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## Executive summary

In-situ observations provide key information about the Ocean environment – its physical, biogeochemical, geological and ecological characteristics. To ensure the long-term stability of ocean information, the totality of the underlying in-situ ocean-observing system, comprising networks of different observing platforms and sensors, needs to be recognized as a critical global infrastructure.

Currently, there are numerous programmes, projects and initiatives working to develop and implement effective ocean observing capacities, operating at different geographical scales (local, national, regional, pan-European and international) and different timescales (real-time, daily, monthly, annually, etc). These capabilities are, by their nature, highly fragmented and complex. While there is some coordination at global level, for example under the auspices of GOOS and the OCG, a strengthening in coordination at regional scale is necessary to ensure that the right observations are made and that they are made on a systematic and sustained basis. An overarching strategy across all measurement platforms is required to ensure that best use is made of limited resources in Member States and at European level. The European Ocean Observing System (EOOS) links the currently disparate components of the observing system in Europe and will promote novel technology and infrastructure development, standardization, open access to data, and capacity building.

Autonomous and uncrewed systems have significantly improved and evolved in the last decades to provide a key platform for several sectors and domains, including ocean observing systems. Transition from research concept to commercial product and related services has not always been easy due to technology, business and policy framework constraints. Autonomous Surface Vehicles (ASV) development and implementation illustrates this evolution. Starting as small custom-prototypes operating near shore for survey and research applications, ASV have evolved into more complex and capable platforms that are now able to operate in highly demanding scenarios and the open-ocean for long periods in routine-fully-autonomous mode. This progress has paved the way for small and large-scale autonomous ships (MASS) to be used as an ultimate step in maritime autonomy.

Within the framework of in-situ ocean-observing technologies acting as recognized international network in support to global observing strategies, this initiative is aiming to engage key actors from the “triple-helix” perspective representing developers, industry, research, end-users and regulatory bodies to provide an overview on current trends in ASV technology, while seeking a baseline understanding of the sector from lessons learned and current status at technical, operational, data management and policy/regulatory levels to be used as the basis for a ASV Network implementation.

Technology developments enabling ASV include a multidisciplinary set of cutting-edge sensors and systems for measuring, sampling, guidance, navigation, control, telemetry, propulsion, path planning, as well as specific tools for oversight of operations and situational awareness, including key applications of machine/deep learning and artificial intelligence techniques. ASV capabilities and applications presently include a wide range of operations and services that address specific needs from marine and maritime sectors, highlighting ocean observing in both coastal and open-ocean areas, as well as providing unique features like monitoring at the same time Essential Climate and Ocean Variables in support to WMO and GOOS respectively or acting as gateway to link in real time underwater observations with satellite platforms.

The EU-funded EuroSea project provides a unique framework opportunity to define the basis and implement a recognized useful ASV Network in support to international ocean-observing initiatives such as GOOS or EOO from a synergetic approach with already existing ocean-observing networks (moorings, floats, gliders, radars, FerryBox, tide-gauges, etc.).

This document reports on the main actions undertaken and objectives achieved within the framework of the execution of activity 3.7 of the EuroSea project. For this, both the execution and results derived from the execution of the two workshops (one online and the other hybrid) are described, as well as the promotion and engagement actions through attendance and participation in national and international conferences, seminars and technological forums, where the EuroSea ASV-Network initiative has been shown. As a whole, this activity has mainly allowed 1) To identify the main agents of the public and private sector related to ASV technologies, of which a large number have already shown their interest and commitment in supporting and being part of the initiative, 2) To define the main topics and priorities (technological development, applications, regulatory framework, good practices, etc.), where the ASV network should focus its development and implementation both specifically and in relation with other existing ocean-observing networks to fulfil the global ocean-observation strategy, 3) To define a roadmap on which to base the future development and implementation of the ASV network, which includes nominating working group leaders and national delegates as coordinators, 4) To identify and synergistically approach strategies with the OASIS initiative which is being developed by NOAA in the USA endorsed by the UN Ocean Decade program, 5) To propose ways in order to sustain the ASV Network initiative beyond EuroSea project framework (annual meeting, site meetings during attendance to other conferences and seminars, new project proposal, endorsement from existing ocean-observing programs and initiatives such RIs or similar, etc.).

## 1. Ocean Observing: Why a need?

The ocean is a key component of the Global Earth System influencing the global/regional climate, weather, ecosystems, living resources and biodiversity. The ocean plays a key role in many human activities such coastal protection, tourism, search and rescue, defense and security, shipping, aquaculture and fisheries, offshore industry, and marine renewable energy, among others. Ocean observation enables us to better understand ocean functions and meet societal needs related to these activities. The Intergovernmental Oceanographic Commission (IOC of UNESCO) developed the Global Ocean Observing System (GOOS) more than two decades ago to coordinate different national efforts in terms of sustained ocean observations throughout the world and to maximize the societal benefits of ocean observations. GOOS was established in 1991 by the Member States of the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), with the World Meteorological Organization (WMO), UN Environment, and the International Science Council (ISC) later joining as sponsors. Over the past quarter-century, the GOOS community and partners have worked in a good progress coordinating global ocean climate observing and information products and in supporting observations for operational forecast systems. More recently, GOOS has had a growing focus on an integrated global observing system including a wider range of data types and serving a broader range of users, consisted with the Framework of Ocean Observing (FOO). In 2012, the IOC General Assembly unanimously endorsed all the FOO recommendations. A new GOOS Steering Committee was established to replace the IOC Intergovernmental Committee on GOOS and its supporting GOOS Scientific Steering Committee. Three new recommended expert panels were formed, and the GRA Council was reinvigorated.

The resulting Framework for Ocean Observing has been widely endorsed by the ocean observing community and adopted formally by GOOS as a guiding document. In addition to its extensive recommendations on the design of an enhanced ocean observing system, the FOO made two recommendations on governance: (1) To simplify and strengthen the high-level governance of GOOS, establish a single, expertise-based Steering Committee reporting directly to the IOC officers and members; and (2) Establish two new GOOS Panels – for Biogeochemistry, and for Biology and Ecosystems, to complement the existing Observations of Ocean Physics and Climate Panel. (Tanhua et al., 2019)

The FOO argues that it is essential that governance of the global ocean observing system reflects the needs and contributions of both the broad ocean observing system community (scientists, institutions, observing system managers) and the IOC member states who should represent their national and collectively the international community's interests and users of ocean information. The FOO provides a structure that allows ocean observing providers and users to engage in the system at various points. It traces the path from Inputs (e.g., essential ocean variables) to Processes (observations and maintenance), to Outputs (data and products). It has helped form an understanding of the elements of the system as a whole and has facilitated the activities of GOOS in many areas. (Miloslavich et al., 2018)

The common language and system design principles introduced by the FOO are: (1) Essential Ocean Variables (EOVs); (2) Requirements; (3) Observing system elements; (4) Data management and information products; (5) Readiness levels for requirements, observations, and data/information; (6) Incorporation of both coastal and open ocean observations; (7) Feedback loops addressing science challenges and social needs.

In the last two decades, discussions on GOOS highlighted the tremendous potential value for physical, biogeochemical, and biological observations, particularly in the transition between the open-ocean and the coastal environment, which is a key area for societal issues, economical applications and at the same time is a prime area for autonomous technologies' observations. (Lindstrom et al., 2012)



Figure 1. Schematic overview of the ocean observing system based on autonomous in-situ platforms retrieved from ATLANTOS project website.

In-situ observations provide key information about the ocean environment – its physical, biogeochemical, geological and ecological characteristics (Figure 1). They are essential to monitor critical aspects of the state,

change, and variability of the subsurface Ocean, which comprises 97% by volume of the global biosphere, takes up and redistributes 93% of excess heat in the Earth system, and absorbs over 25% of all human-produced carbon emissions. (Lubchenco and Gaines, 2019)

To ensure the long-term stability of ocean information, the totality of the underlying in situ ocean-observing system, comprising networks of different observing platforms and sensors, needs to be recognized as a critical global infrastructure. This mostly publicly funded infrastructure generates openly accessible data as a global public good from which specific information products and knowledge are created to deliver direct and indirect benefits to society as a whole by informing public policy, governance and business decisions. Such infrastructure needs a strong mandate, including a legal basis to secure binding commitments in a sustained way and in accordance with international standards, including an appropriate data policy for open access and sharing of data. National observing systems and roadmaps should be better aligned and deeper cooperation with regional governing bodies is needed. The required growth of the system urgently needs to be matched with more innovative, holistic and integrative thinking about how to sustainably finance and coordinate these observations.

Autonomous platforms are making measurements over a wide array of spatial and temporal periods is a more efficient and sustainable way than traditional ship-based technologies. Observations range from large-scale processes to small-scale variabilities in salinity, temperature, nitrate, pressure, oxygen, biomass; and many other parameters, depending on the needs of the user. Autonomous technologies for ocean observations in use today include aerial, surface, and subsurface vehicles, satellites, buoys, subsea moorings, and bottom nodes. Observation systems can use any or all of these elements. True autonomy is still unavailable; all these observation systems still require a significant deal of human interaction and support. The largest platforms now support payloads that many years ago would have required manned research vessels. These platforms are still quite expensive and complex. Conversely, systems of numerous, small, and inexpensive observing platforms can increase spatio-temporal coverage, but only for a limited number of ocean variables because small size and limited power implies a limited scientific payload.

Sustained, long-term global in-situ Ocean observations are required to support climate and environmental policies, i.e. the European Green Deal, and policies aiming to reach net zero carbon, achieve a sustainable blue economy, protect nature, and reverse the degradation of ecosystems. They are crucial for discovering unexplored parts of the ocean, and to better observe, monitor and predict the physics, chemistry, biology and geology of the ocean from global to coastal scales. This is needed to better understand and predict climate change and its impacts on global Ocean ecosystems, increase resilience, develop sound mitigation and adaptation strategies to natural and man-made hazard impacts, and better protect marine ecosystems, among many other uses. These benefits are linked to the need to protect biodiversity, ensure a healthy ocean and allow a sustainable use of marine resources, which rely on biological observations and need further efforts to be fully integrated into the global ocean-observing system. They generate baseline knowledge informing ocean governance, ocean economic opportunities, and sustainable development. In-situ Ocean observations are also pivotal to improve weather predictions, predict extreme events such as Harmful Algal Blooms, and inform tsunami warning systems, among many others. (European Marine Board, 2021)

Globally, meteorological services are driven by a primary purpose: to deliver weather forecasts to protect lives, property and livelihoods. A report on the value of surface-based meteorological observations (including at the sea surface) makes the case for the development of the Global Basic Observing Network, indicating that this could generate more than USD \$5 billion annually, with a benefit-to-cost ratio of 25. As weather and climate predictions extend further into the future, sub-surface Ocean observations will be increasingly

necessary. National weather prediction services are coupling atmospheric models to Ocean models – because heat energy that fuels weather systems is stored in the subsurface. The impact of ocean observations on future weather predictions will therefore require close partnering with meteorological services. (Fujii et al., 2019)

Operational oceanography systems such as the Copernicus Marine Environmental Monitoring Service (CMEMS) integrate in-situ and satellite observations with model predictions to provide a wide range of Ocean services with large socioeconomic impacts such as for maritime transport, fisheries and aquaculture, oil and gas, and marine renewable energy.

Although the benefits of ocean-observing are difficult to comprehensively identify and value, a high benefit-to-cost ratio for investing in ocean-observing has been described in several case studies. However, more work needs to be done to value the social, economic and environmental benefits of ocean-observing, as many of the societal benefits are also associated with improved science and therefore do not have a readily measurable economic value. It is indisputable that it is necessary to invest in in-situ observations and satellite constellations to have reliable systems to enable ocean predictions.

Rapid technological innovations that have reached certain maturity and reliability have made systematic, sustained ocean measurements possible that would not have been achievable two decades ago. However, the institutional and funding landscape are yet to catch up with the technological innovations that have made sustained ocean-observing possible. Each country has its own national landscape of institutions responsible for ocean observations: meteorological agencies, ocean agencies, the navy, national research agencies, research councils, environmental agencies, national laboratories and academic institutions all play a role. This situation has led to fragility, in particular on the product side of the ocean-observing value chain. More coherent governance, a better-defined core mission, together with a more strategic approach to evolve the observing system would enable more sustained funding to continually observe the ocean in a smarter and sustainable way.

## 2. Autonomous Surface Vehicles Technology: An Overview

### 2.1. 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. For thousands of years sailors have placed their trust, and their lives, in constructions of wood, then steel, in the face of a challenging ocean. It could be said that the age of “autonomy” has been slow to come to ships. But this is changing. Nowadays there are many small and medium-size unmanned boats in routine-use paving the way toward fully autonomous vessels as ultimate step in this sector.

Global investment in technology has transformed maritime domain awareness and is set to continue into the future (Friedman et al., 2020). Automatic Identification System (AIS), Vessel Monitoring Systems (VMS) and satellite technology are examples of strategic investments used to improve monitoring, control and surveillance, particularly in large ocean nations (Wood and Weigel, 2011; Dunn et al., 2018). Recently, remotely operated and autonomous technologies such as gliders, uncrewed aerial vehicles, smart buoys and Argos profiling floats have filled spatial and temporal voids (Manley, 2008). However, these are limited by their design and implementation in their capacity to communicate and persist simultaneously.

Uncrewed and autonomous surface vessels are promising innovations due to their continuous access to communications, renewable surface energy, available propulsion sources, scalable payload and simultaneous access to the water-surface interface (Roberts and Sutton, 2006; Liu et al., 2016; Manley, 2016; Manley, 2019; Costanzi et al., 2020). Uncrewed Surface Vessels (USV), also referred to as Autonomous Surface Vessels (ASV), have varying levels of autonomy, and most rely on human decision making for the safety of crewed vessels at sea [the International Regulations for Avoiding Collisions at Sea (COLREGs, 1972)] and for maintaining operational environmental awareness. Definitions of autonomy vary worldwide, with eight different institutional standards of autonomy levels discussed in the Committee on Coast Guard Maritime Domain Awareness (2020).

USVs are relatively simple and low-cost. Continuous real-time communications analogous to an onboard environment allow operational flexibility and human decision-making for a multitude of applications, such as national security and surveillance, scientific data collection, and asset monitoring and protection (Ziegwied et al., 2016; Eleftherakis and Vicen-Bueno, 2020; Siddle et al., 2021; Sutton et al., 2021). USVs can increase precision for some tasks (Li et al., 2019; Raber and Schill, 2019) and be scaled in numbers to operate in bricks or service multiple locations concurrently for the price of a single crewed ship (Cole, 2020; Costanzi et al., 2020). Successful technological diffusion of innovations such as USVs depends on the gradual uptake of the technology by the community. USV uptake is apparently constrained despite scores of commercial prototypes rapidly becoming available (Liu et al., 2016). Suggestions for the slow uptake include low consumer confidence (Costanzi et al., 2020), lagging legal and regulatory frameworks (Campbell et al., 2012; Negoro et al., 2020) and high capital costs of specialized new assets (Gu et al., 2020) where investments have already been made in multi-use flagships. However, there has been no overarching and systematic study to determine what might be limiting this hopeful technology's uptake.

Many institutions, universities and companies have begun developing Autonomous Surface Vehicles (ASV) aiming to cover a wide range of applications and services, evolving rapidly (Figure 2). 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 ASV with advanced guidance, navigation, and control (GNC) functionalities. The development of fully autonomous ASV is underway aiming to minimize both human control needs and the effects to the effective and reliable operation from human errors. (Campbell et al., 2012)

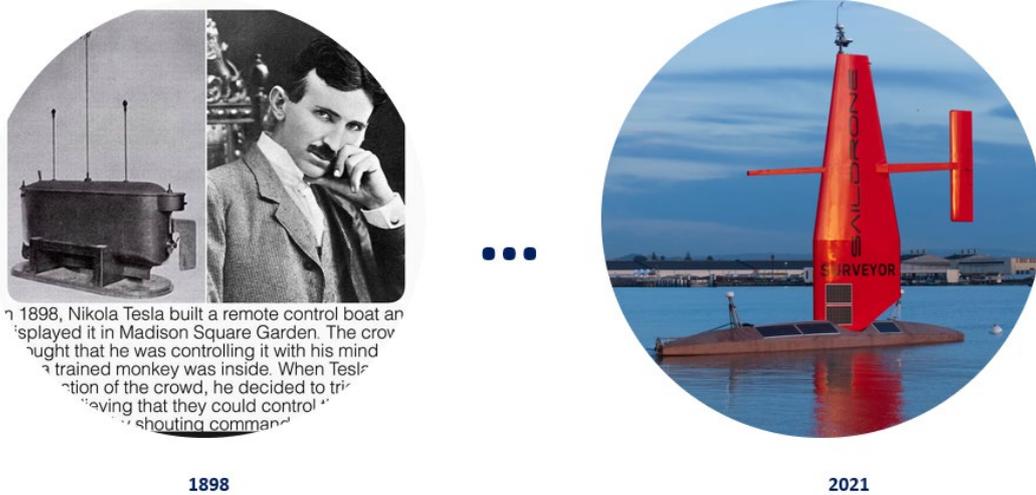


Figure 2. On the left, the first prototype of ASV developed by Nikola Tesla in 1898. On the right, a current ASV manufactured by Sairdrone company.

ASV are defined as unmanned vehicles which perform tasks in a wide range of environments without any human intervention with highly nonlinear dynamics. Further improvements on ASV technology are expected to bring tremendous benefits, such a lower development and operation cost, improved staff safety, extended operational range and precision, greater autonomy, as well as increased flexibility in sophisticated environments and dangerous missions (Roberts et al., 2006; Bertram, 2008; Breivik, 2010). 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 such artificial Intelligence, machine/deep learning, etc. (Nilsson, 1982; Michalski et al., 1983; Marichal et al., 2001; Matia et al., 2014), the applications range for ASV has significantly increased and improved in key domains and sectors such as scientific research, environmental missions, ocean exploration, military uses and other applications (transportation, communication relays, refuelling, unmanned aerial or unmanned underwater vehicles platform, etc.) (Marichal et al., 2016; Liu et al. 2016; Barrera, 2019). (Table 1)

Country	Year	USV Name	Research Purpose & Major Achievements
USA	1993	ARTEMIS (Vaneck et al., 1996)	1) Systems test; 2) Bathymetry sampling
	1996	ACES (Manley, 1997)	1) Oceanographic data collection
	1998	SCOUT (Goudey et al., 1998)	1) Cooperative control; 2) Testbed
	1990s	Roboski (Bremer et al., 2007)	1) Surveillance; 2) Target drones
	1990s	Owls USVs (Motwani, 2012)	1) Harbor and ship security
	2000	AutoCat (Manley et al., 2000)	1) Survey of shipwreck
	2001	Spartan Scout (Motwani, 2012)	1) Port surveillance; 2) Force protection
	2003	USSV-HTF (Motwani, 2012)	1) Towing various sensors and effectors
	2005	WASP (Mahacek, 2005)	1) Stability test; 2) Bathymetric mapping
	2005	Seadoo Challenger 2000 (Ebken et al., 2005)	1) Collision avoidance; 2) Autonomous recovery
	2005	HUSCy (Curcio et al., 2005)	1) Hydrographic survey
	2008	Wave Glider (Bingham et al., 2012)	1) Data collection
	2008	Nereus (Beck et al., 2009)	1) Stability test; 2) Bathymetric mapping
2009	SeaWASP (Furfaro et al., 2009)	1) Environmental monitoring; 2) Testbed	
2010	Piranha (Yang et al., 2011)	1) Reconnaissance	
2011	MUSCL (Bertram, 2008)	1) Surveillance and reconnaissance	
UK	1990s	MIMIR (Roberts & Sutton, 2006)	1) Shallow water search and survey
	2000s	C-series USVs (Anonymous, 2014a)	1) Assets security; 2) Environmental monitoring; 3) Mining
	2000s	FENRIR (Roberts & Sutton, 2006)	1) Relay between UUV and control center
	2000s	Sentry (Murray, 2008)	1) Harbor and shore survey and protection
	2003	SWIMS (Roberts & Sutton, 2006)	1) Mine sweeping
	2003	SeaFox (Yakimenko & Kragelund, 2011)	1) Maritime security operations
Canada	2004	Springer (Naeem et al., 2008b)	1) Environment monitoring; 2) Test platform
	2008	Blackfish (Sonnenburg, 2012)	1) Harbor protection and patrol
	1983	DOLPHIN (Curcio et al., 2005)	1) Bathymetric mapping
Italy	2000s	Barracuda (Bertram, 2008)	1) As sea-surface target system
	2000s	Hammerhead (Bertram, 2008)	1) Simulating a multi-vehicle swarm threat
Portugal	2004	SESAMO (Caccia et al., 2005)	1) Environmental sampling
	2005	Charlie (Caccia et al., 2007)	1) Environmental sampling and survey
	2007	ALANIS (Bibuli et al., 2012)	1) Environmental sampling and survey
	2008	U-Ranger (Motwani, 2012)	1) Mine sweeping; 2) Harbor protection
Norway	2000	CARAVELA (Pascoal et al., 2006)	1) Oceanographic sampling; 2) Testbed
	2004	DELFIN (Alves et al., 2006) and DELFIMX (Gomes et al., 2006)	1) Oceanographic sampling; 2) Communication with UUVs
	2006	ROAZ I & II (Martins et al., 2007a)	1) Search and rescue
Israel	2006	Swordfish (Ferreira et al., 2007)	1) Environmental survey
	2008	Kaasbøll (Breivik et al., 2008)	1) Navigation and control systems test
Germany	2008	Viknes (Breivik, 2010)	1) Multi-purpose system tests
	2000s	Mariner (Breivik, 2010)	1) Environmental surveillance and sampling
	2003	Protector (Breivik et al., 2008)	1) Reconnaissance; 2) Counter-mine
France	2005	Seastar (Yang et al., 2011)	1) Port, coastal survey; 2) Reconnaissance
	2005	Stingray (Bertram, 2008)	1) Homeland security and coastguard
Sweden	2007	Silver Marlin (Bertram, 2008)	1) Surveillance and reconnaissance
	1998	MESSIN (Majohr & Buch, 2006)	1) Water ecological study
Singapore	2005	Basil (Bertram, 2008)	1) Offshore pipelines survey
	2005	MiniVAMP (Bertram, 2008)	1) Remote survey of offshore pipelines
China	2007	Inspector (Yang et al., 2011)	1) Surveillance and reconnaissance
	2002	Piraya (Yang et al., 2011)	1) Cooperative control
Japan	2010	Venus (Bertram, 2008)	1) Multi-tasks test
	2008	Tianxiang One (Yan et al., 2010)	1) Meteorological survey
India	2010	USV-ZhengHe (Yang et al., 2011)	1) Inshore marine data collection
	2000	Kan-Chan (Desa et al., 2007)	1) Study of global warming
	2004	UMV series (Bertram, 2008)	1) Ocean and atmosphere exploration
	2006	ROSS (Desa et al., 2007)	1) Oceanographic sampling

Table 1. Representative USV developments at academia level according to bibliography review by Liu et al. 2016.

An ASV is, by definition, an unmanned vessel that operates on the sea surface without real-time input or control from human operators (Bratić et al., 2019). This platform can be equipped with many of the same sensors as an AUV. Pre-planned mission paths, often following a ‘lawn-mowing’ pattern, are transmitted to the ASV and, once it is in the water, the AUV will navigate to the first monitoring location, conduct the entire mission, and then return to its starting point. The ASV is always at the surface, therefore, it can constantly maintain a GPS fix, eliminating the need for dead-reckoning navigation as used by AUVs. ASVs can range from small platforms that carry only one sensor, to large vessels greater than 10 m in length that carry comprehensive sensor suites. Differences in propulsion, as with AUVs, are also seen in different types of ASVs. Some ASVs are propelled solely by wind like a sailboat, some use rechargeable batteries, while others are propelled using fuel.

## 2.2. ASV Technology: Main Developments and Milestones

Through the last two decades, several ASV developments have been undertaken through public and private initiatives with diverse scope and purpose (Manley, 2008; Motwani, 2012; Verfuss et al., 2019). After clearly experimental first steps with limited capabilities in terms autonomy, endurance, payload, power outputs, etc., in recent years significant progress has been made in all ASV subsystem components (hull and structural elements, propulsion and power system, GNC, telemetry, payloads, data management and ground station), enabling ASV a leading commercial technology solution in several applications and services (some on a routine basis) beyond the military and research (Fossen, 1994; Caccia, 2006).

The initial reference on the path to autonomous ships is technical (Lambert et al., 2007; Fossen, 2011; Bibuli et al., 2012). The core technologies that enable unmanned vessels have come about largely due to developments in other fields (Bremer et al., 2007; Ferreira et al., 2007; Martins et al., 2007; Cruz et al., 2008). Improved ASV 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 ASVs, 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.

While small ASV developments are usually deployed within sight of the operator there are many others that go further (Figure 3). Considering hull dimension and propulsion system as classification factors, several flagship developments have been released in the last decade, highlighting Sailbuoy (Offshore Sensing, Norway) tested as pre-commercial solution at PLOCAN open-ocean observatory in 2012 (Fer and Peddie, 2012); Wave Glider (Liquid Robotics, USA) robust enough to complete a crossing of the Pacific Ocean from California to Australia (Hine et al., 2009; Daniel et al., 2011); AutoNaut (Autonaut-Seiche, UK) performed trials at PLOCAN test-site waters for marine mammal monitoring (Johnston and Poole, 2017); C-Enduro (L3 Harris, UK); the Saildrone (Saildrone, USA) able to perform long-range missions such circumnavigate the Antarctica and ATL2MED (Zhang et al. 2019; ATL2MED-ICOS Saildrone Mission, 2019); DriX (iXblue, France) with specific applications on routine off-shore survey-services for industry (iXblue-DriX USV, 2018); Mayflower (MARS, 2015) expecting to sail between Plymouth-Cape Cod (MA, USA); Sphyrna (SeaProven, France) that focusses on passive acoustic monitoring applications (SEAPROVEN, 2015); XO-450 (Xocean, UK) mainly addressed for energy and seabed mapping commercial survey services (XOCEAN XO-450, 2018); SeaTrac (USA) and SeaSats (USA); S10-submaran (Ocean Aero, USA) as hybrid concept able to both sail the ocean surface and glide the water-column as underwater vehicle (OCEAN AERO S-10, 2015); GPASEABOTS (GPA, Spain); etc. among other existing ASV technologies.



Figure 3. Some examples of the ASV technologies currently available for science and industry services. From left to right and top to bottom, WaveGlider (Liquid Robotics), Drix (EXAIL), Sailbuoy (Offshore Sensing), XO-450 (XOCEAN), (SeaTrack), (GPA-SeaBots), Explorer (Saildrone), SeaKit (Fugro), Spyrna (Seaproven), C-Enduro (L3 ASV), Sounder (Kongsberg Maritime) and AutoNaut-ASV (AutoNaut).

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 and Ocean Infinity have also been released for specific seabed-mapping and survey-services in industry applications at ocean-basin level worldwide (Patterson et al, 2022). These developments, many of them already commercial, demonstrated that specialty ASV could withstand the harsh ocean environment for extended periods and their software and systems were reliable enough for extended voyages and missions (Table 2).

Existing ocean surveillance and monitoring tool	Limitations	USV capability to overcome existing limitations	Niche opportunity for USVs
Targeted ship-based instrument-based metocean data collection	<ul style="list-style-type: none"> <li>Expensive overheads leading to sparse spatiotemporal metocean data</li> <li>Numerous specialised personnel required to be onboard</li> <li>Weather limited</li> <li>High carbon emissions</li> </ul>	Increased spatiotemporal scales of instrument-based metocean data collection	<ul style="list-style-type: none"> <li>Specialists can participate in instrument-based data collection from anywhere in the world</li> <li>Access to severe weather conditions (Siddle et al., 2021)</li> <li>Survey methods emit less carbon into the environment (Zaghi et al., 2016)</li> <li>High complexity USV a significantly lower-cost alternative</li> </ul>
Opportunistic metocean data collection, e.g., "Ships of Opportunity" (commercial ships fitted with scientific instruments collecting opportunistic data)	<ul style="list-style-type: none"> <li>Data collection limited to shipping routes</li> <li>Non-realtime data collection</li> <li>Non-realtime data access instrument diagnosis tools (White and Bernstein, 1979; Emery et al., 1997; Beggs et al., 2012)</li> </ul>	Opportunistic metocean data collection whilst undertaking other tasks (e.g., surveillance, offshore infrastructure protection).	<ul style="list-style-type: none"> <li>Flexibility in locational data collection (may be opportunities to direct USV to targeted areas)</li> <li>Ability to switch instrument(s) on and off remotely</li> <li>Real-time data stream, data quality collection and instrument performance.</li> </ul>
Aerial surveillance and monitoring	<ul style="list-style-type: none"> <li>Expensive overheads</li> <li>Intermittent</li> <li>Short spatiotemporal range</li> <li>May be limited to daytime or unable to see covert craft</li> <li>Weather limited</li> <li>May be predictable</li> </ul>	Multiple surveillance USVs to improve awareness	<ul style="list-style-type: none"> <li>Persistent</li> <li>Covert</li> <li>Flexibility in locational data collection (may be opportunities to direct USV to targeted areas)</li> <li>Can detect night-time activities via camera, radar or sonar.</li> <li>Simultaneously undertake metocean data collection</li> <li>Radar detection of vessels</li> <li>More frequent data collection</li> <li>Real-time instrument diagnosis (Ferreira et al., 2007)</li> <li>Reduces risk of losing data</li> <li>Perpetually provides near-real-time seismic operations</li> </ul>
Subsea fixed-point oceanographic or seismic detection moorings	<ul style="list-style-type: none"> <li>Most are non-realtime data collection or instrument diagnosis tools (~6 months) (Fuji et al., 2019)</li> <li>Risk of data and infrastructure loss at sea</li> </ul>	Gateway data collection capability	<ul style="list-style-type: none"> <li>Water-surface interface data (SST, SSS) collection irrespective of cloud cover (Zhang et al., 2019; Vazquez-Cuervo et al., 2020)</li> <li>Sea surface height measurements for calibrations and verification of satellite altimetry in shallow (e.g., continental shelf) water (Penna et al., 2018)</li> <li>Real-time data retrieval for instrument diagnosis and model assimilation</li> </ul>
Satellite observations	<ul style="list-style-type: none"> <li>Sparse altimetry calibration or verification data in remote locations</li> <li>Cloud cover reduces ocean surface observations such as SST, salinity, sea level and colour for long periods (months), especially in tropical monsoon areas (Kilpatrick et al., 2001)</li> <li>Calibration and validation of sensors cannot be undertaken remotely, therefore some satellite sensors can be redundant after a number of years.</li> </ul>	Targeted or opportunistic water-surface interface data collection	<ul style="list-style-type: none"> <li>Water-surface interface data collection</li> <li>Real-time data retrieval for model data assimilation (Cole et al., 2019)</li> </ul>
Coupled ocean-atmosphere forecasting	<p>Sparse global spatiotemporal metocean data availability reduces certainty in model predictions</p> <ul style="list-style-type: none"> <li>Expensive</li> <li>Time consuming to determine optimal location of acoustic receiver array</li> <li>Underway passive acoustic detection too noisy</li> </ul>	Targeted or opportunistic metocean data collection whilst undertaking other tasks	<ul style="list-style-type: none"> <li>Quiet (Ziegwied et al., 2016)</li> <li>Real-time data retrieval to guide dynamic monitoring</li> <li>Real-time data-based decision-making</li> </ul>
Ecological acoustic tracking	<ul style="list-style-type: none"> <li>Expensive</li> <li>Time consuming to determine optimal location of acoustic receiver array</li> <li>Underway passive acoustic detection too noisy</li> </ul>	Targeted or opportunistic, underway or fixed, flexible receiver capability on one or multiple USV	<ul style="list-style-type: none"> <li>Quiet (Ziegwied et al., 2016)</li> <li>Real-time data retrieval to guide dynamic monitoring</li> <li>Real-time data-based decision-making</li> </ul>

Table 2. Niche opportunities for USVs to support existing methods for ocean surveillance and monitoring.

The current global trend on autonomy developments in mobility seems to be widely yet accepted by the maritime community, primarily due to budgetary issues. Up to date, autonomous and remotely operated platforms at sea have been mainly used as carriers of sensors and other measuring devices mainly addressed to oceanography, hydrography and off-shore applications in near-shore, controlled test-site areas or outside shipping routes. However, nowadays we are 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 (Figure 4). 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 (Burmeister et al., 2014; Remote and Autonomous Ships-The Next Steps, 2016; Rødseth, 2017; Munim, 2019).



*Figure 4. A schematic view for the new ASV developments associated with the cyber-physical systems and the big data from IMO's Regulatory Scoping Exercise completed in 2021.*

Under these premises, the development and future implementation of vessels as MASS (Maritime Autonomous Surface Ship) by IMO will represent an inflexion point for the paradigm shift in the industry and maritime shipping system as a whole (Poikonen et al., 2016; Wróbel et al., 2017; Kim et al., 2020; Wright, 2020). Therefore, for a successful and smooth settlement of MASS as well as the relevant infrastructures in the maritime sector, key aspects related to autonomous shipping and their impact on technology, regulation and societal aspects should be envisaged (Autonomous and Remotely Operated Ships, 2020; Gu et al., 2020; Guidelines for Autonomous Shipping, 2021).

From the purely technology perspective, ships should be built with enhanced control capabilities, broadband telemetry, graphic interfaces, complex sensor payloads, etc. to be operated by means of remote land-based or off-shore services (Komianos, 2018). However, the technology replacing manning needs to re-shape the crew in terms of safety, efficiency and environmental protection. On the industry side, MASS is expected to change shipbuilding and equipment, as well as shipping protocols and port infrastructures. 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.

Therefore, despite the rapid development of science and technology in the ocean industry, ASV indisputably need to be subject to the international regulations necessary for the vessels to operate safely across nations and even the seabed areas beyond national jurisdiction. 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 considering the characteristics of unmanned vessels as well. While technology and market push are required for any innovation to take hold, regulation aspects become a major consideration. This is especially right in the case of ASV developments, where certain key developments can be noted as advancing the field.

During the period of roughly 2000-2010 early work on software and algorithms to enable unmanned vessels to adhere to the COLREGs (Convention on the International Regulations for Preventing Collisions at Sea) began including the launch of the ASTM (American Society for Testing and Materials) Committee, designed to develop technical standards for unmanned maritime vehicles, including a sub-committee for regulatory

issues. This catalysed further policy developments. The Association for Unmanned Systems International (AUVSI) began to engage the issue through their Maritime Advocacy Committee in 2011. A particular focus was informing and engaging the U.S. Navigation Safety Advisory Council (NAVSAC). This body informs the U.S. Coast Guard, the relevant regulator for U.S. Waters. Through a series of meetings this work eventually resulted, in late 2012, in a resolution offering advice on both technology solutions, such as use of the Automated Identification System (AIS) and policy steps, such as amendments to certain COLREGs (Karlis, 2018).

The UK's industry group, Maritime UK, launched an effort to develop voluntary best practices for unmanned vessels, though they referred to them as maritime autonomous systems (MAS). The first version of the UK Industry Code of Practice focused mainly on technical aspects such as design and construction of MAS. The UK Maritime Autonomous Systems Regulatory Working Group (MASRWG) released this first document in 2017. While the guidance in the first version of the code was for design, construction, and operation, it was heavily focused on design and manufacture. Seeing significant growth in the autonomous systems the MASRWG updated the Code of Practice to increase focus on the ASV operations, with firstly guidance on skills, training and platform's registration (First Unmanned Vessel Joins UK Ship Register, 2019; Maritime Autonomous Surface Ship UK Code of Practice, 2020).

A multidisciplinary group of Spanish research centres, companies and public agencies, under the coordination of DGMM (General Directorate of Marine Merchant) are joining forces since late 2020 in order to setup a working group on autonomous maritime navigation, aiming to setup the right national framework to develop and operate ASV and autonomous ships that currently are under development becoming PLOCAN an active partner providing both test-site capabilities and owner of the first autonomous boat flagged in Spain.

### 3. The meaning of Ocean Observing Network

Several organisations and initiatives (EuroGOOS, EOOS, OCG, ERICs etc.) at international level are promoting and attempting to sustain ocean observing networks somehow through different initiatives, approaches, and level of commitment from their members (working groups, task teams, etc.) In this context, key references could be ARGO, EMSO, Ocean-Gliders, OceanSites, EuroGOOS, among others.

The GOOS Observations Coordination Group (OCG) coordinates across the major, sustained, global oceanographic and marine meteorological observing networks. The requirements for ocean observations are expanding and new technologies, variables, platforms, and networks are being developed, deployed and measured (Figure 5). Observing networks need sufficient maturity and scale to engage with OCG and the coordination towards supporting GOOS and GCOS (OCG-Observations Coordination Group, 2018).

Networks may not fulfil all attributes; however, these can act as a roadmap to help guide development towards achieving the elements that OCG has understood make networks of global scale effective, productive, engaged and responsive members of the GOOS.

Within OCG, one of the funding coordination groups is the Data Buoy Cooperation Panel (DBCP) that presently coordinates the network of over 1,250 drifting buoys and around 400 moored buoys all collecting so called "metocean" data and in real time. DBCP also includes an ASV pilot activity "Evaluation of Unmanned Surface Vehicles" ([https://www.ocean-ops.org/dbcp/overview/evaluation\\_usv.html](https://www.ocean-ops.org/dbcp/overview/evaluation_usv.html)). The primary interest of the DBCP community is on the potential of Autonomous Surface Vehicle (ASV) platforms for collecting

meteorological and oceanographic data from the oceans. It will be a key activity of the EuroSea task 3.5 to closely coordinate with DBCP for joint operations.

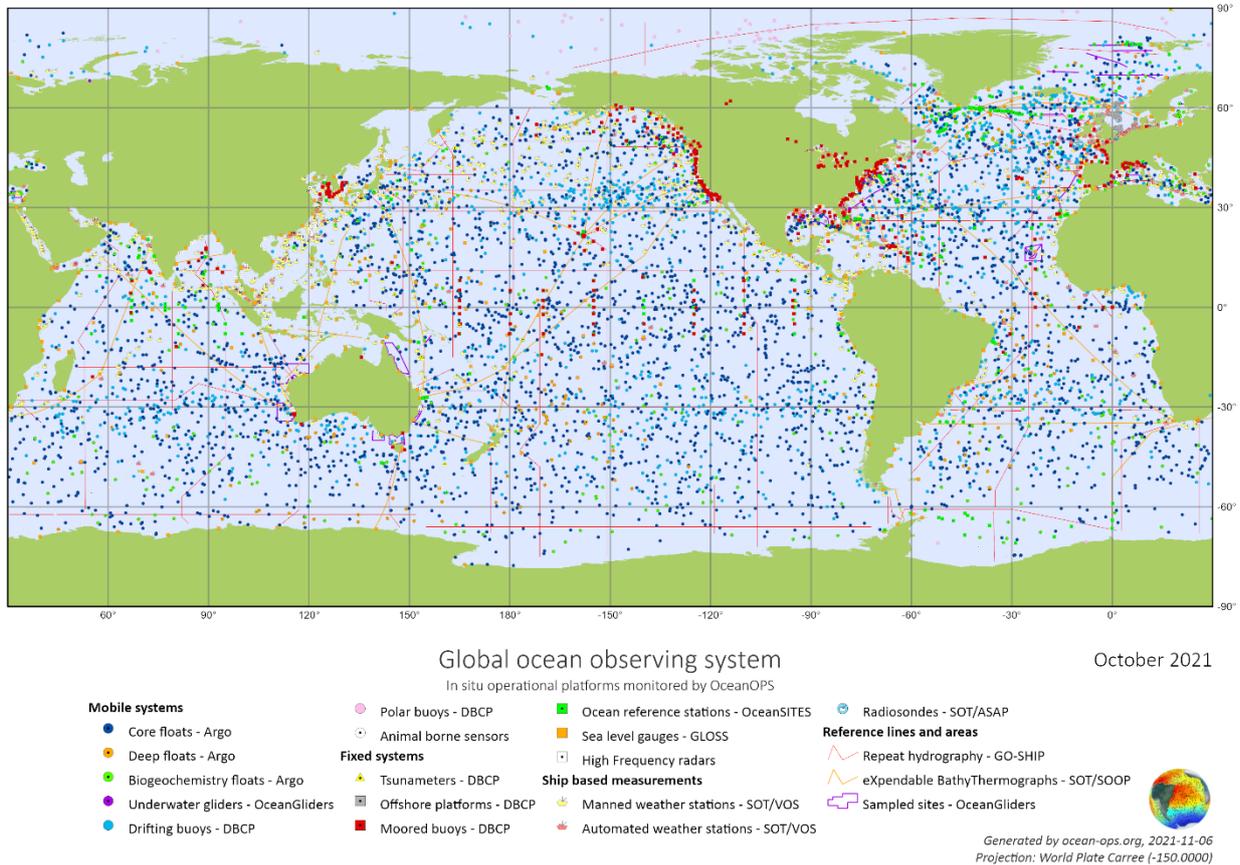


Figure 5. A global view of the observational coverage from the different ocean-observing platforms at OceanOPS portal.

The aim of a multisector basin-wide network is to optimize observations at basin-scale and maximize the benefits of the data collected. Data from observing platforms should be used for many different observing objectives in real-time and over and over again in delayed mode. The capacity and gap analysis should be done on the full value chain, for both societal benefit and improved scientific understanding.

### 3.1. Network Attributes

Some of the main attributes of a network framework provided by OCG in the GOOS Report N.266:

- Global in scale (greater than regional and, as far as possible, intention to be global)
- Sustained over multiple years, beyond the timespan of single research projects.
- Coordinates a community of best practice and governance, i.e., a means of developing multi-year strategy, implementation standards and development plans.
- Data are free, open and available in a timely manner, i.e., a data management infrastructure that delivers interoperable/inter-comparable data in real-time, or with minimal delay, through internationally recognised data centres or services.
- Contributes to meeting requirements for one or more Essential Ocean Variables or Essential Climate Variables

- Defined observation mission/s and implementation targets, such that a role in the GOOS is defined and progress towards targets can be supported.
- Agreed to develop, update and follow best practices to ensure consistent delivery of observational data (from deployment to delayed mode quality control). These best practices should be documented, utilised by members and consist with other OCG networks.
- At least development stage 'Pilot' in technological readiness level in all aspects of the Framework for Ocean Observing and WIGOS Observing System Network Design Principles, with a roadmap towards maturing.

### 3.2. Benefits for Networks

OCG coordination supports cross-network observing planning towards global integrated requirements, builds on synergies, supports technology and best practice transfer, provides visibility to the global network, a common voice and supports network development towards common objectives. Benefits include:

- Visibility as part of the integral global observing system i.e., OceanOPS Report Card.
- Support for sustainability through demonstrated global role.
- Technical support and coordination for network monitoring, reporting and deployment coordination through OceanOPS as a global service.
- Support in areas of coordination, including standards and best practices, new technology adoption, deployment opportunities, open data availability, network development, etc.
- Opportunity to provide feedback into GOOS/GCOS development and representation at the global level with IOC, WMO, GOOS, GCOS for issues of relevance, i.e., EEZ, etc.
- Support for Capacity building activities (via IOC or OBP).
- Integration into WIGOS (optional).

### 3.3. Commitment

Main derived commitments for a globally accepted observation coordination network:

- Participation in GOOS OCG annual meetings, quarterly calls and actively contributing to and supporting the implementation of the OCG proposed cross-network activities.
- Provision of network metadata information to OceanOPS and of routine updates on the status and evolution of the network, i.e., for the Ocean Observing System Report Card.
- Support the monitoring of the overall system status, progress, data flow, and development through OceanOPS (depending on financial contributions).
- Coordinate with and support the activities of other networks.

### 3.4. Process to become a partner network

Main steps or stages that define the procedure:

- It will be a key activity of the EuroSea task 3.5 to closely coordinate with DBCP for joint operations. DBCP is already an OCG network and all integration of ASV could theoretically be processed through DBCP.
- If it can be demonstrated that ASV cannot be sufficiently accommodated by DBCP as a subproject the ASV community may wish to establish its own network. The network then would need to outline its status, a justification why DBCP is not the "home of choice" and its project and implementation plan. This plan shall be brought to the attention of OCG directly via the secretariat or IOC/UNESCO

GOOS Program through the global working groups i.e., GOOS Panels and GRAs, WMO or GCOS, or may directly approach GOOS.

- A "review" by OCG is undertaken to assess that the network meets sufficient criteria and an operation within DBCP is not feasible. Networks who do not meet all criteria but have plans to address deficiencies can be provisionally designated an 'emerging' OCG network and recommendations for network improvements will be given by the OCG.
- Formal acceptance of emerging networks is reviewed/approved by OCG.
- Progress of emerging networks is reviewed annually until such time the network is fully accepted and/or the OCG determines the network is not making progress and removed from consideration.

#### 4. ASV Network contributions to EOOS Strategy

International coordination takes place through the Global Ocean Observing System (GOOS). However, the existing coordination at the global level needs to be supported by clear regional, national and local arrangements, with connections between those coordination structures based on common methods and practices to ensure compatibility and interoperability across scales. Today, GOOS is organised around globally coordinated regional observing systems, and a heterogeneous set of regional alliances established around regional groupings of nations (GRAs) with common interests, such as EuroGOOS for Europe.

Currently, there are numerous programmes, projects and initiatives working to develop and implement effective ocean observing capacities, operating at different geographical scales (local, national, regional, pan-European and international) and different timescales (real-time, daily, monthly, annually, etc). These capabilities are, by their nature, highly fragmented and complex. While there is some coordination at global level, for example under the auspices of GOOS and OCG, a strengthening in coordination at regional scale is necessary to ensure that the right observations are made and that they are made on a systematic and sustained basis. An overarching strategy across all measurement platforms is required to ensure that best use is made of limited resources in Member States and at European level.

EOOS is a coordinating framework designed to align and integrate Europe's ocean-observing capacity, promote a systematic and collaborative approach to collecting information on the state and variability of our seas, and underpin sustainable management of the marine environment and its resources. Specifically, what EOOS does is:

- Align and connect existing initiatives to ensure efficiency and value for money.
- Identify gaps in the European observing capacity and foster initiatives to fill those gaps.
- Promote observing capacities which can benefit multiple sectors including research, policy, management, and industry.
- Ensure that European ocean observing is integrated into the global observation system(s) by providing a focal point for interaction with international programmes and partner initiatives outside of Europe.

EOOS can help add value to existing observing efforts, empowering those who are already working to advance ocean observing in Europe, and catalysing new initiatives in a strategic way, targeting identified gaps and communicating progress to a wide range of stakeholders. EOOS will act as a framework to bring the community together to set priorities and act as a single, well-organized voice for Europe, as well as facilitating the exchange of best practice and capacity within Europe.

EuroGOOS Task Teams are operational networks of observing platforms. They promote scientific synergy and technological collaboration among European ocean observing infrastructures. Task Team members exchange open-source tools, collaborate in areas of common interest, and jointly make European data available to the EuroGOOS ROOS regional data portals, which in turn are feeding data to EMODnet and Copernicus Marine Service (CMEMS).

The following Task Teams are currently coordinated by EuroGOOS: FerryBox; Tide gauges; Gliders; HF radars; floats (Euro-Argo); Fixed platforms.

Task Teams are important operational components of the EOOS framework setting out a vision and coordination mechanisms for a truly integrated ocean observing in Europe, for the benefit of society, Science and innovation. Task Teams work to:

- Coordinate the existing efforts of the individual observation communities.
- Provide an up-to-date picture of the reporting platforms in Europe.
- Facilitate development of common operational data procedures and services (incl. data quality control and data management).
- Foster scientific and technological development, joint programmes and concerted actions, enhancing the European marine infrastructure capacity.

In compliance with the organizational and functional structure already implemented for the set of the main ocean-observation networks, it is intended to establish the new ASV Network, considering at the same time the particularities and specific capabilities of this technology aiming to contribute synergistically to cover current gaps.

## 5. First EuroSea ASV Workshop: Brief summary

### 5.1. Workshop Motivation

ASV-Network definition and roadmap addressed to cover current and future user's needs, including access to infrastructures, community roadmap monitoring, promoting knowledge exchange, enhancement, and partnership worldwide with the establishment of an ASV User Group. Improvements on Standard Operating Procedures (SOP) for derived Best Practices (BP) implementation on operational protocols, data management, knowledge transfer, risk assessment, legislation, etc. to properly improve the ASV technology, contributing to the EOOS implementation plan.

Two workshops (WS) have been planned within the framework of EuroSea aiming at ASV technology status, applications, synergies, challenges, opportunities, member engagement, Best Practices and roadmap definition and implementation.

### 5.2. Workshop Attendees and Agenda

The first WS was held online (5<sup>th</sup> and 6<sup>th</sup> October 2021) despite efforts -including two postponements- in order to be able to carry it out in person. Despite difficulties, the 1<sup>st</sup> WS was successful and very fruitful in terms of engagement from potential members of the ASV network from industry, academia, science community, agencies and policy framework from worldwide (Figure 6). In terms of convening capacity, considering that the WS registration was only under invitation, 117 people were finally registered, of which 24 were speakers.

## WP3 – Network Integration and Improvement

### Task 3.7

## Autonomous Surface Vehicles (ASV) Network

1<sup>st</sup> Workshop (online)  
October 5<sup>th</sup> – 6<sup>th</sup>, 2021

Attendance by invitation – Contact: [carlos.barrera@plocan.eu](mailto:carlos.barrera@plocan.eu)



Figure 6. Dissemination call for the 1<sup>st</sup> ASV workshop held on October 2021.

The two days WS agenda (Figure 7) were divided in 4 thematic sessions: (1) Technology status and overview, (2) Applications and Operations, (3) Regulatory Framework and (4) Best Practices and Roadmap definition.

### Day 1

2:00 PM	Welcome + Workshop goals	Carlos Barrera (PLOCAN)
2:10 PM	EuroSea Project Overview	George Petihakis (HCMR)
<b>Session 1 - ASV Technology</b>		
2:20 PM	Offshore Sensing	David Peddie
2:30 PM	AutoNaut	Sarah Haesman
2:40 PM	GPASeabots	Pau Guasch/Adria Fradera/Daniel Sanchez
2:50 PM	iXblue	Guillaume Eudeline
3:00 PM	UTEK	Cesar Martinez
3:10 PM	SeaSats	Mike Flanigan / Declan Kerwin
3:20 PM	Saildrone	Andy Ziegwied
3:30 PM	Panel Discussion	All attendees
3:45 PM		Break
<b>Session 2 - ASV Applications /Operations</b>		
4:00 PM	UEA	Karen Heywood
4:10 PM	GEOMAR	Bjorn Fiedler
4:20 PM	XOCEAN Ltd.	Michael Huskilson
4:30 PM	Tidewise	Rafael Coelho / Sylvain Joyeux
4:40 PM	Ocean Infinity	Ramsay Lind
4:50 PM	Saildrone	Andy Ziegwied
5:00 PM	NOAA	Christian Meinig
5:10 PM	MARUM	Christoph Waldmann / Sebastian Meckel
5:20 PM	SEAPROVEN	Antoine Thebaud
5:30 PM	Panel Discussion	All Attendees
5:50 PM	Wrap up and closure	Carlos Barrera

## Day 2

2:00 PM	Welcome + Session goals	Carlos Barrera (PLOCAN)
2:05 PM	EOOS Overview	Inga Lips (EuroGOOS)
Session 3 - ASV Regulatory Framework		
2:20 PM	National Oceanography Center	Roland Rogers
2:40 PM	DGMM / MITMA	Hernan del Frade
3:00 PM	XOCEAN Ltd.	Michael Huskilson
3:15 PM	NOAA	Chris Meinig
3:30 PM	LSTS FEUP	Joao Tasso / Sergio Ferreira
3:40 PM	Panel Discussion	All attendees
3:50 PM	Break	
Session 4 - Best Practices and ASV Network Roadmap Definition		
4:00 PM	Ocean Best Practices (OBPS)	Jay Pearlman /Johannes Karstensen
4:20 PM	EMODNet	Patrick Gorringer
4:40 PM	iXblue	Guillaume Eudeline (TBC)
4:50 PM	NOAA	Andy Chiodi
5:00 PM	MARUM	Christoph Waldmann
5:20 PM	Panel Discussion	All Attendees
5:40 PM	Next steps - AOB	Andres Cianca
5:50 PM	Wrap up and closure	Carlos Barrera

Figure 7. Agenda and speakers list of the 1<sup>st</sup> ASV workshop for Day 1 and Day 2.

Some highlights (from Figure 8 to Figure 30) from presentations are as follows:

The slide, titled "Network Integration and Improvement" with the EuroSea logo, outlines tasks for network integration and provides a status overview of various observing networks. On the left, seven tasks are listed, including making European networks fit for global integration, ensuring data flow, and developing multiplatform strategies. On the right, a table compares European and Global networks across different platform types.

	European networks	Global networks
HF Radar	HF Radar	Global HF Radar
Glider	Glider	Ocean Gliders
Fixed Platforms	No logo yet	OceansITES
Surface vehicle	Not established yet	
Profiling floats	Argo	Argo
Research ships	No logo yet	Research Ships
Commercial ships	FerryBox + ...	Commercial Ships
Tide gauges	Tide Gauge	Tide Gauges

Figure 8. Overview and status of main EU and Global Observing Networks.

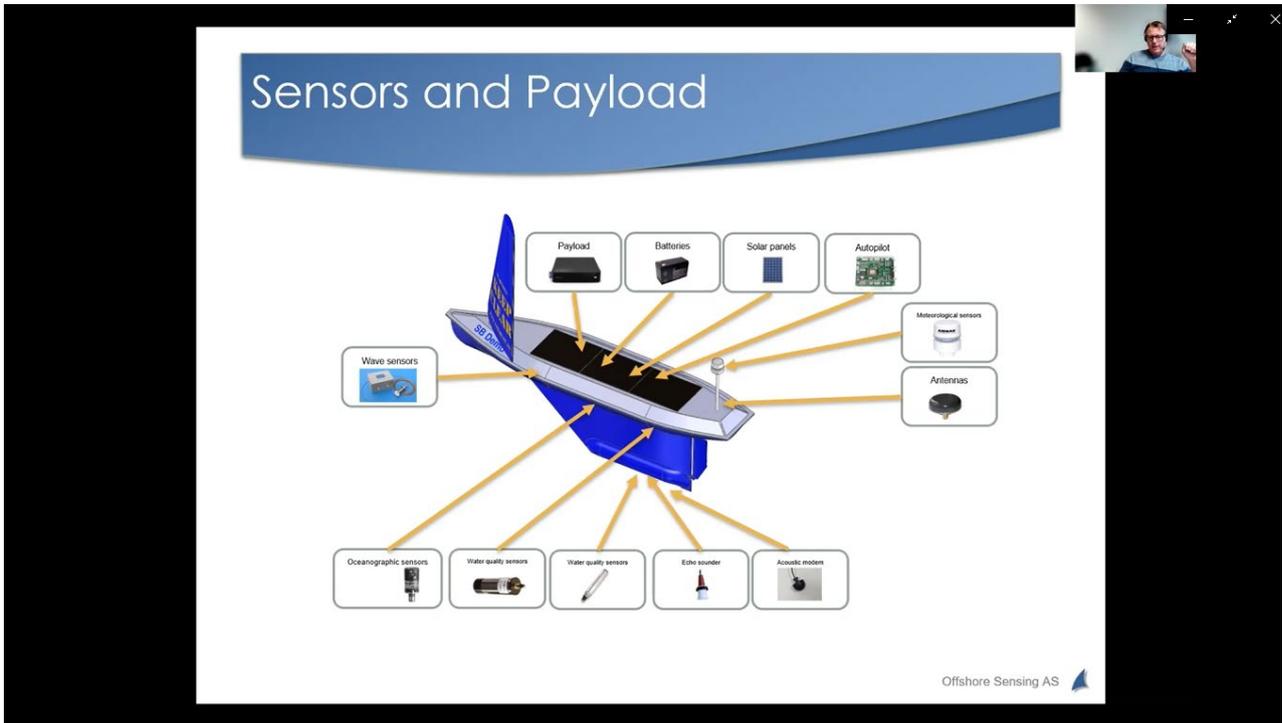


Figure 9. Sailbuoy ASV technology architecture developed by Offshore Sensing company.

**AutoNaut** AutoNaut Projects

SEICHE WATER TECHNOLOGY GROUP

Extreme Environments Extension project

Oceans 2020 – European defence demonstration project

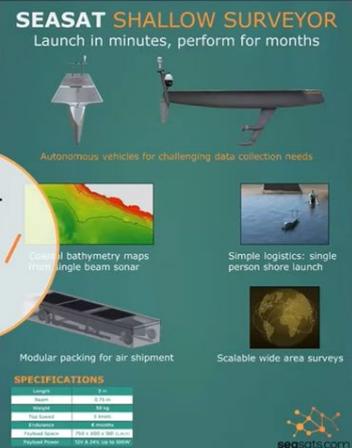
Confidential 2021.10.05 – EuroSea Page 9

Figure 10. Example of AutoNaut ASV capabilities in terms of mission performance.

Available for data-as-a-service or turnkey purchase

### SEASAT SHALLOW SURVEYOR

Launch in minutes, perform for months



Autonomous vehicles for challenging data collection needs

Cost-effective bathymetry maps from single beam sonar

Simple logistics: single person shore launch

Modular packing for air shipment

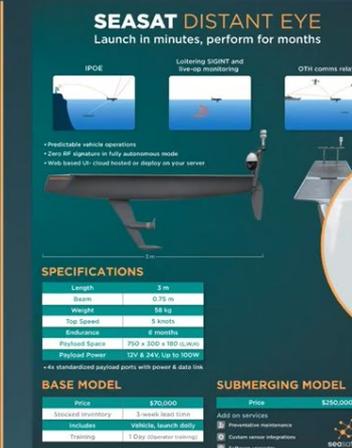
Scalable wide area surveys

SPECIFICATIONS	
Length	2.5m
Weight	150kg
Top Speed	8 knots
Endurance	8 months
Payload Capacity	350 x 300 x 160 (LxWxH)
Payload Power	30V & 24V (up to 100W)

seasats.com

### SEASAT DISTANT EYE

Launch in minutes, perform for months



• Predictable vehicle operations  
• 24x 24 operations in fully autonomous mode  
• Web based UI: cloud hosted or deploy on your server

SPECIFICATIONS	
Length	2.5m
Beam	0.25m
Weight	58 kg
Top Speed	8 knots
Endurance	8 months
Payload Capacity	350 x 300 x 160 (LxWxH)
Payload Power	30V & 24V (up to 100W)

• 4x standardized payload ports with power & data link

BASE MODEL		SUBMERGING MODEL	
Price	\$70,000	Price	\$250,000
Stocked Inventory	5 weeks lead time	Add on services	
Hardware	Software, Training, Data	• Operational experience	
Training	1 Day classroom training	• Custom sensor integration	
		• Software upgrades	

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6

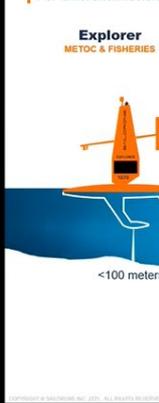
Figure 11. SEASAT ASV technology features overview.

### DIFFERENT SIZE VEHICLES

For different missions

#### Explorer

METOC & FISHERIES



<100 meters

#### Voyager

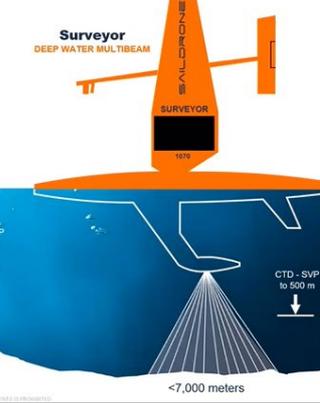
MDA | ISR | SHALLOW MULTIBEAM



<300 meters

#### Surveyor

DEEP WATER MULTIBEAM



<7,000 meters

CTD - SVP to 150 m

CTD - SVP to 500 m

Figure 12. Saildrone ASV technology models overview




**AutoNaut**



**Caravela: a specially-designed 5-m AutoNaut to carry and release a Seaglider**






- Specially-adapted AutoNaut stern arrangement to accommodate the Seaglider
- Seaglider is released when triggered by remote pilots
- Seaglider is transported in 'recovery' mode

Figure 13. Caravela – A synergistic project between ASV and underwater glider technologies conducted by UEA.

## Wave Glider operations - Biogeochemistry

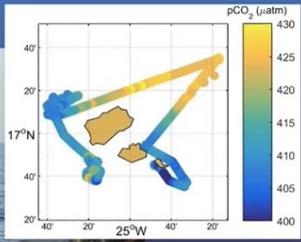



**Wave Glider 1:**

- Parameters:  $p\text{CO}_2$ ,  $\text{O}_2$ ,  $\text{CH}_4$ , T, S, P, chlorophyll a, gas tension ( $\text{N}_2$ ), meteorology, ADCP
- Iridium/GPS
- Eddy identification
- Air-sea gas exchange, bgc hotspots

**Wave Glider 2:**

- Parameters: 200 kHz echo sounder (fish/zooplankton), T, S, P, meteorology
- Iridium/GPS
- Biomass distributions, DVM



**31 days at sea  
631 nautical miles**



<http://waveglider.geomar.de/navigator/>

Figure 14. ASV experiment by GEOMAR using Waveglider ASV technologies.

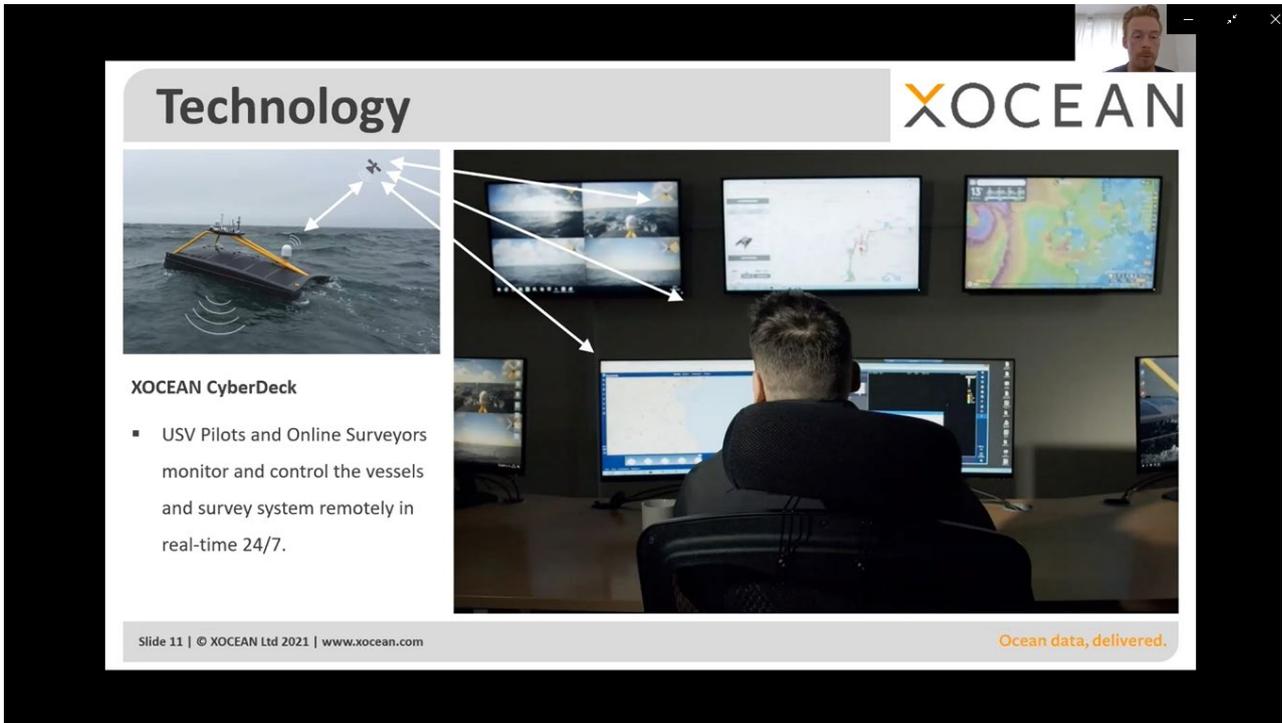


Figure 15. Remote Control Centre of XOCEAN for ASV operations

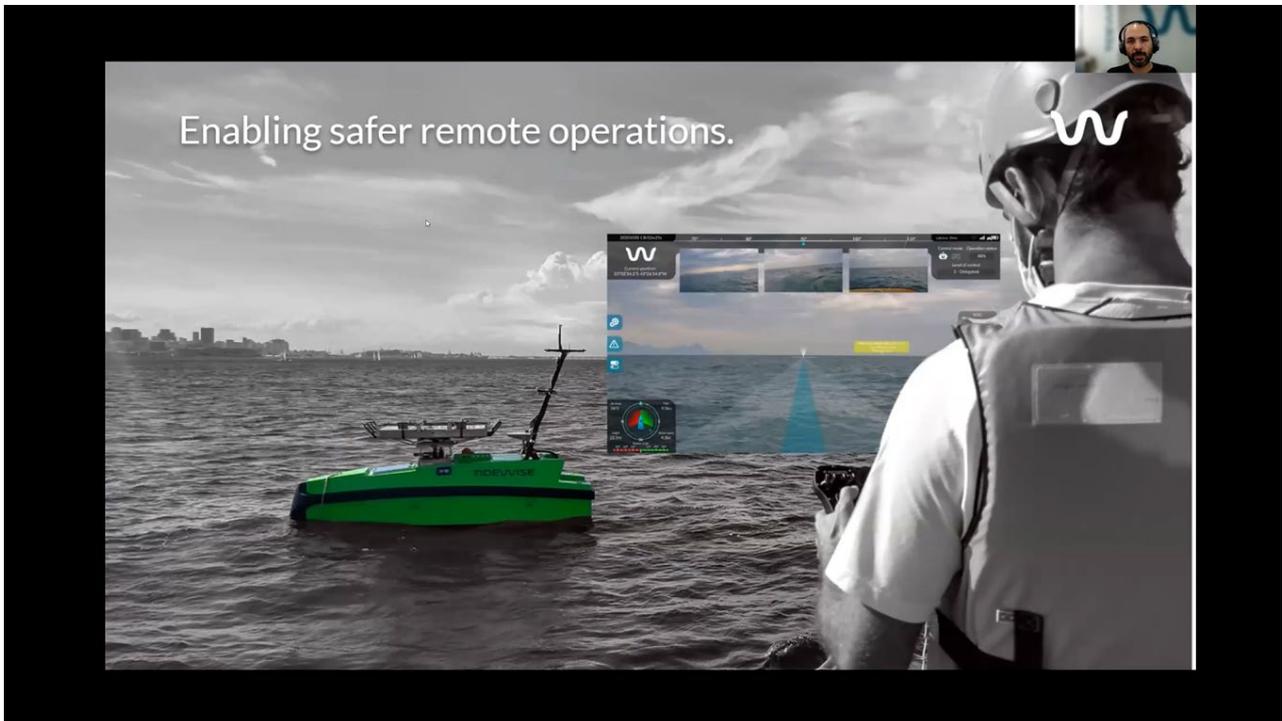


Figure 16. TIDEWISE as service provider using ASV technologies for a safer sea operations.



Figure 17. Long endurance SAILDRONE ASV mission performed in the Arctic region.

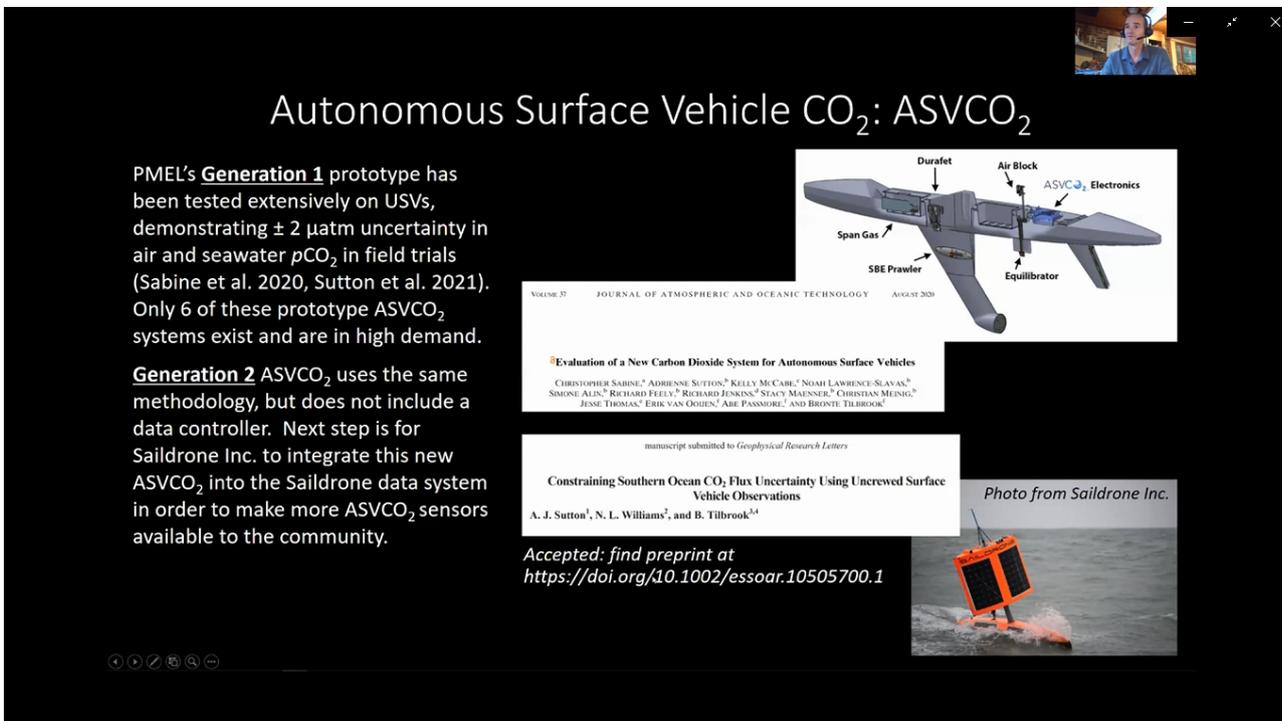


Figure 18. Evolution of the SAILDRONE ASV technology for CO<sub>2</sub> measurements by NOAA.

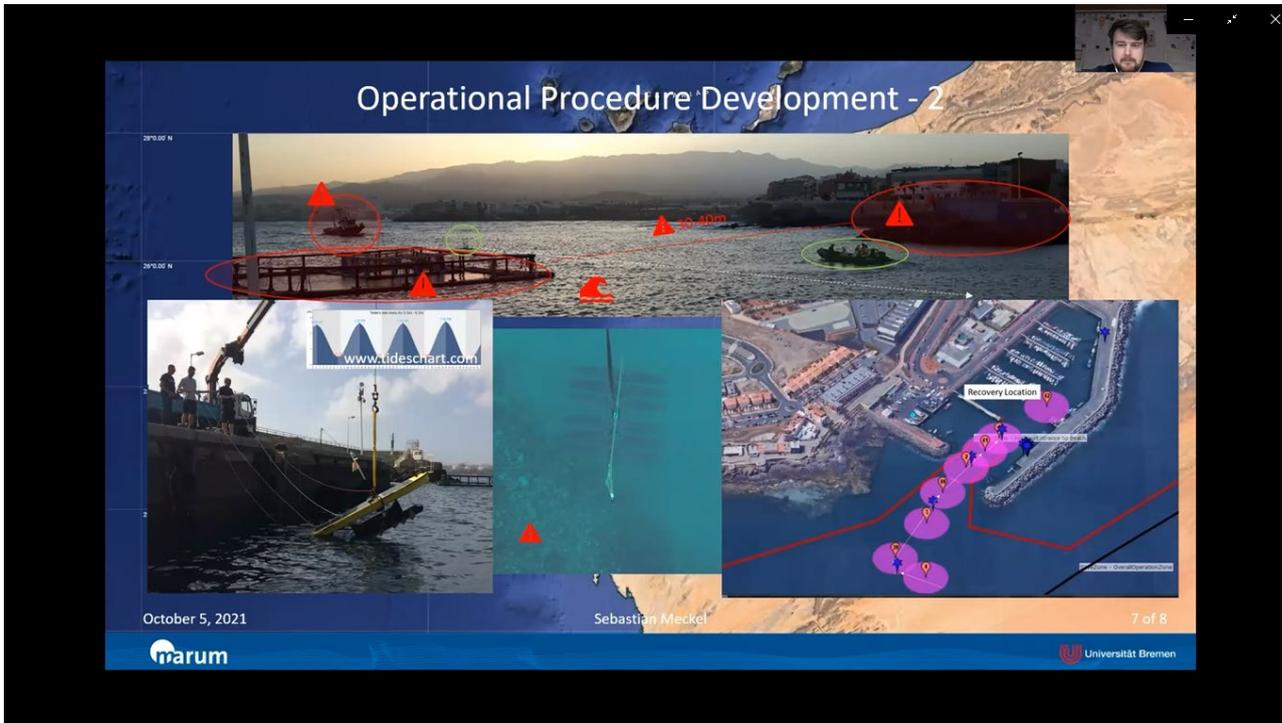


Figure 19. Example of operational procedure for a Waveglider deployment conducted by MARUM.

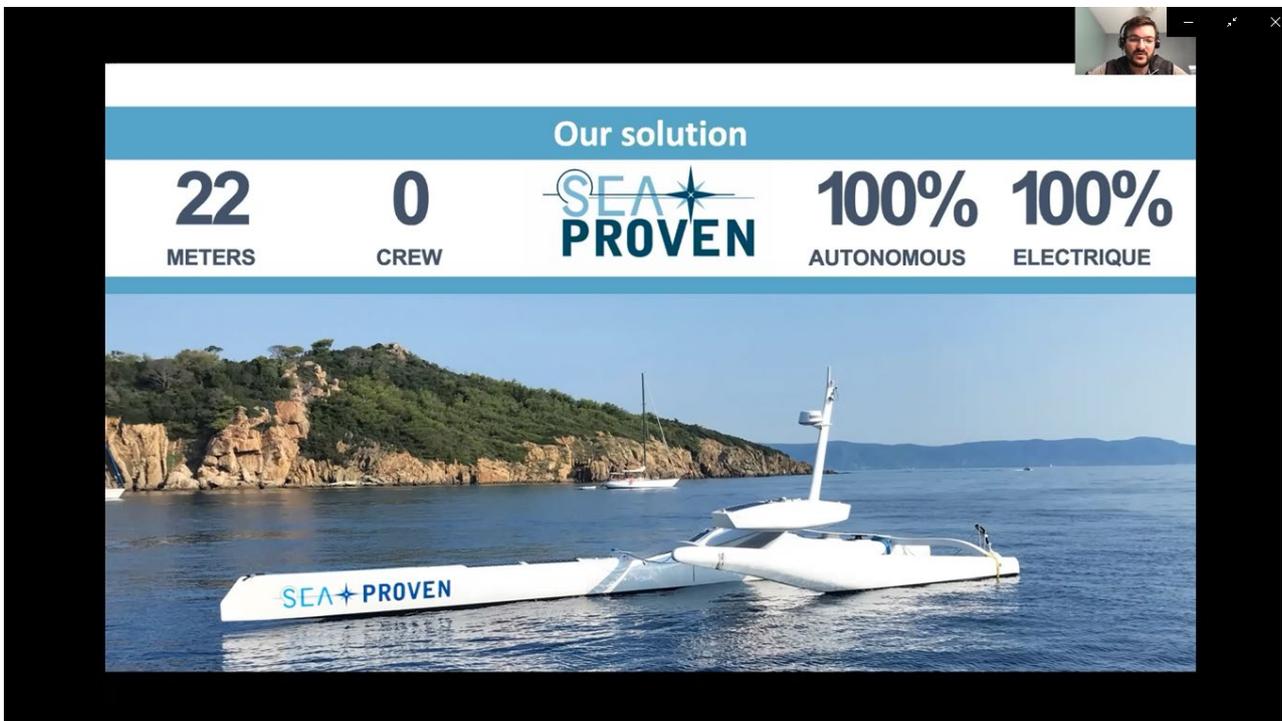


Figure 20. SeaProven: example of large and very capable ASV technology for ocean-observing.



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Figure 21. Overview on the European Ocean Observing System approach (EuroGOOS).

0:05:39 14:29

SHOW TASKBAR DISPLAY SETTINGS END SLIDE SHOW

### ASV Regulatory Framework - Does one exist?

Sources of Regulation

- Written Law
- Customary Practice
- Case Law

Three levels

- International
- Regional
- State

Legal Scope

- Status
- Access
- Liability/Risk
- Human Safety
- Environmental Safety
- End of Life/Dispose
- Classification/Registration/Insurance

Next slide

No Notes.

Slide 4 of 13

Figure 22. Status of the regulatory framework for ASV in UK.

## MASS and the Spanish Law

- The DGMM (Merchant Marine General Directorate) is aware of the international developments on MASS and the internal needs
- Spain took part in the MASS-RSE (COLREGs, SAR & STCW sub-groups)
- We are also in the MASS WG of the EC, as well we're watching EMSA's developments
- The internal needs are, at this moment, related more to the regulation of small crafts than vessels
- First step was the Service Instruction 1/2019
- It's related with register, survey, certification and licenses
- It's not a rule, but a guidance on how to apply the existing national regulations to the MASS

Figure 23. Regulatory framework status of MASS and ASV in Spain, lead by DGMM.

## Canadian Ops Case Study

XOCI

### Operations on Lake Superior for the Canadian

#### Hydrographic Service

- XOCEAN was commissioned to collect hydrographic data near Thunder Bay, Ontario
- Canada's waterways are governed by Transport Canada, including their Collision Regulations
- Multiple paths to operations
  - Coastal Trading Licence
  - Applying for Canadian Flag Registration



Figure 24. Study case conducted by XOCEAN in Canada waters as contribution to Regulatory framework session.

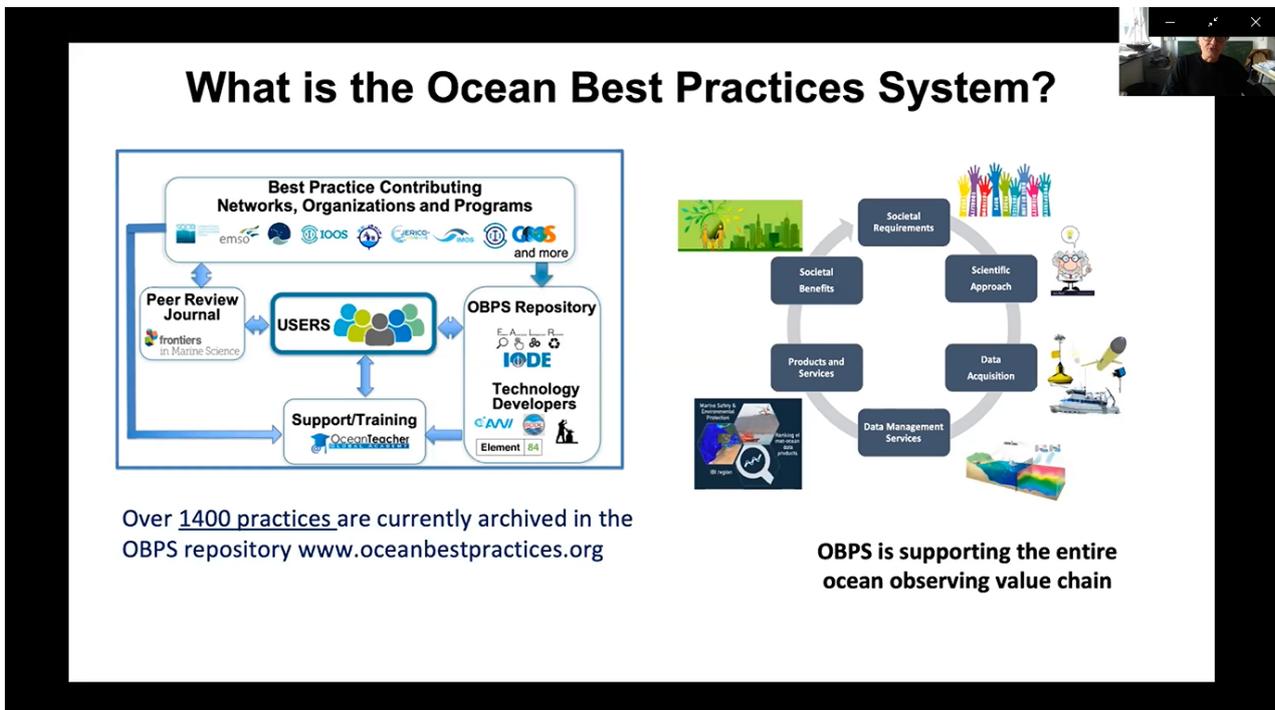


Figure 25. Ocean Best Practices System structure overview.

- ## Needs for “creation” of a new observation coordination network ASV
- From: Observation Coordination Group (OCG) network requirement document*
- Network **coordinates a community of practice**
  - Long term (>10 years) sustained **observing needs** are defined for network operations
  - EOV based **sensor SOP/BP** (deposited at [oceanbestpractices.org](http://oceanbestpractices.org))
  - Networks is **open to all operators**
  - **Internal coordination established** – guided by scientific/engineering expertise and supported by a technical coordinator
  - Network **FAIR (findable, accessible, interoperable, re-usable) data policy is defined**
  - Network **specification and governance structure** is defined and documented (e.g. Terms of Reference)

Figure 26. List of main needs to create and implement a new observation coordination network for ASV technologies based on OCG approach.

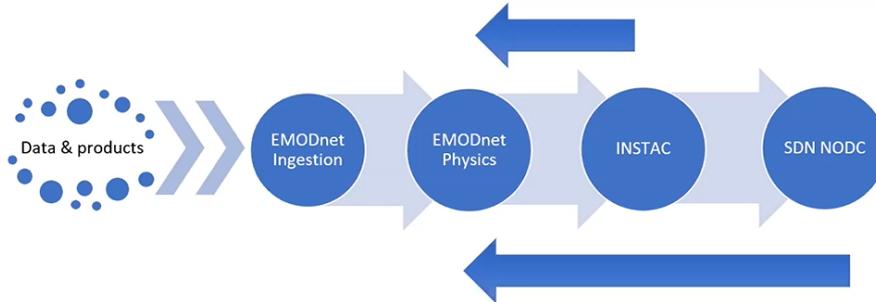
EMODnet DATA INGESTION PORTAL  
Wake up your data - set them free for Blue Society

Search CONTACT US

EuroGOOS European Global Ocean Observing System

GOVERNOR GENERAL  
Chairman  
WORLD OCEANOGRAPHIC  
COMMISSION  
GENERAL SECRETARY

The EMODnet Data Ingestion is a component of the present EU marine data management infrastructure and existing pathways towards the EMODnet data portals



- If the data provider can set up the data flow according to the defined standards, then we only have to link and include the new catalogue and data stream
- If the data provider cannot setup the data flow (lack of experience, technical capacity etc.), we work on harvesting the data from the provider, harmonize and format the data and make them available

Figure 27. EMODNet data ingestion structure as part of the EU marine data management infrastructure.

## Sensor Calibration & Integration

- Calibrated before and after mission
- **Comparison across platforms during mission**

### SPURS2 Saildrone and WHOI Buoy Compar

Saildrone within 5-km of Buoy

Zhang, et al., 2019: Comparing air-sea flux measurements from a new unmanned surface vehicle and proven platforms during the SPURS-2 field campaign. *Oceanography*, 32(2), pp.122-133.

Figure 28. SPURS-2 best practices related to sensor calibration and integration between ASV Saildrone and moored buoy conducted by NOAA.

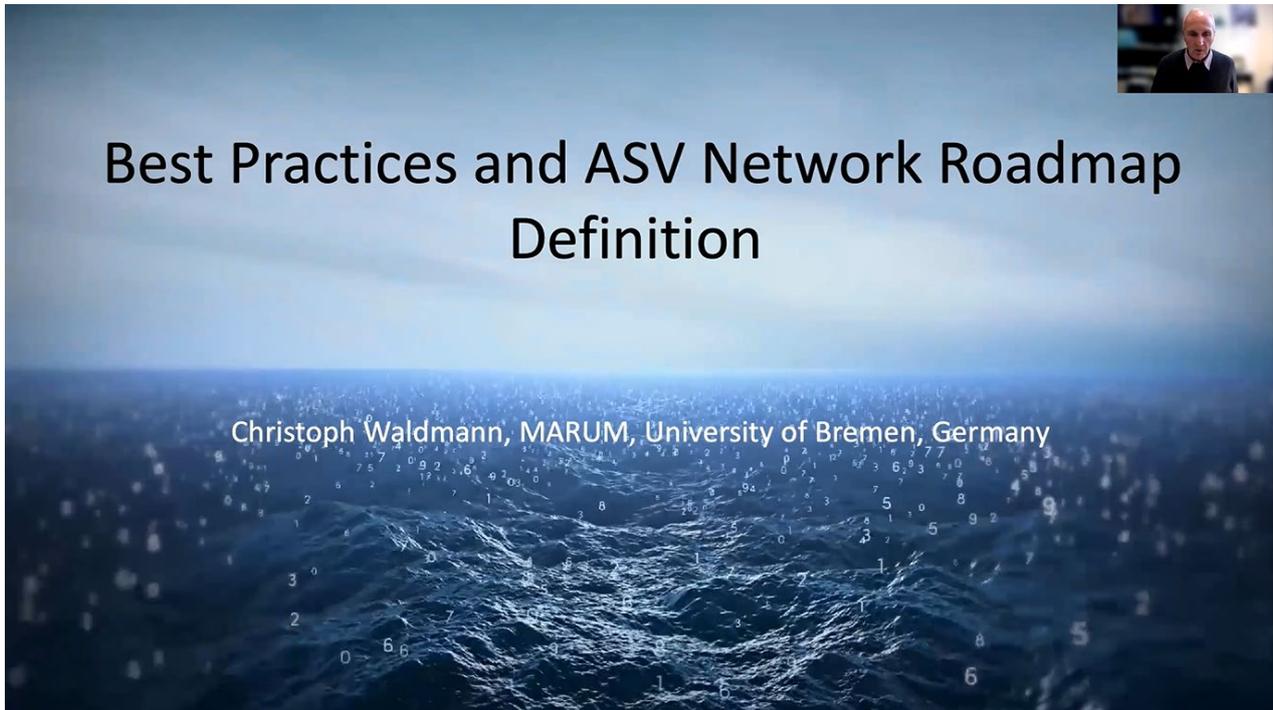


Figure 29. Overview on ASV Best Practices and Network Roadmap definition by MARUM.



Figure 30. Key recommendations to implement an ASV Network.

A 2<sup>nd</sup> EuroSea ASV-workshop was held on April 13<sup>th</sup> and 14<sup>th</sup> at PLOCAN headquarters in Gran Canaria, Spain, engaging forty attendees in-person (Figure 32) and fifty on-line attendees all of them as experts in this domain representing leading company manufacturers, agencies, research institutions, NGO, etc. The 2-day workshop was organized in four main sessions that included enlightening talks prior to round tables for open discussion on Regulatory framework, Standard Operational Procedures, Best Practices, Risk Assessment, Data and Metadata Management, Services, Network Implementation, Roadmap and Future Trends, were the main topics discussed along these 2-days workshop through sessions chaired by the EuroSea’s task 3.7 leaders NOC, MARUM, FEUP and PLOCAN as shown in the agenda (Figure 31)

April 13 <sup>th</sup> , 2023	April 14 <sup>th</sup> , 2023
<p style="text-align: center;"><b>Morning Session REGULATORY FRAMEWORK</b></p> <p style="text-align: center;">Chair: James Burris (NOC)</p> <p>09:20 - Welcome + Intro + WS Goals (Carlos Barrera)</p> <p>09:45 – Enlightening &amp; Context</p> <ul style="list-style-type: none"> <li>• Talk 1 - UNIV. OF PLYMOUTH</li> <li>• Talk 2 - DGMM/MITMA</li> <li>• Talk 3 - CENTRO JOVELLANOS</li> <li>• Talk 4 - VLIZ (on-line)</li> <li>• Talk 5 – NOAA (on-line)</li> <li>• Talk 6 - MARITIME ROBOTICS (on-line)</li> <li>• Talk 7 - NOC</li> </ul> <p>11:00 - Coffee break</p> <p>11:30 - Open Discussion / Round Table (All)</p> <p>12:45 - Session's summary and conclusions (Chair)</p> <p>13:00 - Lunch break</p> <p style="text-align: center;"><b>Afternoon Session STANDAR OPERATIONAL PROCEDURES / BEST PRACTICES / RISK ASSESSMENT</b></p> <p style="text-align: center;">Chair: Christoph Waldmann (MARUM)</p> <p>14:00 - Enlightening &amp; Context</p> <ul style="list-style-type: none"> <li>• Talk 1 - EXAIL</li> <li>• Talk 2 - HERIOT WATT</li> <li>• Talk 3 - LAMMA</li> <li>• Talk 4 - VLIZ</li> <li>• Talk 5 - NOAA</li> <li>• Talk 6 - NOAA</li> <li>• Talk 7 - MARUM</li> </ul> <p>15:45 - Coffee Break</p> <p>16:00 - Open Discussion / Round Table (All)</p> <p>17:15 - Session's summary and conclusions (Chair)</p> <p>17:30 - Wrap up &amp; Hotel transfer</p>	<p style="text-align: center;"><b>Morning Session DATA &amp; METADATA MANAGEMENT / SERVICES /</b></p> <p style="text-align: center;">Chair: Andres Cianca (PLOCAN)</p> <p>09:30 - Enlightening &amp; Context</p> <ul style="list-style-type: none"> <li>• Talk 1 - GEOMAR</li> <li>• Talk 2 - NOAA (on-line)</li> <li>• Talk 3 - HERIOT WATT</li> <li>• Talk 4 - INRIM</li> <li>• Talk 5 - PROOCEANO</li> <li>• Talk 6 - CLS</li> <li>• Talk 7 - EMODNET (on-line)</li> </ul> <p>11:00 - Coffee break</p> <p>11:30 - Open Discussion / Round Table (All)</p> <p>12:45 - Session's summary and conclusions (Chair)</p> <p>13:00 - Lunch break</p> <p style="text-align: center;"><b>Afternoon Session NETWORK IMPLEMENTATION / Ris/ ROADMAP &amp; FUTURE TRENDS</b></p> <p style="text-align: center;">Chair: Joao Sousa (FEUP)</p> <p>14:00 - Enlightening &amp; Context</p> <ul style="list-style-type: none"> <li>• Talk 1 - NOAA</li> <li>• Talk 2 - GROOM-2 (on-line)</li> <li>• Talk 3 - SUBSEASAIL</li> <li>• Talk 4 - EMS/Liquid Robotics</li> <li>• Talk 5 - PML</li> <li>• Talk 6 - TIDEWISE</li> <li>• Talk 7 - EXAIL</li> <li>• Talk 8 - OCEAN AERO</li> </ul> <p>15:45 - Coffee Break</p> <p>16:00 - Open Discussion / Round Table (All)</p> <p>17:15 - Session's summary and conclusions (Chair)</p> <p>17:30 - Wrap-up &amp; Hotel transfer</p>

Figure 31. Agenda overview of the 2<sup>nd</sup> Eurosea ASV workshop.



Figure 32. 2nd Eurosea ASV workshop announcement and meeting room at PLOCAN headquarters.



Figure 33. Group picture with the on-site attendees to the 2<sup>nd</sup> Eurosea ASV workshop.





Figure 34. Representative screenshots from the 2<sup>nd</sup> Eurosea ASV-workshop's sessions. All presentations and recordings from this 2<sup>nd</sup> EuroSea ASV Network workshop can be found through this link <https://drive.google.com/drive/folders/1ueL437sRwMTeCLKsuVgi8AUqZp52dYj1>

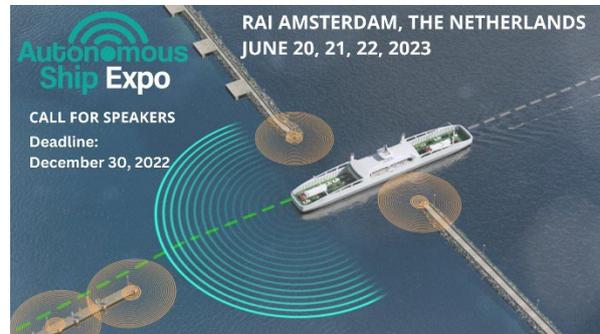
In addition to the two workshops, several activities for promotion and engagement related to Eurosea ASV Network initiative have been conducted throughout Task 3.7 execution where leading ASV developers, manufacturers, operators, users and stakeholders have joined in order to contribute and support the initiative. In particular, PLOCAN has led in cooperation with the other task 3.7 partners several oral presentations in different events at national (Spain) and international level. Among others, some of the most significant actions have been as follows:



Some links to these events for a more detailed information:

- <https://www.aslo.org/osm2022/scientific-sessions/>
- <https://www.oceanologyinternational.com/london/en-gb/conference.html#/sessions>
- <https://www.oceanologyinternationalamericas.com/en-gb/conference.html#/sessions>
- <https://mcedd.com/agenda/>
- <https://www.eoos-ocean.eu/events/eoos-technology-forum-2022-workshop/>
- <https://transnav2021.umg.edu.pl/>
- <https://www.oceanbusiness.com/>
- <https://isms-canarias.com/>
- <https://www.imo.org/en/OurWork/Safety/Pages/MASS.aspx>
- <https://www.mitma.gob.es/marina-mercante/i-jornada-tecnica-sobre-buques-autonomos>
- <https://airseaobs.org/resources/webinars>

Already scheduled by not yet conducted at the time of writing this document, it is expected to present the EuroSea's ASV Network initiative also at the following national and international events related to ocean-observing and autonomous marine navigation technologies:



- <https://limerick23.oceansconference.org/>
- <https://www.autonomousshipexpo.com/index.php>
- <https://gulfcoast23.oceansconference.org/>
- <https://sarti.webs.upc.edu/martech/>
- <https://noc-events.co.uk/mats-2023>
- <https://eurogoos-conference2023.marine.ie/event/133655:eurogoos-international-conference-2023>

### 5.3. Workshop's main preliminary outcomes

Preliminary but at the same time very helpful and promising outcomes derived from the 1<sup>st</sup> ASV workshop are listed below:

- Great level of interest, attendance and contribution from current key ASV-community members representing the “triple-helix” perspective (industry, academia/science and agencies). Some other key members unable to attend by committed for
- The ASV technology is already well developed and mature (TRL 8-9) in many cases.
- Huge technological and operational capabilities to cover in a synergistic way current ocean-observing gaps, being two of the main ones (1) to be able to monitor essential climate variables (ECV) and essential ocean variables (EOV) at the same time on an unprecedented space-time scale, and (2) act as gateway to link in real-time underwater observations with satellite platforms.
- Several helpful synergies already identified (and tested) with other ocean-observing platforms (fixed and mobile).
- Wide range of applications/services for several Blue Growth sectors on ocean-observing, survey, intervention, border security, etc. some of them already implemented in routine mode.
- Several technologies already as commercial product (important difference from other ocean-observing technologies).
- Risk assessment and management system is key.
- Clear lack at network level (main motivation to undertake this initiative under EuroSea project) from key aspects like technical -platforms and subsystems components-, coordinated operations/missions, data/metadata, legal framework (links with IMO/MASS strategy), best practices and standards, etc.

## 6. ASV Network: The way ahead

ASV technology is already present in various areas of the main seas and ocean, to carry out a large variety of measurements of physical and biogeochemical variables. The ASV-Network aims at integrating and leveraging the efforts of the ASV community becoming this activity an important building block towards an integrated end-to-end International/European Ocean Observing System, EOOS. Through their unique sampling capabilities, ASV enhance the panel of observing systems and contribute to the design of the EOOS. Sustained ASV observations link the open-ocean to the shore with physical, chemical, and biological observations in a synergistic way with other platform, such as floats, moorings, drifters etc. They contribute to fulfill the establishment of an operational service for ecosystem-based management and boost the improvement of modelling and forecasting of the ocean.

The ASV Network aims at boosting scientific collaboration and information resources to address the following priorities:

- International cooperation
- Sustained observation, operational oceanography and scientific research
- Technology development and relationship with industries
- Data management
- Support to EU/international policies and research Infrastructures (RIs)

In terms of aim and objectives, the below are the envisaged so far:

1. Act on behalf of the global ASV community.
2. Further develop the ASV network, coordinate and assist in the standardization and sharing of best practices for ASV operations and applications and harmonization of data and metadata.

3. Ensure data availability for the Copernicus Marine Environment Monitoring Service (CMEMS), WMO, EMODnet data portals and other data aggregators and appropriate users via the Global Data Assembly Centre (GDAC) for ASV data.
4. Set up a framework for:
  - Promoting ASV applications and operational oceanography services through liaison between industry, operators, users, advocacy, and provision of expert advice.
  - Sharing success stories and difficulties.
  - Maintaining and sharing reference material on ASV-related technologies (sensors, protocols, readiness levels and specifications, data management standards and quality control).
  - Providing and exchanging source tools (data analysis, applications...).
  - Promoting scientific synergies for key questions.
  - Filling gaps and looking for complementary with other ocean-observing technologies
  - Promotion of joint proposals.
5. Contribute to the development of the GOOS, initially focused on the EOOS for the coastal area and the open ocean.
6. To enhance the number of EOVs and ECVs measurements.
7. To provide recommendations on metadata, data structure, format and dissemination (interoperability of datasets) and Quality Control procedures.

The ASV Network should be composed by a Chair and can have one or two Co-chairs, and members. The mandate, role and responsibilities of potential co-chairs are the same as for the Chair. Chair and Co-chair are responsible for: (1) Oversight of the ASV Network management; (2) Alignment of the “Task Team Work” (if any) with its terms of reference and with the ASV; (3) Developing the task team (if any) yearly implementation plan in line with the above; (4) The organization of regular meeting with ASV Network members (i.e. once a year); (5) Represent the working group at external meetings.

Members are selected based on a call for nominations to the ASV network members and an external call or expression of interest among experts at international level. Members are selected by the Chair and the ASV Network, keeping in mind the spread and representativeness in expertise, geographical representation and the gender balance of the group. Membership is reconsidered by the Chair and the ASV Network on a regular basis and can be terminated if the member does not fulfill the below responsibilities. Members’ responsibilities are to: (1) Be a committed advocate for ASV Network goals and objectives; (2) Understand strategic implications and outcomes of the ASV Network; (3) Provide guidance for ASV Network goals and objectives; (4) Participate to the working group activities; (5) Monitor and review ASV Network activities, orally or in writing, in a timely manner; (6) Represent the activity at external meetings, upon agreement with the chair; (7) Attend working group meetings; (8) Follow-up on the developments related to the working group’s activities, to ensure the working group’s work is timely and topical.

Terms of reference (ToR) for the ASV Network should be defined for approval by the ASV community. Once approved, the ASV Network chair will launch a call for member nominations and the working group is formally established according to these ToR. A kick-off meeting should be organized with all the members to develop the first annual implementation plan. ASV Network chair oversees the communication related to the working group activities. To this end, the working group implementation plan should be cognizant of general strategy at upper level (board, steering committee -SC- or similar).

The ASV Network should run according to its ToR and annual implementation plans. The ASV Network will report to upper level its activities to be reviewed and approved at General Assembly meetings (minimum in a year basis, desirable every six month).

At the kick-off meeting, the members and the chair(s) brainstorm on the target audience for the ASV Network outputs and the main communication messages. This brainstorming is prepared with support of the SC to align the plans with other strategic initiatives on Ocean Observing at international level. The group also establishes the expected/desired impact of its activities on the target audience.

### 6.1. Future specific actions

- Based on the success derived from the two workshops conducted, the following specific actions are envisaged within the framework of EuroSea (and hopefully beyond) to accordingly setup and implement the ASV Network as one network component more aligned with the main international ocean observing strategies:
- Keep the promotion of the initiative to engage new potential members in the upcoming months. Part of this strategy is the session *“Uncrewed Surface Vehicles (ASVs). Technology Trends and Improvements on Observing Applications for the Ocean Decade”* (<https://www.aslo.org/osm2022/scientific-sessions/#ot>) already included in the science/technical program of the Ocean Sciences Conference 2022, to be held virtually from February 27<sup>th</sup> to March 4<sup>th</sup>. In parallel, dedicated additional meetings as side-event within the framework of scientific and/or workshops, conferences, trade shows, etc. are planned at least once a year.
- Define possible synergistic cooperation frameworks with initiatives already ongoing and implemented, such organizations, initiatives, programs and projects (i.e. EuroGOOS, OceanGliders, GROOM II, EUMarineRobots, TechOceans, etc.).
- Define a business model and a cooperation framework within “triple-helix” (industry, academia and agencies) approach in matters of technological development, applications and related services.
- Build up links to the existing Uncrewed Surface Vehicle Network for GOOS (USV Network for GOOS that is part of the UN Ocean Decade Programme Observing Air-Sea Interactions Strategy (OASIS))
- Help to develop the Community of Practice for ASVs/USVs, by contributing to the monthly organized “USV Network for GOOS” webinar: <https://airseaobs.org/resources/webinars>
- Seek for a continuation of the started ASV activities by exploring links to running EU projects like GROOM II and future EU projects.
- Activities to identify possible test sites for ASV/USV systems will be continued. That will include developing criteria (requirements) for those test sites.
- Recommendations on enhancing the operational capabilities of ASV/USV systems, in particular by identifying needs for further software and hardware developments.
- As a result of the 2<sup>nd</sup> ASV Workshop recommendations for operating ASVs in national and international waters will be compiled, i.e., addressing legislative aspects and training of operators.

Derived from these general outcomes, some key questions are still open to further discuss, such 1) What is the difference between a **network** and a **patchwork** of missions?; 2) What is the function of a **Community of Practice** for the emerging network?; 3) Which parts of the emerging USV network are near an **operational readiness level?**; 4) What is the **roadmap** for gaining all **attributes of the emerging USV network?**

In particular, and according to the main topics considered for discussion through the two workshops conducted, these are the main outcomes for each one as driver on which to keep building the ASV Network:

#### REGULATORY FRAMEWORK:

- Who is responsible in case of an accident? The pilot? The company? Nobody?
- If the pilot is the captain, what type of license is required?
- What is a USV vs. ASV vs. Ship vs. Boat vs. etc?
- Different national regulations are emerging (France, UK, Spain, Norway, Belgium, USA, Brasil, USA,...)
- International Maritime Organization (IMO) as umbrella framework. <https://www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx>
- In general, proactive actions by USV operators to inform all authorities that are involved in marine traffic surveillance etc. will lower the risk of conflicts and damage.
- A knowledge hub providing information about rules & regulations and Points of Contact in different nations should be developed and maintained.
- Task Team Group on regulatory framework for USV.
- Specific regulations for USV operation as “specific platform” for ocean observing.

#### STANDARD OPERATIONAL PROCEDURES / BEST PRACTICES / RISK ASSESSMENT

- There are many choices now for USVs made from companies around the world. Each has unique capabilities, e.g. ability to dive and become an underwater glider, motorized, wave propulsion, wind propulsion, multiple propulsion systems, launched from a dock or shore slip or at sea, ...
- USVs are being used around the world for many different applications: monitoring Fisheries, Weather & Climate prediction, Satellite validation, Air-sea interaction & Ecosystem research, Naval applications, Aquaculture and offshore energy production monitoring, Monitoring soundscape, Subsurface telemetry, Bathymetry mapping, etc.
- The private sector is interested to using Reference Test Sites that are fit for purpose for their particular USV system and their related requirements – example the AARC concept, OceanSITES, U. Plymouth Marine Station. Testing & Intercomparisons are key for raising Readiness Levels and can provide field calibrations.
- Need for a Task Team Group with special focus on Standard Operational Procedures, Best Practices and Risk Assessment.
- Training – Certification for USV operation, with particular focus on piloting (IMO certification)
- Test Site Facilities – Standardization.
- Distributed piloting Infrastructure.

- Science payloads (sensors) definition and standardization according to GOOS and WMO protocols.
- Best Practices (OBP)

#### DATA / METADATA MANAGEMENT AND SERVICES

- USV can measure many Essential Ocean Variables & Essential Climate Variables that are monitored by the Global Ocean Observing System
- Need to standardize metadata according to WMO Integrated Global Observing (WIGO) standards
- ERRDAP servers and repositories can help make the USV data Findable – Accessible – Interoperable – and Reusable (FAIR) – Data Hub / Repository (GTS, CORIOLIS,...)
- USV data provided through Global Telecommunication Services (GTS) can be used operationally to improve weather and climate service forecasts.
- End Users / Bluegrowth sectors (energy, fisheries, science, aquaculture, tourism,...)
- Standard data formats (NetCDF,...)
- Need for a Task Team Group nomination with special focus on data / metadata management.
- Telemetry - Flat rate proposal in order to make the operation more efficient and sustainable.
- WMO National Data Centers as part of the data management infrastructure.

#### NETWORK IMPLEMENTATION / RODAMAP AND FUTURE TRENDS

- White paper describing network principles (diverse platforms, public-private-partnerships, legal frameworks, oversight, ...) and the driving applications for the USV network for GOOS.
- Definition of the Community of Practice governance (co-chairs, executive committee, steering committee, data management committee, ...)
- Need to find diverse set of mid-senior leaders/co-chairs and ECOP leads.
- National commitment (Spain, Germany, UK, Belgium, Portugal, France, USA, Brasil,...) - National POC nomination
- To held and year-basis in-person meeting to keep initiative ongoing.
- Strength synergies with existing sister initiatives and programs (GROOM, OceanSites, Emodnet, ESA, OCEANOPS, etc.)
- Nominate a Steering Committee of five truly committed members representing private/public sector members.
- Ocean Sciences Meeting 2024 (USV Session lead by OASIS-NOAA program). It has been identified as the next event to keep the USV Network initiative ongoing beyond the EuroSea project, as part of

the cooperation between USA and EU in this particular topic. EuroSea ASV Network members are already part of the OSV24 event organization.

- To define a Program Framework (UN Decade,...) as next step to frame the USV initiative (i.e. OASIS). A particular synergistic action has been started in conjunction with OASIS program (more information here <https://oceandecade.org/actions/observing-air-sea-interactions-strategy-oasis/>) In this particular topic, the EuroSea USV initiative has already joined the OASIS Webinar Series <https://airseaobs.org/resources/webinar>

## 7. Conclusions

Task 3.7 "Autonomous Surface Vehicles" has accomplished the final objective of establishing the basis for an ASV network implementation in order to improve coordination, technological innovation and good practices at EU and international level. The operation of this network would make it possible to strengthen the use of these technologies in the field of ocean observation following the good practice guidelines that are being undertaken with other more mature observation platforms and generating products, especially those linked to the atmosphere-ocean interface that they are currently necessary for the progress of knowledge about climate. Among the specific actions, the two workshops conducted enabled to engage leading manufacturers, users and stakeholders, both in the public and private sectors, as well as in the European and international community.

The pandemic situation limited the meeting options during the first half of the project, which prevented the holding of the first workshop in face-to-face mode, and despite various changes to the event date, it had to be held virtually and with a significant level of success despite limitations. The second workshop did favor the meeting, bringing together the main ASV actors at the PLOCAN facilities with an agenda conducive to achieving the objectives.

During these events, the uses and applications that are currently being addressed with these technologies were shared, which due to their wide and multidisciplinary characteristics and execution areas (public and private) are extensive. Thanks to international participation, it was possible to find out the development situation of each area and favour contacts to search for regional improvements (Capacity Building to Ocean Observing Strategies). In addition, the contributions during the workshops favour to identify the current strengths and weaknesses of the ASV technology to contribute with global ocean observing strategies (EOOS, GOOS, etc.)

One of the main points of progress has been linked to the national and international regulatory framework for operations with ASVs. The contributions from the different national groups responsible for participating in the modifications that have been made in the framework of operations with this type of vehicle have generated a more global and common knowledge that will allow contributing in a more coordinated way in the respective national and international regulatory systems. In addition, the useful and enriching conclusions of the meeting were addressed to the definition of the main working topics on which the ASV network initiative should be built, such as the regulatory framework (national and international), Applications and Derived Services, Data & Metadata management, Standard Operating Procedures and Future trends in the market.

Finally, thanks to the EuroSea project, synergies and a particular collaborative framework have been established (even beyond EuroSea) with the OASIS-NOAA USV network initiative (already endorsed by UN Ocean Decade) for a more comprehensive and lasting ocean-observing approach. Furthermore, the ASV network initiative should be developed beyond EuroSea through EuroGOOS Glider TT- GROOM RI and OASIS

(USA) initiatives to build a valued and recognized international community that coordinate step-change increase in oceanic, atmospheric and ecosystem surface and boundary layer observations for estimating air-sea fluxes and interactions across the global ocean in a coordinated and sustainable strategy way.

## Acknowledgements

The authors of this document thank all members from industry, academia, government agencies, NGO and stakeholders who have shown interest and contributed to all the actions undertaken to date within the initiative to define and implement an international ASV Network. Your trust and willingness are very much appreciated and encouraging for the way ahead.

A special mention of acknowledge is for the WP3 leaders for their support and understanding despite difficulties that occurred during these last project months. Sometimes things do not go as expected, but in this case what is undoubtedly is the interest and enthusiasm with which the four lead partners in charge of task 3.7 face the opportunity that EuroSea offers to implement a new ocean-observing network based on ASV technology in benefit to EOOS and GOOS, among other ocean-observing initiatives.

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