization for ARM based single-board computers. The  $\gamma$ Sniffer has been independently tested in the Kolumbo (Greece) hydrothermal field, at 500 m depth.



Fig 1. The TWR Slocum glider with the USBL/Modem payload (centre) and the radioactivity sensor (front). A floating Wi-Fi access point allows for real-time glider debugging while underwater

Acoustics payload. The AUGs are also retrofitted with USBL/MODEM payload for geo-localization and to allow near real-time data upload and mission updates. The payload is based on Evologics S2CM 18/34 OEM systems and is powered from an independent 800 Wh battery bank.

All the electronics, batteries, and transducers are housed as a single module in an extension cylinder allowing easy reconfiguring of the glider. Moreover, the new system expedited the inclusion of a new silent interrogation scheme, enabled by the chip-scale atomic clocks integrated in the modem-USBLs, thereby reducing active signaling and minimizing energy consumption.

The software interface is a wrapper of AT commands, that acts as a ROS driver for Evologics modem-USBLs and allows other ROS nodes to send and receive messages through the acoustic channel, as well as, relative positioning messages from other modem-USBL, typically in pairs of range and bearing/elevation angles by means of “synchronous” uni-directional transmissions, bi-directional, or “silent” localization through triangulation using measurements of the USBL antenna. Being all the nodes in the network equipped with a precise clock (above water with constant updates from GPS and below water with atomic clocks), travel time and consequently exact relative positions are inferred by the communication protocol.

**Payload and glider control.** A Raspberry Pi 4 single-board computer is in charge of payload data, control, and coordination with the glider. It is connected via USB with the  $\gamma$ Sniffer, via ethernet with the USBL/Modems, and via RS232 with the glider. The robot operating system (ROS) framework is used for data collection and messages exchange. A ROS wrapper node takes samples from the  $\gamma$ Sniffer. It saves raw spectral files with all the data and configuration, and publishes the spectrum and counts per second. The counts-per-second are consumed by the glider decision making and navigation nodes to adapt glider motion based on the readings.

**Mission planning.** The glider is running a custom firmware with the so-called “backseat driver” ability, allowing the modification of parameters during the mission, instead of it being set in stone at glider launch. This enables the glider to react to the ensemble of radioactivity and adapt its mission to optimally search for the radioactivity source. The glider can run a ROS node onboard which computes new volumes of interest (VoI) and paths to follow based on

gamma radiation measurements or, as envisioned for a RAMONES mission, can receive the VoI or paths from a surface vessel aggregating radioactivity measurements from several gliders. The onboard software is implemented as ROS nodes and there exists a ROS node for interacting with the backseat driver. This latter node converts glider state and mission parameters ROS topics to the appropriate serial port messages (and vice-versa) for interaction with the glider’s onboard computer.

**Field tests.** Underwater glider dynamics are very sensitive to weight / volume distribution because of their buoyancy engine limitations. Ballasting has to be within a few grams at neutral position and the distance between the centres of buoyancy and weight within a few millimetres. These were considered on the design of the abovementioned modifications and the ballast was achieved inside the specifications. Glider dynamics and acoustic comms were tested at Castelo de Bode Dam reservoir lake (Portugal) with a number of short dives due to the lake’s shallow waters (50m at its deepest). Dive profiles suggest proper glider dynamics and behaviour paving the way for open-sea trials (Fig. 2).

### III. CONCLUSIONS

New AUG payloads have been presented for long term and persistent radioactivity measurements. A gamma radiation instrument has been installed externally to the front of the glider and an USBL/MODEM has been integrated in a glider extension bay with its own power bank. Adaptive planning and decision algorithms allow near real-time mission re-planning while underwater

### IV. ACKNOWLEDGEMENTS

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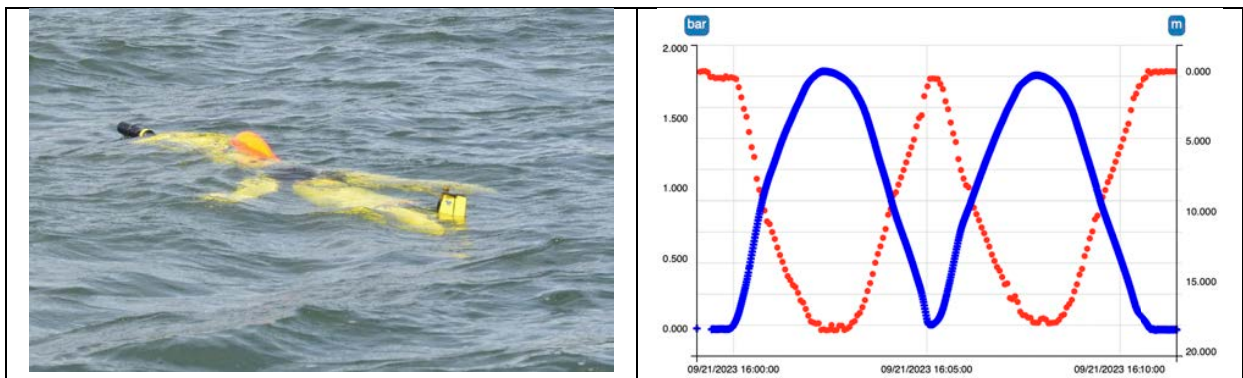


Fig 2. Test dive at Castelo de Bode Dam reservoir lake (left). Glider flight profile showing estimated depth (red) and measured pressure (blue) (right).