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Uncrewed Surface Vehicles (USV): from survey to shipping

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***Abstract* – Autonomy and unmanned systems have evolved significantly in recent decades, becoming a key routine component for various sectors and domains as an intrinsic sign of their improvement, the ocean not being an exception. This paper shows the transition from the research concept to the commercial product and related services for Uncrewed Surface Vehicles (USV). Note that it has not always been easy in most cases due to limitations on the technology, business, and policy framework sides. An overview of current trends in USV technology looking for a baseline to understand the sector where some experiences of the authors are shown in this work. The analysis presented shows a multidisciplinary approach to the field. USV's capabilities and applications today include a wide range of operations and services aimed at meeting the specific needs of the maritime sector. This important consideration for USV has yet to be fully addressed, but progress is being made to best contribute, among others, to the development and consolidation of the European Research Infrastructure (RI) on Marine Robotics (EUMR) where USV should play a key role.**

Keywords *- ASV, USV, Robotics, Research Infrastructure, Ocean Observing*

I. INTRODUCTION

As a key element of exploration, commerce and war, ships have always involved engineering solutions to difficult problems and talented humans to build and operate them. Nowadays there are many small and medium-size uncrewed boats in routine-use paving the way toward fully autonomous vessels as ultimate step in this sector. Many institutions, universities and companies have begun developing Uncrewed Surface Vehicles (USV) aiming to cover a wide range of applications and services, evolving rapidly. With growing worldwide interest in commercial, scientific, and military issues associated with both open-ocean and shallow waters, there has been a corresponding growth in demand for the development of more complex USV with advanced guidance, navigation, and control (GNC) functionalities. The development of fully-autonomous USV is underway aiming to minimize both human control needs and the effects to the effective and reliable operation from human errors. USV are defined as unmanned vehicles which perform tasks in a wide range of environments without any human intervention with highly nonlinear dynamics. With the inclusion of a more robust, commercially available and affordable navigation equipment (GPS, IMU, etc.), wireless telemetry systems, "blue" power sources and trending intelligent-analytics technologies (Artificial Intelligence, etc.) the applications range for USV has significantly increased and improved in key marine and maritime domains and sectors.

II. USV-TECHNOLOGY: DEVELOPMENTS AND MILESTONES

After clearly experimental beginnings with limited capabilities in terms autonomy, endurance, payload, power outputs, etc., in recent years significant progress has been made in all USV subsystem components (hull and structural elements, propulsion and power system, GNC, telemetry, payloads, data management and ground station), enabling USV a leading commercial technology solution in several applications and services (some on a routine basis) beyond the military and research. The initial reference on the path to autonomous ships is technical. The core technologies that enable uncrewed vessels has come about largely due to developments in other fields. Improved USV capabilities allow to undertake missions both in coastal and open-ocean areas for long periods of time due to a more efficient power and propulsion systems based in some cases on renewable energy sources (solar, wind, waves). State-of-the-art broadband telemetry systems enable remote real-time operation and decision-making by the operator. In parallel with the mechanical and electronic system architecture improvements for USVs, software advanced rapidly as well, with special focus on autonomous navigation methods and techniques in compliance and contribution to ocean digitalization and e-navigation framework initiatives. Considering hull dimension and propulsion system as classification factors, several flag-ship developments through last decade have been released (Fig. 1) highlighting Sailbuoy tested as pre-commercial solution at PLOCAN open-ocean observatory in 2012; Wave Glider robust enough to complete a crossing of the Pacific Ocean from California to Australia or successfully accomplish routing transects across the Macaronesia region by PLOCAN; AutoNaut performed trials at PLOCAN testy-site waters for marine mammal monitoring; C.-Enduro; the Saildrone able to perform long-range missions such circumnavigate the Antarctica and ATL2MED being PLOCAN an active member in the second one providing its test-site facilities for launching and initial field validations; DriX with specific applications on survey-services for industry; Mayflower expecting to sail between Plymouth-Cape Cod (MA, USA); Sphyrna hat focusses on passive acoustic monitoring applications; Data Explorer; XO-450 for energy and seabed mapping commercial survey services; SeaTrac; S10-submaran as hybrid concept able to both sail the ocean surface and glide the water-column as underwater vehicle. All of them are fully or partially powered by endless ocean-energy sources. In parallel, half-way to autonomous ship concept, developments such Sea-KIT; Ocean Infinity have also been released for specific seabed-mapping and survey-services in industry applications at ocean-basin level worldwide. These developments, many of them already commercial, have demonstrated that specialty USV could withstand the harsh ocean environment for extended periods and their software and systems were reliable enough for extended voyages and missions.

Fig 1. USV technologies currently available for operation

III. AUTONOMOUS VESSELS: THE ULTIMATE STEP TOWARDS SHIPPING 4.0 IMPLEMENTATION

We are nowadays facing a step further towards a new paradigm associated with cyber-physical systems, big data and autonomy as part of Shipping 4.0 and Digital Ocean international trends and strategies. Efforts in transport cost reduction, the global need of minimize emissions and the demand for improving safety at sea are three base reasons on why autonomous shipping is under consideration and early stages of implementation. The development and future implementation of vessels as MASS (Maritime Autonomous Surface Ship) will represent an inflexion point for the paradigm shift in the industry and maritime shipping system as a whole. Industries related to high specialized technology base sectors such autonomy and automation, unmanned operations, big data, artificial intelligence, machine learning, enterprise-grade connectivity and analytics will be essential. Although some regulatory aspects of manned vessels may be compatible with unmanned vessels, such as certain clauses of the International Safety Management (ISM) Code, there is a need for specific international regulations taking into account the characteristics of unmanned vessels as well. As ultimate regulator responsible for the COLREGs, the International Maritime Organization (IMO) in 2017 agreed to include marine autonomous surface ships (MASS) in agenda and started with a scoping exercise to determine how the safe, secure and environmentally sound operation of MASS might be introduced in IMO policies and rules.

Level	Description
1	Ship with automated processes and decision support
2	Remotely controlled ships with seafarers onboard
3	Remotely controlled ships without seafarers onboard
4	Fully autonomous ships

Table 1. MASS Levels of Control according to IMO's regulatory scoping exercise from 2018

IV. CONCLUSIONS

In this paper, a global vision of the USV sector has been shown from the experiences of the authors in PLOCAN. A detailed analysis about the present and future of this sector has been depicted. An especial emphasis has been done in showing the interdisciplinary nature of the field, involving technological, commercial and regulatory aspects. The technological developments presented include a multidisciplinary set of state-of-the-art: sensors and systems for positioning, navigation, control, telemetry, propulsion, route planning, as well as specific tools for supervision and situational awareness operations, being key the inclusion of the AI techniques. IMO is developing a global regulatory framework for MASS implementation in coming years.

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