Triennial Appraisal of the ROV LUSO Project

Calado, A*; Afonso, A.*; Lourenço, N.*; Abreu, M. and LUSO Team[1]**

** Task Group for the Extension of the Continental Shelf (EMEPC), Paço de Arcos, Portugal (e-mail:{apgcalado}{aafonso}{nlourenco}@emepc-portugal.org)*
*** Ministry of Agriculture, Sea, Environment and Territory Planning Lisbon, Portugal (e-mail: manuel.abreu@mamaot.gov.pt)*
[1] LUSO Team: Bruno Lourenço (U. Lusófona), Miguel Souto (EMEPC), Luís Bernardes (EMEPC), Pedro Neves (U. Algarve), Renato Bettencourt (DOP, U. Açores), Rui Gomes (FEUP, U. Porto)

Abstract: The ROV LUSO, a 6000m rated work class ROV which supports a large range of multidisciplinary research activities on the deep ocean become operational in 2007, by the Portuguese Task Group for the Extension of the Continental Shelf. Here, we report on the LUSO project background, its characteristics and perform a three year appraisal, LUSO seagoing operations, operational performance and team building efforts. So far, ROV LUSO operated in three scientific campaigns (2008-2010), targeting the Azores Platform, southern Azores seamounts, the Mid-Atlantic Ridge, and the Selvagens Islands at Madeira Archipelago. Overall, 80 LUSO dives were accomplished, corresponding to a total of 320 hours of submarine operations. Since early 2011 EMEPC has a new facility for the ROV and other marine equipment maintenance, repair and development. This infrastructure is also used as an in-house training center and the logistics base of all the maritime operations. It will enable the implementation of LUSO development plans (2012-2015) which comprise, developing task specific skids (e.g. geological and fluid sampling), fitting an electromagnetic survey system, a vibracorer system, a 3D camera and integrating Video annotation system in LUSO video record infrastructure.

Keywords: ROV LUSO system, facilities, sea operations, research, team buildup

1. ROV LUSO ACQUISITION, TEAM BUILDUP AND CURRENT STATUS

The ROV LUSO (hereafter referred to as the LUSO), is managed by the Portuguese Task Group for the Extension of the Continental Shelf (EMEPC), a governmental organization, currently operating under the Portuguese Ministry of Agriculture, Sea, Environment and Territory Planning. The EMEPC was created in 2005 through Ministers Council Resolution Nº 9/2005 with the main goal of preparing the Portuguese proposal for extension of the continental shelf, beyond the 200 nautical miles, in accordance with the application of the United Nations Convention on the Law of the Sea (UNCLOS) article 76. The Portuguese submission was presented to the United Nations in May 2009, and will be evaluated in the near future by the Commission on the Limits of Continental Shelf (CLCS). Until that time, the EMEPC remains focused in consolidating the Portuguese submission, supporting it with additional data to be collected in scientific cruises.

In the scope of article 76 application, any coastal state is required to collect a batch of multidisciplinary scientific data to characterize both the morphometry, the sedimentary architecture of the subsurface and the geochemical nature of the seafloor. The later requirement triggered the decision by the Portuguese Government, following an EMEPC recommendation, to acquire the LUSO, in order to suppress the need for selective geological sampling and enable scientific observations and characterization of geological settings, to support the Portuguese Continental Shelf Extension Project (CSEP) on the different study areas in the North Atlantic.

The acquisition of the LUSO served additional purposes such as to enable strategic access to the deep ocean floor, which constitutes the majority of the Portuguese legal continental shelf, its ecosystems and natural resources. Furthermore, the relative worldwide scarcity of this equipment's provides a competitive advantage for Portugal in deep sea exploration and research, which is enabling the build-up of scientific and technological competence to the ever growing Portuguese technical and scientific community of marine sciences and technologies (Abreu *et al.*, 2008).

LUSO was acquired in mid-2007, following an in-depth prospective analysis of ROV market, and entered into operation in September 2008. During that first year, the development of the project comprised: 1) the preparation of the N.R.P. "Almirante Gago Coutinho" to support LUSO system, which included the preparation of the ship's after-deck to enable installation of system containers, render the vessel Dynamic Positioning operational and installing USBL capacity; 2) Technical requirements definition and selection of the scientific instrumentation to be assembled on the LUSO; 3) Launch and Recovery System development and 4) Definition of the LUSO Pilot Team and training.

In Portugal, up to 2007, there was a lack of experienced personnel to sustain ROV activities and operations. To build the ROV team, the EMEPC, addressed a query to Portuguese

Research labs, Universities and State Labs in a search for a body of volunteers. In that process, EMEPC gathered about 200 names that were later reduced to an initial group of 15 ROV pilots. The ROV pilots team comprises EMEPC members and researchers from different national research centres and encompassed skills in areas such as electronics, mechanics, hydraulic or marine sciences. An informal agreement was made between the selected volunteers and the EMEPC, in which the latter would commit to provide adequate training for ROV operations and maintenance and the volunteers committed to participate in EMEPC ROV operations at sea during one month per year, during three years.

In the first year, the pilots had an introductory ROV training course. In the following years training involved a ROV Operations course and a specific course based on the LUSO 7-function manipulator, the Titan 4 - Level 1 & 2 Manipulator Maintenance course. The 2012 main training course will comprise specific areas such as Electrical, Power & Distribution, Control Systems, Fiber optics, Hydraulic Systems including Launch and Recovery Systems, High Voltage Safety and First Aid. The training will provide the team in line qualifications with the International Maritime Contractor Association (IMCA) standards.

The most remarkable sign of evolution and capacity building within the team has been the gradual decrease of support by Argus Remote Systems AS (Argus) ROV technicians and supervisors, during the EMEPC campaigns. In the first campaign, held in 2008, Argus committed a staff of four elements. The last campaign, held in 2010, had a single element from that company. The involvement of Argus personnel in the EMEPC campaigns enabled on-job operations training and, as result of their in-depth knowledge of the system, contributed to significantly reduce ROV downtime due to on-site troubleshooting, in the early stages.

Currently, the EMEPC team has an 8 people core group with a very complete set of training and operational experience. During 2012, the EMEPC is considering the admission of a new set of trainees.

2. TECHNICAL SPECIFICATIONS OF LUSO AND ITS FACILITIES

LUSO is an electric propulsion work class Bathyssaurus XL, 75HP, rated to 6000 m, developed by Argus which operates in free fly latch mode, both in launch and recovery. It has 2 separate hydraulic power units connected to 2 valve packs for manipulators and tooling, and 2 electronic bottles with titanium grade 5 housing for all electronic parts of command, control and telemetry of the vehicle. The propulsion is ensured by a set of 4 horizontal and 3 vertical thrusters, allowing a 3knt forward speed and 1,6knt vertical speed. LUSO's underwater position is assured by an USBL system, with 2 transponders mounted on the ROV, one powered by LUSO and the other by batteries, allowing system redundancy, and a transceiver mounted in a ship's pole. Other details of LUSO technical specifications can be checked in:

http://www.lexiinfobase.eurocean.org//subs_pictures/320_details.pdf.

The LUSO system has a total weight of 35 tons, consisting on a 10'' container workshop, a 20'' container control room and a 20'' LARS (Launch and Recovery System) which includes a winch with a 6100m x 25,7mm soft tether umbilical (Fig. 1). The umbilical combines 3 cores for energy supply and 12 SM optic fibers for real time data and telemetry. The LARS has an A-frame with a loading winch that supports the latch system for deployment and recovery, and a rotating snubber, to stabilize and align the LUSO. The ROV ascent/descent to the snubber is provided by a scissor lifting table avoiding harmful ROV rolling in rougher weather conditions.

Fig. 1. From top to bottom: LUSO system with workshop, control container and LARS; ROV during recovery; control room during dive.

In case of a power supply insufficiency in the support vessel, a 10'' size generator can be added to the system. The generator has an output power of 150kVA, 120kW, 400V (3-phases+N) and 50Hz, is equipped with fire detection and extinguishing system, CCTV system and can be remotely controlled from the ROV control room.

LUSO system is currently assembled on top of 2 truck trailers ensuring a rapid mobilization in case of any emergency situation. Such configuration also brings flexibility to mobilize LUSO into vessels of opportunity, which can be performed in approximately 2-3 days (national territory). However, so far, LUSO has only been operated from a single vessel, the N.R.P. “Almirante Gago Coutinho” where the ROV system is fitted on the stern of the vessel (Fig. 1).

In the N.R.P. “Almirante Gago Coutinho”, a normal dive operation involves 3 ROV technicians working in specific positions. One ROV technician controls the winch and is responsible for all deck operations being in constant communication with the control room through a dedicated channel. One pilot flies the LUSO using three navigation monitors, and finally one co-pilot manages the 7 function arm operations and is in charge of the dive logs and HD video image recording and control.

The scientific sensors data, as well as the HD camera image, visible inside the control room, are replicated in the ship’s lab, enabling the scientific team to follow the ROV dives in real time. The scientific coordinator for the dive is inside the control room, deciding on routes, dive scientific operations and ensuring the communication between the scientists at ship’s lab and the ROV control cabin.

The LUSO has enabled the Portuguese community to perform scientific research in deep waters in fields such as benthic biodiversity inventory (Henriques *et al.*, 2011), habitat mapping (Berecibar *et al.*, 2011), mineral resources exploration (Costa *et al.*, 2008), multidisciplinary seafloor observations (Carvalho *et al.*, 2008), hydrothermalism (Marques *et al.,* 2012) (Fig. 2), ocean physics and chemistry, among others.

Fig. 2. Lucky Strike hydrothermal vent captured during LUSO dive.

The data supporting these sciences are obtained by a set of state of the art scientific equipment assembled on LUSO (Calado *et al.*, 2008). The system is equipped with 2 robotic manipulators, an HD camera, a CTD with fluorescence, turbidity and dissolved O_2 sensors, CO_2 and CH_4 sensors, a Doppler Velocity Logger (DVL), a sample box, a suction sampler with 5 independent chambers, 4 niskin bottles, 3 push-corers and laser scaling devices. If needed other sensors may still be adapted.

In 2010, EMEPC built the LUSO logistics base at EMEPC Headquarters, which provides conditions for in-house LUSO system maintenance, to test equipment and to practice launch and recovery operations and manipulators training. These facilities also allow marine equipment maintenance, repair and development, logistics management, and personnel training (Fig. 3). The infrastructure is in operation since early 2011 and is currently being outfitted with the equipment to respond to all the identified needs.

Fig. 3. EMEPC headquarters LUSO system facilities.

3. EMEPC LUSO OPERATIONS (2008-2010)

Since 2007 EMEPC organized nine oceanographic campaigns, three of them with LUSO on board the Portuguese oceanic class vessel the N.R.P. “Almirante Gago Coutinho”. The main targeted areas, in those three campaigns, were: Azores Platform, southern Azores seamounts, the Mid-Atlantic Ridge, and the Selvagens Islands at Madeira archipelago (Fig. 4).

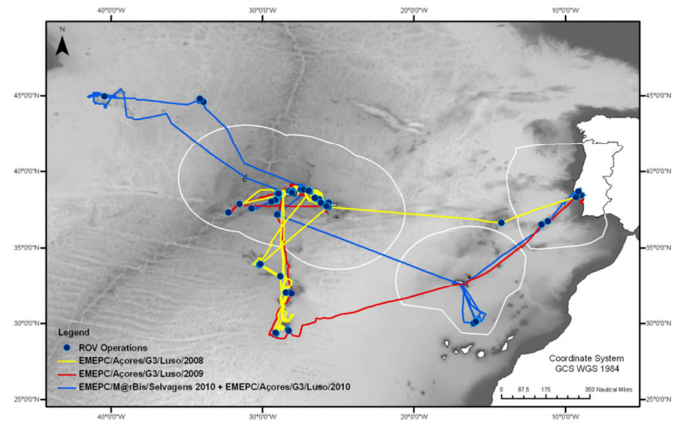

Fig. 4. – LUSO Campaigns.

All ROV cruises had embarked a multidisciplinary team of researchers from several universities and public institutions on board, covering a wide spectrum of marine research topics: geology, geophysics, oceanography, biology. The embarked scientific party had the opportunity to conduct their own research, while assisting the cruise main objectives in the framework of UNCLOS Article 76. Such collaborative environment aims to maximize the potential of committed ship time in terms of operations, data collection and scientific knowledge acquired in each oceanographic campaign.

Considering the three campaigns, LUSO accomplished 80 dives and a total of 320 hours of operation distributed as shown on figure 5. The deepest dive was performed at the Hirondelle basin (Azores), in 2009, reaching a depth of 3248m (Madureira *et al.*, 2010).

One of the challenges, in going to greater depths, is the positioning system. The associated error increases significantly and most of times, to obtain updated positions, thrusters have to be stopped.. One cause that may influence the acoustic communication is the cavitation caused by the proximity between transponders and the ROV thrusters on one side, and the pole's transceiver and the ship's lateral propellers on the other. Two systems were tested by the ROV team and they both started to be less effective from 2000m on.

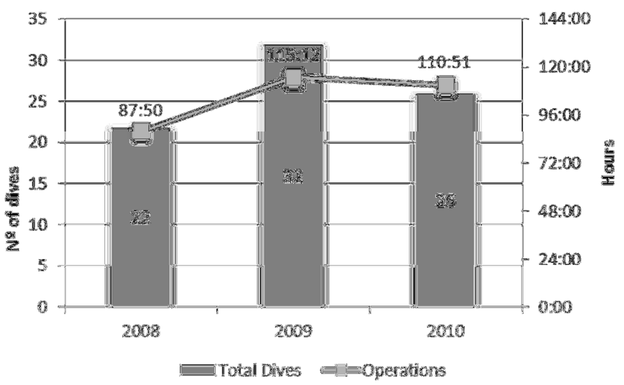

Fig. 5. LUSO operations overview – hours of operations vs. number of dives.

During 2009, following a lessons learned process from the first campaign, some upgrades to the sampling capacity of the LUSO were performed. These included the development of a new skid fitted on the base of the original ROV, increasing its height by 60 cm. The skid gathers all the geological sampling tools, a larger and sectional sampling box and the DVL system. Finally a new, more robust, suction sampler with 5 chambers was also fitted on LUSO.

3.1. ROV OPERATIONS AND INCIDENTS REPORTS

Following the first year of LUSO operations, and considering its overall performance, LUSO has performed fairly well and in a consistent manner. Most of the experienced in-job problems are classifiable as minor, and were solved on board by the ROV team. The major incidents we had comprise 3 dead vehicle recoveries and one ROV "temporary out of order", at the seafloor, due to umbilical parted from ROV.

This was the major incident we had to face so far. It occurred during the 2010 campaign, close to the Selvagens Islands. On the 23rd of June, with calm sea conditions (1m waves and force 4 winds), while recovering the LUSO to surface, the umbilical parted from the ROV at a depth of 133m, and the ROV sank to the seabed to a depth of, approximately, 615m. Its descent and its final position at the seabed were track through constant pinging to the USBL backup transponder (battery fed) on LUSO.

The LUSO was recovered 10 days later using a rescue ROV provided by Argus, attached to LUSO's LARS and control room, and with a new positioning system fitted. In the operation, the LUSO emergency cargo strap was attached to a recovery hook that was pulled by a winch installed on board. At the surface the ROV was attached to a crane and brought back to the ship main deck. When the LUSO was recovered, a careful evaluation led to the conclusion that the umbilical appeared to have been rapidly pulled tight, through both kellums grips and then parted where the umbilical had been stripped back to the inner layer for re-termination. Both the incident and the LUSO recovery raised important technical questions and diagnosis which lead to specific improvements in LUSO system.

The ocean is a harsh operating environment, and the three intensive years of the LUSO, are helping the team to develop solutions which minimize risks and caveats and allow for better performance and more reliable operations. The LUSO team is and will remain committed with this continuous lessons learned process, throughout the live span of the LUSO.

4. LUSO FUTURE DEVELOPMENTS

The experience gathered from the LUSO campaigns and the consequent knowledge exchange between the ROV team, technicians and researchers, allowed the identification of key areas for improvements. These refer to geological sampling capacity in old oceanic terrain, navigation quality, dive data management and ideas for new scientific tools, which will render a more capable vehicle. Consequently, for the 2012 to 2015 period the following developments are being considered: 1) Integration of MBARI Video Annotation and Reference System (VARS) to catalogue and analyse video data; 2) Construction of a Vibracorer to improve LUSO capabilities in soft sediment corer sampling (1 and 2 in cooperation with MBARI); 3) Integration of electro-magnetic (EM) survey equipment, as part of a project to map mineral marine resources (cooperation with Nautilus Minerals Inc. under evaluation); 4) Fitting a 3D camera, to ease the piloting and expedite manipulator operations; 5) Modify the free fly umbilical geometry by fitting soft floats on the first meters of the tether which will improve manoeuvrability by decoupling ROV motion from ship's heave, allowing safer dives on areas with rougher terrains; 6) Developing task specific skids and tools (e.g. Geological and fluid sampling) to improve LUSO sampling capacities and 7) Integrating AUV's and ROV's operations, by developing a docking station in LUSO to charge and upload data from AUV's, easing operations in deeper waters, decreasing dive time and efficiently maximizing the collected data (cooperation with FEUP).

5. CONCLUSIONS

LUSO was acquired in mid-2007 by the Portuguese Government and is being managed, by the EMEPC since then. The project development arose from the selective geological sampling requirements of the Portuguese Continental Shelf Extension Project in the framework of UNCLOS article76 application. Here we presented the LUSO system, its supporting team and infrastructure and perform a three year appraisal on the project evolution.

LUSO is 75 HP, electric propulsion work class Bathyssaurus XL, rated to 6000 m which operates on free fly mode, from developed by Argus. Overall the system is very flexible and adaptable to setup in vessels of opportunity. The LUSO is equipped with state of the art scientific sensors. Data retrieved from each dive serves a range of marine science disciplines. The LUSO is therefore the most fundamental tool in Portugal for deep sea exploration and research.

Considering the 3 campaigns already performed between 2008 and 2010, LUSO achieved a total of 80 dives, corresponding to 320 hours of submarine operations in domains such as the Azores Plateau, the southern Azores seamounts, the Mid-Atlantic Ridge, and the Selvagens Islands (Madeira archipelago). Overall, all campaigns were successful and the LUSO has performed consistently. Most of the incidents were minor setbacks, normal to ROV operations with these characteristics.

Diving in so many different environments, brought different challenges to EMEPC ROV Team and resulted in a continuous lessons learned process. In the future, LUSO will be continuously developed based on that process, to ensure the quality of results in the exploration of the Portuguese deep sea, to better support the CSEP and the Portuguese marine scientific and technological community.

REFERENCES

Abreu, M; Calado, A., Dias, F., Lourenço, N., Madureira, P. Costa, R. and EMEPC Team (2008). The LUSO ROV: Portugal gains deep sea Research capacity. International Multi-Conference on. Engineering and Technological Innovation 2008, Orlando, Florida, USA.

Calado, A., Lourenço, N., Dias, F., Madureira, P., Costa, R., Abreu, M. and EMEPC Team (2008). LUSO: Portugal's new 6000m rated R.O.V. for deep sea research. American Geophysical Union, Fall Meeting, 2008, abstract OS51C-1271. S. Francisco, EUA

Carvalho Dias, F., Lourenço, N., Lobo, A., Santos de Campos, A., Pinto de Abreu, M. and EMEPC Team (2009). "Fried Egg" an oceanic impact crater in the Mid-Atlantic?. American Geophysical Union, P43B-1435, S. Francisco,EUA.

Costa, R., Mirão, J., Martins, M. A., Lourenço, N., Abreu, M. P., Fouquet, Y., Madureira, P., Calado, A. (2008). Cobalt: rich manganese crusts in the Azores region: preliminary results. Underwater Mining Institute Conference 2008 – Marine Mineral: Technological Solutions and Environmental Challenges, Mississipi, USA.

Henriques, A., Carreiro-Silva, M., Tempera, F., Porteiro, F., Jakobsen, K., Jakobsen, J., Albuquerque, M., Serrão Santos, R. (2011) Carrying behavior in the deep-sea crab Paromola cuvieri (Northeast Atlantic). Marine Biodiversity, 1-10.

Madureira P., Moreira M., Nunes J., Lourenço N., Carvalho M., Mata J., Pinto de Abreu M. (2010). He and Ne isotopic ratios along the Terceira Rift: implications for the Azores mantle source. American Geophysical Union, Fall Meeting, 13th-17th December 2010, S. Francisco, EUA.

Marques, A.F.A., Scott, S.D., Madureira, P.; Rosa, C.J.P., Lourenço, N., Conceição, P.; and TerRiftic Team. (2012). Sulfide and silicate melt inclusions in the D. João de Castro Volcanic Seamount, a hydrothermally active area on the Terceira Rift, Azores. European Geosciences Union, General Assembly. Vienna, Austria.

Dias F., Berecibar E., Tojeira I., Albuquerque M., Souto M. 2011. Testing M@rBis (Marine Biodiversity information system) as a useful tool for the creation of Marine Protected Areas. Case study - Selvagens Islands. World Conference on Marine Biodiversity. 26-30 September 2011, Adberdeen, United Kingdom.