A MINIATURE UAV FOR NAVAL SURVEILLANCE

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Abstract: *The current state of an ongoing project of a miniature unmanned aerial vehicle (UAV) for naval surveillance is presented here. The UAV under development will operate from the Portuguese Navy fast patrol boats (FPB), which implies the capability of taking-off and landing in 27 m length, 5.9 m breadth vessels, with a 5x6 m small and irregular landing zone located at the boat's stern. In the final version, the UAV will have a 32 nmi operational range, and the ability to perform GPS-supported autonomous flight, automatic take-off and landing and geo-referenced imaging with real-time radio transmission to the FPB.*

1. Introduction

The Portuguese coastline — including Madeira and Azores islands — is 1860 km (1000 nmi) long. This represents approximately 41300 km^2 of territorial waters that must be controlled, a huge mission for which the fast patrol boats (FPB) of the Portuguese Navy contribute a remarkable share. The efficiency of those boats could be improved if their operation could be supported by unmanned aerial vehicles (UAV) with basic electronic surveillance capability *i.e.*, the ability to carry out geo-referenced imaging with real-time radio transmission to the FPBs.

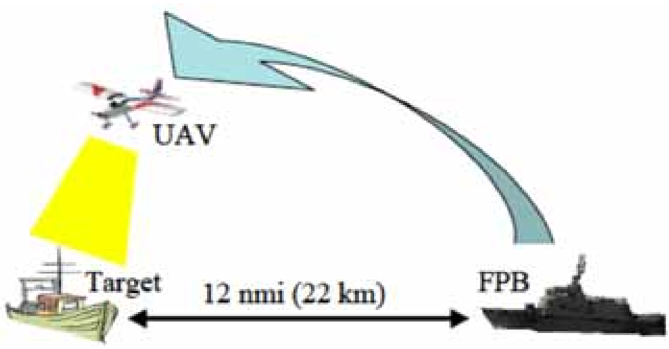

Fig. 1. Reaching the target

An operational flight range of 60 km (32 nmi) should be suitable for a typical territorial waters surveillance mission. Flying at around 80 km/h, this should allow for reaching a target located 22 km apart (see Fig. 1) — well beyond the line-of-sight of the FPB — and for returning after around 8 minutes abeam the target.

Due to the specific operating environment, the adopted UAV should be simple, light, small and reliable. In addition, it should be low-priced, not only due to the required number of units but also to the intrinsically high operational risk. In fact, along with the ability for operating under severe weather conditions, the UAV should be deployed and recovered onboard Argos Class FPBs, which are 27 m long, 5.9 m in breadth, draft 2,8 m, and 97 tonne displacement. Centauro Class FPBs (28,4 m long, 5.95 m in breadth, draft 2,8 m, and 98 tonne displacement) should be considered as well.

Therefore, the project started with the search for the most appropriate solution for the above-mentioned requirements.

The need for mechanical simplicity, reliability and cost effectiveness lead us to the selection of a fixed wing aircraft solution. However, the UAV wingspan should not exceed 1.8 m to allow it’s handling both inboard (for storage and maintenance) and at the take-off and landing zones. With such a wingspan, the UAV’s maximum take-off weight should not exceed 6 kg. For a matter of superior impact strength, as required for very hard landings, the UAV structure should be made of expanded polypropylene (EPP). As a bonus, the EPP structure should provide improved buoyancy for the case of a crash landing at sea.

For this small sized aircraft, the power plant should be a two-stroke, glow-plug internal combustion engine, because this type of engine is powerful, easy to operate, and delivers a substantial amount of energy at a relatively small payload.

Not a single document was found about UAVs with the required characteristics. Therefore, some inspiration was drawn from the RQ-11 Raven [1] and the Dragon Eye [2] miniature UAVs. Although they are powered by electric motors, the size and weight of both the Raven and the Dragon Eye are the same order of magnitude.

The take-off of our UAV could be carried out by hand launching at the forecastle of the FPB. As for the landing, the sole eligible part of the ship is the stern section, a very small and irregular area with a size of around 5x6 m.

Different concepts for the onboard landing support system were evaluated, and it was found that the best system should be a nylon cord net. In fact, some preliminary tests that where carried out in *terra firma* with different types of stopping systems — such as horizontal and vertical stop cables and different types of nets — have shown that a nylon-cord net is able to sustain very hard crash landings without noticeable damage of the UAV.

The survival of the UAV’s airframe under very adverse operating conditions was a crucial point of the project, and the present paper is an attempt to show the appropriateness of the main design decisions that have been made on this particular subject.

2. The adopted solution

A commercially available 1.72 m wingspan, radio-control aircraft model with EPP structure has been selected as a means to proof the adopted concepts (Fig. 2).

The prototype was carefully arranged for possible crash landings at sea, with all the electronic equipment made watertight by means of rubber balloons, lubricant grease and glue. It proved to be water-resistant after being submerged in a water tank for a 24-hour test period.

Some active flight stabilization systems have been set up as well, such as an inertial platform [3] and a system that senses the difference in infrared signature between the earth and the carbon dioxide in the atmosphere [4].

Fig. 2. The UAV prototype, as used in the flight tests at the sea.

The prototype was equipped with one or two fixed video cameras for some of the flight tests. A radio link between the UAV and the vessel was set up to allow real-time video acquisition, and Fig.s 3, 4 show some details of the used equipment. The typical take-off weight for this configuration is approximately 3 kg, well below our 5-6 kg first guess.

Fig. 3. One of the video cameras, as used in some flight tests.

Fig. 4. The video acquisition system that was used onboard the FPB.

On the FPB side, a football-goal type net made of nylon cord was set at the FPB's stern to make available the UAV's landing zone (Fig. 5).

Fig. 5. Installing the stopping net at the stern section of the FPB.

The stern section of the FPBs is mostly occupied by a bay with a hydraulic-operated stern door for sheltering an auxiliary rigid hull inflatable boat (RHIB). Fig. 6 shows that the landing net fixed to the vessel's superstructure does not disturb any essential function of the FPB. Most important, the stern door can be easily operated, so that the RHIB operation is not disrupted.

Fig. 6. The stern section of a Centauro Class FPB.

3. The flight tests and the results

Nine test sorties have been done so far, the first four ashore, at different locations, followed by five sorties at sea, onboard NRP Centauro, NRP Cassiopeia, and NRP Hidra.

The purpose of the ashore tests was to understand the UAV's flight behaviour and to test the eligible stopping systems in a much more favourable situation than the onboard conditions.

A typical flight test at the sea begins with hand launching the UAV from the FPB's forecastle (Fig. 7), and ends with a very hard landing at the stopping net mounted at the stern of the vessel (Fig.s 8, 9).

Fig. 7. Hand launching the UAV at the forecastle of a FPB.

Fig. 8. The UAV in the final approach for landing on NRP Centauro.

Fig. 9. The UAV over the stopping net immediately after landing.

Since hand launching from the forecastle deck was used, no special onboard measures where required for take-off. Usually, after takeoff it followed a short flight around the FPB since the main objective was to evaluate the behaviour of the complete experimental take-off and landing setup. Some longer flights of 10 to 15 minutes were made to test the active flight stabilization systems and the video cameras.

The speed of the UAV relative to the vessel was continuously monitored during the final approach by using a police type hand-held Doppler radar. The range of the landing speed has been 30 – 50 km/h (16 – 27 knot).

Fig.s 10 and 11 contain frames of video streams that were collected during the flight tests.

Fig. 10. NRP Hidra, as captured by one of the UAV's video cameras.

Fig. 11. An aerial view of the Portuguese Naval Academy taken by the UAV.

Over the course of our experiments, more than 100 successful landings were accomplished. Although we did have some crash landings in the water during the first onboard tests, during the last three sorties a 100% success rate was attained, leading us to believe that the UAV prototype is now robust and reliable. Moreover, due to its remarkable buoyancy, it proved to be able to fly without any problem almost immediately after crash landing at the sea (see Fig. 12).

Fig. 12. The UAV after a crash landing at the sea.

4. Concluding remarks

The goal of this project is to design and build a miniature UAV with a 32 nmi operational range, capable of taking-off and landing on the Portuguese Navy's Argos and Centauro classes fast patrol boats.

The flight tests were performed along a 12-month period, under different atmospheric conditions, ranging from sunny weather with almost still air to heavy raining with strong wind and 33 knot gusts.

Tests so far have shown that the adopted solution is feasible, and one of the most critical aspects of the UAV, *i.e.* landing on such a small vessel, was proved possible with a high success rate. In addition, it was proved that the operation of the UAV does not disturb the original functions of the FPB, which includes the operation of the RHIB.

The active flight stabilization systems have been tested as well, and the inertial platform type was found to be reliable and very efficient under severe atmospheric conditions.

The video cameras were found to be sufficiently steady to allow the acquisition of sharp images. Yet, the adoption of remote controlled zoom lenses and stabilized gimbals would make easier the overall UAV operation, which in this case could acquire sharper images at a larger distance to the target.

No attempts were made to check the operational range of the prototype, since the main goal of the tests was to appraise the solutions that were found for taking-off and landing.

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