REX 16 – Robotic Exercises 2016
Multi-robot field trials

Mario Monteiro Marques
CINAV
Escola Naval
Alfeite, Portugal
mario.monteiro.marques@marinha.pt

Ricardo Mendonça
FCT-UNL
New University of Lisbon
Caparica, Portugal
rmm@uninova.pt

Francisco Marques
FCT-UNL
New University of Lisbon
Caparica, Portugal
fam@uninova.pt

Tiago Ramalho
TEKEVER
Aerospace Defense and Security
Óbidos, Portugal
tiago.ramalho@tekever.com

Victor Lobo
CINAV
Escola Naval
Alfeite, Portugal
vlobo@novaims.unl.pt

Aníbal Matos
INESC TEC
FEUP
Porto, Portugal
anibal.matos@inescporto.pt

Bruno Ferreira
INESC TEC
Porto, Portugal
bruno.ferreira@inesctec.pt

Nuno Simões
UAVISION
Torres Vedras Portugal
nuno.simoes@uavision.com

Inês Castelão
TEKEVER
Aerospace Defense and Security
Óbidos, Portugal
ines.castelao@tekever.com

***Abstract* — Nowadays, one of the problems associated with Unmanned Systems is the gap between research community and end-users. In order to emend this problem, the Portuguese Navy Research Center (CINAV) conducts the REX 2016 (Robotic Exercises). This paper describes the trials that were presented in this exercise, divided in two phases. The first phase happened at the Naval Base in Lisbon, with the support of divers and RHIBs (Rigid-Hulled Inflatable Boats), and the second phase, also with divers' support, at the coast of Lisbon-Cascais. It counted with many participants and research groups, including INESC-TEC, UNINOVA, TEKEVER and UAVISION. There are several advantages of doing this exercise, including for the Portuguese Navy, but also for partners. For the Navy, because it is an opportunity of being in contact with recent market technologies and researches. On the other hand, it is an opportunity for the partners to test their systems in a real environment, which usually is a difficult action to accomplish. Therefore, the paper describes three of the most relevant experiments: underwater docking stations, UAV and USV cooperation and Tracking targets from UAVs.**

Keywords: Unmanned Vehicles, Cooperation, Experiments

I. Introduction

Portugal is a country with one of the largest European Exclusive Economic Zone (EEZ). In fact, it has the 5th largest among the European countries [1]. Therefore, it is important to invest and develop Unmanned Systems technology, as they are important in many tasks, such as coast coverage.

This year, the exercise had two phases. The first phase was realized at the Naval Base in Lisbon, counting with the support of divers and RHIBS. The second phase of the exercise was conducted at the Lisbon-Cascais coast, also with diver support. There were five participating institutions during the REX16 exercise: INESC-TEC (with three different research groups), UNINOVA, TEKEVER, and UAVISION, besides some research groups from the Portuguese Navy Research Center (CINAV).

The paper is organized as follows. In section II Portuguese Navy and partners that were present in this exercise are presented, revealing the importance of this exercises. Section III describes the tests regarding to underwater docking station tests. In Section IV UAV and USV cooperation trials between two vehicles is presented. Finally, section V describes tests realized in order to track targets from UAVs.

II. Portuguese Navy and partners

According to one of the Portuguese law decrees, the Portuguese Navy primary mission is to participate, in an integrated way, in the defense of the Republic, following the Constitution and law. To conduct naval operations and participate in military missions is also one of the focus of the Navy.

Moreover, the Portuguese Navy is also responsible for exercising state authority in maritime areas under the national jurisdiction. It is also responsible for covering and guaranteeing the maritime Search and Rescue functioning. However, as a result of having one of the largest EEZ, the costs associated of covering this large area are high.

It is essential to investigate and develop means in order to assist in these missions, reducing the costs while covering large areas at the same time. Unmanned vehicles can be a fundamental support in these tasks. These systems can be used in various missions and ways. For the military, they can be used for surveillance and reconnaissance, air attacks, mine counter measures, search and rescue, oil spills detections [3] [4], and much more tasks.

They can be used individually or in a team, in order to change information and cooperate with each other. There are already many projects that prove the success of having a multi-robot team, proving that these vehicles can be an important asset for almost any environment [5] [6].

Therefore, it is extremely important for the Portuguese Navy to conduct exercises, especially with civil partners, including universities and companies. These exercises are a way of strengthen ties and create protocols, which are beneficial for both sides. For the Navy, because they are a mean of getting familiarized with recent technologies advances. On the other hand, these exercises are also important for the partners because they are an opportunity to test their systems in a real environment, which is usually difficult to accomplish.

III. UNDERWATER DOCKING STATION TESTS

The use of docking stations placed in area of interest for the operation of Autonomous Underwater Vehicles (AUVs) is an efficient and effective way of enabling persistent operations with reduced logistics, as these docking stations can be used to recharge vehicle batteries and receive and forward to shore data collected by them. At the same time, they can serve as base of operations platforms with vehicles ready to come into action in response to episodic events.

Within the scope of the ENDURE project, INESC TEC is developing components of a docking station for the MARES AUV (Figure 1).

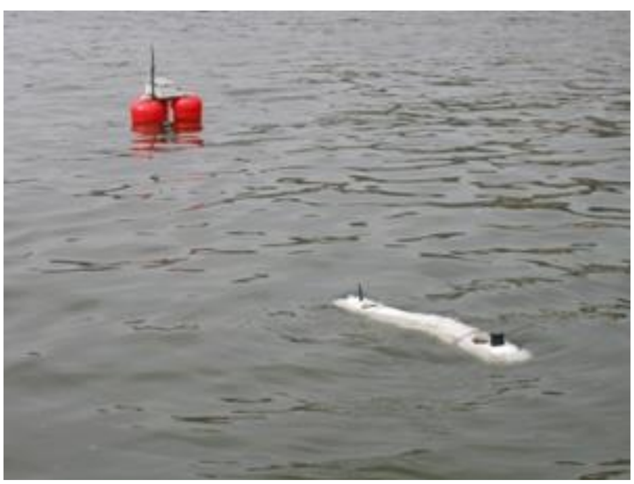
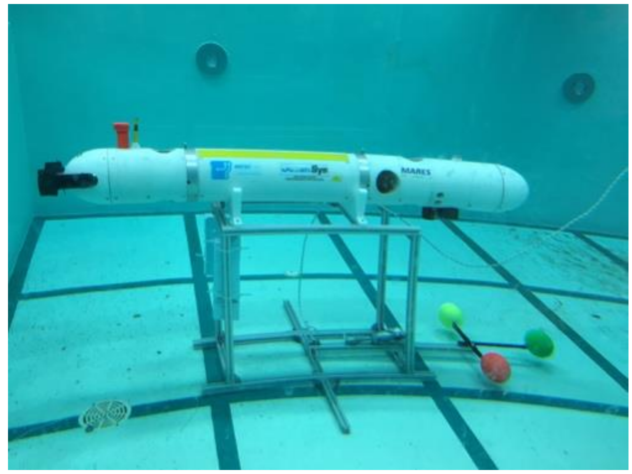


Figure 1 - MARES AUV and navigation buoy connected to docking station

This docking station will allow for recharging AUV batteries and transfer data collected by the vehicle during the execution of autonomous missions. Besides, the challenges directly related to the development of the components of the docking station (Figure 2), complementary developments have been carried out on the MARES AUV to make docking maneuvers possible. In particular, a new vision-based position system was integrated on the vehicle and novel motion behaviors have been



developed and implemented on the on-board control system.

Figure 2 - MARES and visual target for docking maneuver

The REX exercise provided the opportunity to test the developments performed on the MARES AUV in operational scenarios. More specifically, the following experiments were carried out:

- Calibration of active visual marks under different underwater conditions;
- Tuning of mark detection thresholds for the visual positioning system;
- Calibration of visual positioning algorithms to provide accurate relative position and attitude of the AUV with respect to the docking station;
- Tuning of controller parameter for approach and final docking maneuvers;
- Collection of data for assessing the relative accuracy of the MARES acoustic positioning system in docking operations.

These experiments were carried out in both operational scenarios where REX 16 took place, in order to validate the system under very different operational conditions. The experiments carried out inside the Naval Base turned out to be very challenging due to the low visibility conditions, while the trials conducted off Cascais provided much more relevant data, as the environmental conditions (mainly visibility and currents) were much more favorable.

IV. UAV AND USV COOPERATION

Today all the missions require more than one type of Unmanned System (UxV) to accomplish their mission and most of the times these vehicles have different producers and need to talk one with the others because of that is important to have cooperation between vehicles and in our particularly case Unmanned Air Vehicles (UAV) and Unmanned Surface Vehicles (USV) cooperation.

UAV and USV can provide alone a wide variety of capabilities, but the two type of vehicles, when used together, can provide better solutions for surveillance tasks, such as searching for survivors of accidents. These unmanned vehicles together can search over large areas and making the detection way more accurate than when operating alone.

There are two types of unmanned air vehicles that are used for different types of operations. On the first hand, there are the fixed-wing UAV's, that can operate on a larger area and at greater speed, providing better coverage overall. On the other hand, there are rotary wing UAV's that can't reach such high speed or cover a wide area in little time, but they have the advantage of stationary flight that extends the capabilities of the vehicle such as delivering life jackets or other life changers.

However, there are a lot of things that a rotary wing unmanned air vehicle can't transport due to its weight. That's where the unmanned surface vehicles come in. These vehicles can provide heavier and larger resources to shipwrecked such as life rafts, food and water. They also can provide everything that an unmanned air vehicle does, but these surface vehicles are slower, harder to transport and launched from a larger ship.

V. TRACKING TARGETS FROM UAVS

The AR4 Air Ray system is a hand launch mini UAV that is being adapted for naval uses. It's low cost and potential to considerably extend the surveillance capabilities of any naval platform make it an attractive proposal for the Navy, but it is necessary to test and adapt it to maritime environments. During REX 2016, the target localization algorithms, and the communication relay mechanisms were tested. A scenario was devised, and the results were encouraging. Examples of the target tracking developed, both of the visual interface and of the target orientation estimates, are shown in Figure 3 a) and 3 b).

Figure 3 a) - Image from AR4 Light Ray acquired on the proposed

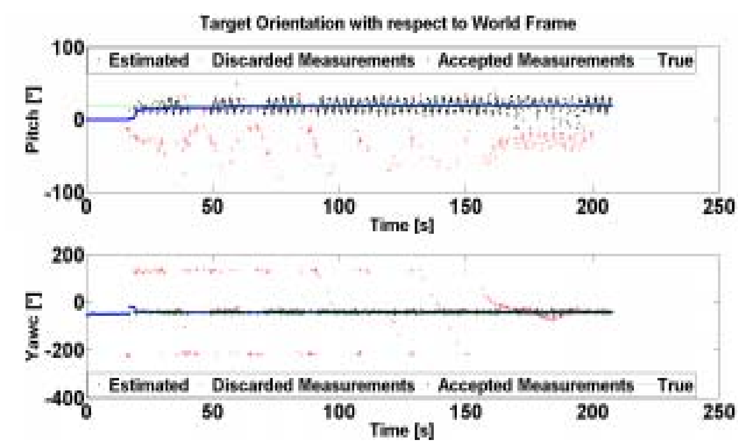


Figure 3 b) - Target orientation result from the experience

Even though satellites are currently being used for maritime wide area monitoring, unmanned aircrafts have been able to thrive in multiple naval surveillance applications (e.g. oil spill detection and monitoring, illegal fisheries and immigrations recognition, support to Search & Rescue operations, etc.); overcoming the limitations of availability and latency associated with satellites, the utilization of UAVs allows for a more frequent and more dedicated surveillance effort, being able to steer it towards certain areas of interest like oil and gas production fields.

Offering multiple options for optical sensors (e.g. IR and multispectral cameras), laser illuminators and biological and chemical analysis, the AR4 Air Ray is able to detect vessels and oil spills, and to track and follow a specific target in the water chosen by the operator. Yet, due to the difference in speed between the AR4 and its target, the AR4 must adapt its flight path and sensor orientation in order to maintain eyes on a specific visual marker of the target, thus requiring superior navigation algorithms to allow sensor/UAV synchronization by which the AR4 may control the sensor orientations or, conversely, a sensor field of view determines the vehicle's flight path.

AR4 Air Ray vehicle has a wingspan of 1800 mm, length of 1200 mm, a 5 kg maximum take-off weight. It reaches a cruise airspeed of 57 hm/h and a maximum of 80 km/h with a 2-hour autonomy. It is hand launched and retrieved by parachute with autonomous navigation.

Tracking trials using other vehicles were also conducted, this time with UX-Spyro, a multirotor UAV, as it is shown in Figure 4. This vehicle has been designed for advanced missions, offering very good payload capacities. UX-Spyro can operate under difficult environments, and it offers flight stability. Trials done by this vehicle were positive and consisted on tracking a small ship.

Figure 4 - UX-Spyro in field trials

The UX-Spyro is a quadcopter, capable of vertical take-off and landing. It has 8 electrical water proof engines and ultra-low noise propellers. This quadcopter has 540mm height and approximately 1131mm of wingspread dimensions. One of its big advantages is the fact that it can support 7 kg payload. Also, as it was previously referred, this vehicle can work under difficult environments. The range of temperatures that the UX-Spyro can operate goes from -10ºC to 50ºC. Therefore, these vehicles provide very good means to track targets and to realize many more tasks, because of the payload and conditions that he can support. It reaches a maximum speed of 55 km/h and has an operational range of 15 km, with an autonomy of 1 hour.

VI. Conclusions

In conclusion, Portugal has one of the largest EEZs in Europe, and because of that is has to have means to secure it and to provide safety for those who navigate on it. Unmanned vehicles are in constant development, and they can be a way to help in this process. Therefore, the Portuguese Navy conducts these types of exercises, in order to promote experiments with unmanned vehicles.

It is also advantageous for the Portuguese Navy to conduct these types of exercises so the Navy can keep up with the technology evolution that is rising exponentially as years go by.

Once again, the REX exercise was an opportunity for the research community to have "time at sea" with support from the navy, and for the Navy to have first-hand experience with what is being developed at our universities and technological companies. It was also an opportunity to develop new technologies, apply them to a specific objective and get to know whether they are more efficient on the field.

REX 16 provided an excellent opportunity of having underwater docking station, UAV and USV cooperation and tracking targets from UAV tests. These trials are also a way to promote the next REX exercise, and to bring even more partners to it.

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