# Research submersible ICTINEU 3, a tool to serve the scientific community

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Introduction.

The company ICTINEU Submarins has designed, developed and built a new generation of manned submersible. The vehilcle, named ICTINEU 3 as a tribute to Narcís Monturiol and his first Ictineus, is a modern submarine, designed and built with cutting-edge technology in order to achieve a very versatile and highly operational vehicle. It incorporates outstanding innovations with respect to the other submarines that are currently on the market, in terms of design, construction materials, and in particular its energy system.

The ICTINEU 3 is a scientific submersible, a work class vehicle with high capabilities for work, observation and intervention. It has been designed for 1.200 meters depth, and a crew of three: one pilot and two observers (passengers). It will be certified and classified by Germanischer Lloyd according to the highest standards of quality and safety.

Design and performance.

When the team though about building a submersible, the first thing in mind was science and ocean exploration. All the development of the vehicle has been focussed on achieving a very versatile tool, capable for a wide range of tasks, from ocean observation to industrial works and even leisure, but always focusing on research capabilities.

So at the design phase it was decided that it had to be easy in operation, highly automated and efficient. The main goals to be achieved were: high observation capabilities, very low weight (<6 tones), easy to transport and operate worldwide, highly operational and passenger access from sea. It might seem only a few goals, but it has been a really difficult challenge to accomplish them all together. It has taken 8 years of development. Main facts and performance are described next.

The pressure hull is 1.7 meters in diameter and it has two acrylic domes, one on top (entry hatch) and one in front, 1.5m in diameter. The position of the front dome has an inclination of 10 degrees forward in respect of the vertical, so the vision on the sea floor is improved This allows the three passengers a large field of view and excellent capabilities for ocean observation, as well as the possibility to take high quality photography and video recording from inside, without the need of special pressure tolerant cameras and housings. In fact it's the first vehicle to go below 1000m with an hemispherical acrylic window.. Ergonomics have also been taken in account so working in a sub does not mean any more uncomfortability.

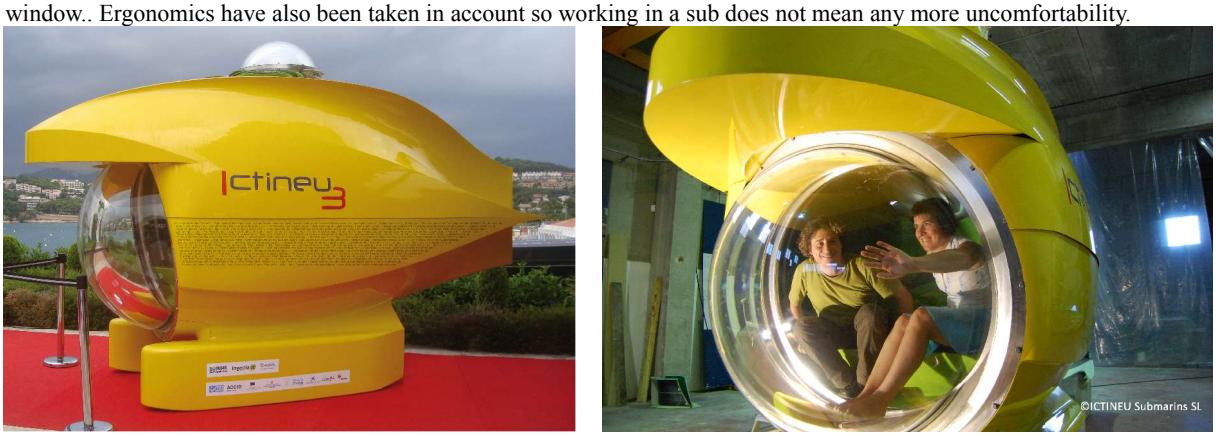


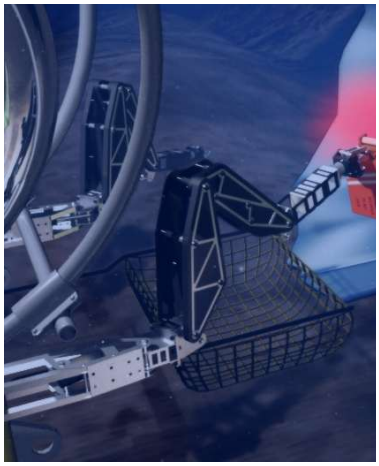

Image of unfinished submersible assembly and detail of visibility in the front acrylic window, in summer 2011.

The weigh of the vehicle will be about 5.300kg, a very reduced weight for a 1.200m and 3 people rated submarine, so it can be operated from most research vessels. As it has a very reduced size it can fit in a 20 feet open-top container, so it's easy to transport to the work place by road, ship or air.

Passengers can go in/out from water surface in good sea state, what makes easier the exchange of passengers, without the need of lifting and recovery operations from mother ship every time a shift is needed. It can also be towed from harbour if working area is near the coast.

The power system is based on last generation lithium-ion-polymer batteries, which give the vehicle a high power capacity: 30kW continuous, 42 kWh (10 hours full autonomy at normal load capacity). This means that it is able to work for more than 8 hours with thrusters, lights and all instruments and sensors simultaneously, and can travel up to 20 miles underwater.

Propulsion and manoeuvring are based on a complete 6 controllable degrees of freedom system. The configuration of the 8 thrusters, 2,5kW each, provide a vectorial propulsion system on 5 axis: 3 translation (XYZ), 1 yaw, 1 roll. Trimming (pitch) is provided by internal buoyancy tanks, that also provide the buoyancy system, so that Z axis is redundant (thruster and ballast). Piloting is done by a PLC- assisted console: 1 joystick, 3 axis (advance, lateral translation and yaw), plus 12 manoeuvring control buttons (buoyancy, pitch, up/down).



Illustrations of ICTINEU 3 configuration and detail of basket and manipulators.

As it is said, it has always been a must the versatility and capacity of operation of the vehicle. In this sense the power and communications system has been dimensioned in order to be able to adapt to any task and mission requirements. A sensors platform has been designed in a way that it is capable to upload any instrument or sensor from the client in an easy and quick way. This is done through an oil filled, pressure tolerant junction box, with 18 extra shielded twisted pairs for connections, and a choice of 12VDC or 24VDC in series for power. Inside the pressure hull, direct access to distribution board is allowed.

The payload of the submersible is 300kg that can be distributed between instrumentation, samples collection or any tools or markers to be placed on the sea floor. A basket will be available for that purpose in front of the vehicle. Front protection bars pay also the role of masts and support for cameras, flashes and other instrumentation that can be easily fixed on them.

As basic equipment the vehicle will have an underwater telephone, VHF for surface communications, flux-gate compass, GPS, sonar, altimeter, redundant depth control, Doppler velocity log, 6 LED lights and a couple of 6-function hydraulic manipulator. Additionally, a CTD and multi-parametric probe will be always mounted on board, continuously logging data. Information recorded during the mission and during the ascent and descent along the water column will be available to the scientific community after each dive. The Doppler velocity log, a Teledyne Workhorse Navigator, can be used also as a current profiler.

| **General Specifications** | |
|---|---|
| Max. Operating depth | 1200 m |
| Weight in air | 5300 kg |
| Length | 4800 mm |
| Beam | 1950 mm |
| Height | 3000 mm |
| Hatch diameter | 540 mm |
| Main (front) acrylic window diam. | 1200 mm |
| Hatch acrylic window diameter | 540 mm |
| Crew | 1 |
| Passengers | 2 |
| Payload | 300 kg |
| Classification authority | Germanischer Lloyd |

| **Life Support** | |
|---|---|
| Daily life support | 24 hours for 3 people |
| Emergency life support | + 96 hours for 3 people |
| Atmospheric control by 2 digital $O_2$ and $CO_2$ analysers | |

| **Buoyancy and trimming** | |
|---|---|
| Diving tanks | 600 L |
| Buoyancy tanks | 240 L |
| Trimming | +/- 3 deg |

| **Safety devices** | |
|---|---|
| Emergency drop weigh | 500 Kg |
| Diving tanks | 600 L |
| Emergency buoy | 1800 m long rope |
| Total buoyancy generation of | 800 Kg at max. Depth |

| **Propulsion** | |
|---|---|
| Stern thrusters | 4 x 2,5kW, 43Kg |
| Manoeuvring thrusters | 4 x 2,5kW, 43Kg |

| **Batteries** | |
|---|---|
| Main group 150V, 42kWh | Lithium-ion-polymer |
| Service and Emergency group | 24V, 1,3kWh |
| Working autonomy | 10h |
| Emergency autonomy | 5 days |

| **Dynamic Characteristics** | |
|---|---|
| Maximum surface speed | 2,5 Knots |
| Maximum submerged speed | 4,2 Knots |
| Cruising submerged speed | 1,5 Knots |
| Autonomy range at cruising speed: 20 nautical miles | |

| **Equipment** |
|---|
| Underwater telephone |
| VHF for Surface communication |
| Flux-gate compass |
| GPS |
| Sonar |
| Altimeter |
| Depth control by two analogue depth gauges and one digital pressure sensor |
| Doppler Velocity Log |
| 8 LED Lights of 6,000 Lumen each |
| 6- function hydraulic manipulators |
| Basket for sampling |
| CTD multi-parametric probe with pH sensor, ORP (Redox) sensor, Dissolved Oxygen sensor, Fluorometer. |

Technical specifications of the ICTINEU 3 vehicle

Status of project.

The design of ICTINEU 3 submersible started in 2004, engineering and pressure hull calculations started in 2008 and main construction works in 2009. Eight years later the vehicle is about to be finished. All engineering has been finished, as well as the construction of pressure hull, exostructure, tanks, etc. All equipment is ready for final assembly and testing. Final certification, sea trials and classification are expected for second half of 2012. One of the main steps in the construction of a submersible is the pressure test of the pressure hull, that for ICTINEU 3 was successfully completed in summer 2011.

Operation and missions.

Once the vehicle is finished, the company will operate the submersible and give diving services to any client that is interested in. Operation of ICTINEU 3 submersible is though in different ways, so it can be adapted to different needs and budget of clients.

Normal operation should be that carried on during a scientific campaign, on board of a research vessel, with one pilot and two observers or researchers. A daily mission of 8 hours can be run, and a time lapse of 5 hours is needed to re-charge the batteries. Implementation of instrumentation and sensors can be done previously or on board. Campaigns can last several weeks provided that enough oxygen bottles have been boarded on mother ship.

If operation is needed near the coast, the vehicle can be as well towed from harbour.

Due to its small size and lightweight, the vehicle can be transported to any country or any ocean by different transportation means: road, air-plane, ship.

It is expected to establish an operation centre in the Costa Brava, Catalonia, in the western Mediterranean sea. That will provide easy access and operation to all the deep canyons existing in that area. It's expected to make a good contribution to the knowledge of the area ecosystems, geomorphology, dynamics and archaeology.

New models are being explored to fund research and exploration projects. In this way the company is studying to implement a formula where leisure clients can pay for a scientific dive, and join together in a fruitful experience. Biologists, geologists, oceanographers or archaeologists would be able to make free dives to run their works, and normal people should be sensitized about the importance of ocean research and exploration. Even influential people, decision-makers, might happen to make dives in this conditions, with a positive result in a better management of our seas.

Collaboration

ICTINEU Submarins SL wants to collaborate with the scientific community, and contribute to the better understanding of the seas and oceans. To provide new data and knowledge to help us understand the mechanisms behind their complex ecosystems, to help to improve their management and exploitation, and ultimately to improve the coexistence between humans and this great unknown world.

We glimpse different ways of collaboration, aside of typical scientific campaigns -not affordable by all the scientific community. An approach should be made between researchers and vehicles operators to optimize the technological resources available.

This submersible can be used as a test platform for new instrumentation and applications. It can upload instrumentation for systematic oceanographic data logging without the need of a researcher on board. Photography and filming can be taken by the submarine crew from locations of interest previously agreed with researchers. During non-scientific work, for instance tourism dives or industrial work, probably a big amount of footage will be produced. As it will be georeferenced, it can be provided to researchers for species identification. If tourist dives are made in a normal basis, points of interest can be re-visited and sampled or pictured for a follow-up.

The ICTINEU 3 team is eager and open to proposals for cooperation to the improvement of the oceans knowledge.