

## Operational Validation of GIRONA500 AUV

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**Abstract** – GIRONA500 is a lightweight 500 meters rated hovering type AUV designed and built at the University of Girona. It has been conceived as a highly reconfigurable research platform, able to carry our advanced research in marine robotics as well as an applied research in applications like science or cultural heritage. During the summer 2012, GIRONA500 was operationally tested as a high-resolution opto/acoustic imaging platform in 2 cruises: CALDERA and “La Lune”. This paper reports the experience about the operational use of the AUV.

**Keywords** – Marine Robotics, AUV, Seafloor Mapping.

### I. INTRODUCTION

GIRONA500 AUV [1] was the result of the GIRONA500 Subproject of the RAUVI Spanish funded coordinated project, which had the aim of building a low cost, low weight Intervention AUV. During the design, our team tried to conjugate two goals: 1) Building a flexible and reconfigurable platform for advanced underwater robotics research and, 2) Building an operational capable vehicle. The project started in 2009, and the first dive in a water tank happened at the end of 2010. Since then, the AUV has been successfully used in 2 Spanish (RAUVI [2] & TRITON) and 3 European projects (TRIDENT [3], MORPH [4] & PANDORA [5]) achieving objective 1. During the summer 2012, two cruises were scheduled to face objective 2: making GIRONA500 AUV an operational vehicle for field operations up to 500 m.

This paper presents the vehicle and its operation validation in CALDERA12 EUROFLEETS [6] and “La Lune” [7] cruises. The paper is organized as follows. The robot is described in section 2 and its mapping capabilities are presented in section 3. Section 4 reports the integration with the MBSsystem multibeam mapping software suite. The field validation of the vehicle is described in section 5 before conclusions in section 6.

### II. GIRONA500 AUV

The GIRONA500 (Fig.1) is a compact-size AUV designed for a maximum operating depth of 500m. The vehicle is built around an aluminium frame, which supports three torpedo-shaped hulls as well as other elements like the

thrusters. The overall dimensions of the vehicle are 1m in height, 1m in width, 1.5m in length and a weight (on its basic configuration) of about 140 Kg. The two upper hulls, which contain the flotation foam and the electronics housing, are positively buoyant, while the lower one contains the more heavy elements such as the batteries and the payload. This particular arrangement of the components provides the vehicle with passive stability in pitch and roll, making it suitable for tasks requiring a stable platform such as video surveying or intervention.

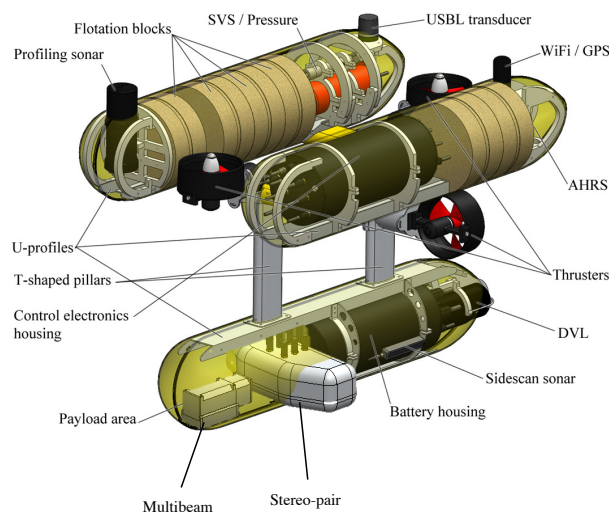


Fig.1. GIRONA500 Sensors & Systems

The most remarkable characteristic of the GIRONA500 is its capacity to reconfigure for different tasks. On its basic configuration, the vehicle is equipped with typical navigation sensors (DVL, AHRS, pressure gauge and USBL) and basic survey equipment (profiler sonar, side scan sonar, stereo camera and sound velocity sensor). In addition to these sensors, almost half the volume of the lower hull is reserved for mission-specific payload, which allows an easy modification of its sensing and actuation capabilities as required. A similar philosophy has been applied to the propulsion system which can be set to operate with a different number of thrusters, ranging from 3 to 8, to actuate

the necessary degrees of freedom and provide, if required, some degree of redundancy.

### III. HIGH RESOLUTION IMAGING CAPABILITIES

#### A. Optical Imaging

GIRONA500 is equipped with a custom developed high-resolution stereo imaging system (Fig. 2). The system is contained in a cylindrical pressure housing made from hard-anodized aluminium alloy with two rectangular viewports made of highly transparent polymethyl methacrylate. The cylinder contains two high resolution Canon EOS 5D Mark II still cameras, with sensors of 21MPixel and Canon 24mm lenses as well as an echosounder whose transducer is mounted between the two viewports (Fig. 3, right). The echosounder produces direct range measurements, which assist the focusing of the cameras. The lighting system comprises four 40W LED lamps, which can operate either in continuous or in strobe mode.

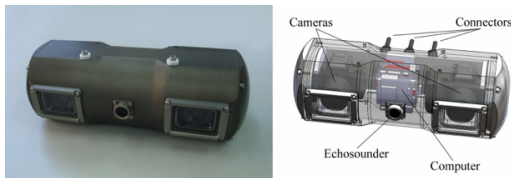


Fig. 2. High Resolution stereo imaging system.

#### B. Acoustic Imaging

The basic acoustic survey equipment is composed of a sidescan sonar and a multibeam echosounder. The sidescan sonar can be operated at three different frequencies, (260, 330, and 800 kHz, with a maximum range of up to 100 m and a resolution of 1000 data points per side. The multibeam sonar is an Imagenex DeltaT profiler operating at 260kHz. It can provide 120, 240 or 480 beams with a respective effective horizontal beam width of 3°, 1.5° or 0.75°, having a minimum detectable range of 0.5 m. The sonar may provide scans at a maximum frequency of 20 Hz.

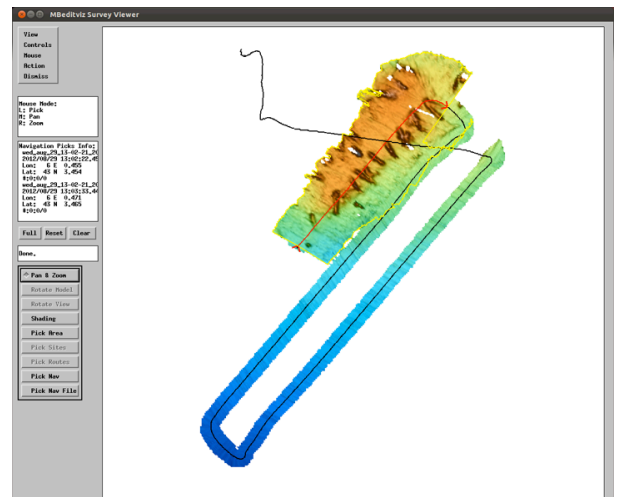


Fig. 4. Example of a draft bathymetry of the "La Lune" shipwreck with data gathered with GIRONA500 AUV.

### IV. MBSYSTEMS INTEGRATION

The navigation and mapping sensor suite of the GIRONA500 AUV vehicle have been adapted to be used with the MBSYSTEM open-source AUV mapping software [8]. A set of shell scripts and MATLAB files has been developed to implement a processing pipeline to allow fast construction of bathymetry maps. Fig. 3 shows the dataflow for bathymetry mapping. The workflow starts extracting the navigation data from the \*.bag files collected by the ROS-based software architecture. The multibeam \*.837 files of the DeltaT multibeam are downloaded and the beam forming process is executed offline exporting the data to the \*.83P Imagenex file-format which is recognised by MBSYSTEM. Next the navigation data in comma separated values (\*.csv) file format are converted to navigation (\*.nav), sonar depth (\*.sdf) and attitude (\*.att) file formats compatible MBSYSTEM. To this aim, a set of MATLAB scripts (mb\_g5002mb, mb\_gusblg5002mb and the mb\_gpsg5002mb) was implemented. Once all the data has been converted to MBSYSTEM compatible file formats, the conventional dataflow followed in MBSYSTEM is used to clean the scans, edit the bathymetry and produce a bathymetry grid. A final step has also been introduced to convert the bathymetry grid

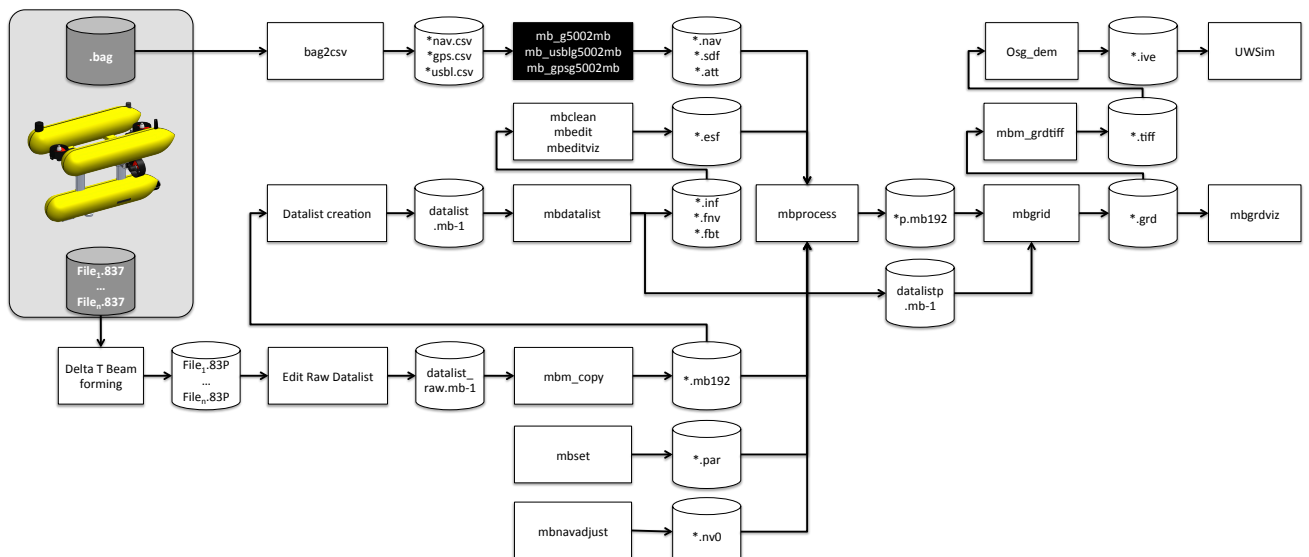


Fig. 3. MBSYSTEM workflow for GIRONA500 AUV

file to an OSG (Open Scene Graph) compatible file format (.ive). The OSG file is then imported within the UWSim [9] (Underwater vehicle simulator) to perform a mission playback for post-mission analysis.

## V. FIELD VALIDATION

During the summer 2012, GIRONA500 was operationally tested as a high-resolution opto/acoustic imaging platform in 2 cruises: CALDERA and “La Lune”.

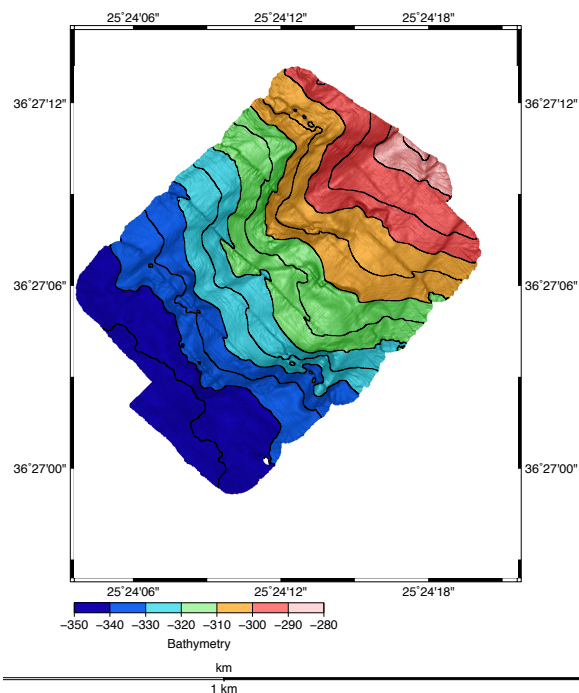


Fig.5 Lava landslide bathymetry gathered in dive 20.

### A. CALDERA 2012 cruise

During the cruise GIRONA500 performed 20 dives. Dive 1 was dedicated to the calibration of the multibeam-heading sensor. Dives 2-4 revealed problems with the acoustics telemetry. Beyond 150 m depth, the robot disappeared from the USBL tracking system. Those dives were automatically aborted after a pre-programmed timeout and before starting the actual mission. The issue about the USBL tracking was then systematically investigated in dives 5-10. In those dives the robot was deployed from the ship crane to the bottom of the caldera. Different operational configurations were investigated until we found that the noise generated by the thrusters was disturbing the USBL at depths beyond the 150 m. During the dives, an alternative transponder and an alternative transponder location were found and the system was reconfigured. Dives 11 to 14 were devoted to solve engineering issues and dive 15 was the first operational dive. It consisted in a square trajectory at 20 m altitude while gathering multibeam data. During dive 16, the robot explored the northing-base hydrothermal site at 10 m altitude gathering multibeam data. In Dive 17, the WHOI mass spectrometer was mounted on the robot payload area. The robot was

programmed to perform the same survey but a 4 m. altitude capturing monocular imagery, multibeam and spectrometric data. A significant drift was observed during the mission in the USBL telemetry. The robot was recovered far from the expected recovery point. Next, dive 18 performed a vertical profile followed by a small square trajectory at 3 m altitude to test visibility and dive 19 targeted the northing base again at low (3 m) altitude, but the navigation still drifted. Under the hypothesis that the navigation drift was due to interference with the mass spectrometer, we decided to remove it for the final survey in dive 20. In this dive, the mission consisted on the execution of a bathymetric survey over a lava landslide found at depths between 280 and 330 m and covering an area of approximately 230 x 300 m. The vehicle flew 15 m over the seabed. The mission was carried out as expected and the USBL telemetry tracked the expected trajectory. Fig. 5 shows the obtained non-edited bathymetry.

### B. The Survey of a XVII Century Shipwreck

The GIRONA500 AUV was deployed from the R/V Bon Pígal. This 24m vessel illustrates an important advantage of low-weight AUVs, which can be deployed from small ships. Also, the ship's 200Kg crane was enough for the deployments and recoveries of the AUV. The data were collected in two consecutive dives of one hour each. At the nominal survey altitude of 3.45 m, the imaging setup leads to a pixel footprint of 0.66mm. Such high ground resolution enables accurate artefact interpretation while allowing for a safe navigation clearance from the bottom.

Part of the data collected during the survey were used to rapidly produce a highly detailed optical base map of the whole site (Fig.6). This map was created using an offline, batch optimization approach based on monocular image registration in 2D. This process encompasses the following steps: (1) image pre-processing for the correction of lens distortion, uneven illumination and loss of contrast; (2) feature based pairwise image matching; (3) Global alignment, (4) Image blending, and (5) texture draping over the acoustic bathymetric data previously collected by IFREMER (Fig.7). The acoustic bathymetry was also used to provide ground control points as additional constraints in the global alignment step.



Fig.7 2.5D multimodal map of la Lune consisting on a photomosaic rendered over the microbathymetry of the shipwreck.



Fig. 6. Photomosaic of the “La Lune” Shipwreck

## VI. CONCLUSIONS

This paper has reported the operational validation of GIRONA500 AUV in two field cruises: CALDERA2012 and “La Lune”. In these cruises, the optical and acoustic mapping capabilities of the vehicle have been demonstrated. The conjugation of the operational and advanced research capabilities of the robot is not an easy task, since often they have contradictory needs. Nevertheless, this is a challenging path that we must follow if we want to achieve new field capabilities.

## VII. ACKNOWLEDGEMENTS

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