Advantages and disadvantages of some unmanned aerial vehicles deployed in maritime surveillance

Sanja Bauk[1,2], M.Sc. Nexhat Kapidani[2,*], Luis Sousa [3], Žarko Lukšić[2], Agim Spuža[2]

ARTICLE INFO	ABSTRACT
	The paper discusses the advantages and disadvantages of some unmanned aerial vehicles used for maritime surveillance. As examples, the Zephyr pseudo-satellite, as well as the AR5 and the AR3 medium altitude unmanned aircraft have been presented. A high-level Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis is applied in this regard, as a tool to help assess the potential benefits of UAVs in the current maritime surveillance context. Strengths as lightness, possibility of manual launching, low energy consumption, lower price in comparison to satellites, high seeing, sensing and communication features, capacity of both line of sight (LoS) and beyond line of sight (BLoS) operations, large coverage, and durability of flight and like are highlighted. Threats such as high risk to operations due to severe weather conditions, loss of human control over the systems due to their high degree of autonomy, potential users' reluctance to accept high-risk innovation and similar are agued, as well. In addition, weaknesses as complexity of the systems and the requirement of highly skilled personnel for these aircraft design, production, operation and maintenance, along with opportunities like lower costs, lower ecological and logistics footprints and higher efficiency are also taken into consideration. The appropriateness of these advanced aerial vehicles for monitoring and securing sea borders has been intertwined within the context.

1. Introduction.

Unmanned aerial vehicles (UAVs) are being increasingly used for numerous purposes in both military and civilian domains. For instance, current applications of this kind of systems include surveillance, reconnaissance, remote sensing, target acquisition, border and maritime patrol, infrastructure monitoring, communications support, aerial imaging, industrial inspection, as well as emergency medical support, among others. The UAVs have capacities of sensing and perceiving the environment, processing the sensed information, communicating, planning and decision making, as well as acting using control algorithms and actuators (Becerra, 2019). Although these systems have historically found their main technological drive and applications in the military domain, their capabilities, alongside an increasing dissemination and consequent accessibility of this kind of technology, have attracted the interest of the civilian markets for several applications. As a result, the integration of UAVs in civil (non-segregated) airspace commonly used by conventional manned aircraft has been subject of intense study in recent years, with many initiatives currently approaching the initial implementation stages (e.g. the U-space initiative from the European Union's SESAR Joint Undertaking (JU) (Karpowicz, 2019)). In addition to applications such as agriculture and infrastructure monitoring, this has also paved the way to a growing use of unmanned aircraft in support of civil security missions, with particular emphasis in border and maritime surveillance.

Considering the context described above, this research paper has the main goal of providing an overview of the potential impact of deploying specific types of unmanned aerial systems in support of maritime surveillance missions and adjacent roles. As such, this paper describes the main features of the Zephyr

[1]Department of Maritime Studies, Durban University of Technology, South Africa.

[2]Administration for Maritime Safety and Port Management of Montenegro, Montenegro (III) Tekever, Portugal.

[*]Corresponding author:M.Sc. Nexhat Kapidani.

High Altitude Pseudo-Satellite (HAPS), as well as the AR5 and the AR3 UAVs, which are part of a broader maritime surveillance and reconnaissance system for monitoring and control of the European sea borders, being developed within the context of the COMPASS2020 (Coordination Of Maritime assets for Persistent And Systemic Surveillance 2020) Project. The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the above mentioned UAVs will be conducted and presented, as well.

The question of motivation for developing and implementing the COMPASS2020 project logically arises in this context. The project has as overarching goal the deployment of unmanned aerial, sea surface and underwater vehicles, in operational coordination with manned oceanic patrol vessels used by EU Maritime Authorities, to enhance current maritime border surveillance operations, with a particular focus on the detection, monitoring and control of irregular migration and narcotics smuggling. The project aims at setting up a solution to ensure long range and persistent surveillance, increasing the situational awareness of maritime authorities, as well as to upraising the cost-effectiveness, availability and reliability of related operations. It has been conceived to help authorities handle the pressure put on European external borders by the vast amount of irregular border crossings observed in recent years, through improving coordinated actions supported by both manned and unmanned vehicles. Besides struggling with irregular migrants, Europe has a problem with other incidents of the most disperse nature, such as the long lasting issue of narcotics trafficking (EU Comission, 2020). Consequently, COMPASS2020 has also been conceived to help address this issue. In order to address these two big challenges, the project proposes the development of a unified system based on open standards that will enable the combined operation of multiple unmanned assets, manned platforms currently used for marine surveillance and the future accommodation of other platforms and services with minor integration efforts. The project contributes to improve the situational awareness beyond coastal waters in different environmental conditions, ranges and altitudes. In addition, pollution monitoring is also an increasingly important part of maritime safety, as global commerce increases from and towards Europe, leading to a growth of vessels and cargos crossing European sea borders. Marine traffic of high density results in a higher probability of occurrence of pollution incidents, such as oil spills, as well as an increase in ships sulfur emissions. Those incidents, especially the ones that occur due to severe weather conditions such as strong winds and high sea state, can lead to high negative impacts to the environment (Bauk, 2019). The capability to establish a persistent maritime surveillance infrastructure such as proposed in the project will allow a better monitoring, control and management of these and other threats, and allow for better decision making to ensure the safety and security of European maritime borders.

As it is stated afore, the paper deals with unmanned aerial vehicles (UAVs) deployed within the project. Accordingly, the rest of the paper is organized as follows: the second, third and fourth sections comprise the description and high level analysis of the Zephyr, the AR5 and the AR3 UAVs crucial technical features and operational capacities, respectively; the fifth section contains the SWOT analysis of the considered UAVs; while the last section contains some conclusion remarks along with the directions for further research work in the field.

2. The Zephyr: Key Features.

The Zephyr 7 has been invented in 2000 at the Flemish Institute for Technical Research in the context of the Pegasus project. This solar airplane has been later transferred to Airbus in 2013. The only solar-powered airplane has demonstrated a unique mission of 14 days duration at more than 21 km flight altitude carrying a payload of 5 kg (Gonzalo, 2018). In 2014, work on Zephyr 8 began. The Zephyr S is a new variant of Zephyr family developed upon an agreement settled between the UK Ministry of Defense and Airbus Defense and Space. It is the first unmanned aircraft capable to fly in the stratosphere, harnessing the sun's rays and running on a combination of solar cells and high-power lithium sulphur batteries (i.e., on solar-electric power), above the weather and conventional air traffic. It is a High Altitude Pseudo-Satellite (HAPS) (Kramer, 2018), able to fly for a month at a time, combining the persistence of a satellite with the flexibility of an unmanned aerial vehicle (UAV). As HAPS, the Zephyr uses high-definition electro-optical and infrared cameras to produce real-time visuals in any lighting (Figure 1). The Zephyr unit costs around 5 million $, while an orbital satellite costs between 50 and 400 million $ (Thisdell, 2019). Airbus now possesses two types of the Zephyr, designed to accommodate a variety of payloads. The production model Zephyr S has a wingspan of 25 m and weighs less than 75 kg. It is able to carry see, sense and connect payloads. Briefly, Zephyr S is capable to:

- *See* with clarity (facilitate disaster management, e.g., wildfires and oil spills);

- *Sense* with efficiency (trace environmental changes; monitor and secure borders);

- *Connect* with precision (connect securely across the globe; connect the isolated, since four billion people in the world do not have Internet access, etc.).

Presently, the larger Zephyr T, which is under development, has a wingspan of 33 m and a Maximum Take-off Weight (MTOW) of 140 kg (Airbus, 2019). The Zephyr's main features include, but they are not limited to:

- *Flexibility* - The Zephyr's launch requirements are simple compared to traditional aviation. It requires no runway and no airport. It is launched manually. After taking-off and reaching the stratosphere, the Zephyr navigates to the desired location, which may be hundreds or thousands of kilometers away. It transmits real-time imagery, voice and data in the perimeter of around 1000 km^2. The Zephyr can be controlled from ground control stations anywhere in the world deploying both line-of-sight (LoS) and beyond line of sight (BLoS) operations.

- *Safe and secure* - The Zephyr has both civil and military applications, which include maritime surveillance, border patrol, intelligence, reconnaissance, navigation, satellite communications, missile detection, environmental surveillance, continuous photo capturing, humanitarian and disaster relief, among others (Airforce Technology, 2019).

- *Persistence* - The Zephyr's persistent flight is unmatched. It uses solar-electric power, with secondary batteries charged in daylight powering overnight flight.

- *Revolutionary* - the first unmanned aircraft capable to fly the stratosphere, the Zephyr might upgrade defense, humanitarian, and environmental missions all over the world.

Figure 1: Zephyr.

Source: Web.

The Airbus' Zephyr S has been firstly launched on 11th July 2018 in Yuma, Arizona, USA. Previously, it has been transported from Farnborough, UK. It used to have a small ground infrastructure. It was a historical take-off, when after eight hours Zephyr reached the stratosphere. Its lower altitude was 18 km, and the highest was 23 km. This was, at the time, the longest flight without refueling, lasting 25 days, 23 hours and 57 minutes (Airbus, 2018). Unfortunately, on 15th March 2019 the Zephyr aircraft with 25 m wingspan and mass of less than 75 kg has crashed near its launch site in Wyndham, Western Australia. This was caused by severe adverse weather. Luckily, it happened in an extremely remote location and caused no injuries or property damage. Work on the Zephyr improvements is continued and it is to be expected that the Zephyr's mechanical launcher will be tested in 2020 (Bauk, 2020).

The Zephyr was conceptually integrated in the proposed COMPASS2020 architecture, as a valuable asset for future concepts of operation. More specifically, due to its potential of acting as a high altitude platform capable of performing early detections and providing the respective warnings to the system, this platform is considered to bring added value to the solution, by providing persistent surveillance means and the first detection of potential events of interest. The goal of the project is to develop the solution in such a way that it will be possible and simple to integrate the Zephyr (both physically and in terms of data processing) within the overall system.

3. The AR5: Key Features.

The AR5 Life Ray Evolution (EVO) was chosen by the European Maritime Safety Agency (EMSA) in an international tender to be the first Unmanned Aerial System to act as a European wide marine patroller (Figure 2). It is a medium-endurance and medium-altitude fixed wing Unmanned Aerial System (UAS). This medium-endurance and medium-altitude fixed wing UAS is designed for wide area land and maritime surveillance, pollution monitoring, fisheries inspection and communication relay (Bold Business , 2017). The AR5 has advanced on board capacities in terms of data processing. It can simultaneously process Electro-Optical/Infra-Red (EO/IR), radar and AIS data. Since EO/IR systems are less known in sea surveillance and navigation than radar and AIS, they will be shortly described below (Teledyne FLIR, 2019).

The EO/IR systems are imaging systems used for military, airborne homeland security, combat, patrol, surveillance, reconnaissance, and search and rescue programs, which include both visible and infrared sensors. Because they span both visible and infrared wavelengths, the EO/IR systems provide total situational awareness both day and night and in low light conditions. Critical features of EO/IR systems are long-range imaging abilities and image stabilization. The EO/IR sensors are usually mounted on aircraft or vehicles, used at sea, and must be able to identify targets, track them, and assess threats from a distance and in challenging environmental conditions. The EO/IR technology is being fit to smaller payloads, including traditional commercial drones and reconnaissance UAVs, and allow for transmitting live video and high-definition (HD) images back to the operator to improve their awareness and reduce risk to ground forces.

Figure 2: AR5 EVO Unmanned Aerial Vehicle.

Source: Tekever.

The AR5 Life Ray Evolution is sub-tactical UAS ranging up to 180 kg MTOW. It allows highspeed BLoS satellite communications. More precisely, it fully manages LoS and BLoS datalink handover. It also provides high precision video, imagery and sensor data in real time. Its features include, for instance, a flexible architecture, supporting multiple types of payloads and datalinks. Moreover, this platform complies with the

highest production standards as the first European-wide UAS-based maritime surveillance system, which is International Traffic in Arms Regulations (ITAR) free (Space Solutions, 2018). As a UAV that requires a runway for take-off and landing, its automatic take-off and landing capabilities, as well as the fact that it can use short and unpaved airstrips, are great advantages. The AR5 EVO has a cruise speed of 100 km/h and a standard endurance of 16 hours (its endurance is mission and payload dependent, being able to reach up to 20 hours). The available payload capacity is up to 50 kg, wingspan 7.3 m and length 4.0 m.

The AR5 EVO is suitable for both wide area surveillance as well as near shore and maritime missions. Among its main applications are (Lord, 2019):

- Autonomous surveillance of large maritime and land areas, with onboard multi-sensor pattern detection;

- Use of both LoS and BLoS datalink to maximize performance and minimize operational costs;

- Multi-mission support, including border protection, fire surveillance and infrastructure monitoring;

- Optimized onboard and ground algorithms for oil spill detection;

- Multi-sensor fusion and specialized support to Search and Rescue (SAR) operations;

- Anti-piracy and traffic control missions; - Support to fisheries using high precision sensors.

The AR5 EVO is equipped with a three axis multi-sensor gyro-stabilized gimbal, capable of supporting the integration of multiple types of payloads. This includes, for example, AIS transceiver, multiple EO/IR sensors, Emergency Position Indicating Radio Beacon (EPIRB), maritime radar, among others. It uses the following communication packages (Tekever, 2019)(Naval Technology, 2020):

Line of Sight (LoS)

- Configurable control and non-payload communication software - defined radio datalink between 400 MHz and 1.2 GHz;

- Configurable control and non-payload communication software - defined radio back-up datalink between 400 MHz and 1.2 GHz;

- Configurable payload datalink between 1.2 GHz and 6 GHz.

Beyond Line of Sight (BLoS)

- Configurable control and non-payload communication data - link over commercial Satcom service at 1.5-1.6 GHz (L-Band);

- Payload datalink over commercial Satcom service at 1.5-1.6 GHz (L-Band shared).

Within COMPASS2020, the AR5 EVO UAV plays an important role as a middle layer platform, which is able to provide wide maritime area surveillance, complementing the operational gap between the wider coverage but lower resolution capabilities of the Zephyr, and the lower altitude and more localized situation monitoring provided by the AR3 UAV described in the next section.

4. The AR3: Key Features.

The AR3 Net Ray is a ship-borne UAS designed to carry out several types of maritime and land-based missions (Figure 3). These missions include intelligence, surveillance, target acquisition, reconnaissance (ISTAR) actions, pollution monitoring, infrastructure surveillance, communication support operations and like. This UAS is capable of delivering an endurance up to 10 hours (depending on the mission), which makes it an ideal solution to carry out both maritime and land based missions. The payload capacity is 4 kg and it includes multiple options for EO/IR sensors, near infrared to long-wave infrared (LWIR) sensors, laser illuminators, communication relay systems, AIS transceivers, EPIRB, etc. Therefore, it can provide real time collection, processing and transmission of high definition video. Its communication range is up to 80 km within Radio Line of Sight; cruise speed is 85 km/h; MTOW is 23 kg; launch is conveyed via catapult; recovery via parachute and airbags (for land based operations) or a net system (for maritime based, ship-borne operations). The AR3 dimensions are 3.5 m of wingspan and a length of 1.7 m (Tekever, 2019). The AR3 missions include both wide area surveillance and near shore and maritime surveillance, comprising the following:

- Autonomous surveillance of large maritime and land areas, with onboard multi-sensor pattern detection;

- Multi-mission support, including border protection, fire surveillance and infrastructure monitoring;

- Environmental monitoring, including heat-tracking;

- Fire prevention;

- Anti-piracy and traffic control missions;

- Support to fisheries inspection using high precision sensors;

- Long range monitoring of large infrastructures, like pipelines or aerial electricity networks; - Support for "over the hill" or beyond radio line of sight missions, etc.

Figure 3: The AR3 Net Ray taking-off.

Source: Tekever.

The AR3 Net Ray UAV will be included in the COMPASS20-20 surveillance ecosystem as an organic asset of the oceanic patrol vessels operated by the maritime authorities. This UAV will be operated (launched, piloted and recovered) from the vessel to provide the tactical teams with enhanced real time information to help decision-making. The AR3 will cover a surveillance level below the AR5, providing a more localized monitoring of events and situations of interest.

5. The UAVs Swot Analysis.

In this subsection, some indicative positive and negative factors connected with the above presented UAVs are given. These factors are organized in the form of the SWOT analysis (Figure 4). After the strengths and weaknesses, the authors identified the main threats and opportunities of the considered UAVs (Alop, 2019).

Figure 4: The SWOT concept.
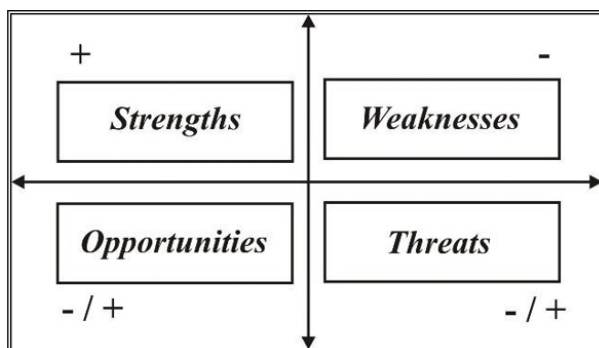
Source: Authors.

Strengths:

- Lightness;
- Manual launching or reduced logistics footprint;
- Low energy consumption;
- Lower acquisition price in comparison to satellites;

- Better quality of information in comparison to satellites;
- Lower operational costs in comparison to manned aircraft used for the same mission profiles;
- Ability to fly for more hours continuously in comparison to manned aircraft, as there is no need for aircraft downtime for pilot rendition;
- High seeing, sensing and communication capacities;
- Capacity of both LoS and BLoS operations;
- Large coverage and durability of flight without recharging;
- High level of automation;
- Resistance to environmental disturbances;
- Possibility to be safely integrated with commercial aviation;
- Capacity to support high risk activities;
- Capacity to reach areas inaccessible for humans, etc.

Weaknesses:

- Complexity of the UAVs makes them more vulnerable;
- Requirements for highly skilled personnel for designing, creating, operating-controlling, maintaining and upgrading the UAVs;
- Lack of law regulations at a wider scale;
- Lack of management and operational knowledge at different levels of the UAVs operation;
- Lack of common communication capacities between the UAVs and other vehicles within integrated traffic and transportation system;
- The link between the UAVs and ground control stations;
- Maneuvering and obstacles' avoidance algorithms are under development; - Computer vision is also still until development, etc.

Opportunities:

- Increasing safety and security at sea and in general;
- Reduction of traffic congestion in areas with high density traffic;
- Approaching up to now inapproachable areas;
- Approaching areas of high risk for humans;
- Gathering more information on distance areas, entities, constructions, etc.;
- Lower ecological footprint;

- Developing 3D path planning with obstacle avoidance;

- Developing potentials of autonomous systems;

- Further development of artificial super-complex UAV systems, etc.

Threats:

- Collapse of the UAVs due to severe weather conditions/harsh environments; - Negative effects of external factors as natural forces and cosmic impacts;

- Losing human control over the craft;

- Unsafe landing and recovering;

- Internal disturbances and faults in the systems as super-complex ones;

- Over-reliance on technology, i.e., UAVs in the analyzed context;

- Unauthorized malicious intrusion into the system (hacking);

- Scarcity of the cost-benefit analysis;

- High investment risks;

- The lack of readiness of entrepreneurs to support further development of UAVs;

- Uncertain revenue of investments;

- Users' reluctance to accept high risk investments in the UAVs innovations; - Questionable innovation acceptance success, etc.

The efficiency of the UAVs is always at the expense of their robustness. Therefore, there should be a balance between the efficiency and robustness of these systems (Chavaillaz et al., 2016). Besides, it is well known from the theory of automated systems that the more complex the system, the greater the possibility of errors and its disturbance (Andrews, 2019). A way to make the UAVs more reliable is to make them layered, while the communication between layers and maintaining efficiency should be boosted.

6. Acknowledgment.

Conclusions.

A review of the UAVs within the context of the COMPASS20-20 project has been presented in this article. The Zephyr, the AR5 and the AR3 UAVs have been described through highlighting their key features. Based on the findings from secondary literature resources and experiences from the project up to now, some strengths, weaknesses, opportunities and threats of the considered UAVs have been identified and highlighted.

The future research in this area should provide a deeper insight of compatibility of the UAV systems with the existing and well-established manned and unmanned craft used for the same or similar purposes. In addition, harmonizing and rationalizing communication among all assets involved within the considered project should be taken into more depth consideration.

There is a strong argument in favor of increasing initiatives for testing, validating and integrating unmanned systems within current surveillance infrastructures (both land and maritime based), as these assets can help enhance current surveillance and monitoring capabilities of authorities in a cost-effective way. However, the so-called "blind-belief" in technology, including the analyzed UAVs, should be interrogated. The willingness of various stakeholders to implement and adopt these advantageous systems should be investigated, as well, with the aim to provide the innovation implementation success in both military and civil traffic and surveillance missions.

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