NEW CAPABILITIES OF THE REDERMOR UNMANNED UNDERWATER VEHICLE

Norbert TOUMELIN, Jérôme LEMAIRE
GROUPE D'ETUDE SOUS-MARINE DE L'ATLANTIQUE
Underwater Robotics Department
B.P. 42 29240 Brest Naval, France
Phone : 33 (0)2 98 22 60 57
E-mail : toumelin@gesma.fr

Abstract

Since the beginning of the Nineties, GESMA continues very actively its works concerning self-propelled vehicles and robotic systems. The GESMA's Unmanned Underwater Vehicle (U.U.V.) ***REDERMOR*** *is an experimental platform that was developed during the French-British collaborative project (DGA/DCE/GESMA-DERA) «Remote Mine Hunting Project» as a support for UUV technologies studies. We developed a Remote Operating Vehicle (ROV) to test different concepts of mine hunting using a ROV. This vehicle is versatile and we have three different versions.*
Today, we work on a non-traditional navigation unmanned undersea vehicle guidance and control research project. This work consists in the use of a side scan sonar and of a front looking sonar (traditionally used to detect mines) to improve the navigation. For that, we had to develop specific software and we modified our vehicle. Recent development efforts have improved the ***REDERMOR*** *design and performances and comprise integration of several new sensors. The* ***REDERMOR II*** *is now able to execute missions in an autonomous mode during several hours.*

first versions

UUV **REDERMOR** was born during the Franco-British project "Remote MineHunting System" (RMHS). During this project, GESMA and DERA studied new concepts to have a mine detection sonar in front of a ship. To validate some results, we had to build an experimental tool, the REDERMOR. The vehicle is characterized by the property to be easily modified in order to test different configurations [LEM 00]. Three versions were developed. They have a tight central section that contains electronic sensors and actuators, the calculators and eventually a battery. Four main thrusters are distributed around the central section. They are orientable in order to rule their center of action. Two pair of independent horizontal fins makes it possible to control the roll and the pitch of the vehicle. All the versions are equipped with a motion reference unit, a Doppler log, a vertical echosounder and a pressure transducer to have sufficient data of navigation to control the vehicle. An electromagnetic log makes it possible to control the water speed on the surface of the vehicle. It can

be used for navigation when the Doppler log is out of order. A CTD realizes measurements of environment. A pinger is used to locate the vehicle versus the boat equipped with an ultra-short base. Some safety sensors control electric current, voltage, temperatures, detection of water entry, pressure in the central section, detection of gas in the vehicle.

Common Features
• cylindrical (Ø 1.03 m) watertight section common to all versions with exchangeable face and aft shares and cylindrical section in option • 4 hand thrusters (7.5 kW one shaft each) • Sensors: MRU, Doppler Log, EM Log, CTD, safety sensors • maximum depth: 200 m • Control Loops: Speed, heading, altitude, depth, pitch-roll stabilization • Man Machine Interfaces for the supervision

Two versions are maneuverable. They include four auxiliary thrusters in addition to the elements previously stated: three vertical thrusters and a transverse engine. With these actuators, it is possible to move the UUV in all the directions and to make a fix. These two versions are powered and controlled through a cable fixed on the top of the vehicle. It transmits a three-phase 3000V at 400 Hz voltage as well as data through six optical fibers. In one of the two versions, the vehicle is equipped with a UK sonar and in the second with an experimental French T-form antenna. The third version is called fast version. In the opposite to the other two versions, it

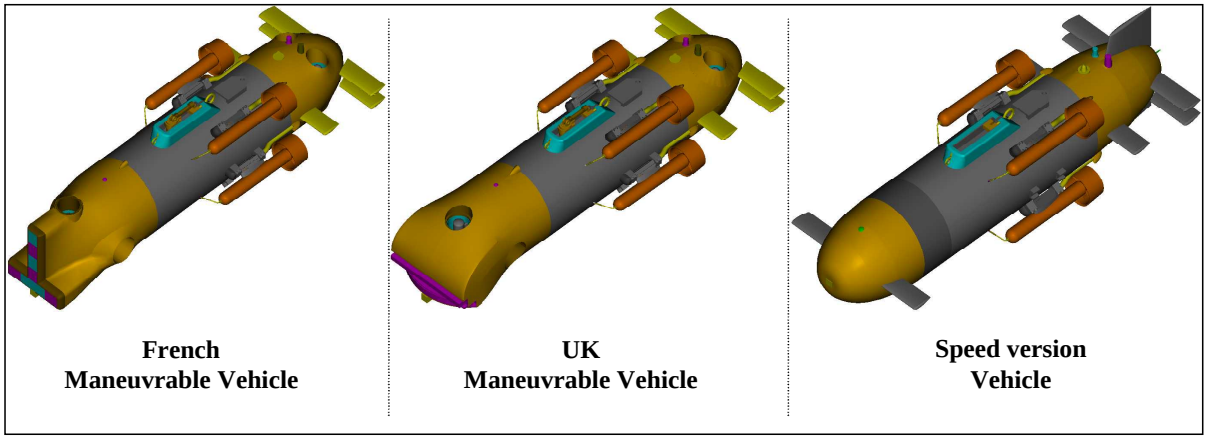

Figure 1: The different versions of REDERMOR

does not embark a sonar, which enables to have a sympathetic hydrodynamic form. As it was built to realize tests at speeds greater than 2 nodes, it has no auxiliary engine. However, it is equipped with a rudder and a canard. This last actuator makes it possible to change altitude while preserving a constant pitch with the assistance of the two pairs of horizontal fins. This version is equipped with a Cd-Ni battery. The vehicle is controlled either by a cable equipped with two optical fibers, or by a radio modem during tank tests. A GIB pinger is used to know the absolute position of the vehicle when it is under water.

	Maneuverable version	High speed version
weight	2600 kg	3100 kg
length	5 m	5.5 m
speed ranges	0 to 6 knots	2 to 10 knots
auxiliary actuators	1 transverse thruster 3 vertical thrusters	1 canard 1 rudder

During this project, we realized more than 250 hours at sea trials. We succeeded to navigate at 3.5 knots with the vehicle. The

distance between the ship and the REDERMOR was 450 meters and the immersion of the UUV was 215 meters.

The Non-Traditional Navigation UUV Guidance and Control Research Project (NTN UUV G & C Project)

The aim of This Fr-US project is to demonstrate the feasibility of missions including the survey and the recognition of itineraries or zones by autonomous underwater robots. For that, we essentially work on the capacity to realize an autonomous precise navigation. The idea is to associate a system of fix based on images sonar to the traditional navigation sensors (Inertial Navigation System + Doppler log + Kalman filter). The sonars are used to consider successive movements of the vehicle (front looking sonar) and to relocate the vehicle compared to known landmarks (side scan sonar) using algorithms of image processing. In order to realize at sea demonstrations, it is necessary to develop the other necessary functionalities of an autonomous system: planning of trajectory and mission, guidance, piloting, obstacle avoidance, mission control [BAR 98].

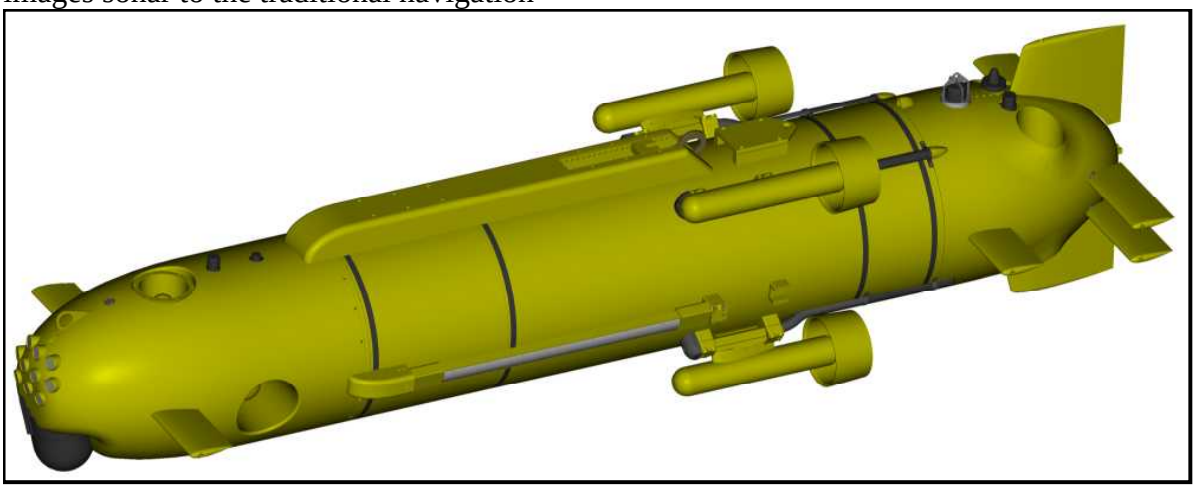

Figure 2: The Redermor II

The mission was defined like a whole of phases of rallying and operations. The operationswhich will be realized in a first time, are: survey, research of an object, follow-up of object, waiting on zone, inspection of object. Each operation is defined by a degree of importance, a 3D localization and a temporal window for realization.

To carry out the planning and the management of mission, it is necessary to take into account the constraints on the vehicle (limited energy, performances (mobility, maneuverability), performances of the sensors, performances of the filter of navigation). It is also necessary to take account of the constraints on the environment (limits of the free space, currents, tides, map of the bottom) and the constraints on the mission (forbidden areas, zones of use of active sensors).

The new version

UUV **REDERMOR II** was realized from the three last version of **REDERMOR.** It is about a version adapted for the NTN UUV G & C Project.

Actuators

In this version, the UUV is equipped with eight thrusters. The four main thrusters

allow a maximum speed of 10 nodes along the main axis of the vehicle. Three vertical thrusters ensure a vertical displacement of the vehicle up to two nodes. Finally a transverse engine makes it possible to turn or to move laterally up to two nodes. With all these thrusters, it is possible to make a fix or to turn around a point to observe an object with the front looking sonar. Compared to the first versions, each electronic bloc of the thrusters was changed in order to improve the reliability of the vehicle and in addition to measure the rate of the thrusters and the torque generated by each engine. The propellers will be replaced in the next months being to multiply the output by two, which will result in a longer coverable distance.
The UUV is also equipped with two pairs of independent horizontal fins, rudder and a canard. These actuators control the vehicle when the speed is greater than two nodes. The vehicle can make follow-up of ground with a constant pitch at a constant altitude thanks to the canard and the fins. With all these actuators, the vehicle is fast and maneuverable.

Sensors

In order to have a system of navigation compatible with the missions to realize, **REDERMOR II** from now on is equipped with an inertial Navigation System located in the tight central body. It has a Kalman filter. It is connected to a Doppler log which measures speed compared to the bottom and compared to as many as forty layers of water. To improve the precision of navigation, a pressure transducer and a CTD located behind the vehicle are also connected to the inertial power station. This system has a drift in position of a few meters per hour.

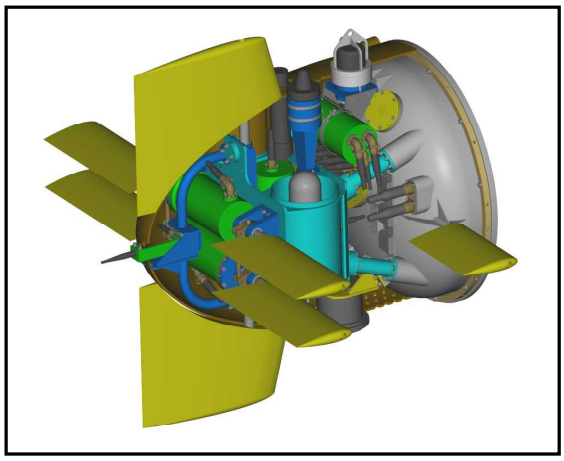

Figure 3: Back of the REDERMOR II

When the UUV is launched or when it is on the surface, a GPS is used on the one hand to align the inertial power station and on the other hand to make a fix.

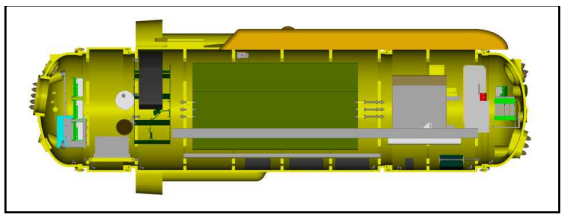

Figure 4: Detail of the tight central body

When the UUV is under water, the side scan sonar and the front looking make a fix to relocate the UUV. The side scan sonar is composed of four distinct parts. The two first, the antennas, are distributed on both sides of the central body of the vehicle. They are connected to an electronics located on the central body so that: in contact with water it does not heat. This block of electronics is finally connected to a calculator located in the central body.

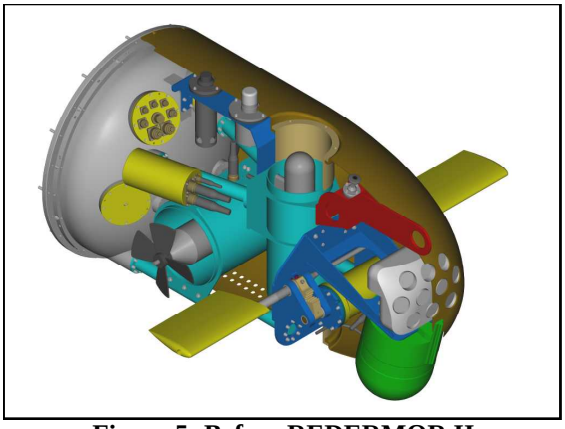

Figure 5: Before REDERMOR II

The front looking sonar sonar, placed at the fore part of the vehicle, forms a bulb. It is directed with an angle of 15 degree downwards. It is connected to a calculator located in the tight part of the vehicle. The front looking sonar helps on the one hand the navigation by estimating successive movements and on the other hand takes part in the function of obstacle detection. Because of its tilting to the bottom, this sonar does not make it possible to detect the obstacles located in front of the vehicle, this is why a network of echosounders are implanted. The network is composed of ten echosounders, three tilted upwards, three downwards and four horizontally.
All safety sensors supervise the following parameters:
The output electric current of battery, the current in the actuators, voltages, the temperatures on various elements likely to heat, the absence of water in the tight central body and in the thrusters, the rate of hydrogen and the pressure in the central body to verify the nice functioning of the battery.

Exchanges with the outside

The communication with surface takes place according to various manners.
On the one hand, the vehicle is equipped with a low rate acoustic modem which ensures an exchange made safe (a few hundreds of kbps). The exchanged data are in the descending direction some high level orders such as a modification of the mission or an order of emergency stop. In the ascending direction, there are informations to indicate in which state the vehicle is. A high rate acoustic modem (a few tens of kbps) will make it possible to send small pictures from the UUV to the ship. When the vehicle is on the surface, a radio link ensures the dialogue between the UUV and the operator in order to realize tests of correct operation and to move away the UUV from its launching zone.
A pinger placed at the rear of the vehicle is used to know the position of the UUV compared to the position of a following boat equipped with an ultra-short baseline. Lastly, a GIB (Intelligent GPS Buoy) pinger and buoys connected to a GPS give the absolute position of the vehicle to an operator.

Structure of the vehicle

In the preceding versions, the equipments were connected between them by serial connection. For **the REDERMOR II** , we replaced this architecture by CAN technology. From now on, the actuators and sensors are connected to CAN bigboxes. These boxes transmit the data to a shared memory to which the software modules have access. The software developed in this project is distributed on several calculators.
Lastly, it should be noted that energy is provided to the vehicle by a Cd-Ni battery. of 160 Ah. This battery is subjected to a particular control in order to precisely know its state constantly.

weight	3100 kg
length	6 m
speed ranges	0 to 10 knots
auxiliary actuators	1 transverse thruster 3 vertical thrusters 1 canard 1 rudder

Conclusion

The REDERMOR II is an experimental tool designed from the first versions tested at sea. It has very complete equipment of navigation, two sonars and calculators. This equipment makes it possible to realize complex missions. Today completely defined, it will be used in at sea trials until 2002.

Bibliography

[LEM 00] LEMAIRE J., DEVIE F., MAILFERT G., TOUMELIN N., « REDERMOR : Description and Results with a versatile tool for Autonomous Underwater Vehicle Research », *Unmanned Underwater Vehicle Symposium* , Newport, April 2000

[BAR 98] BARROUIL C., LEMAIRE J. « An Integrated Navigation System for a long range AUV », *Ocean 98*, Nice, France, September 98