The Ictineu 3 Project: A Modern Manned Submersible for Scientific Research and Intervention

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Abstract: This paper describes the current state of Ictineu 3, a modern manned submersible for scientific research and intervention at a maximum depth of 1200m. This will be the first manned scientific submersible to be built and operated in the Iberian peninsula since the Ictíneos of Narcís Monturiol, and will help reduce the gap in our ocean exploration and intervention capabilities as well as pay a tribute to its old ancestor. This new submersible will employ state of the art technologies in areas such as material engineering, energy storage, navigation, control, and communication systems. Its main applications will range from deep seabed research, science dissemination, environmental protection, and archaeology to salvage operations and support to the offshore industry. The first sea trials are scheduled for the second half of 2010.

Key words: *Manned submersibles, Ictíneo, Monturiol, propulsion systems, navigation and control systems, sensor platforms, ocean exploration, structural design.*

I. INTRODUCTION

In June 1859, Narcís Monturiol launched the Ictíneo submersible in Barcelona's harbour, the first operative civil submersible in history. The Ictíneo (7m long, 10 tons displacement) could fit up to six people and made 69 successful dives without incidents. Later in 1864 a second Ictíneo was built (17m long, 72 tons displacement) which employed an anaerobic engine able to produce heat for propulsion and breathable oxygen among other cutting edge technological solutions [1][2][4]. After 150 years, the company Ictineu Submarins S.L. is building the Ictineu 3, a modern scientific manned submersible which will help reduce the gap in our deep sea exploration and intervention capabilities as well as pay a tribute to Narcís Monturiol [6].

Ictineu 3 is conceived as a modern manned submersible which will incorporate innovative materials and advanced manufacturing techniques, environmentally friendly energy systems, intelligent management and control systems and the most advanced technologies in safety, positioning, navigation, communication, sensing and data logging. It will be a highly versatile tool conceived to be adapted and modified for each specific customer mission needs and as newer technological solutions become available; a submersible that will play a central role in any scientific mission to be imagined under-seas.

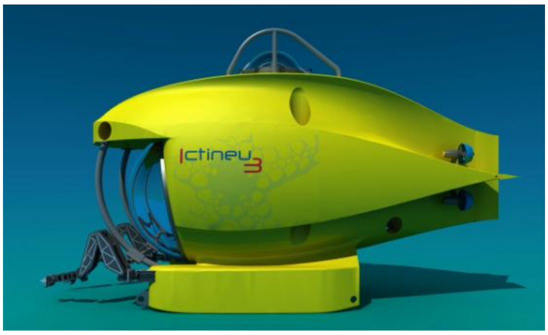

Fig. 1: 3D representation of Ictineu 3

The applications of the submersible range from deep seabed research, science dissemination, environmental protection, and archaeology to salvage operations and support to the offshore industry. The submersible is also thought as an experimental platform where universities, research centers, and private companies can test and validate diverse technological and scientific solutions on the field. The first sea trials are scheduled for the second half of 2010.

II. ICTINEU 3 DESIGN AND CAPABILITES

The Ictineu 3 is a small and light weight manned submersible with high capabilities. Its main specifications are listed in Table 1, and a 3D model is shown in Fig.1. It will dive safely down to 1200 meters, making it one amongst the world's ten deepest submersibles in operation at present. It will be capable of carrying one pilot and two passengers, with an operative autonomy of 10 hours. Although a typical mission lasts between 3 and 6 hours, it will have reserve oxygen tanks and emergency life support autonomy for 5 days. At the front, a big acrylic viewport (Ø1200 mm) will provide the crew with an exceptionally wide field of view, excellent for high quality photography and video capturing.

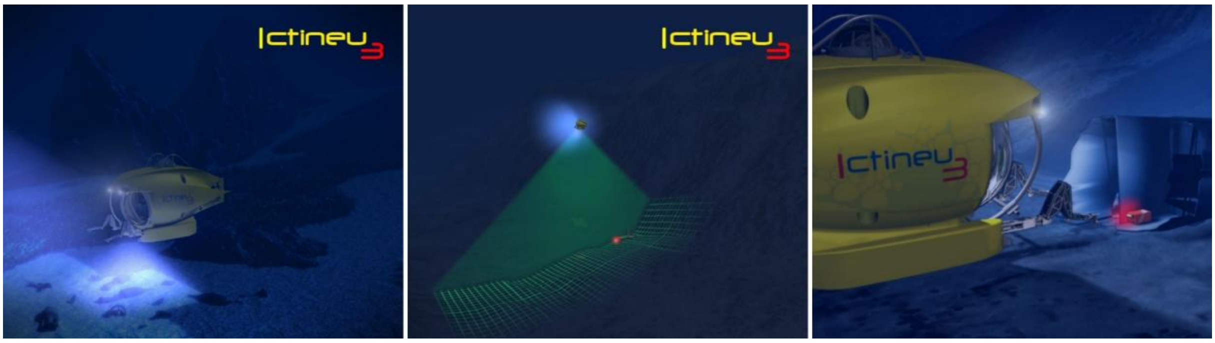

Fig. 2: Ictineu 3 possible missions, from left to right: archaeological site photo-mosaics, fine scale bathymetric surveying, and black box recovery.

From an operational point of view several milestones have been fixed. The reduced size and a wide front viewport will provide easy and comfortable operation, as well as getting very close to the working area. The hydrodynamic shape has been designed for both optimal energy efficiency and for safety reasons (e.g. avoiding stuck into nets). The capability to fully empty the diving tanks while on the surface will provide 600 mm between the design water line and the entry hatch. This height together with the external shape design will allow passengers to get in and out the submersible while it is in the water, in good weather conditions.

Table 1: Main technical specifications of Ictineu 3

General specifications		***Propulsion***	
Operating depth	1200 m	Main electric thrusters	4 x 2.7 kW
Weight in air	5.000 kg	Maneuvering thrusters	4 x 1.25 kW
Dimensions	4.8 x 1.9 x 2.8 m	***Batteries***	
Pressure hull Int. diameter	1.7 m	Main battery group	Li-ion 4 x 70Ah 120V
Passengers	3	Secondary group	Li-ion 160Ah 24V
		Safety	
Air and oxygen		Emergency life support	5 days
Air	4 x 40 l (700 bar)	Jettisonable weight	500 kg
Oxygen	2 x 10 l (200 bar)	Total buoyancy capacity	1580 kg
Emergency O2	2 x 40 l (200 bar)	Emergency buoy	1800 m spectra rope
Dynamic characteristics		***Equipment***	
Cruising speed	1.5 knots	Sonar	Echosounder, Forward looking
Maximum speed	4.5 knots	Robotic manipulators	2 x 6 DoF
Range	10 NM	Lights	LED 1000 W
		DVL	RDI 300 kHz
		Acoustic Positioning	USBL

The maximum dimensions (4.8 x 1.9 x 2.8 m) will allow loading the submersible in a standard open top container so that it will be possible to transport it on the road with a conventional truck, by train or by ship without requiring special transportation. The use of composite materials will allow reducing the weight, still meeting the certification requirements: all the exterior hull, the water tanks and many supports/reinforcements will be carbon fiber/epoxy resin composites. Given its reduced weight (5 tones) it can be operated with standard launch and recovery systems on harbours and from most oceanographic vessels.

A. Pressure Hull

The pressure hull is probably the most important element in the design of a manned submersible. The pressure hull of Ictineu 3 is composed of two stainless steel spheres of 1700mm and 800mm of internal diameter. The material was specifically selected for its excellent mechanical properties and its high corrosion resistance. The main sphere is equipped with a large acrylic spherical sector window that provides the crew with an exceptionally wide field of view. The pressure hull, designed under the ASME PVHO-1-2007 and Germanischer Lloyd rules, will be tested in an autoclave at a test pressure corresponding to 1440m. A 3D representation of the pressure hull is shown in Fig. 3, and pictures of the manufacturing process are shown in Fig. 4. More information and technical details on the pressure hull and the acrylic viewports are given in the companion paper [10].

Fig. 3: 3D model of Ictineu 3 pressure hull.

B. Thrusters / Batteries

The submersible will be equipped with brushless DC thrusters: four for propulsion and four for maneuvering together with custom design high efficiency motor drives. The main propulsion power source is a set of high energy density Lithium ion polymer batteries which provide up to 34kWh and will be hosted in oil compensated outer pads. A state of the art battery management system (BMS) will monitor and control each individual battery cell during charge and discharge ensuring a safe operation. These new generation batteries will allow a weight reduction of around 80% compared to standard lead acid batteries. The resulting Ictineu 3 energy to weight ratio is highly favorable as compared to other submersibles of similar characteristics which will increase payload capability and decrease significantly operational costs.

Fig. 4: Deep drawing of one hemispherical dished head of Ictineu 3 pressure hull (courtesy of ATB Riva Calzoni S.p.A.)

C. Navigation and control systems

Thanks to an advanced navigation system, the position and attitude of the sub will be known with high precision in real time which will allow for fine bathymetric surveying and scientific data georeferencing. The navigation system includes an Inertial Measurement Unit (IMU), Doppler Velocity Log (DVL), and Ultra Short Baseline (USBL) acoustic positioning together with state of the art signal processing and state estimation techniques. An acoustic modem link will allow for simple data exchange between the submersible and the surface. Advanced control systems will enhance the sub capabilities and free the crew from cumbersome tasks, allowing them to focus on the operation of robotic manipulators, observation and sampling. State of the art robust, fault tolerant, and nonlinear control techniques will be implemented to perform station keeping, path following, heading, depth, and altitude control.

D. Safety

To achieve the highest safety warranties, the submersible design and construction process will be certified and classified by Germanischer Lloyd authority. To keep safety as high as possible and allow the submarine to escape from possible entanglement (nets, wrecks) several redundant emergency systems will be implemented. The soft ballast (diving) tanks (600 liter capacity) can be quickly emptied injecting pressurized air (700bar), allowing a quick ascent. If this is not enough, a drop lead weight (500kg) can be gradually released to reduce the weight and increase buoyancy. A safety buoy can be manually released from inside the pressure hull, reaching the surface with a 1800m long, 3.5 tone tensile strength, spectra rope. The two robotic manipulators will be ejectable in case they get stuck. Emergency oxygen tanks and carbon dioxide scrubbers will provide 5 days of emergency vital support.

CONCLUSIONS

In this paper, the main characteristics and current state of the Ictineu 3 project have been presented. The Ictineu 3 is being built in the Catalan Royal Shipyards, a XIV century building that hosts the Maritime Museum of Barcelona. The construction process started in mid 2009 and the first sea trials are expected in the second half of 2010. More information can be found at www.ictineu.net

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