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Underwater Gliders: Mission Profiles and Utilisation Strategies in the Mediterranean Sea

Enrico Petritoli[1], Fabio Leccese[1], Marco Cagnetti[1]

[1] *Science Department, Università degli Studi "Roma Tre" Via Della Vasca Navale n°84, 00146, Roma, Italy, e_petritoli@libero.it, fabio.leccese@uniroma3.it*

***Abstract* – The final aim of this paper is to create peculiar strategies in order to optimise the use platform for underwater scientific research that can accommodate a wide range of different payloads. The main mission profiles and the related employment strategies are optimized, according to the dedicated environment: we will examine in detail the three types of typical mission (pure drift, corrected drift and glider) finally a hybrid one (Jellyfish).**

***Keywords* — Mission, Profiles, Autonomous, Underwater, Glider, AUV.**

I. INTRODUCTION

The final aim of this paper is to create peculiar strategies in order to optimise the use platform for underwater scientific research that can accommodate a wide range of different payloads.

The automatic exploration of the abyss requires highly sophisticated machines capable of withstanding a very severe environment. The use of ROV is limited both by the need to be constantly connected with the support vessel by umbilical cord, and by the manoeuvrability due to the length of the cable. This reduces their use to "spots" of relatively limited area, such as the exploration of a sunken vessel: the possible recognition of a pipeline line would require the contextual displacement of the support vessel with relative increase in operation times and costs.

The sea gliders project has now reached maturity and can be well integrated with other architectures for marine exploration: we will examine a series of mission profiles and consequently strategies of use and use of different underwater drone architectures [1]-[5].

II. THE MEDITERREAN SEA

Since ancient times, Mediterranean Sea has always been a crossroads of civilization due to the great variety of populations he embraced; the ancient Romans called it "Mare Nostrum" (Our Sea) to indicate that the Empire extended well over all the territories it touched. Beyond its placid aspect and apparent smallness, the Mediterranean can become very stormy and treacherous, rich in intense currents and water basins as the Man who crosses it since ancient times knows well.

The Sea is located at mid-latitudes between Europe, Asia and Africa and is an enclosed sea, communicating with the Atlantic Ocean to the west across the Strait of Gibraltar and with the Sea of Marmara and the Black Sea to the east across the strait of the Dardanelles. In the Mediterranean Sea occurs almost all of the bio-geophysical processes like the great oceans occur so it can be considered a "sea laboratory".

It can be subdivided into two large sub-basins, the Western and the Eastern Mediterranean linked together by the Strait of Sicily, which exhibit a noteworthy bathygraphy difference, which prevents the free circulation of great volumes of water.

Fig. 1. – An ancient portolan nautical chart of the Mediterranean Sea.

The bathymetry values of the Sea have a very wide range of variations: e.g.: to the continental shelf (like the Adriatic Sea and the Tunisian platform) have a depth below 100 m, in other areas, like the Tyrrhenian Sea, the Ionian Sea and some areas of the Near East Sea depths reach 4000-5000 m [6]-[9].

The difference between the Mediterranean and the other open oceans lies precisely in the great variety of depth and variation of use scenarios, within a rather narrow area of the sea. A sea glider drone, within its own spatial "flight envelope", can pass from the shallow to the abyss of thousands of meters: it is carried, for example near the island of Capri, a warm shallow sea become a ditch so deep as to serve as a test area for the "Trieste" bathyscaphe.

The Mediterranean Sea is a "concentration basin": the losses of water due to evaporation exceeds the water entrances coming from rivers and rains. To compensate for the increase in density and the decrease in the average sea level with respect to the Atlantic Ocean, a large number of underwater currents have been activated not only horizontally, but also vertically, causing, seasonally, a strong mixing of the salt layers [10]-[13].

This great environment variety cannot be explored with only one aircraft configuration or better: to optimize exploratory performance it is necessary to use, at the state of the art, different architectural solutions [14]-[18].

III. MISSIONS

A. Payload and range

It cannot be denied that the drone has reason to exist is identified with its payload, indeed we can say that the drone is the payload because without it would be useless. In the final analysis, depending on the payload and the range, the mission profile is defined which, in turn, must be optimized according to the architecture of the sub glider. In the following section we will examine in detail the three types of typical mission (pure drift, corrected drift and glider) finally a hybrid one (Jellyfish).

B. Lagrangian Profile (drifting buoy)

The first system is a pure drifting buoy (Lagrangian) that can adjust the depth of navigation and emerges only for the short time necessary to connect with the satellite (see Fig.2 below).

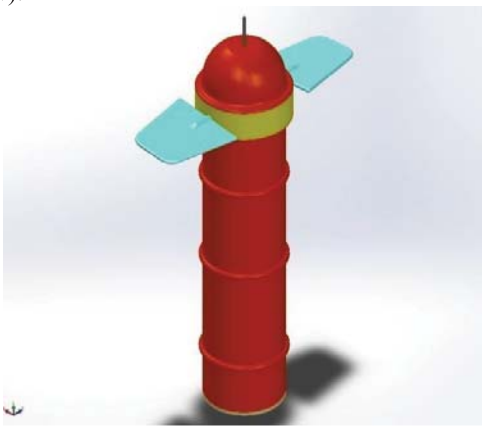

Fig. 2. – Lagrangian mission profile: drifting buoy

Historically, one of the first solutions adopted was ALACE, a drift buoy that could suitably adjust its operational depth: once it reached the surface, it transmitted the data collected to the Argos satellite system.

Today we use buoys that are technologically advanced and have better autonomy and more sensors, but the mission profile remains the same as the first attempt in the 50s of the last century [19]-[21].

The architecture is quite conventional: a constant diameter cylinder that includes the instrumentation, the communication systems and the device that regulates the buoyancy [22]-[25].

C. Quasi Lagrangian Profile

The need to get rid of the randomness of the currents, and an ever-expanding miniaturization of electronic components, have led to the natural development of the underwater gliders that have the ability to move both on the horizontal plane and on the vertical plane [26]-[30].

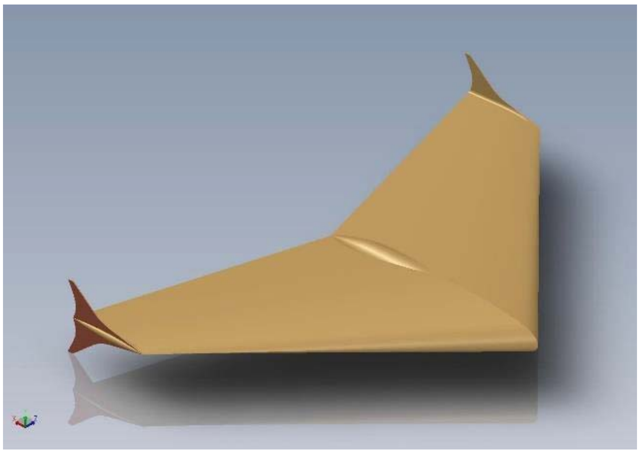

Fig. 3. – Quasi Lagrangian mission profile: manta Architecture

The system can be considered as "quasi-Lagrangian" one, because it is possible to use it as a simple emerging buoy and capable of a variable depth: it essentially includes the whole mission profile of the mentioned system. Furthermore, the innovation lies in the fact that, with very little expenditure in terms of energy, it can also be moved to the horizontal plane, compensating for currents and drifts, thus having the possibility of changing the mission and purpose until the end [31].

Not least the possibility of being able to conduct an active "volumetric" exploration of a stretch of sea [32]. The ideal architecture for this type of mission is the so-called "manta" (see Fig.3): an all-wing vehicle, with very low hydrodynamic drag and a payload optimized to be inserted in the streamlined wing [33].

D. Normal Sea Glider Profile

An underwater glider moves up and down in the sea like by changing its buoyancy: it uses its hydrodynamic wings to convert the vertical motion to horizontal, moving forward with negligible power consumption [34]-[36].

While not as fast as conventional AUVs, gliders using buoyancy-based propulsion increase the range and the duration (autonomy) compared to motor-driven vehicles, may extend the mission from hours (or weeks) to months (see Fig.4), and to several thousands of kilometres of range. An underwater glider follows an up-and-down, sawtooth-like profile through the sea, providing data on temporal and spatial scales unavailable to previous AUVs.

Furthermore, unlike gliders in air, AUVs can have ascending glide slopes if the net buoyancy is positive, producing a negative sink rate.

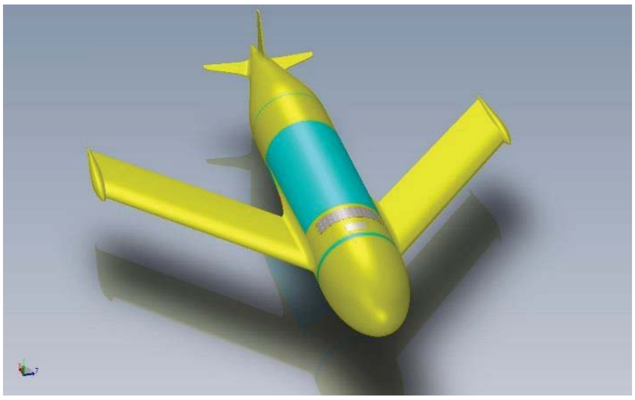

Fig. 4. – A conventional architecture Sea Glider

An underwater glider is unable to proceed straight and level, because is motion is due to the difference between the forces of weight and buoyancy, thus converted by the wings in a smooth dive/climb trajectory

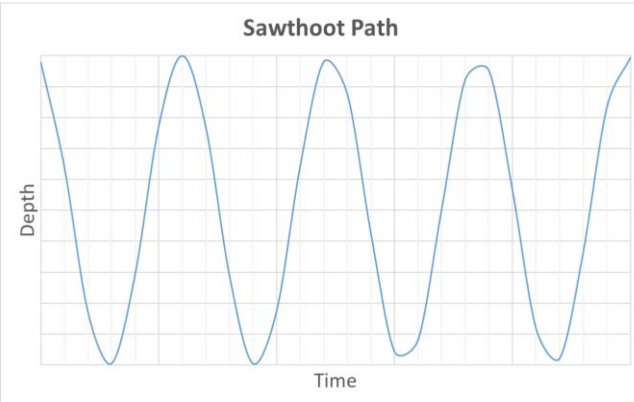

Fig. 5. – Sea Glider Sawtooth glide path (typical)

The glider has a buoyancy engine that allows it to alternately change its net buoyancy between positive and negative states, thereby imparting it with the ability to string together a succession of descending and ascending glide slopes referred to as a sawtooth glide path (see fig.5) [37].

E. Jellyfish mode Profile

a ***b***

Fig. 6. – Two common types of Mediterranean medusae a) Rhizostoma Pulmo; b) Pelagia Noctiluca.

This is a mission profile that we have called "jellyfish": it has been developed in response to a very peculiar requirement: being able to follow and monitor surface debris, drifting plastic garbage or oil spills [38].

Locomotion in jellyfish (see fig.6) is very efficient: the muscles contained in the mesoglea expand radially and contract, generating a toroidal vortex that pushes forward the body. Once the contraction is over, the mesoglea elastically relaxes and returns to its original form, creating a stop vortex without extra energy input and thus giving the possibility to the process to start again [39].

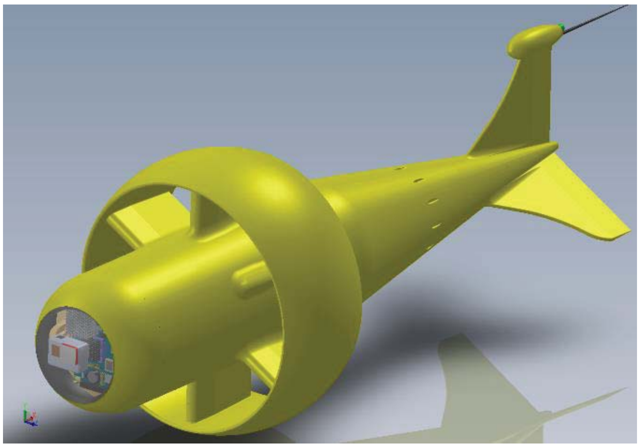

Fig. 7. – Jellyfish vehicle

Our vehicle moves similarly to the jellyfish: it contracts and expands the bladder and, through significant changes of depth, follows the current avoiding being captured by small natural vortices, outcropping rocks or divergent lateral currents. All this in order to complete the mission [40]. For this reason, we have chosen the vehicle shown in Fig. 7.

F. Performance comparison

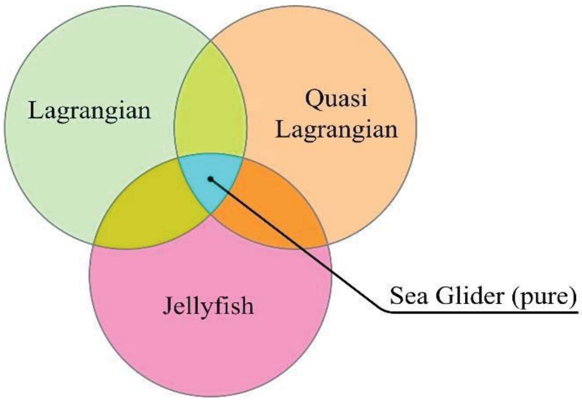

Fig. 8. – Architecture tasks comparison

The first consideration to make about the use of the various vehicles is that the only one who manages to cover all the designated roles is precisely the classic sub glider: apparently, it manages to be endowed with remarkable serendipity which indicates it as the ideal candidate for everything, like it is easy to understand from the Fig. 8 below [41].

In fact, it can accomplish the mission of a drifted Lagrangian buoy but also like the quasi-Lagrangian Manta and, finally, that of the jellyfish mission.

Consider instead the envelope (area) duration / range of the vehicle as shown in Fig. 9, the approach must change drastically.

From the same figure, it can be seen immediately that the vehicle with a Lagrangian architecture is optimized for extremely extensive missions over time but due to its displacement on the horizontal plane of eventual sea currents that generally do not exceed 7 knots in the Mediterranean, the range is extremely reduced.

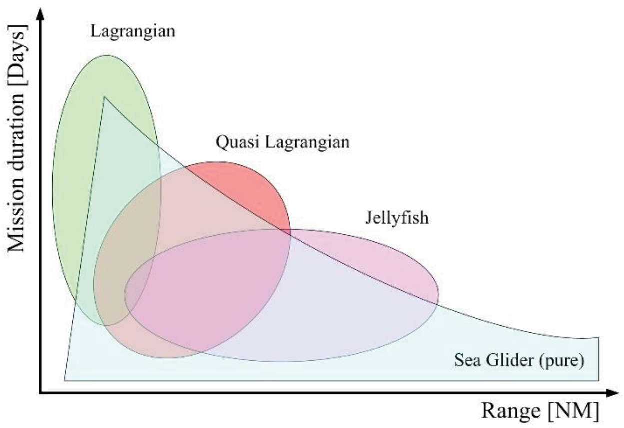

Fig. 9. – range/duration envelope comparisons

The vehicle with a semi-Lagrangian architecture has an intermediate range, which spread well with the duration, whereas the jellyfish architecture allows for long ranges but for missions rather limited in time (but low energy consumption).

It is now evident how the pure sea glider, while performing in an honourable way, all the previous missions, does not excel in any. Its use must then be in mixed missions that are a fusion of two or more scenarios.

IV. CONCLUSIONS

The extreme specialization that is emerging in the field of UAVs could give rise to a spread-out of types and models that can often confuse the end user who will then have to configure the payload. We have examined in detail the four main mission profiles and dedicated a particular drone architecture to each of them, finding the appropriate optimization. Employment strategies have been found for each vehicle and the rational criteria for every architecture. Now is clear that there is no vehicle that possesses the perfect configuration but everything must be born according to a well-tempered compromise between payload and specific mission.

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