PAPER • **OPEN ACCESS**

Autonomous marine vehicles in sea surveillance as one of the COMPASS2020 project concerns

To cite this article: Sanja Bauk *et al* 2019 *J. Phys.: Conf. Ser.* **1357** 012045

IOP Conf. Series: Journal of Physics: Conf. Series **1357** (2019) 012045 doi:10.1088/1742-6596/1357/1/012045

Autonomous marine vehicles in sea surveillance as one of the COMPASS2020 project concerns

Sanja Bauk[1,2], Nexhat Kapidani[3], Žarko Lukšić[3], Filipe Rodrigues[4], Luís Sousa[4]

[1] Maritime Faculty Kotor, University of Montenegro, Montenegro
[2] Dep. of Maritime Studies, Faculty of Applied Sciences, Durban University of Technology, SA
[3] Maritime Safety Department of Montenegro, Montenegro
[4] TEKEVER ASDS, Portugal

E-mail: zarko.luksic@pomorstvo.me;

Abstract: Coordination Of Maritime assets for Persistent And Systematic Surveillance (COMPASS2020) is an EU H2020 project, which has as an overarching goal deployment of Unmanned Vehicles (UxV) - aerial, sea surface and underwater ones, in addition to manned offshore patrol vessels, to enhance current maritime border surveillance operations regarding detection of irregular migrants and narcotics smugglers. This paper gives an overview of several research projects on autonomous marine vehicles, as a key technological, organizational and legislative issue within the project scope: *Kaisa*, an autonomous vessel prototype built at SAMK Faculty of Logistics and Maritime Technology in Rauma (Finland). *Autonomous Ships 101* from Solent University in Southampton (England). A review of other articles has served as a comparative analysis to the surveillance assets proposed by COMPASS2020.

Key words: autonomous marine vehicles, taxonomy, state-of-the-art, concurrent activities in enhancing security of borders at sea.

1. Introduction

In 2015 European Union (EU) has been faced with 1.8 million illegal border crossings. This is more than six times the number of detected illegal migrations in 2014. It takes three years to change the situation and to reduce by nearly 90% the illegal border crossings and reassure the security of EU borders. However, there is still pressure on EU external borders, especially when it comes to the Western Mediterranean route. Therefore, COMPASS2020 project has been conceived to reduce the number of illegal border crossings through improving coordinated actions supported by manned and unmanned (underwater, sea surface and air) vehicles (UxV). Besides struggling with illegal migrants, EU has a problem related to narcotics trafficking. It is estimated that every year approximately 125 tones of cocaine worth USD 33 billion are consumed, the majority coming from Latin America to Europe on transatlantic routes. There are some new narcotics routes from Northern and Eastern Africa targeting Spain and Portugal, while the most traditional routes target Belgium and the Netherlands, i.e., major European shipping ports. Consequently, COMPASS2020 was also conceived to combat this issue. To address these challenges, COMPASS2020 proposes the development of a unified system based on open standards that will enable the combined operation of multiple unmanned assets (from distinct providers), manned platforms currently used under marine surveillance context, and the future accommodation of other platforms and services with minor integration efforts. The project contributes to improve the situational awareness beyond coastal waters through integration of multiple manned and UxVs operating in different environmental conditions, ranges and altitudes. On the other hand, pollution monitoring is also an increasingly important part of maritime safety, as global commerce increases from/to the EU, leading to a growth of vessels and cargos crossing European waters. Higher maritime traffic results in a higher probability of occurrence of pollution incidents, such as oil spills, as well as an increase in ships sulfur emissions. Such incidents, especially the ones that occur due to severe weather conditions (strong winds and high sea state) can lead to high negative impacts to the environment. In this context, the solutions under development in the project represent safe alternatives to monitor such disasters, in particular in remote areas where access through manned assets may represent life-threatening risks to the operators. Therefore, the COMPASS2020 platform can be an answer to such situations, providing a cost-effective solution based on UxVs that can be highly effective and, at the same time, reduce the risk to the humans involved in the operation, with the ultimate goal of minimizing the impact of this kind of incidents [1, p.3].

The paper is organized in a manner that its first part describes COMPASS2020 in some more detail; the second one deals with terminology and different levels of autonomous marine vehicles self-managing capacities; the third one gives literature review on several recent projects and achievements in the filed; while the last one provides conclusion and highlights further research endeavors in achieving concurrent command, control and tracking of multiple manned and unmanned air, sea surface and underwater vehicles in the marine environments which are exposed to the risk of illegal border crossings and threats of trafficking of narcotics, including consequent search and rescue activities.

2. The COMPASS2020 key roles

The COMPASS2020 project is expected to achieve a comprehensive solution for maritime surveillance, based on the coordination of manned and unmanned assets with enhanced capabilities, which will allow addressing many of the challenges currently faced by authorities and governmental organizations with responsibilities in this domain. The ultimate goal of this solution is to help governments contain, control and effectively respond to a growing number of diverse threats and incidents: from piracy and smuggling of goods and narcotics, to irregular migration and maritime pollution, including Search and Rescue operations. Due to the afore stated, the COMPASS2020 project proposes to demonstrate the benefits of the developed solution by tackling two specific scenarios during the project's lifetime: (i) Search and Rescue mission derived from irregular migration and (ii) interception of narcotics smugglers. For these purposes the following assets will be used: (1) the Oceanic Patrol Vessel (OPV) operated by the Portuguese Maritime Authority designed as a multi-mission platform; (2) AR-3 Net Ray - a fully autonomous small-UAV with an endurance of up to 10 hours and a range of up to 150 km, launched by catapult and recovered by a net or parachute. It can serve maritime and coastal surveillance missions, working as operational extender for vessels as well as a communications relay to other vehicles and communications range extender; (3) AR-5 Life Ray - a medium-altitude and medium-endurance fixed-wing UAV specifically designed for search and rescue, long range surveillance and maritime patrol (up to 16 hours of endurance and a range of 1600 km); (4) Zephyr HAPS (UAV) - a high altitude pseudo-satellite (HAPS) that fills the gap between satellites and UAVs (70000 ft). This platform is being conceptually considered as part of the COMPASS2020 solution as it enables real-time mapping, internet and a number of surveillance opportunities to meet a broader range of requirements; (5) the A18-M - an autonomous underwater vehicle (AUV) that can be launched from OPV - it is capable of performing autonomous missions up to 300 m depth and it is easily transportable by plane for overseas missions. Its area of coverage is 2 km^2 per hour and it is widely used for defense and security actions. The layout of the main COMPASS2020 assets is shown in Figure 1.

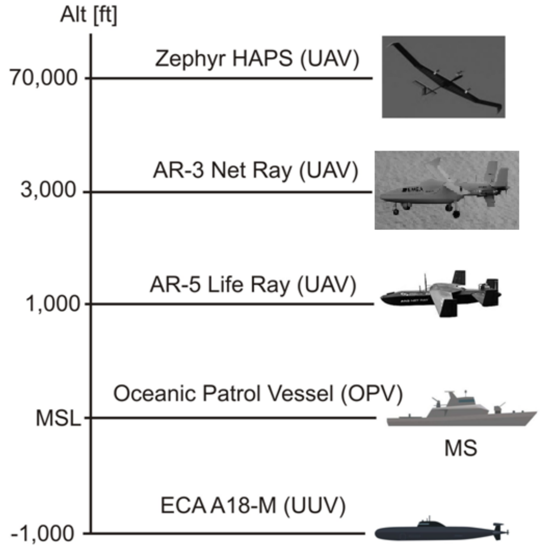

Figure 1. Scheme of COMPASS2020 four layered (un)manned architecture
(Source: Own)

In the case of search and rescue (SAR) mission derived from an **irregular migration situation** – a vessel carrying irregular migrants is in a distress situation beyond coastal waters, sending out EPIRB (Emergency Position Indicating Radio Beacon) signal in order to alert the European authorities. At the first phase of the mission, three types of assets are in the area performing persistence surveillance: the OPV, the Zephyr, and the A18-M. At the moment it receives the EPIRB alert, Zephyr immediately communicates this information to the operational commander that is working from the Marine Operations Center (MOC) through the COMPASS2020 Mission System (MS) replica onboard the OPV. In the following phase, the OPV will launch an AR-3 capable to collect data regarding the vessel in distress, thus enhancing the situational awareness of marine authorities concerning the risk level of the situation and allowing them to act timely and properly [1, p.11]. This action/data flow is schematically shown in Figure 2.

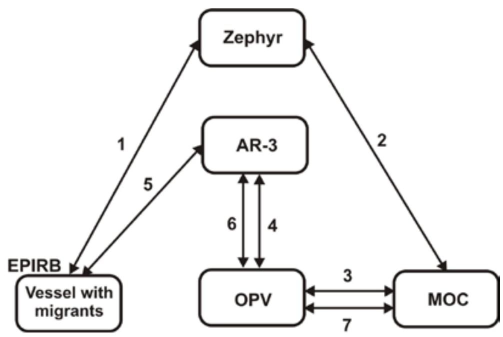

Figure 2. Action/information flow in the case of SAR mission derived from irregular migration
(Source: Own)

When it comes to **interception of narcotics smugglers** – the OPV, the Zephyr and the A-18 M are in action in the border area. The Mission System (MS) is running onboard the OPV and it is always connected with its replica at MOC. Zephyr is launched from MOC and it has to collect an overall picture of the area that is being surveyed. In addition, an AUV was previously deployed from the OPV into a strategic location that is coincident to the traffickers' typical routes. The AUV is programmed to follow circular trajectories in the area of interest, navigating underwater at low depth in order to remain undetected from the smugglers and staying closely enough to the surface in order to optimize the

IOP Conf. Series: Journal of Physics: Conf. Series **1357** (2019) 012045 doi:10.1088/1742-6596/1357/1/012045

possibility of detecting the target. It carries a set of hydrophones that enable detecting speed boats. After detection of the target, the AUV can communicate to the Zephyr, which is used as a communication relay in the system. The Zephyr sends automatically an alert to MS onboard OPV and its replica in the MOC. Once the MOC receives the alert, the officers proceed with the deployment of an AR-5 platform. The AR-5 has to come close to the vessel and acquire more detailed information about it. In accordance to this information, the officer onboard OPV can decide how to intercept the threat and act efficiently. If the smugglers try to get rid of the cargo, the AUV has the capacity of searching for it by making use of side scan sonar [1, p.10]. Data flow in this type of action is given in Figure 3.

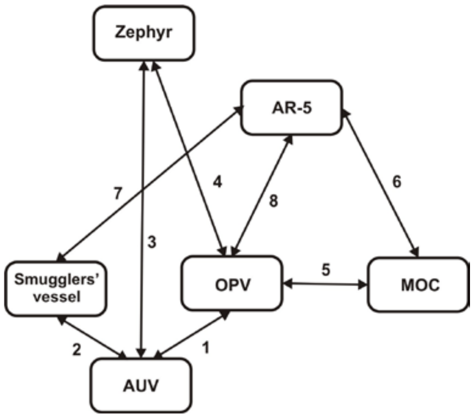

Figure 3. Action/information flow in the case of interception of narcotics smugglers
(Source: Own)

3. Maritime autonomous vehicles taxonomy

The most advanced components of the surveillance and supplementing SAR actions proposed by COMPASS2020 in order to address the challenges mentioned above are unmanned (air, sea, and underwater) vehicles, or shortly UxVs. The operational coordination of thes kinds of assets is an under-explored field and therefore below will be given some basic information concerning operation of marine fully autonomous and unmanned vehicles.

The first implementation of unmanned vehicles took place in space transport. Then, commercial use of rail unmanned transport devices was implemented to carry freight and people. Further applications take place in air transport for both military and civil transport purposes. Commercial use of autonomous cars and trucks on generally accessed roads are still at the phase of research. Similar situation is within sea transport [2].

The implementation of autonomous and unmanned vehicles at sea has to be preceded by solving numerous problems concerning legal, organizational and technological issues. When it comes to legal issues, International Maritime Organization (IMO) is working on it [3]. Recently, Maritime Safety Committee has been established as a working group dealing with safety issues at and in the vicinity of places where tests over autonomous and unmanned vessels are done. Besides this, Loyd's Register (LR) produced a document entitled "Cyber-enabled ships: Ship Right procedure – autonomous ships" (2016). In 2017 it produced another document titled "LR Code for Unmanned Marine Systems", which identifies goals and objectives for different unmanned vehicles [4]. Also, it is important to mention that LR defines seven autonomous levels of marine vehicles:

- AL0: no autonomous functions; all operations are manual;
- AL1: on-vessel decision support; data will be available to crew;
- AL2: off-vessel decision support; shore monitoring;
- AL4: human-on-the-loop; semi-autonomous vessel; crew can intervene;
- AL5: fully autonomous vessel; there is a means of human control;
- AL6: fully autonomous vessel that has no need for any human intervention.

On the latter ends of this scale one can see further class of vessels/ships called **unmanned** and this refers to vessels that are operated remotely so there is no one on board. Today almost all vessels have a certain level of autonomy, since numerous functions operate by themselves. So, the transition from "classical" to autonomous vehicles used at sea will be evolutionary rather than revolutionary. In other words, the transition will be gradual, and it will last most probably several decades.

Different operational issues are still unsolved and under consideration. However, technological solutions are already available to a large extent. Intensive research is done, including simulation tests, experiments on physical models and construction of prototypes. Below are listed some of the relevant projects in this domain [2]:

- MUNN – Maritime Unmanned Navigation through Intelligence in Networks;
- AAWA – Advanced Autonomous Waterborne Applications Initiative;
- STM Validation – Sea Traffic Management Validation Project
- AVAL – Autonomous Vessel with an Air Look, etc.

The basic information on these projects are available online. The COMPASS2020 is relying in terms of technology, safety and security [5] on findings of these and several other projects in the field. They are listed and shortly described in the COMPASS2020 proposal [1, p. 18-20]. It is realistic to expect that research and development (R&D) activities will be continued in order to ensure successful implementation and sustainability of COMPASS2020, including follow-up projects in the future.

4. Some R&D achievements

In attempt to support further activities within COMASS2020 project, we have made a search of similar research endeavors when it comes to autonomous and unmanned maritime vehicles. Thanks to our professional contacts we are introduced with the Faculty of Logistics and Maritime Technology of Satakunta University of Applied Scieneces (SAMK) from Rauma (Finland) work on building and testing of the autonomous ship technology on miniature training ship *Kaisa* (Figure 4). This work has been done in collaboration with Rolls-Royce Ltd and WinNova Ltd, the institute for vocational training education in Satakunta. Namely, the platform called ELSA utilized the miniature training ship *Kaisa* built in 1994, which is a model of passenger cruise ship *Society Adventur*er built in 1991. The detail description of this autonomous sea vehicle can be found in reference [6].

Figure 4. *Kaisa* prototype of an unmanned vessel

(Source: [6])

The model is remotely controlled from the control center. The center is located in the main building of the Faculty of Logistics and Maritime Technology of SAMK. It is equipped with large LCD screens for displaying the image provided by the onboard cameras, sensor data display and human machine interaction panel for remote manual steering of *Kaisa*. The lidar and machine vision data are collected onboard. The track control and DP computers for fully automated operation of the model are located in the remote-control center. The data transmission link between the vessel and the control center is a crucial part of the whole system and 4G network is used for this purpose. *Kaisa* is an objectified experiment used for students training and as an experimental polygon for postgraduate students at SAMK work on their master and doctoral thesis. It has certain advantages in comparison to simulation (more realistic) and full-size testing (more cost-effective). Continuation of experiments over *Kaisa* should bring new findings in the filed, which support (in)directly some challenges within the COMPASS2020 platform, particularly when it comes to data fusion and UxVs self-managing functions.

In addition to this experiment on a prototype in laboratory setting, numerous theoretical studies have been recently conducted. Some of them will be mentioned here as kind of guidelines for further research work within COMPASS. For instance, one research concerns Autonomic Computing (AC) as a potential solution to implement efficient self-management (self-managing capacities as: self-healing, self-protecting, self-organizing, self-optimizing and self-configuring) in autonomous maritime vehicles (AMVs) [7]. The aim of this research work is to indicate that the advanced versions of AC with fully integrated approach to autonomous capacities for next generation of AMVs should be more similar to human physiology and behavior.

There is also a comprehensive research work on AMVs in the domain of optimal path planning and control methods with different sensor technology like sonar, laser, acoustic modems and stereo vision systems for localization, navigation and mapping [7;8]. Also, it is important to mention that underwater wireless communications have recently achieved development [9]. Communication links and data fusion along with central control system and human-machine interface are among the key concerns within the COMPASS2020 and its successful implementation, so that the above listed research studies and similar ones might be use as referential at some point.

It is worth to mention in this context two extensive studies on autonomous/unmanned vehicles perception [10;11]. The first study provides up-to-date information about the advantages, disadvantages; limits and ideal applications of specific sensors. The second one deals with putting men back in the headlines despite the rise of autoimmunization in marine and shipping industry. Namely, according to this study "85% of those surveyed agreed that seafarer skills will remain an essential component in the long-term future of the shipping sector" [11, p.4]. In other words, the findings of the study suggest that the human will remain an essential component in the long-term future of shipping, even if that future is autonomous.

5. Conclusion

The paper gives an overview of EU COMPASS2020 project developed for surveillance and SAR actions at sea in situations of illegal migrations (border crossings) and narcotics trafficking (interception of narcotics smugglers). The architecture at high level and core action/information flows of the system are presented. Since the system deploys autonomous and unmanned (air, sea surface, and underwater) vehicles, taxonomy dealing with these advanced and complex vehicles, including the degree of their autonomy is given, as well. In order to support further R&D activities within the project, some recent experimental and theoretical studies in the field are introduced. As next steps in our research work, we plan to explore in some more detail technological performances of each asset within COMPASS including communication channels and protocols [12], as well as data fusion and presentation on the network application layer. This will be done in parallel with experiments in real setting, i.e., in maritime environment under risk threats.

Acknowledgements

This work has been partially funded by the EU Research and Innovation program HORIZON 2020, COMPASS2020 project - Grant Agreement No: 833650

References:

[1] COMPASS2020 – Coordination of Maritime assets for Persistent And Systematic Surveillance, Project documentation (Boosting the effectiveness of the Security Union, H2020-SU-SEC-2018-2019-2020), pp. 1-70.

[2] Pietrzykowski Z., Hajduk J., Operations of Maritime Surface Ships, Proceedings of the 13th TransNav Conference, June 12-14, 2019, Gdynia, Poland (to appear).

[3] MSC 98/20/2. Maritime Autonomous Surface Ships. Proposal for a regulatory scoping exercise. Submitted by Denmark, Estonia, Finland, Japan, the Netherlands, Norway, the Republic of Korea, the United Kingdom and the United States. 27th February 2017.

[4] Meadow G.C., Cross J., Autonomous Ships 101, The Journal of Ocean Technology, Vol.12, No.3, pp. 23-27.

[5] Laurinen M., Advanced Autonomous Waterborne Applications Initiative – AAWA Seminar Helsinki, Finland. Available from Internet, Last acces on June 6, 2019).

[6] Ahvenjarvi S., Platform for Development of the Autonomous Ship Technology, in Marine Navigation (Ed. A Weintrit), Proceedings of the 12th International Conference on Marine Navigation and Safety of Sea Transportation (TransNav 2017), June 21-23, 2017, Gdynia, Poland, pages 5.

[7] Insaurralde C.C., Autonomic computing technology for autonomous marine vehicles, Ocean Engineering 74 (2013) 233-246.

[8] Hinostroza M.A., Haitong Xu, Guedes Soares C., Cooperative operation of autonomous surface vehicles for maintaining formation in complex marine environment, Ocean Engineering 183 (2019) 132-154.

[9] Sahoo A., Dwivedy S.K., Robi P.S., Advancements in the field of autonomous underwater vehicle, Ocean Engineering 181 (2019) 145-160.

[10] Van Brummelen J. et al., Autonomous vehicle perception: The technology of today and tomorrow,

Transport Research Part C 89 (2018) 384-406.
[11] Meadow G., Ridgwell D., Kelly D., Autonomous Shipping – Putting the human back in the headline, Institute of Marine Engineering, Science & Technology – IMAREST, Sigapore, April 2018, pp. 1-23.
[12] Bauk S., A Review of NAVDAT and VDES as Upgrade of Maritime Communication Systems, Proceedings of the 13th TransNav Conference, June 12-14, 2019, Gdynia, Poland (to appear)