SCIENCE AND TECHNOLOGY ORGANIZATION

CENTRE FOR MARITIME RESEARCH AND EXPERIMENTATION

Reprint Series **CMRE-PR-2019-020**

Current regulatory issues in the usage of Autonomous Surface Vehicles

Fausto Ferreira, João Alves, Carolina Leporati, Andrea Bertolini, Elena Bargelli

May 2019

Originally presented at:

2018 OCEANS – MTS/IEEE Kobe Techno-Ocean (OTO)
doi: 10.1109/OCEANSKOBE.2018.8558875

About CMRE

The Centre for Maritime Research and Experimentation (CMRE) is a world-class NATO scientific research and experimentation facility located in La Spezia, Italy.

The CMRE was established by the North Atlantic Council on 1 July 2012 as part of the NATO Science & Technology Organization. The CMRE and its predecessors have served NATO for over 50 years as the SACLANT Anti-Submarine Warfare Centre, SACLANT Undersea Research Centre, NATO Undersea Research Centre (NURC) and now as part of the Science & Technology Organization.

CMRE conducts state-of-the-art scientific research and experimentation ranging from concept development to prototype demonstration in an operational environment and has produced leaders in ocean science, modelling and simulation, acoustics and other disciplines, as well as producing critical results and understanding that have been built into the operational concepts of NATO and the nations.

CMRE conducts hands-on scientific and engineering research for the direct benefit of its NATO Customers. It operates two research vessels that enable science and technology solutions to be explored and exploited at sea. The largest of these vessels, the NRV Alliance, is a global class vessel that is acoustically extremely quiet.

CMRE is a leading example of enabling nations to work more effectively and efficiently together by prioritizing national needs, focusing on research and technology challenges, both in and out of the maritime environment, through the collective Power of its world-class scientists, engineers, and specialized laboratories in collaboration with the many partners in and out of the scientific domain.

Copyright © IEEE, 2018. NATO member nations have unlimited rights to use, modify, reproduce, release, perform, display or disclose these materials, and to authorize others to do so for government purposes. Any reproductions marked with this legend must also reproduce these markings. All other rights and uses except those permitted by copyright law are reserved by the copyright owner.

NOTE: The CMRE Reprint series reprints papers and articles published by CMRE authors in the open literature as an effort to widely disseminate CMRE products. Users are encouraged to cite the original article where possible.

Current regulatory issues in the usage of Autonomous Surface Vehicles

Fausto Ferreira[1], João Alves[1], Carolina Leporati, Andrea Bertolini[2], Elena Bargelli[3]

I. ABSTRACT

Autonomous Surface Vehicles (ASVs) are becoming increasingly popular for a large number of applications from oceanography to border protection and shipping. In particular, the advent of long-term ASVs allows for months-long missions such as the round globe trips made by Wave Gliders. This introduces both opportunities and challenges. While long-term ASVs can be very useful, for instance, in monitoring applications, legal and safety challenges arise with their increased presence in the seas. Few initiatives are pushing for specific regulations in Civil Law for Robotics. One of them has been taken by the European Parliament. In this article, we present the European Parliament proposed guidelines, identify the most prominent regulatory issues of ASVs in a specific use case and discuss the feasibility of applying these guidelines and other alternatives to regulate the use of ASVs.

II. INTRODUCTION

Autonomous Surface Vehicles (ASVs) are becoming increasingly popular for a large number of applications from oceanography to border protection and shipping. In the research field, this is related to the advent of long endurance ASVs (up to many months or in some cases unlimited). This extended endurance is possible through advances in wave-powered propulsion together with solar panels[1] or through a combination of wind power, solar panels, and diesel generator[2]. This introduces both opportunities and challenges. On one hand, ASVs can stay long periods at sea and for instance, provide real-time information during hurricanes or travel long distances crossing oceans (such as the Wave Gliders [1] round globe trips). On the other hand, such endurance and operational capabilities bring challenges related to safety and legal issues. This applies not only to research activities but also to industry and commercial activities in general.

Indeed, Autonomous Ships are now a hot topic and several projects are working on such challenges both from a technical and legal perspective. When one considers a big industry such as shipping, the legal considerations become even more important as the risk increases when compared to small research-purpose ASVs. The fact that the shipping industry is interested in this topic [2] means that the push for clear legal rules will be stronger. This benefits all kinds of Unmanned Marine Vehicles (UMVs). A clear sign is the recent decision from the International Maritime Organization (IMO) of starting a regulatory scoping exercise to determine safe operation of Maritime Autonomous Surface Ships (MASS) within existing IMO instruments[3]. This is a landmark step as the IMO Maritime Safety Committee recognised the leading role that IMO should take in the regulation of unmanned vessels. The Comité Maritime International (CMI), the oldest international organization that gathers national law associations in the maritime domain, created few years ago a Working Group on Maritime Law for Unmanned Crafts. It has since then produced a position paper [3]. that enumerates a series of rules (from jurisdictional to technical). This position paper concludes that it is not possible to transplant liability rules for manned vessels to unmanned ones and that a more comprehensive review of the current regulatory framework s well as more international dialogue are necessary. With that in mind, the CMI has distributed recently a questionnaire [4] to its national members to encourage discussion and converge towards a consensus.

Other industry/government-driven initiatives are being promoted especially in the Nordic Countries and UK. One example is the Advanced Autonomous Waterborne Application initiative [2], funded by the Finnish government. The Danish Maritime Authority is also investing in Autonomous Ships[4]. It has very recently released both a pre-analysis of Autonomous Ships [5] and an analysis of regulatory barriers [6]. In Norway, the first test area for autonomous ships was recently defined in the Trondheim fjord[5]. In Norway, there is also an interest group[6] called Norwegian Forum for Autonomous Ships (NFAS) that established recently the International Network for Autonomous Ships[7]. The Swedish Maritime Competence Centre has published a report regarding autonomous safety on vessels [7]. DNV-GNL, the biggest classification society has also launched the concept of a zero emission unmanned ship for short trips in the ReVolt

[1]Fausto Ferreira and João Alves are with NATO STO Centre for Maritime Research and Experimentation (CMRE), Viale San Bartolomeo 400, 19126 La Spezia, Italy Fausto.Ferreira,Joao.Alves@cmre.nato.int, [2] Andrea Bertolini is with DIRPOLIS Institute, Scuola Superiore Sant'Anna, Piazza Martiri della Libertà, 33, 56127 Pisa andrea.bertolini@santannapisa.it, [3] Elena Bargelli is with Department of Political Sciences, University of Pisa, Via Serafini, 3 56126 Pisa elena.bargelli@unipi.it

[1]https://www.liquid-robotics.com/platform/overview/

[2]https://www.asvglobal.com/product/c-enduro/

[3]http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-98th-session.aspx

[4]https://www.dma.dk/Vaekst/autonomeskibe/Pages/default.aspx

[5]https://www.oneseaecosystem.net/dimecc-opens-first-globally-available-autonomous-maritime-test-area-west-coast-finland-one-sea-implementation-moves-forward/

[6]http://nfas.autonomous-ship.org/index-en.html

[7]http://www.autonomous-ship.org/

project[8]. Japan plans to have self-piloting ships launched by 2025[9].

At a European level, the European Commission has also been funding several projects. Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) [8] was launched by the EC under its Seventh Framework Programme (FP7) from 2012 to 2015 and investigated the feasibility of operating Autonomous Ships. Some of these initiatives mention the increase in safety by using Autonomous Ships with respect to manned ones as most of the accidents occur due to human erroneous action according to European Maritime Safety Agency statistics (62% in the period 2011-2015). However, few authors have assessed the potential impact of unmanned vessels on maritime transportation safety. In [9], it is shown that the number of groundings or collisions would likely decrease with unmanned ships but in case of accidents, consequences might be more severe (*e.g.* no crew to stop a fire). Therefore, it is important to study the safety and legal issues of ASVs.

The type of questions posed by the use of ASVs for long periods and wide areas are:

- how to classify and register them?
- how to avoid collisions?
- to which rules should ASVs abide?
- are these rules different depending on the operational area? (territorial waters, Exclusive Economic Zone, international waters)
- who is liable in case of an accident?

Currently, there is an obvious regulatory gap for what concerns UMVs of which ASVs are a subset. For example, only very recently the first ASV was registered by the UK Shipping Registry[10], which opens a new world when it comes to ASV operations. Classification and registration of ASVs are essential to close this gap and start establishing liability and legal rules. Some authors define the Juridical Regime of UMVs as enigmatic [10]. Most authors alert to the need for new or adapted rules dedicated to UMVs as the current regulations found in the Law of the Sea are not adequate [11], [12], [13], [14]. Others defend that U.S. Maritime Law could apply to UMVs and that UMVs could be considered vessels if they carry a payload [15].

The legal complexity comes from many different factors including: different types of vehicles and applications (Military, Research or Commercial); degree of autonomy (from remote operated to autonomous); different law application depending on the type of sea (territorial, international); and lack of specific legislation [12]. The last arises because of all other factors but also because the United Nations Convention on the Law of the Sea (UNCLOS) [16] applies to all ships but does not define exactly what is a ship. This increases legal uncertainty regarding whether an ASV can be considered a ship or not. The same happens with the International Convention for the Safety of Life at Sea (SOLAS), 1974 [17]. On the other hand, the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) [18] states that rules apply to vessels defined as "every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation". Research ASVs are not used as means of transportation although some authors [10], [15] believe COLREGs could include UMVs (and thus ASVs). There is no consensus yet regarding this topic. Even in such a case, the regulations set by COLREG 1972 are hard to be fully applicable for ASVs from a technical point (*e.g.* lights of a certain shape, rules of adaptive behaviour depending on sea traffic, fog, presence of a look-out (Rule 5), etc). For an ASV, identifying what kind of vessel is front of it is a complex perception problem that might be hard to solve for certain sea states or weather conditions. Nonetheless, one could argue that Rule 1 e) of COLREGs applies if a Government considers an ASV a vessel of special construction or purpose. This could apply as long as the Government is able to establish classification criteria to define an ASV such a vessel and to define which other provisions should apply that have the closest possible compliance with COLREGs. The fact that several groups are working in COLREGs compliant ASVs can help to converge to a consensus. In this sense, the very recent MAXCMAS (MAchine eXecutable Collision regulations for Marine Autonomous Systems) research project from Rolls Royce[11] is a step forward as it has shown autonomous collision avoidance that is indistinguishable from good seafarer behaviour in accordance to COLREGs.

Nonetheless, an inclusion of specific rules for ASVs in COLREGs and other international conventions is needed for two main reasons. First, to increase the safety of ASVs and other vessels navigating in the same waters. Second, to increase the legal certainty in case of accident but also in case of innocent passage. This is not a theoretical problem as accidents and incidents do happen. For example, the drifting of an ASV in a foreign Exclusive Economic Zone can be an considered an incident [19].

In this paper, the study will be focussed on the case of a small research ASV used in Italian territorial waters. It should be clear that small to mid-size research ASVs and large Autonomous Ships are very different platforms typically employed in very different application scenarios. For example, there is no doubt that an autonomous ferry or an Autonomous Ships transporting containers can both be used as means of transportation. They could therefore fit into the COLREGs definition. Here, we will limit our analysis to a small scale research ASV not capable of carrying people or goods (besides its limited scientific payload). Different use cases and proposals for new/amended regulations will be addressed in future work. Bootstrapping from initial work on analysing the current situation, we present how the European

[8]https://www.dnvgl.com/technology-innovation/revolt/

[9]https://asia.nikkei.com/Business/Deals/Japan-aims-to-launch-self-piloting-ships-by-2025?page=1

[10]https://www.ukshipregister.co.uk/news/uk-ship-register-signs-its-first-unmanned-vessel/

[11]https://www.rolls-royce.com/media/press-releases/yr-2018/21-03-2018-maxcmas-success-suggests-colregs-remain-relevant-for-autonomous-ships.aspx

Parliament (EP) guidelines can be applied in this situation. The choice of this example brings interesting questions as by UNCLOS the State has sovereignty in territorial waters including for Marine Scientific Research purposes (Part XIII of UNCLOS, art. 245). Therefore, one must look also at Italian laws to present the current situation. As Italy is a member State of the European Union (EU), if the guidelines proposed are converted in a EU directive as requested to the European Commission, this might ultimately apply to ASVs navigating in Italian territorial waters.

The fact that different laws can apply to territorial and international waters does not help for the legal certainty of ASVs. Same applies to territorial waters from different countries. If each country starts regulating ASVs by itself, manufacturers might have issues in marketing their products and adapting to the state laws. Therefore, if one finds a way of applying the same set of legal regulations for the different scenarios, it can be very positive for the market. An unified legal framework will bring both legal certainty and standardised systems/rules that producers and users of ASVs can easily comply with. In that sense, if European guidelines can shape EU Member State laws, this will be beneficial and contribute to standard rules.

The remainder of the paper is organised as follows. Section III reviews briefly the state-of-the-art, Section IV presents the EP guidelines on how to regulate robotics, while Section V illustrates the use case. Section VI explains what happens when applying the EP guidelines to this use case and Section VII concludes the paper pointing future work directions.

III. State-of-the-art

There is a considerable set of literature discussing several of the questions posed above. For what concerns safety, there are several groups working on implementing COLREG-compliant ASVs [20], [21], [22], [23]. Other authors propose the transmission of Automatic Identification System (AIS) data from the ASVs [15]. While this is a step forward, one should bear in mind that without a clear set of rules that are public and publicised to the manned vessels operators, ASVs still present a possible hazard to safety (their own and others'). If a large shipping vessel has an accident with a small ASV, perhaps only the ASV gets damaged (and the vessel scratched). In the case of an accident with a small recreational boat, the damage can be considerable and human lives can be put in peril. Most of all, some of these technical solutions do not solve safety issues for all kinds of manned vehicles that can interact with ASVs (*e.g.* small boats do not receive AIS data). Therefore, these ASV safety rules (whether COLREG-inspired or other) must be standardised and disseminated among the whole maritime community and must be able to solve the safety issues related to different kinds of ASVs and manned vehicles.

For what concerns the legal aspects, there are several published studies advocating for more detailed regulations for UMVs [13], [15]. Some of the current initiatives mentioned in Section II are looking at these aspects as part of their effort to operate commercial Autonomous Ships. For instance, MUNIN project did a legal and liability analysis of remote controlled ships [24]. This work assumed a Shore Control Center to which responsibility and liability were attributed. There have been also some works proposing best practice and guidelines. For instance, the Society for Underwater Technology published a Recommended Code of Practice [25] in 2009 and an initiative from the European Defence Agency (EDA) named Safety and Regulations for European Unmanned Maritime Systems (SARUMS) has published a document detailing best practices for Unmanned Maritime Systems handling, operations, design and regulations [26] in 2012, updated in 2015.

Another important work has been conducted by the UK Maritime Autonomous Systems Regulatory Working Group (MASRWG) which also published in late 2017 a Code of Practice [27] focussed on Unmanned Surface Vehicles (USVs), up to 24 meters in length, and as mentioned in the document, of voluntary adoption for its members. One contribution of this group was an Information (INF) paper to the IMO Maritime Safety Committee 95th Session (MSC 95) in June 2015, to raise awareness of Maritime Autonomous Ships and the UK's work on a regulatory framework. The US Navigation Safety Advisory Council (NAVSAC) has been publishing resolutions since 2011 regarding best practices when it comes to safety (COLREG compliance, AIS transmission, etc), professionalism, respect, and procedures but without regulating liability or other aspects. South Korea is also investigating guidelines for regulations through the Infrastructure Technology for Highly Reliable Operation of USVs at Sea (INTEROUS) project. Unfortunately, there is not much information available. Very recently, Bureau Veritas, a certification company has published Guidelines for Autonomous Shipping [28] but these do not include liability or insurance issues. Also, very recently, Lloyd's Register, one of the biggest maritime classification society has published a guidance document on Cyber-enabled ships [29] but again liability or insurance is not mentioned. Nonetheless, these are only guidelines and constitute at most so-called acts of soft law. That is why the recent decision of IMO Maritime Safety Committee is a landmark step as it could create binding international law rules. The same reason justifies testing the feasibility of the EP guidelines as the EP requests the EC to propose a directive which ultimately has binding effects.

IV. EP guidelines on Civil Law Rules on Robotics

An important step towards establishing guidelines for regulating robotics (in general) has been published recently and sums up the work developed in the framework of the European FP7 RoboLaw[12] project - the first European project dedicated to the study of law applied to robotic technologies [30]. This work has also inspired a report with recommendations to the European Commission (EC) on Civil Law Rules on Robotics approved by the European Parliament (EP) recently[13]. While this landmark work applies

[12] http://www.robolaw.eu/

[13] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2017-0005+0+DOC+XML+V0//EN

these guidelines on how to regulate robotics for cases like autonomous cars or healthcare robotics it does not address the marine domain. Another work from Nexa Center for Internet and Society [31] analyses the law for service robots both from civil and criminal liability points of view but again does not refer marine robotics.

The EP report (as well as the Robolaw project) provide an interesting point of view on how Europe should regulate robotics. The report includes guidelines on how to look at the problem taking into account European culture and social norms and provides a series of recommendations to the EC. The difference to the guidelines mentioned in Section III is that this report calls the EC to propose a directive on Civil Law on Robotics which has juridical effects and is not an act of soft law. It is then important to look at this report. The main points made by this approach are the need to look at the social desirability of a given robotic technology when making policy decisions and the need to reflect the EU Charter of Fundamental Rights (such as human rights, justice, privacy, safety etc). It also highlights the fact that current liability rules might be inadequate for the new generation of robots (*e.g.* with self-learning capabilities).

The report then provides a series of recommendations to the EC regarding general principles, ethical principles, liability, and a Charter on Robotics. This includes a code of ethical conduct for robotics engineers, a code for research ethics committees and licence for designers and for users. The considerable importance given to ethics and human values is related to the applications mentioned in the report as all these greatly involve human beings. Indeed, the report mentions autonomous vehicles (i.e. cars), care robots, medical robots, human repair and enhancement, and drones (remotely piloted aircraft systems). All these technologies interact with humans not only from a physical point of view but also psychological with possible safety, privacy, economical and social issues due to their disruptiveness and human-robot interaction.

Marine robotics is very different from medical robotics. UMVs are very different from care robots and even autonomous cars (although some similarities arise in this case). For instance, an ASV might not replace directly a job that a human would perform (like a robotic surgeon does). Or it might not be used as a means of transportation like the autonomous car. ASVs imply a level of human-robot interaction significantly lower than a robotic prosthesis. Thus, not all the recommendations of the EP report apply to ASVs. Nonetheless, some of them do apply and will be enunciated here. Their application to the use case will be explained in Section VI after introducing it.

The most important points that can be applied to the marine domain are those related to liability, classification, standardisation, safety, and security. Indeed, points X to Z of the Liability section highlight the inadequacy of current legislation in terms of liability. This is relevant in particular when the damage is provoked by an autonomous robot with self-learning capabilities.

Among the general principles, the EP motion calls on the Commission to propose a definition of smart autonomous robots based on characteristics such as autonomy, self-learning, physical support and adaptive behaviour (Point 1). The motion also considers the need for a registration system and calls on the Commission to establish classification criteria. Point 11 recalls the need for privacy and data protection guarantees and calls the Commission to foster standards for the concepts of privacy by design and privacy by default. In terms of standardisation, Point 13 calls the Commission to continue the work on international harmonisation of technical standards, through the European Standardisation Organisations and with the International Standardisation Organisation (ISO). More relevant, Point 14 highlights the need for risk assessment of testing robots in real-life scenarios and calls the Commission to draw uniform criteria in order to identify areas where experiments with robots are allowed (*e.g.* test ranges).

The most relevant considerations for what concerns our study are the ones regarding liability. Point 26 considers that whatever legislative instrument will apply to robots, the form of compensation should not be limited on the sole ground that damage is caused by a non-human agent. In Point 27 it recommends the application of strict liability as a rule, which means requiring to prove only that the damage has occurred and it was due to the harmful behaviour of the robot (regardless of fault). Point 28 considers that liability should be proportional to the level of autonomy (and/or instructions received). However, it does not explain how to identify who should be the responsible parties, which is a key aspect. On Point 29, the motion proposes a mandatory insurance scheme to be taken out by the producer. As [30] notes, this can have a chilling effect on technology and might not be the best solution.

Indeed, in Point 30 the report proposes also a compensatory fund as a complement to the mandatory insurance scheme for cases where no insurance cover exists and calls the insurance industry to develop new products. More important, Point 31 calls the Commission to evaluate a series of possible legal solutions and its impact, namely:

- a. compulsory insurance for producers or owners of robots for damage provoked by their robots;
- b. compensation fund not only for cases where damage was not covered by an insurance but also to allow financial operations in the interest of robots;
- c. limited liability for the manufacturer, programmer, owner or user as smart robots would be endowed with a compensation fund, with damage to property claimed within the limits of that fund (and other types of damage not subject to this limit);
- d. general fund for all smart autonomous robots or a fund for each robot category, with a one-off fee or periodic contributions to the fund;
- e. link between robot and fund through an individual registration number in a transparent registry allowing people to know the limits of liability and other details;
- f. specific legal status for robots, such as a status of electronic persons with rights and obligations for the most sophisticated robots.

Point 33 encourages international cooperation with regulatory standards under the auspices of United Nations (of which the International Maritime Organization (IMO) is a specialised agency). Finally, Point 35 requests the Commission to submit a proposal for a directive on civil law rules on robotics, following the recommendations set in this report.

The annex proceeds to detail the recommendations and presents the Charter on Robotics. This includes the code of ethical conduct for robotics engineers, the code for research ethics committees, the licence for designers, and the licence for users. While most of these deal with ethics, there are a couple of points worth mentioning that can be applied to the maritime domain. In particular, it promotes interoperability and recommends the access to the source code to investigate accidents and damage caused by smart robots. This point can be controversial and it will be detailed later. Regarding the code of ethical conduct for robotics engineers, it is worth mentioning the privacy issues. Human informed consent (as requested in this code) in a marine application is hard to imagine and only privacy by design (requested in the licence for designers) can be attained. Instead, the principle of maximising benefit and minimising harm can be applied. Namely, not having a risk of harm greater than the one encountered in ordinary life and the need for risk assessment. The licence for designers includes other desirable aspects in all domains such as kill-switch mechanisms, operation in accordance with law, and identification of robots as such when interacting with humans.

V. Use case of a small research ASV

As mentioned, our specific use case is a small research ASV working in Italian territorial waters within 12 miles from the coast. In this case, UNCLOS assigns sovereignty to the coastal State, *i.e.* Italy. Moreover, Art. 245 of UNCLOS attributes exclusive rights to regulate, authorise and conduct Marine Scientific Research (MSR) in territorial sea to the sovereign state. Therefore, MSR can only be conducted in these waters with express consent and under the conditions set forth by the coastal State.

When using the the small ASV for MSR purposes, the scientific research entity seeks an authorisation from the Italian State, providing the operational details. Currently, the adopted procedure is to “babysit” the ASV with a manned research vessel. For safety reasons, a small work boat is ready to intervene in case of danger. This can happen for instance when other boats/vessels approach the ASV either by negligence or curiosity even when the robot’s path is well defined. There is no doubt that this is an inhibition to the ASV’s capabilities (*e.g.* long-term endurance and autonomy) and increases considerably the operational costs by requiring extra vessels and manpower to conduct research. This happens, at least in part, because of the current legal gap and the difficulty of classifying an ASV as a vessel (and therefore apply current regulations). Without clear definitions, classification, and registration, it will be hard to define more specific rules for ASVs and thus avoid constraints such as extra vessels, etc.

Moreover, even if following the agreed guidelines and procedures, in the event that a third party provokes a damage to the ASV due to negligence, the operating entity will face difficulties to defend itself as there are no specific rules that sea users must respect towards an ASV. Although any third party must avoid collisions, there is no clear rule that obliges them to recognise the ASV by lights or signals as the lights and signs that an ASV should bear are not defined yet. Thus, in case of a collision, the operating entity/owner is in a disadvantaged position. Even if the third party is negligible, this negligence can be hard to prove in court as it is not completely clear what should be the requested behaviour (by law) with respect to an ASV. Finally, currently it is hard to get third party insurance for such vehicle due to the lack of classification and registration. However, there have been insurance products for Remotely Operated Vehicles (ROVs) for many years and recently the insurance market has started covering also Autonomous Underwater Vehicles (AUVs) as long as these are launched from a manned vessel. Thus, insuring ASVs is not a faraway possibility as the insurance market is interested in covering UMVs in general.

VI. Application of EP guidelines to the use case

As seen in Section V, there are no specific rules for the case of an ASV in Italian territorial waters. There is then the need to test the feasibility of application of guidelines from the European Parliament (EP) report (which are in line with [30]) to this use case as Italy is an EU member and an EU directive has to be converted in Italian national law. It must be said however that regulating ASVs at a European level is not ideal. The maritime domain is intrinsically a matter of international law. Thus, while the EP report can shed some light on the direction of civil law on robotics, international laws proposed by the IMO might be the best solution. Nonetheless, Point 33 of the EP report states that international cooperation under UN auspices should be continued and IMO is a UN specialised agency. Therefore, any EU directive or guideline can inform and/or align with IMO future regulations and should follow the work recently initiated by the Maritime Safety Committee of IMO (to be done by mid-2020).

As mentioned in Section IV, there is a set of matters that the EP report brings up that are not the most relevant to this use case. Those include the ethical framework and the grounding of rules to the European values of human dignity, privacy and others. It is worth mentioning that these topics are not irrelevant but can be in some way self-regulated by code. For instance, privacy by design and by default can be easily implemented (by blurring camera images if an ASV is carrying a camera) although human informed consent is impossible to obtain in such an application. If a programmer or producer does not respect ethical standards and uses an ASV to harm a third party on purpose, there is fault and tort laws should apply. In the following, we assume that by conducting scientific research, this will not happen and therefore we will concentrate on other more prominent issues. Of course, if a hacker takes control of an ASV, then security issues apply and liability can be hard to assign. This specific case is out of the scope of this paper. Following the guidelines of [30], we have first identified the most important issues for the given use case.

A. Classification

In terms of classification, as mentioned in Section IV, the report mentions the need to define a smart autonomous robot and their subcategories based on several criteria and to classify in order to register it. This is the most basic step to be able to arrive at any regulation and it is of extreme importance for ASVs. The difficulty of classifying an ASV as a vessel is what makes it hard to apply current regulations and is the issue that needs to be solved *ex ante* any legal rule.

In this respect, it is worth noticing that both the Recommended Code of Practice [25] and especially the Best practices published by the SARUMS initiative [26] are extremely helpful to define such a classification. In particular, in [25], a definition of Autonomous Underwater Vehicle (AUV) is given and in [26], it is proposed a definition of Unmanned Maritime Systems (UMS) with two categories: Unmanned Surface Vehicles (USV) and Unmanned Underwater Vehicles (UUV) and subcategories depending on length, distance and speed. It does also define five levels of control from operated to autonomous.

B. Registration

Registration is the second step required to get to regulate ASVs. The EP report calls the Commission to devise a registration system at European Level based on classification criteria. This register would be managed by a future EU Agency for Robotics and Artificial Intelligence.

There is no doubt that registration is an essential step. Very recently, the first ASV was registered in the UK Shipping Registry[14]. While this opens a new era, individual country-based registries with different classification criteria should be avoided as it could have a chilling effect on the market (*e.g.* producers need to respect different criteria in different countries). In that sense, an EU registry would help to have a more standard classification. Nonetheless, the best would be to have a Classification and Registry system promoted by IMO. In such a way, even if each country has its own Registry, the classification criteria would be the same in all countries (members of IMO). This would definitely help the manufacturers, owners, and users as well as improve legal certainty.

C. Safety and Testing

Other important issues in the path to be able to form a legal basis for ASVs are their safe operation and the need for extensive testing. The EP report highlights the need for risk assessment of experimental robotics and the need to define conditions upon which certain areas can be used for experiments with robots. It does also promote safety in the Code of Conduct for Robotics Engineers.

[14]https://www.ukshipregister.co.uk/news/uk-ship-register-signs-its-first-unmanned-vessel/

In terms of safety, currently safety by design is common and several mechanisms can be used in ASVs to embed this principle. Doubtless, the most important feature to be included in safe ASVs is collision avoidance. This can be performed in many different ways and with different types of sensors (radar, camera, LIDAR, etc). Nonetheless, even it the ASV has built-in algorithms for collision avoidance, these might not work as the ASV cannot expect the dynamical behaviour of the other vessel (and vice-versa). For instance, some authors propose to use COLREGs [10] and as mentioned there are several groups working on implementing COLREG-compliant ASVs [20], [21]. It remains a technical challenge though to implement fully COLREGs in ASVs (*e.g.* for fog conditions etc) and it remains a dissemination challenge to inform all other vessels (including small recreation boats) that an ASV complies with COLREGs. Without this, it is hard to be 100% sure that collision avoidance mechanisms will work.

In such a case, dedicated sea lanes can help to avoid collisions. Other research groups declare an ASV as a vessel restricted in her ability to manoeuvre and thus will keep its course and speed so other vessels need to keep out of the way. This is neither an optimal solution as if the other vessel is also in distress and the ASV cannot identify this situation by recognising the emergency lights and signals, a collision can take place. COLREGs rely heavily on human control of navigation and depending on the type of vessel, tonnage and navigation situation. For an ASV, recognising automatically all the possible variants might be hard. Other authors proposed AIS data transmission [15] which can help but is not enough (not all boats receive AIS data). Whatever the solution will be, the most important thing is that it is well disseminated across all spectrum of different vessels from small recreational boats to large shipping vessels.

For what regards testing and risk assessment, the need for defining test areas highlighted by the report is urgent. While it can be more critically to define the criteria for urban areas, at sea, it is still possible to find remote areas with low navigation traffic and close this to navigation creating test ranges for ASVs (and in general UMVs). This is already a reality in Norway[15] and other countries have the same long-term objective (Finland) [2]. The need for test ranges and risk assessment without which new insurance products can be hardly well defined is also recalled by other authors [32].

Finally, the report also mentions the need for interoperability and access to source code in order to investigate accidents. Interoperability is very much desired and there is a considerable amount of work on that aspect (including different robotics domains interoperability) both in the military (US Air Force, US Navy) and in the civilian domain (*e.g.* ICARUS FP7 project [33]). Instead, access to source code might raise Intellectual Property (IP) issues regardless of the robotics domain (maritime or not). This might have again a chilling effect on the market as manufacturers might not

[15]https://www.oneseaecosystem.net/dimecc-opens-first-globally-available-autonomous-maritime-test-area-west-coast-finland-one-sea-implementation-moves-forward/

be willing to give full access to their code, or programmers when it comes to scientific research. There is no doubt a need to investigate accidents and to be able to find the responsible for damages. Thus, a possible solution is to have access to the ASV logs. In order to facilitate the investigation, increase fairness and legal certainty, a standardised black-box with logs in a precisely defined format could be sufficient (instead of source code). Moreover, it is much easier to analyse logs than source code and the time and effort spent to investigate the accident can be shorter.

D. Liability and Insurance

Coming to the most complex aspect (as it depends on the previous), the EP report contains several interest points regarding liability. As seen, the fact that the form of compensation should not be limited on the sole ground that damage is caused by a non-human agent. Then, the recommendation regarding using strict liability as a rule (without fault). While this might be possible to check on the maritime domain (i.e. if the damage occurred and was provoked by the ASV), it is still hard to identify who is the responsible party. Same on Point 28 when it proposes that liability should be proportional to the level of autonomy (and/or instructions received). Other authors [32] declare that robots are products and thus product liability rules do apply which makes the producer responsible for all damages caused by the user and third parties by the functioning of the device. This is not ideal in the case of marine scientific research where the user normally integrates other sensors in a basic platform and thus the ASV producer should not be deemed responsible for a defect on a sensor that is not sold by him. Moreover, in scientific research the user is not always a "passive" user that just uses the robot but it modifies its software, programming advanced tailored algorithms, etc. Thus, product liability rules hardly apply in such a case and strict liability (product type or not) has the issue of identifying the responsible party. As the CMI Position paper argues [3], third party liability is hard to attribute, namely, it is not clear if it may attach to software designers and manufacturers and whether the liability should be fault-based or strict. For instance, if one applies ordinary liability principles, the liability derived from an accident involving a pre-programmed autonomous ship could be assigned in some proportion between the shipowner, the software manufacturer and the programmer. To what extent these proportions should amount remains to be investigated and decided.

Liability rules have the benefit of inducing *ex ante* socially desirable behaviours by the manufacturer (such as safe products) by shifting costs of a harmful event to the responsible party while allowing for proper compensation of the harmed property/individual [30]. The most common way of dealing with liability is to have an insurance system. The EP report proposes a mandatory insurance scheme (similar to cars) to be taken out by the producer. This might be not always the best solution and the report indicates several legal options to be assessed by the Commission. Among them, is the proposal for a compensatory fund as a complement to the mandatory insurance for cases where no insurance cover exists. This could perhaps apply in the maritime domain. For instance, while Autonomous Ships with installed pre-programmed autonomy algorithms could possibly be more easily insured, research ASVs pose more issues due to their experimental characteristics. Therefore, if insurance companies would be reticent to insure a research vehicle (because of the difficulty of assigning responsibility to producer, owner, user or programmer, and thus possible amount of litigation), research ASVs could be covered by the compensation fund. It is worth mention that ROVs are insured and recently AUVs could also be insured as long as they are launched from a manned vessel. Thus, the insurance market is looking at UMVs and a solution will be found.

Another option proposed by the EP report is to attribute limited liability for the manufacturer, programmer, owner or user as the robots would be endowed with a compensation fund. This is also a possible solution in a research ASV case where liability can be actually shared among different people (*e.g.* the fault could be both from the producer and the user) and it is hard to identify who is liable. For instance, even using the black-box solution mentioned in the previous subsection, if a team of programmers modified the product sold by the manufacturer, it might be hard to identify exactly which programmer is to blame for negligence or fault.

Finally, the report asks to investigate if it would be better to have a general fund for all smart autonomous robots or one per category. Due to the nature of each category and the variance (even within category), we believe that it is better to have a separated one for UMVs (and eventually specifically for a subcategory) as the market values of shipping vessels or some service robots are very different. The link between robot and fund through its individual registration number could be made available also in the maritime domain.

Whatever solution is to be taken, there seems to be consensus in the literature on how to regulate liability. Both the Best Practice Guidelines from SARUM [26] and [32] recommended to follow two parallel paths:

- assess what would happen by applying existing regulations (*e.g.* IMO based like UNCLOS, COLREGs) with a narrow-tailored technological assessment;
- develop in parallel an internationally-accepted set of guidelines of desirable regulations.

The Danish Maritime Authority analysis [6] recommends, instead, to amend existing regulations as much as possible, creating new ones only when necessary. It also recommends to regulate internationally by IMO to ensure that ASVs can operate in a large geographical area with no jurisdiction issues.

VII. Conclusion and Future Work

This work presented the EP report regarding guidelines on Civil Law rules on robotics and their application to some of the most important issues related to the regulation of ASVs. The application of the guidelines was motivated with the specific use case of a small research ASV operating in Italian territorial waters. While some of the work proposed by the EP report is not relevant, the liability issues are well discussed and different interesting solutions could be applied to the use case. Moreover, the general principles are in line with the requirements of ASV regulations. Classification, registration and safety are specific urgent aspects to be solved in order to be able to provide a legal frame to ASV operations, assign liabilities and define clear third party insurance scheme.

While following European guidelines is desirable, it is equally important to consider which current regulations can already be applied to ASVs (with amendments). In particular, IMO regulations should be considered for this purpose as the Danish Maritime Authority report [6] recommends. The EP report also mentions international cooperation with UN institutions, so we hope there will not be conflicting rules from the future EU directive against IMO-based regulation. Finally, while the several individual countries' efforts on defining best practices and guidelines are well intended, only through cooperation with IMO can these practices be adopted worldwide. This adoption will contribute to diminish market barriers, jurisdictional issues and increase legal certainty. It is interesting to note that working groups defining best practices are well aware of this need [27]. We believe that only through international cooperation and international, well defined laws, the field of ASVs can grow without chilling effects derived from new legal regulations.

It was not in the scope of this work to offer a solution to the issues presented, but rather to investigate the feasibility of applying EU guidelines to the maritime domain when compared to what is already being done. As future work, the issue of liability and insurance, one of the most relevant, will be better studied, in particular for different cases, *e.g.* research/commercial ASVs, small/large ASVs, modified by the user or programmer/pre-defined producer missions, etc.

ACKNOWLEDGMENT

We would like to thank our colleague Ian Sage, Head of the Ship Management Office at CMRE for his valuable feedback and review.

REFERENCES

[1] J. Manley and S. Willcox, "The wave glider: A persistent platform for ocean science," in *OCEANS 2010 IEEE - Sydney*, May 2010, pp. 1–5.
[2] F. C. Henrik Ringbom and M. Viljanen, "Legal implications of remote and autonomous shipping," in AAWA white paper "Remote and Autonomous Ships The next steps, Rolls-Royce plc.
[3] C. IWGUS, "Cmi international working group position paper on unmanned ships and the international regulatory framework," online. [Online]. Available: http://comitemaritime.org/Uploads/Questionnaires/CMI\%20Position\%20Paper\%20on\%20Unmanned\%20Ships.pdf
[4] ——, "Cmi questionnaire on ummaned ships," online, March 2017. [Online]. Available: http://www.comitemaritime.org/Uploads/Questionnaires/CMI\%20IWGUS\%20Questionnaire\%2024\%2003\%2017.docx
[5] M. Blanke, M. Henriques, and J. Bang, "A pre-analysis on autonomous ships," Technical University of Denmark, Tech. Rep., 2016. [Online]. Available: https://www.dma.dk/Documents/Publikationer/Autonome\%20skibe_DTU_rapport_UK.pdf
[6] D. M. Authority, "Analysis of regulatory barriers to the use of autonomous ships," Danish Maritime Authority," Final Report, December 2017. [Online]. Available: https://www.dma.dk/Documents/Publikationer/Analysis\%20of\%20Regulatory\%20Barriers\%20to\%20the\%20Use\%20of\%20Autonomous\%20Ships.pdf
[7] R. Rylander and Y. Man, "Autonomous safety on vessels - an international overview and trends within the transport sector," Lighthouse, Tech. Rep., 2016. [Online]. Available: https://www.lighthouse.nu/sites/www.lighthouse.nu/files/attachments/autonomous_safety_on_vessels_-_webb.pdf
[8] MUNIN, "Research in maritime autonomous systems project results and technology potentials (final brochure)," 2016. [Online]. Available: http://www.unmanned-ship.org/munin/wp-content/uploads/2016/02/MUNIN-final-brochure.pdf
[9] K. Wróbel, J. Montewka, and P. Kujala, "Towards the assessment of potential impact of unmanned vessels on maritime transportation safety," *Reliability Engineering & System Safety*, vol. 165, pp. 155 – 169, 2017. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0951832016303337
[10] L. Giunta, "The enigmatic juridical regime of unmanned maritime systems," in *OCEANS 2015 - Genova*, May 2015, pp. 1–9.
[11] S. E. Showalter, "The law governing autonomous undersea vehicles: what an operator needs to know," in *Proceedings of OCEANS 2005 MTS/IEEE*, Sept 2005, pp. 52–54 Vol. 1.
[12] R. Rogers, "The legal regime governing auv operations how far and how wide," in *2012 IEEE/OES Autonomous Underwater Vehicles (AUV)*, Sept 2012, pp. 1–5.
[13] E. Van Hooydonk, "The law of unmanned merchant shipping: an exploration," *THE JOURNAL OF INTERNATIONAL MARITIME LAW*, no. 20, pp. 403–423, 2014.
[14] L. Carey, "All hands off deck? the legal barriers to autonomous ships," NUS Centre for Maritime Law, NUS Law Working Paper No. 2017/011, 2017. [Online]. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3025882
[15] S. Showalter and J. Manley, "Legal and engineering challenges to widespread adoption of unmanned maritime vehicles," in *OCEANS 2009*, Oct 2009, pp. 1–5.
[16] U. Nations, "United nations convention on the law of the sea." [Online]. Available: http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf
[17] I. M. Organization, "International convention for the safety of life at sea (solas) 1974." [Online]. Available: http://www.imo.org/en/About/conventions/listofconventions/pages/international-convention-for-the-safety-of-life-at-sea-(solas),-1974.aspx
[18] ——, "Convention on the international regulations for preventing collisions at sea, 1972." [Online]. Available: http://www.imo.org/en/About/conventions/listofconventions/pages/colreg.aspx
[19] W. J. Kirkwood, "Auv incidents and outcomes," in *OCEANS 2009*, Oct 2009, pp. 1–5.
[20] Y. Kuwata, M. T. Wolf, D. Zarzhitsky, and T. L. Huntsberger, "Safe maritime autonomous navigation with colregs, using velocity obstacles," *IEEE Journal of Oceanic Engineering*, vol. 39, no. 1, pp. 110–119, Jan 2014.
[21] M. R. Benjamin and J. A. Curcio, "Colregs-based navigation of autonomous marine vehicles," in *2004 IEEE/OES Autonomous Underwater Vehicles (IEEE Cat. No.04CH37578)*, June 2004, pp. 32–39.
[22] H. N. H. Oh, A. Tsourdos, and A. Savvaris, "Development of collision avoidance algorithms for the c-enduro usv," *IFAC Proceedings Volumes*, vol. 47, no. 3, pp. 12 174 – 12 181, 2014, 19th IFAC World Congress. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1474667016435524
[23] S. Campbell and W. Naeem, "A rule-based heuristic method for colregs-compliant collision avoidance for an unmanned surface vehicle," *IFAC Proceedings Volumes*, vol. 45, no. 27, pp. 386 – 391, 2012, 9th IFAC Conference on Manoeuvring and Control of Marine Craft. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1474667016312605
[24] MUNIN, "D7.2 legal and liability analysis for remote controlled vessels," 2013. [Online]. Available: http://www.unmanned-ship.org/munin/wp-content/uploads/2013/11/MUNIN-D7-2-Legal-and-Liability-Analysis-for-Remote-Controlled-Vessels-UCC-final.pdf
[25] C. Carleton, C. Fay, G. Griffeiths, A. Holt, R. Rogers, and A. Tonge, *The Operation of Autonomous Underwater Vehicles: Volume One: Recommended Code of Practice. 2nd Edition*, J. Dering, Ed. Society for Underwater Technology, 2009.

[26] EDA, “Working paper - best practice guide for ums handling, operations, design and regulations.” EDA SARUMs Working Paper, 2012.
[27] M. UK, “Being a responsible industry: An industry code of practice,” Tech. Rep., November 2017. [Online]. Available: https://www.maritimeuk.org/documents/197/CODE_OF_PRACTICE_V1.0_-_Up_to_24m_-_Final.pdf
[28] B. Veritas, “Guidelines for autonomous shipping,” Bureau Veritas, Tech. Rep., December 2017. [Online]. Available: http://www.bureauveritas.jp/news/pdf/641-NI_2017-12.pdf
[29] L. Register, “Cyber-enabled ships shipright procedure assignment for cyber descriptive notes for autonomous & remote access ships,” Lloyd’s Register, Guidance document Version 2.0, December 2017. [Online]. Available: https://www.lr.org/en/cyber-safe-for-marine/
[30] R. Leenes, E. Palmerini, B.-J. Koops, A. Bertolini, P. Salvini, and F. Lucivero, “Regulatory challenges of robotics: some guidelines for addressing legal and ethical issues,” *Law, Innovation and Technology*, vol. 9, no. 1, pp. 1–44, 2017. [Online]. Available: https://doi.org/10.1080/17579961.2017.1304921
[31] G. Noto La Diego, M. A. Senor, C. Artusio, M. Alovisio, C. Blengino, M. Ciurcina, G. B. Gallus, U. Pagallo, M. Travostino, G. Vaciago, and P. Zampella, “The law of service robots,” Nexa Center for Internet & Society Papers,” Research Paper, 2015. [Online]. Available: https://nexa.polito.it/nexacenterfiles/robots-2015.pdf
[32] A. Bertolini, P. Salvini, T. Pagliai, A. Morachioli, G. Acerbi, L. Trieste, F. Cavallo, G. Turchetti, and P. Dario, “On robots and insurance,” *International Journal of Social Robotics*, vol. 8, no. 3, pp. 381–391, Jun 2016. [Online]. Available: https://doi.org/10.1007/s12369-016-0345-z
[33] D. S. Lopez, G. Moreno, J. Cordero, J. Sanchez, S. Govindaraj, M. M. Marques, V. Lobo, S. Fioravanti, A. Grati, K. Rudin, M. Tosa, A. Matos, A. Dias, A. Martins, J. Bedkowski, H. Balta, and G. D. Cubber, “Interoperability in a heterogeneous team of search and rescue robots,” in *Search and Rescue Robotics - From Theory to Practice*. Rijeka: InTech, 2017, ch. 06. [Online]. Available: http://dx.doi.org/10.5772/intechopen.69493

Document Data Sheet

Security Classification		Project No.
Document Serial No. CMRE-PR-2019-020	**Date of Issue** May 2019	**Total Pages** 9 pp.

Author(s)

Fausto Ferreira, João Alves, Carolina Leporati, Andrea Bertolini, Elena Bargelli

Title

Current regulatory issues in the usage of Autonomous Surface Vehicles

Abstract

Autonomous Surface Vehicles (ASVs) are becoming increasingly popular for a large number of applications from oceanography to border protection and shipping. In particular, the advent of long-term ASVs allows for months-long missions such as the round globe trips made by Wave Gliders. This introduces both opportunities and challenges. While long-term ASVs can be very useful, for instance, in monitoring applications, legal and safety challenges arise with their increased presence in the seas. Few initiatives are pushing for specific regulations in Civil Law for Robotics. One of them has been taken by the European Parliament. In this article, we present the European Parliament proposed guidelines, identify the most prominent regulatory issues of ASVs in a specific use case and discuss the feasibility of applying these guidelines and other alternatives to regulate the use of ASVs.

Keywords

Issuing Organization

NATO Science and Technology Organization
Centre for Maritime Research and Experimentation

Viale San Bartolomeo 400, 19126 La Spezia, Italy

[From N. America:
STO CMRE
Unit 31318, Box 19, APO AE 09613-1318]

Tel: +39 0187 527 361
Fax:+39 0187 527 700

E-mail: library@cmre.nato.int