atlantis The Atlantic Testing Platform for Maritime Robotics

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Survey on legal and regulatory specifications for IMR robots operating in offshore wind farms

EDP and RINA-C

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Disclaimer

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Acronym	Meaning
AC	Alternating current
AI	Artificial Intelligence
AMN	Autoridade Marítima Nacional
ANAC	Autoridade Nacional da Aviação Civil
ASV	Autonomous Surface Vehicles
ATS	Air Traffic Service
AUV	Autonomous Underwater Vehicle
BVLOS	Beyond Visual Line of Sight
CC	Civil Code
COLREG	International Regulations for Preventing Collisions at Sea
CRP	Constitution of the Portuguese Republic
DC	Direct Current
DSC	Digital Selective Calling
EASA	European Union Aviation Safety Agency
EC	European Commission
EDA	European Defence Agency
EEA	European Environment Agency
EEC	European Economic Community
EEZ	Exclusive Economic Zone
EF	Emission factor
EIA	Environmental Impact Assessment
EP	European Parliament
EPIRB	Emergency Position Indicating Radio Beacon
EU	European Union
FMECA	Failure Mode Effects and Criticality Analysis
FP7	Seventh Framework Programme
FPV	First-Person-View

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GAIRS	Generally Accepted International Rules and Standards
GMDSS	Global Maritime Distress Safety System
GPDR	General Data Protection Regulation
H&S	Health and Safety
HAZOP	Hazard and Operability
HES	Health, Environment and Safety
HM	Harbour Masters
HSC	High-Speed Craft
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
IMR	Inspection, Maintenance and Repair
IP	Intellectual Property
ISM	International Safety Management
ISO	International Organization for Standardisation
ITU	International Telecommunication Union
LARS	Launch and Recovery System
LF	Load factor
LIDAR	Light Detection and Ranging
LUC	Light UAS Operator Certificate
MAR	Madeira's International Shipping Registry
MASRWG	Maritime Autonomous Systems Regulatory Working Group
MASS	Maritime Autonomous Surface Ships
MAV	Maritime Autonomous Vehicle
MCA	Maritime & Coast Guard Agency
MF	Medium-Frequency
MMO	Marine Management Organisation
MMS	Maintenance Management System
MNTB	Merchant Navy Training Board

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MPA	Marine Protected Area
MSP	Maritime Spatial Planning
MSR	Marine Scientific Research
MTOM	Maximum take-off Mass
NAVTEX	Navigational text messages
NORSOK	Norsk Sokkels Konkurranseposisjon
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OSPAR	Oslo/Paris convention
OW	Offshore Wind
OWF	Offshore Wind Farm
Pp	Peak Power
PPE	Personal Protective Equipment
QA	Quality Assurance
QR	Quick Response
RCC	Remote Control Centre
ROV	Remotely Operated Vehicle
RPS	Remote pilot station
SAC	Special Areas of Conservation
SAM	System of the Maritime Authority
SARUMS	Safety and Regulations for European Unmanned Maritime Systems
SCC	Shore Control Centre
SEA	Strategic Environmental Assessment
SME	Small and Medium-sized Enterprise
SMS	Safety Management System
SOLAS	International Convention for the Safety of Life At Sea
SORA	Specific Operations Risk Assessment
SPAs	Special Protection Areas

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SPS	Special Purpose Ships
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UMV	Unmanned Maritime Vehicle
UNCLOS	United Nations Convention on the Law of the Sea
USV	Unmanned Surface Vehicles
VHF	Very High Frequency
VLOS	Visual Line of Sight
WFA	WindFloat Atlantic
WIN	Watercraft Identification Number

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1. Introduction

The regulations, laws and guidelines at both international and national level have been assessed to have a clearer understanding about essential legal aspects to comply with to ensure safe operations involving robotic technologies. Robots are an emerging technology and thus, in many cases, there are not ad-hoc legislations: the most likely scenario is trying to fit these technologies into already existing regulatory frameworks, although it is a common perception that tailored regulations might be necessary to overcome uncertainties due to the unmanned nature of these vehicles.

The purpose of this document is to provide an overview about regulatory requirements to be met to deploy robotic solutions in offshore wind farms. This document is framed by the work package 1 (*Industry-oriented Showcases for Offshore Wind Farms*) to act as deliverable D1.2. The document is articulated as follows:

- Section 2 provides an overview about the so-called "General Regulations" which are not robot-oriented. These regulations deal with paramount aspects which must be considered when dealing with OWFs. Particularly, topics such as environmental and social impact and health and safety of workers are treated.
- Section 3 addresses the main aspects related to ROVs' operations. In particular, topics like classification, administrative requirements, personnel qualifications and responsibilities and operational requirements are discussed. For this section, guidelines and well-accepted practices defined by recognized certification bodies (such as IMCA, NORSOK) are analysed.
- Section 4 provides a wide overview about the current legal status of ASVs. International treaties and national laws (for Portugal and UK) are reported: a special focus is paid on how these regulations deal with matters such as classification, registration, liabilities, insurance, operational and technical requirements.
- Section 5 deals with AUVs.
- Section 6 describes the main European directives and Portuguese regulations governing the use of UAVs. Particular attention is paid to classification, operational requirements, personnel qualifications and liabilities and insurance issues.

In each section, besides reporting and discussing the aforementioned regulations, is presented a special window with a focus on ATLANTIS' compliance with them.

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2. GENERAL REGULATIONS

The scope of this Section is to describe all the general regulations which must be fulfilled during operations in an Offshore Wind Farm (OWF), with special focus on O&M activities performed through robots as per the scope of ATLANTIS. The topics cover:

- *Environmental impact*: the main European and International legislations (most of them converted in national legislations by the Member States) governing the preservation of the natural ecosystems are herein described. Hazards coming from the use of robotic technologies during O&M activities, as well as possible mitigation measures, are discussed.
- *Social and commercial impact*: the key International regulations aiming at ensuring the peaceful use of sea by different actors (such as: fishermen, merchant ships, tourism companies etc.) are reported. Moreover, how ATLANTIS may enhance the coexistence between different marine stakeholders is also tackled.
- *Health & Safety of workers*: main international laws aiming at guaranteeing the health and safety of workers are described. Typical risks that workers face during O&M activities are illustrated. Finally, the impact of robotic technologies on these risks is assessed.

2.1. Environmental impact and mitigation actions

Even though key regulations aiming at the conservation of natural ecosystems must be assessed and fulfilled during the whole project development, some hazards and risks may arise during the operational phase of the OWF and consequently jeopardize the marine-environment. The aim of this sub-section is to explain the current instruments capable of ensuring both birds and habitats' conservation, paying attention on harms due to robotic usage and describing possible countermeasures to mitigate these hazards.

2.1.1. International regulations and conventions

Several international instruments (legislations, conventions and directives) were adopted to reduce the environmental impact of human activities on the natural ecosystem. *Habitats Directive* (92/43/EEC) and *Birds Directive* (2009/147/EC) represent the holy grail of European nature conservation policy.

The **Habitats Directive**[1], adopted by the European Union in 1992 in order to meet its obligations under the Bern's Convention[2], aims to protect the biodiversity by safeguarding natural habitats, wild flora and fauna in the European Territory where the Treaty is applied. Member States are required to identify Special Areas of Conservation (SACs) to preserve the status of habitats and species mentioned in the Annexes I and II of the Directive. Beside SACs, the Directive asks to identify wild species which require strict protection even if they are not included in SACs or Special Protection Areas (SPAs) [1].

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[1] The entire Habitats Directive can be found at:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF

[2] The Bern Convention, entered into force in 1982 and ratified by 50 countries, is a binding international legal instrument in the field of nature conservation, which covers most of the natural heritage of the European continent and extends to some States of Africa. The convention pays particular attention to the conservation of habitats and vulnerable species, including migratory species. All the State Parties must take action to: promote national policies for the conservation of habitats and their living species, consider the conservation of natural ecosystems in their policies, disseminate general information on the need to conserve both habitats and species, cooperate in order to enhance the effectiveness of these measures. The convention can be found at:

https://www.coe.int/en/web/bern-convention

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Because of the continuous decrease of wild bird populations in Europe (most of them recognized as a shared heritage among European States), due to anthropological activities resulting in pollution, deterioration of habitats and unliveable conditions, the EU Member States in 1979 have adopted the **Birds Directive**[3]. According to the Directive, Member States have to indicate SPAs, which are strategic areas for rare and vulnerable birds they benefit for breeding, feeding, wintering or migrating to/from [1]. Moreover, Member States are obliged to take special measures aiming at preserving those areas.

These two directives do not exclude OWF installation, and hence their operational activities: within protected areas, they provide that the activities will not harm the conservation goals defined for that particular area.

Natura 2000 Network[4] is a European Ecological Network aiming at preserving biodiversity by protecting natural habitats, wild flora and fauna in the EU territory. It is a consequence of the definition of SACs and SPAs from the Habitats and Birds Directives, and it covers more than 18% of EU's land area and more than 6% of its sea territory. Human activities are allowed in Natura 2000 sites as long as they are compatible with the preservation of the ecosystem. The management of these areas and hence of the activities undertaken therein, must be ecologically, economically and socially sustainable.

Article 6 of the Habitat Directive has specific implications for spatial planning and plays and important role in the consideration of Natura 2000 plans and projects, requiring both preventive and proactive measures to conservation and planning [2].

In particular, while Article 6(1) and 6(2) require Member States to take appropriate measures to protect the habitat and avoid damaging activities which may jeopardize the habitat and its species, Article 6(3) and 6(4) lay down the procedures to be followed when planning activities that might impact a Natura 2000 site.

Article 6(3) requires Member States to perform appropriate assessments on the impact that any plan or project can have on the site's conservation. National Authorities shall agree to the plan only after having ascertained that it will not affect the integrity of the site.

Article 6(4) states that, if in spite of a negative assessment, a plan or project must compulsorily be carried out for imperative reasons (overriding public interest) the Member State shall take compensatory measures aiming at ensuring that the overall coherence of Natura 2000 is protected. Moreover, the State should inform the Commission about the measures adopted.

The Convention for the Protection of the Marine Environment of the North-East Atlantic, referred as **OSPAR**[5] Convention, was signed in 1992 by fifteen Governments of the western coast of Europe together with the Energy Community, to cooperate in the protection of North-East Atlantic's marine environment. The Convention deals with six strategic areas:

1. Biological Diversity and Ecosystems;
2. Hazardous Substances & Eutrophication;
3. Human Activities;
4. Offshore Industry;
5. Radioactive Substances;

[3] The Birds Directive can be found at:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:en:PDF

[4] For more details check out at:
https://ec.europa.eu/environment/nature/natura2000/index_en.htm

[5] For more details consult:
https://www.ospar.org/convention

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6. Cross-cutting issues.

For the scope of Atlantis issues from 2 to 4 may be the relevant categories.

Under the Biological Diversity and Ecosystems Strategy, the convention establishes a list of threatened or declining species in the North-East Atlantic. The list provides an overview of the species needing protection.

Within OSPAR, Marine Protected Areas (MPAs) are defined as areas for which precautionary and protective measures need to be established to protect and conserve the habitat and its species. Moreover, the convention in the Biological Diversity and Ecosystems Strategy indicates a list of human activities including OWFs, that can affect the marine environment. OSPAR evaluates those activities and if needed develops programmes to mitigate their impact on the marine area.

2.1.2. Environmental Impact Assessment

The Environmental Impact Assessment of an OWF projects is a process that is performed by project developers to inform regulatory bodies in their assessment and decision-making process, from the approval to the decommissioning of the plant. The most used tools are:

- *Environmental Impact Assessment (EIA)*, widely used to assess and tackle environmental impacts of a given project.
- *Strategic Environmental Assessment (SEA)* is a tool used to assess and identify likely environmental effects and programme mitigation actions or alternatives.

Even though EIA and SEA are processes that have to be carried out at the beginning of the project to obtain its approval, are herein described in order to lay down the groundwork for the following section (2.1.3), where the most likely hazards related to robotic O&M activities will be described. However, throughout the lifetime of the plant surveys and monitoring of the marine environment are required on a periodic basis, to assess the health of the ecosystem and the impact of human activities.

Directive 85/337/EEC (also called EIA Directive) ratified by the European Commission (EC) established the EIA concept and successively amendments have been introduced (Directive 97/11/EC and Directive 2003/35/EC). The current version of the Directive is available on the EU website. The Directive refers to both Wild Birds Directive and Habitats Directive of the European nature conservation policy and it indicates which kind of project should be subjected to EIA (the Annex I lists a set of project for which the assessment is mandatory), which procedures shall be followed, and which contents shall be tackled within the assessment.

The **EIA** is articulated over several steps which are briefly described below, and its application is not discussed in this document.

Screening

It is the first step, during which it is decided if the EIA is required or not for the project at issue. This process is carried out by a Competent Authority designated in each Member State.

Scoping

It is the process that determines which context and matters should be covered in the assessment. It is a pivotal step to ensure that all the relevant information is gathered and presented, focusing on the most important impacts and project alternatives if any. General aspects to be covered in the EIA for an OWF are the following: consideration of CO_2 emissions, compatibility of the OWF with other human activities (e.g. fishing), visual impacts, socio-economic impact (jobs creation, the provision of local services and

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opportunities, the impact on tourism and SMEs, etc.) and avoidance or minimization of noise. The last one, as explained in Section 2.1.3, is one of the most impactful effects that occur also during O&M activities, that may be reduced by adopting the ATLANTIS solution.

Furthermore, CO_2 emissions, that have to be considered in all project phases (construction, transportation, operation and decommission) might be reduced by ATLANTIS provided that the project will strongly reduce the use of heavy vessels by the adoption of lightweight (and hence less pollutant) Autonomous Surface Vehicles.

It is possible to estimate the annual reduction of $C0_2$ emissions due to the substitution of one crew-transfer vessel by an ASV. Thanks to the use of robotic solutions, we can assume that a crew-transfer vessel is no longer needed: for instance, the use of robots has reduced the number of human operators necessary, but to transfer task-related tools (e.g. to deploy an ASV or ROV) to the OWF an ASV is required.

For what concerns the time of the operation at issue, the following assumptions are made:

- The OWF is 20 km far from the coast (as in the case of the WFA)
- The crew-transfer vessels employed to reach the plant navigates at 10 knots while the ROAZ II at 3 knots. This means that the crew-transfer vessel would take 2 hours during the day (to bring workers to and then back to the shore) whilst the ROAZ II would take 7 hours to deploy the tools, wait the performing of the task and go back to the shore.
- Once it has started the task would take 3 hours during which both crafts would keep the same speed (as it is in proximity of the plant a low speed must be kept).

Having made these assumptions, the crew-transfer vessel would be involved for 5 hours per day, while the ROAZ II for 10 hours (see Figure 2.1). Moreover, to estimate the emissions produced by the crew-transfer vessel, the following assumptions are made [3]:

- The watercraft operates for 5 hours per day, for 4 months in one year. Total hours =600;
- Load factor (LF) of the vessel equal to 0.43 (typical value for work boat as indicated in [3]);
- Peak power (Pp) of the vessel's engine equal to 1528 kW [3];
- An emission factor (EF) for the vessel equal to 0,690 kg/kWh, as indicated in [3].

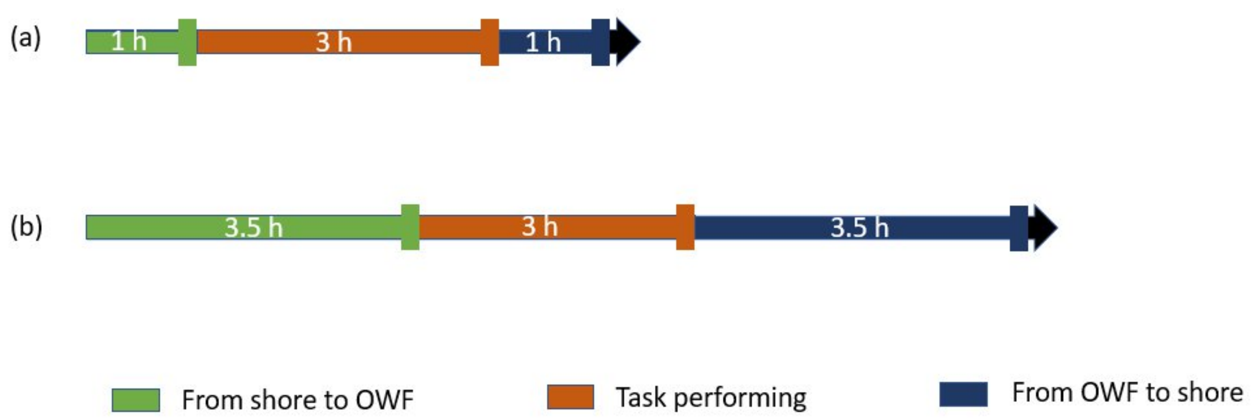

Figure 2.1: Timeline of the mission performed: a) by crew-transfer vessel, b) by ROAZ II.

For the estimation of the ASV's emissions, the model ROAZ II is used as a reference: it is involved in ATLANTIS and provided by INESCTEC. For this vehicle the following assumption are made:

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- The ASV operates for 10 hours per day, for 4 months in one year. Total hours =1200;
- Peak power (Pp) of the vessel's engine equal to 3 kW as per datasheet;
- An emission factor (EF) for the vessel equal to 0.295[6] kg/kWh (mean value of CO_2 emissions to produce 1 kWh of electricity in Europe);
- Load factor (LF) of the ASV equal to 0.16. In this case it represents the ratio between the mean power delivered by the propeller motors (able to allow operations up to 10h) and the nominal power. This power is the ratio between the total energy installed in the battery pack of the vehicle (4800 Wh, as per datasheet) and the working hours (10 h, which is equal to the autonomy declared in the ROAZ II datasheet).

Having assumed the abovementioned parameters, the $C0_2$ emissions are computed as follows [3]:

$$E = h * LF * Pp * EF$$

In case of crew-transfer vessel, the watercraft emits more than 270 000 kg of CO_2 per year, while the ASV emits only 170 kg of $C0_2$. As we can notice it is a huge difference, which may become even bigger if the use of robots would reduce furthermore the number and size of heavy manned vessels involved.

<u>Prediction and mitigation</u>

The magnitude of the harmful effects is determined and possible mitigation measures aiming at minimizing, avoiding or compensating these effects are established.

<u>Management and monitoring</u>

The predicted effects are compared with the real impacts of the project by monitoring the results. Monitoring impacts on the environment and sharing knowledge gained would improve the common understanding of environmental impacts due to an OWF, thus facilitating the definition of possible countermeasures and mitigation actions. Moreover, socio-economic impacts need to be monitored to understand changes to local communities.

<u>Audit</u>

The audit will assess the quality of the implementation in the planning of the requirements and recommendations defined in an earlier stage of EIA, with a focus to minimize the project's impact on the environment

After EIA being completed by the project developers, the competent authorities make the decision upon it and communicate the consultations' result.

The **SEA** was established by the SEA Directive (2001/42/EC) in order to provide a high level of protection of the environment as well as to ensure public participation in decision-making and approval of projects, thus strengthening the quality of the decision. The steps to be followed are similar to the EIA.

- *Screening:* to determine whether or not SEA is required.
- *Scoping*: to define which kind of environmental issues need to be covered by the SEA.
- *Environmental report:* in which the most likely effects on the environment and possible alternatives are identified.
- *Consultations:* designated authorities have their consultations, where they define recommendations and measures to be incorporated.

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[6] This value dates back to 2016, it represents the average CO2 emission per kWh of electricity produced in Europe. It has been indicated by EEA and can be found at:
https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-2/assessment-4

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- *Integration:* recommendations and measures defined by the authorities are integrated in the Plan.
- *Sea Statement:* the consultations' results are published.

2.1.3. Likely hazards on seabirds and possible mitigation

The European offshore waters are a fundamental stopover for several species, such as migratory birds: most of them use European waters for passage, breeding and resting. The hazards that may arise for birds and habitats due to OWFs are: disturbance, collision, barrier effect and habitat modification. In this sub-chapter the likelihood as well as the severity of these dangers are discussed with a focus on the operation of an OWF; moreover, eventual pros and cons that could result from the adoption of the ATLANTIS solution are taken into account.

During the operational phase of an OWF the presence of the structures themselves, as well as the presence of vessels involved in inspections and/or maintenance activities may be considered as *disturbance* either physical (hence barrier effect) in the first case and acoustic in the second one. The acoustic disturbance has major impact on fish and marine mammals, even though it can have an indirect effect on birds: if preys move to another place, birds move according to them or lose food. Although the noisiest phase is the installation, because of the high number of vessels involved, O&M activities might impact as well. ATLANTIS, because of its limited dependence on vessels, thanks to the deployment of autonomous robots supported by lightweight autonomous marine vehicles, may have positive effects on this regard. Considering that a vessel produces a noise in a range [4] from 152 db (for a small vessel) to 196 db (for a large container ship), the noise pollution becomes even higher when several vessels with different sizes are involved. ATLANTIS may reduce the noise pollution produced during the operations, provided that the use of robotic technologies will reduce the need of heavy manned vessels. Another disturbance may be represented by the underwater vehicles to be deployed within the ATLANTIS solution, that may interfere with both bird diving behaviour (when they have to catch their preys) and fish routes. It's worth to say that because of the reduced dimension of this kind of vehicles, their impact will be lower than the one due to the structure itself. In fact, it is a matter of fact that submerged offshore structures affect bird diving behaviour and are an obstacle for fish routes [1] more than AUVs do.

A disturbance for birds' flight may be represented by drones which inspect the blades either autonomously or with the guide of an operator. Even in that case, it is possible to state that this impact will be surely neglectable if compared to the one due to the presence of the Wind Turbines themselves.

Collision between birds and OW structures is one of the most likely hazards. It might be said that the use of drones, which can increase the aerial traffic in OWF skies, would increase the likelihood of bird collision. Reasonably, because of their small size compared to either fixed and/or floating structure, the drones do not represent a probable cause of collision. It is more likely that, thanks to the reduced need of human operators to inspect and maintain wind towers and blades, and hence to the lower need of helicopters (which may represent a hazard of collision for birds) ATLANTIS may reduce the likelihood of collision. Moreover, in order to reduce the risk of collision, drones may be equipped with lights in order to signal their presence. However, some studies [1] indicate that some species of birds are attracted by fixed lights: to overcome this problem intermittent lights may be used.

Habitat modification or loss is one of the most dramatic hazards associated to OWF operations. The major impact is surely due to the installation itself of the plant, since it produces permanent changes of the habitat [1]. A significant impact may be due also to operational activities such as the ones carried out on the seabed, for instance by increasing the turbidity of the water that may lead to the loss of favourable living conditions for some marine species. If ATLANTIS will demonstrate the effectiveness of continuous monitoring of the OWF conditions and also through more frequent but less invasive IMR activities, robotic

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solutions may reduce the impact of activities in the marine habitats, helping in the conservation of the ecosystem.

On the other hand, the use of robotic solutions may increase the risk of marine pollution due, for instance, to the emission of pollutant substances (e.g. if electrochemical storage is used, in case of collision part of the toxic substance could spill into the sea water). In that case, in order to reduce the negative impact as much as possible and the likelihood of marine pollution caused by robotic technologies, all the necessary measures have to be considered in the design and manufacturing phase (e.g. avoid as much as possible the use of toxic and polluting substances).

2.2. Social and commercial impact of OWFs

As well known, OWFs have a huge impact on other maritime commercial activities such as fishing, marine shipping and tourism. Many conflicts arise from the use of water resources by all these different actors. Several national and international instruments have been adopted aiming at guaranteeing the peaceful use of water resources by all the maritime stakeholders. In this section the major conflicts between OWFs and other marine sectors are discussed as well as the possible impact that ATLANTIS might have in their resolution. Moreover, the main international instruments such as Maritime Spatial Planning (MSP) and specific directive are described.

2.2.1. Commercial conflicts

OWFs-Shipping sector. The growth of OWFs leads to an increase of potential risks for the safety of the navigation. This increase is mainly due to a higher traffic density (either in the construction phase and the operational one because of the vessels involved in the O&M activities) and also to visual limitations [5]. Furthermore, during O&M activities, beside the increase of maritime traffic, OWF vessels might cross designated routes. Other hazards are due to radar shielding and reduced visibility caused by wind farms. Moreover, during OWFs' developments, navigational restriction may arise, which might have a negative impact on both costs and the environment. This happens when the rerouting of the vessels results in longer distance of navigation [5]. Rerouting of well-established shipping routes might happen also in normal conditions, right after the installation of the OWF. For this reason, a safety distance of 500m should be kept between shipping lines and wind farms.

OWFs-Tourism sector. The deployment of offshore infrastructures may limit the access to sea space for leisure purposes such as sailing and other water sports [5]. Moreover, conflicts with the tourism sector may arise because of the modification of the “seascape” by the OWFs when viewed from land or ships [5].

OWFs-Fisheries. The conflict between OWFs and fisheries might be considered as the toughest one as it can result in a commercial and a social conflict. In fact, especially for small maritime communities, fisheries activities still represent a pivotal livelihood and the most profitable activity.

Conflicts between the offshore wind and the fisheries sector are mainly related to accidental damages and ship strikes, which represent the main concerns for the first category, while fear of exclusion and displacement represent the restrictions and problematics that fisheries have to face [6]. Displacement becomes particular troubling for small-scale and coastal fisheries as they do not have the capacity to move to fishing further offshore or cannot switch to other fishing methods [6].

Several conflicts' drivers between OWFs and fisheries have been identified by the MSP Platform and they are herein reported.

- *Damage:* accidental damages and ship strikes, as well as damages that bottom trawling may cause to subsea cables, are the major concerns for OWFs operators due to fisheries [6].

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- *Disturbance of species:* noise and damages to habitats produced during construction and operation of OWFs, resulting in disturbance and reduction of mobile species of fish and shellfish can affect fishing activities [6].
- *Ecological impact of the spatial exclusion:* due to the exclusion, fisheries activities have to move towards other fishing ground which may be less profitable or reliable. Due to the lower available fishing grounds, competition may become more though and may lead to the risk of catching vulnerable species [6].
- *Economic impact of the spatial exclusion:* the re-displacement of fisheries in other fishing grounds might result in higher costs of operation for fishermen in order to keep the same catch levels which ensure their livelihoods [6].

2.2.2. MSP and other instruments to mitigate conflicts

The **Maritime Spatial Planning** (MSP) is an instrument aiming at guaranteeing the peaceful use of the sea and at the same time protecting the entire ecosystem. It is a comprehensive process which, through the involvement of stakeholders, aims to analyse and plan when, where and how human activities take place at sea [5]. As marine ecosystems and human activities evolve constantly, in the same way MSP must be continuously updated, by adapting itself to new scientific developments as well as to changes of the environment.

In 2014, the European Parliament adopted a new Directive (2014/89) establishing a framework for MSP. In this Directive, Member States are required to establish their own maritime spatial plans, with the purpose to contribute to the sustainable development of marine sectors, ensuring that the interests of each of the marine sectors are equally treated and covered. Moreover, by 2016 Member States were requested to translate MSP into national legislation.

One of the major objectives of the MSP is to ensure *spatial synergies* between different sectors. Multi-use of infrastructures may be facilitated by MSP, when the planning of all the activities is considered at the same time. An example might be the co-operation between OWFs and aquaculture, in fact when the OWF structures are located in proximity of the coast they can be used for aquaculture purposes too [5]. Another possibility might foresee fishing and/or sealing inside wind farm areas: nowadays researchers are investigating this possibility with a close eye on safety requirements. Anchoring systems can be also shared among different infrastructures. Moreover, OWFs can increase local biomasses and might be developed in synergy with protected areas. Currently many researches have been carried out with the scope of identifying possible benefits that OWFs may introduce in the regeneration of fish stocks [5]. Finally, it is worth to say that a synergy between OWFs and tourism can be identified. In fact, even though it is a common belief that OWFs impact negatively on the seascape, they can contribute positively on local tourist activities, if well and timely planned together [5]. Guided tours inside OWFs areas and observation of platforms might be considered at an early stage: an example of this is the *UK Scroby Sands*[7] wind farm which, through the creation of a visitor information centre, welcomes about 35000 annual visitors to observe both wind farms and marine mammals.

OWFs activities have to be planned in accordance with MSP as well as other dedicated regulation bodies for other sectors, such as fisheries. It is a matter of fact that O&M activities might be limited during fishing periods or areas, which are enshrined by:

- Common fishery policy;
- General Fisheries Commission for the Mediterranean;

[7] For more information about the visitor centre check out at: https://www.group.rwe/en/our-neighbourhood/rwe-erleben/visitor-centres/scroby-sands-visitor-centre

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- North East Atlantic Fisheries Commission.

If it is true that these policies protect both the environment and the fisheries' rights, on the other hand they might have a negative impact on OWFs. In fact, if during fishing seasons, faults and damages to wind turbines occur and the operators are not able to perform IMR (Inspection, Maintenance and Repair) activities (or have to limit these activities) this will result in longer downtimes for the turbines, causing economic losses.

2.2.3. ATLANTIS: a way to strengthen coexistence between marine sectors and a mine of opportunities

As explained in Section 2.2.1, OWFs have to face a lot of conflicts with other marine sectors which may result in lower acceptance of this kind of renewable energy plants and slow down their deployment.

Even though policies and instruments (such as MSP) have been already adopted to ensure and guarantee an equal access to marine resources, part of the solution proposed might affect economic interests of the involved party.

As seen, for instance, fisheries may be forced to tack towards new fishing areas or to change their fishing methods and these actions could require a non-negligible economic investment. In the same way, shipping vessels may be bound to reroute their paths resulting in longer distances and hence more expensive operations (as a later consequence transport costs of products will increase, as their prices for the final buyers). Finally, even OWFs might see their economic interests jeopardized by other sectors, for instance because of the limited operations allowed during fishing seasons, which may result in protracted downtimes of the plant and hence losses in the revenues.

It is worth to say that policies undertaken by international bodies are on the right track to ensure a peaceful coexistence between the different stakeholders. Technological developments and new sustainable procedures for the use of sea are key drivers that, in co-operation with the well-established existing instruments, may pave the way towards a more peaceful and conservative use of the water resources.

In this sense ATLANTIS, thanks to the use of robotic technologies, might lower the impact of O&M activities for OWFs on the sea and its users. In fact, if ATLANTIS will demonstrate that the use of these technologies will result in a lower involvement of heavy vessels, part of the reasons of conflicts might be solved.

It is a matter of fact, and as described in Section 2.2.1, that heavy vessels involved in O&M activities produce an increase of the marine traffic, which represents the major concern for the shipping sector. Moreover, the use of vessels and their consequent noise has an important negative effect on the fisheries, as they may lead fishes to change their living area, consequently forcing fishermen to follow these changes.

Moreover, ATLANTIS might represent an important opportunity for local communities to grow in terms of technological development and welfare. The use of robotic solutions and the ATLANTIS approach would produce a lot of opportunities for local communities, like: job opportunities for building enterprises (because of the construction of the SCC), new jobs creation (both in the SCC and in the field of robotic, like maintainers for robots and others). Besides these benefits, the project ATLANTIS itself represents a great opportunity for technologies providers, either academic and industrial, to test their products first in a near-real and successively in a real environment, at very low costs.

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2.3. Health and Safety

	PROBABILITY OF OCCURRENCE					
SEVERITY		A	B	C	D	E
	1	LOW	LOW	LOW	LOW	MED
	2	LOW	LOW	LOW	MED	HIGH
	3	LOW	LOW	MED	HIGH	HIGH
	4	LOW	MED	HIGH	HIGH	HIGH
	5	MED	HIGH	HIGH	HIGH	HIGH

PROBABILITY OF OCCURRENCE	SEVERITY	RISK
A May never occur	**1** Negligible	Low = No immediate action required, proceed with care
B May occur	**2** Moderate	
C Might occur	**3** Serious	Medium = Review & implement preventative measures
D May occur infrequently	**4** Major	
E Will probably occur	**5** Catastrophic	High = Unacceptable. Find alternative method

Figure 2.2: Task Risk Assessment matrix [7].

This section deals with Health and Safety (H&S) for workers involved in the OWF with a focus on the O&M activities. The most likely hazards and related international guidelines and mitigation actions are explained. Moreover, a dedicated discussion on how ATLANTIS may or not help to make the workplace safer for workers is held.

Risk is the measure for the likelihood of a hazard, which is an event that might harm people, the environment and the power plant itself. The risks are typically evaluated in two dimensions [7]:

- *Probability of occurrence*, which quantifies the likelihood of an event;
- *Severity associated to the hazards*, which quantifies the magnitude of the incident.

Usually the hazards are classified in three categories: *low* (which does not require an immediate action), *medium* (that might require timely interventions) and *high* (which cannot be accepted and hence must be avoided by adopting appropriate countermeasures).

Figure 2.2 shows a typical matrix used to assess the category of the hazard.

H&S guidelines, directive and regulations aim at mitigating risks for employers are either formulated by national and/or international institutions. The main directives emended by the European Union concerning H&S issues are the following:

- *Framework 89/391/EC*[8]: it introduces measures to enhance improvements for the safety and health of workers at work. It contains general principles concerning the prevention of

[8] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31989L0391&from=IT

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occupational risks, elimination of risk and accident factors, the protection of safety and health and general guidelines for their implementation.

- *Workplace (89/654/EEC)*[9]: lays down the minimum requirements for safety and health at the workplace.
- *Work equipment (2009/104/EC)*[10]: lays down the minimum safety and health requirements for the use of work equipment by workers at work.
- *Personal Protective Equipment (89/656/EEC)*[11]: lays down the minimum requirements for personal protective equipment used by workers at work.
- *Manual Handling (90/269/EEC)*[12]: lays down the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers.
- *Noise (2003/10/EC)*[13]: lays down the minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to noise and in particular the risk to hearing.
- *Vibration (2002/44/EC)*[14]: lays down the minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to mechanical vibration.
- *Temporary or Mobile Construction Sites (92/57/EEC)*[15]: lays down the minimum safety and health requirements for temporary or mobile construction sites.
- *Safety and/or Health signs (92/58/EEC)*[16]: lays down the minimum requirements for the provision of safety and /or health signs at work.
- *Medical treatment on board vessels (92/29/EEC)*[17]: the objective of this Directive is to improve medical assistance at sea since a vessel represents a workplace involving a wide range of risks.
- *Work equipment for temporary work at a height (2001/45/EC)*[18]: sets out requirements for the management of risks from working at height, by for instance adopting ergonomic tools that ensure the worker's comfort all over the working time.

The main hazards likely to happen during O&M activities in OWFs are associated, but not limited to [7]: access to the structure (either aerial with helicopters or maritime with boats), electricity (when electric

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[9] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31989L0654&from=EN

[10] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0104&from=EN

[11] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31989L0656&from=en

[12] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31990L0269&from=EN

[13] Full text of the directive available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:042:0038:0044:EN:PDF

[14] Full text of the directive available at: https://eur-lex.europa.eu/resource.html?uri=cellar:546a09c0-3ad1-4c07-bcd5-9c3dae6b1668.0004.02/DOC_1&format=PDF%20

[15] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0057&from=EN

[16] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0058&from=en

[17] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0029&from=en

[18] Full text of the directive available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0045&from=EN

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devices are involved), noise (due to both working tools and blades rotation), confined spaces, vibration, height, weather and sea conditions, fire, ergonomics. These hazards are a direct result of different activities such as but not limited to: cable laying and/or lifting, navigation, subsea operations, vessels operations, drilling, painting and grouting.

Below are described the major risks associated to OWF O&M activities for workers: wherever possible their positive or negative impact connected with the use of robotic technologies has been assessed. Risks and consequent countermeasures for each specific robotic technology are, wherever possible, discussed in the dedicated sections.

Table 2.1: Most common failures of wind turbines.

Failure	Means of failure
Tower collapse	The tower may collapse for several reasons, such as an improper installation of the fastening system, currents and waves that may overload the structure or a corrosive environment that ruins the integrity of the tower.
Blade failure	This failure may arise as result of fatigue, excessive vibration and collapse from external loads.
Tower strike	It occurs when a blade hits the support tower: they are not frequent in modern wind turbine blades.
Fire	It can be caused by lightning, by a fault in the power system or strong winds.
Lightning strike	Lightning strikes as well as thunderstorms can be dangerous for workers, especially if they are working in the nacelle. They may cause fires, requiring the workers either to be rescued or to evacuate the structure.

When operating, OWFs are unmanned facilities, with personnel accessing them only to carry out maintenance and repairs activities. There are many ways in which a wind turbine could fail and jeopardize the H&S of workers, the most common ones are summarized in Table 2.1 [8].

Weather is another element that can create risks for workers. Work plans should consider information from national meteorological offices. It might happen that weather conditions result favourable during the beginning of an operation, but they become harsh through the development of the activity. In this situation, workers may be stranded in the structure itself which hence needs to be equipped with safety and survival equipment. Planned maintenance should be preferably conducted during the summer time, when weather conditions are more favourable, although during this period high temperature may arise especially in the nacelle, representing a possible cause of cardiovascular problem for workers.

Another hazard is represented by the mean of transportation, which can be either aerial (helicopter) or marine (boats). In both cases the risks increase when weather conditions become harsh.

Noise and shadow flicker effect, due to the movement of the blades, may be a harm for workers. Noise level is generally between 35-50 dB [8], comparable to indoor background noise, but it can cause symptoms such as headaches, dizziness, nausea, anxiety, depression, anger, concentration and learning issues [8]. Shadow flicker effect, which occurs during sunny days, represents a potential risk for only the 3% of people with epilepsy.

With regard to the risks aforementioned, ATLANTIS cannot certainly mitigate them directly, because they are due to the presence of wind turbines weather conditions and means of transportation, which are aspects that are not going to change thanks to the use of robots. Besides this, however, ATLANTIS might

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help to reduce the number of people exposed to those risks. In fact, if part of the work will be performed by robots or it will foresee their support, a lower number of workers will be required. Actually, part of them will be re-allocated to the Shore Control Centre (SCC) to monitor and control the operations from a place where they face less severe risks than the ones described.

Once a wind turbine is running there are several O&M activities to be performed throughout the lifetime of the plant. These activities are characterized by several risks with different degrees of severity, the more a worker is involved in the operation the greater is his/her chance to be exposed to these risks.

Maintenance work in or around the nacelle entails a risk due to its access. In fact, workers have to climb, often even several times during a shift, vertical ladders where there is no lift in the wind turbine. This may result in cardiorespiratory issues for the workers. Moreover, maintenance of towers and blades requires operations such as buffing and resurfacing, which expose workers to harmful gases, dusts and vapours [8]. Ventilation and use of respirators may be the right countermeasure to mitigate these risks. In the case that these operations are performed by robots, even with the supervision and/or control of operators, workers will not face these risks anymore.

OWFs require diving operations such as cleaning or inspection of the submerged parts of the structures. Divers may be exposed to hazards during their activities such as pressure changes during both the descent and the ascendant phase resulting in dizziness, disorientation, pulmonary barotrauma, subcutaneous emphysema and arterial gas embolism [8]. Moreover, other risks are related to the tools involved either if task or diving related. Even in this case, the involvement of robots such as ROV with high working capability will result in a less exposition of divers to the mentioned risks.

To conclude, the use of autonomous or remotely-controlled robots in O&M activities will have a huge impact in ensuring the safety of workers because of the lower exposition of human operators to risks, while ensuring precision in the execution of operations.

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3. ROV

Remotely Operated Vehicles (ROVs) are suitable tools used either in the marine industry, such as in the oil and gas sector or the offshore wind one to perform IMR activities, but also in the marine research to monitor and explore maritime habitats and species. A ROV is an underwater robot connected to and operating from the water's surface. Its simplest configuration consists of the main body, propellers, lights, video cameras and other task-related equipment (e.g. grabbers, suction samplers). Through a tether (also called umbilical) the ROV is connected to the surface and it transmits electrical power, command and control signals to the vehicles and sends back to the surface operator a video and data set (e.g. telemetry).

ROVs are typically launched and deployed into the operating area from a vessel. The launch and recovery process of the vehicle is different, depending on its size. Small ROVs are launched and recovered manually while bigger ROVs are deployed by using a LARS (Launch and Recovery System), basically made up of a tether winch and a crane able to lift the ROV at its maximum weight.

In this section the main guidelines and well-accepted practices regarding the deployment and use of ROVs are reported.

The document starts with the classification of these vehicles based on several aspects such as dimension, power, tasks performed and type of control.

Successively, all the necessary administrative requirements are listed. These requirements are paramount either in the design phase and during the operations. Different figures are responsible to provide these documentations at different stages. Generally, these documents are reports, whose purpose is to allow the tracking and control of ROVs' functionalities throughout their use.

This section touches and describes the different figures who deal with a ROV as well as which competences and responsibilities they should comply with. The different figures described are the ones commonly involved in ROV operations as indicated by the guidelines assessed and herein discussed.

Moreover, in this section the responsibilities and liabilities applicable to each of the abovementioned figures are discussed.

The section ends with a focus on the operational requirements and procedures which are commonly followed during ROVs' missions and aim at ensuring safe operations.

3.1. Classification

A wide range of vehicles and equipment fits under the umbrella of ROV, which may differ not only for their own designs but also for the tasks they have to carry out. Within the scope of ATLANTIS, ROVs are seen as unmanned vehicles which are controlled and manipulated by human operators. Users must comply with operational requirements, usually emended by standardization bodies, according to the class to which the vehicle applies. In the scope of this assessment, the classification made by NORSOK STANDARD in "Remotely operated vehicle (ROV) services" [9] is used.

Class I – Pure observation: vehicles equipped with video camera, lights and thrusters, whose task is limited only to video observation.

Class II – Observation with payload option: vehicles equipped with additional sensors such as sonar, still colour cameras, protection measurement systems.

Class III – Work class vehicles: vehicles equipped with additional sensors and/or manipulators. Further division is made based on the vehicle's power:

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- *Class III A* – Work class vehicles < 100 Hp
- *Class III B* – Work class vehicles from 100 Hp to 150 Hp
- *Class III C* – Work class vehicles higher than 150 Hp

Class IV – Seabed-working vehicles: are much larger and heavier than Class III vehicles. Usually they are configured ad hoc for special-purpose tasks such as cable trenching, excavation and another seabed construction works. These vehicles are moved by wheels or belt traction systems, water jet or thruster propellers, or by a combination of these propulsion systems.

Class V – Prototype of development vehicles: special-purpose vehicles which do not fit into the other classes or prototypes under development are included in this class.

It is worth to mention that Class III, IV and V vehicles might represent the most suitable ROVs in the context of ATLANTIS, which aims is to demonstrate and validate ROVs' capabilities in supporting human operators while performing IMR activities at both under and above the sea.

3.2. Administrative requirements

Documentations are required for the design, contracting and operating phase. For each stage, a different responsible party has to provide the needed documentation: in the first case the responsibility falls on the manufacturer, in both contracting and operating phase the contractor is in charge of it.

The manufacture process can start once the certification Society has approved the documentation submitted containing all relevant data necessary to validate the design (wherever requested, calculations and descriptions related to the system's components shall be included). Any further and successive modifications need the approval from the Society before being implemented.

Contractors should establish and maintain matrices to be reviewed by the clients, such as compliance to: relevant regulations and standards, project's specifications and personnel's qualifications [9]. Information on compliance shall be evaluated by contractors and forwarded to the client to be accepted. Wherever possible qualified alternative solutions may be suggested.

Before the mobilisation, the Contractor shall define the documentation providing information regarding [9]: a list of services required from work-site, a mobilisation plan, a procedure for normal and emergency operation of the equipment, a procedure for the maintenance of all the equipment in service, a list of spare parts, a personnel's competency matrix for the allocated personnel.

The contractor must make available and update documents on the work site, concerning: the project's QA (Quality Assurance) and HES (Health, Environment and Safety) plan, operational manuals, a contingency plan, relevant risk analysis, maintenance programmes and records for the previous 12 months, a log in order to document all operational activities.

Contractors have to report ROV operations, demonstrating the compliance with both administrative and regulatory requirements and, wherever applicable, internal requirements have to be met. Several kinds of reports need to be provided.

Firstly, contractors have to report to the client's representative a brief summary of the last 24h. ***Daily reports*** should include but not be limited to the following information [9]:

- Date, reference to contract, job;
- Name of installation/vessel;
- Name of personnel involved in the activities;
- Arrival/departure of the personnel;
- Timing and description of the activities;

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- Summary of hours in: water, standby, maintenance and breakdown;
- List of additional equipment;
- A plan for the next 24h.

The daily report should be signed by both contractors and client representative.

Maintenance work, performed in accordance with the established maintenance program, shall be reported in the ***Maintenance report***, which is available to the client upon request [9].

System's failures should be registered and tracked by the contractors in accordance with ISO 9001:2000 clause 8.

Report of undesired events [9] should be updated every time an undesired event occurs such as accidents, non-conformance and near-accidents with potential hazards to personnel and/or equipment.

Contractors should produce an ***experience report***, by the end of the year or 30 days after the operation, which appraises the operations, procedures and equipment involved [9].

3.3. Personnel qualification

All personnel involved in tasks that imply a ROV should be competent to carry out their own assignments. Their competence can be demonstrated by both possession of suitable qualifications and experience. Skills vary according to the personnel's category for which different requirements must be fulfilled.

Four main figures can be identified according to NORSOK Standards [9] (Superintendent, supervisor, pilot and trainee): for each one the necessary competences are discussed, based on the requirements defined by the International Marine Contractors Association (IMCA) [10]. In this section three main figures (superintendent, supervisor and pilots) are discussed as they represent the main operators involved in the operations in line with the scope of ATLANTIS.

ROV superintendent and supervisor: they have to be experienced in planning and management of offshore activities. In the specific, for what concerns *safety* issues, they have the responsibility of the risk assessment as well as the definition of suitable countermeasures to mitigate risks. They shall encourage their subordinates to always report incidents and be compliant with the safety measures [10]. In case of an *emergency situation*, they must demonstrate an effective handling of the emergency, as well as a good management of the team in such situation, taking appropriate actions to de-risk threats for both personnel and equipment [10]. Their responsibility is to assess and ensure training and skills for all their subordinates, by providing both a competence assessment and training sessions (*Performance Management*) [10]. *Supervisory skills* are necessary to manage the team and at the same time ensuring safe, cost-effective and timely execution of the job in accordance with the defined procedures [10]. Competences and experience are fundamental to ensure all *project's activities* are carried out in compliance with the project's requirements and the necessary equipment. Reporting, project planning and management are tasks that need to be fulfilled by both the superintendent and the supervisor [10]. ROV superintendent must have at least 2 years' experience as ROV supervisor.

ROV pilots: Three different subcategories are identified based on both competences and experience of the pilot: ROV pilot Senior, ROV pilot Grad I, ROV pilot Grade II. ROV pilot Senior, in order to stick to *safety* requirements, should be aware of legislation/guidelines regarding the reporting of accidents and capable of managing the safety of the team. To effectively respond to *emergency situation*, should prove knowledge of emergency procedures as well as management of the team during these situations. *Communication skills* are required in order to ensure an effective communication and explanation of the instructions to the subordinates, showing leadership abilities and supervising the team when the supervisor is absent [10]. Familiarity and knowledge of ROV sub-systems may be needed in both *fault*

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identification and *preventive maintenance* which may require possible modification of the equipment [10]. Capability to determine weather and current conditions which may limit *ROV operation* is a key skill that a ROV pilot must fulfil [10]. *Administrative* tasks are under ROV pilot responsibility, such as the production of clear and comprehensive reports and the completion of logs data by subordinated personnel [10]. *Technical* competences are fundamental: understanding of underwater operations is necessary for ROV pilots to provide instructions and supervision to less experienced personnel [10]. *Project management* skills are also requested, in order to stick to the project plans. *Knowledge of operational scope* combined with experience might be a benefit to suggest improvements/alterations of the operation to guarantee a better outcome of the activity [10]. *ROV pilot Grade I,* should prove awareness of *safety* legislation/regulations as well as company safety management instruments. In fact, in case of *emergency situation*, they must know emergency procedures and processes, team members' roles and responsibilities, and understanding of company emergency procedure documents and where they are placed [10]. Knowledge and understanding of English must be fulfilled for both oral and written communication, in order to assist both subordinates and superiors during the operations through the communication with other team members [10]. For what concerns *preventative maintenance*, they need to identify likely hazards and know how mitigate them: *faults and defects* need to be correctively diagnosed [10]. *Piloting skills* must be owned by Pilot Grade I, who should be able to [10]: drive ROV under several circumstances, identify environmental conditions that may jeopardize ROV operations, understanding of the work site and manipulator functions. *Administrative functions* are also required, such as video logs and information in line with the client's specifications, ensuring compliance between the collected information and the defined Quality Assurance standards [10]. *Technical knowledge* of tools and *special equipment* may be required to ensure correct maintenance procedures, as well as plan operations, prepare the work site, remove, test and inspect and install specialist equipment. *ROV pilot Grade II,* have less responsibility than the others, he/she has to support his/her superiors during the operation and take the control of the ROV in case of necessity (such as absent or incapacitated of ROV pilot senior and Grade I).

With increasingly complexity of ROV, necessary competences of the personnel need to be carefully investigated to ensure safe and efficient operations. An ROV encapsulates many technologies (fibre optic, electric and electronic systems, hydraulically and mechanical systems) and the team must be capable of maintaining and repairing all the subcomponents.

Table 3.1: Minimum manned requirements.

Task Duration / ROV Class	12 h	24 h
Class I	2	4
Class II	2	4
Class III	3	6
Class IV	4	8

Safety of personnel is crucial during the operations and it is a contractor's responsibility to provide a well-balanced and as competent as possible team. Team size strongly depend on several drivers, such as ROV class, type of tasks and duration of the operations. Both NORSOK Standards [9] and IMCA R004 "The Safe & efficient operation of ROV" [11] deal with a required manned level for the operations: the minimum requirements are summarized in Table 3.1 based on ROV class and task duration. As accidents are more likely when people work long hours because of concentration lack and efficiency deterioration, long working times should be exceptional and limited wherever strictly necessary. Working hour should be planned so that each person does not exceed 12 continuous hours, while under normal circumstances a

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ROV pilot should not go beyond 6 hours in every 24-hour period, even though non-piloting work may be included up to the 12-hour maximum [11].

3.4. Responsibilities

Liabilities are different for all the personnel involved according to their grade.

ROV contractors are liable for defining the management organigram for ROV operations, which, together with a clear handover of supervisory responsibility, should be defined in writing [11]. ROV contractor has to grant that every member of the ROV team has at least one meal break during 12-hour operations, as well as they can make use of the toilet and snack breaks. Two common ways can guarantee this: having other qualified personnel who can replace the one on break or by planning the activities in order to ensure breaks availabilities. ROV contractors have to ensure that [11]:

- all the possible risks and the related mitigation actions are analysed;
- the working place is suitable and safe;
- the team owns all the required competences;
- emergency and contingency plans are well-defined and disclosed among ROV team members;
- there is a clear reporting and responsibility structure in writing;
- all relevant regulations are not breached.

Responsibility structure and individual liabilities need to be clarified before the operations take place. As suggested by [12], a possible structure might be the one depicted in Figure 3.1. The **Master officer** is at the top of the pyramid and he/she is in charge of all the decisions and authorises the mission plan. **RCC (Remote Control Centre) or SCC watch officer**, which in the scope of ATLANTIS might be played by the personnel who monitors ROV operations from the SCC, has the responsibility to report any possible hazard that might be going to happen to the ROV personnel and it operates from the SCC (it can be considered as the ROV superintendent).

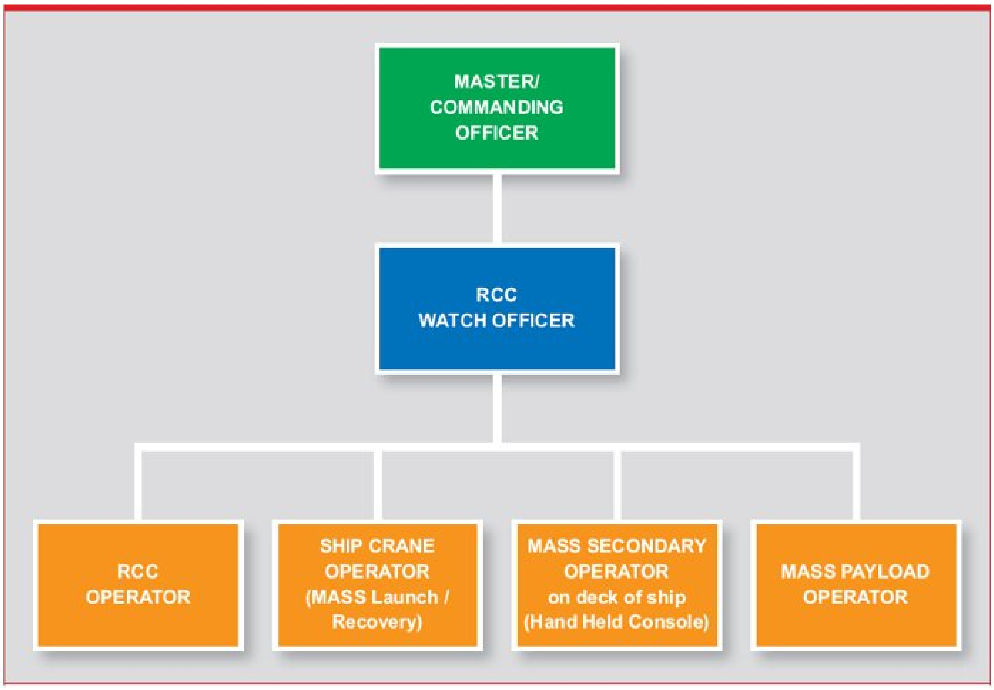

Figure 3.1: Possible hierarchy structure [12].

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The **RCC operator** operates from the SCC and receives commands from the Watch Officer. It is responsible for the mission planning, execution and post mission evaluation. It is responsible (together with the ROV operator) for the launch and the recovery of vehicle. He/she communicates with the operators, crane operator and ROV operators.

Ship Crane Operator is responsible for lifting and lowering the ROV to/from water and it deploys the vehicle in the operating area.

Mass Secondary Operator is on deck of the ship and through a hand-held console pilots the ROV receiving command from the RCC Watch officer and the RCC operator. It can be considered equal to a ROV pilot.

Mass payload is responsible for the operation of payload, sharing the responsibility with the RCC operator for the launch/recovery of the ROV.

When combined operations are being carried out by divers and ROV, the figure of the **diving supervisor** is necessary. Accepted industry practice is that the diving supervisor always has authority over the ROV supervisor and he/she is the only person who can order the start of the operations [13]. This figure has to ensure that all divers, as well as ROV operators, are aware of possible hazards and operational constraints. The diving supervisor has to ensure that the ROV supervisor understands the emergency procedures to recover the diving bell as well as those emergency procedures to recover the ROV are agreed by the ROV supervisor and understood by the diving personnel. The diving supervisor is the responsible for authorising ROV deployment and recovery, and he/she coordinates all divers and ROV's movement by either co-working with the pilot or communicating with him/her.

ROV supervisor has different responsibilities, based on how the tasks are performed (basically if they are performed in combination with divers or not).

If a task involves diving, as already explained, the diving supervisor has authority on the ROV supervisor, whose responsibilities are minor. In this situation, the ROV supervisor has to ensure that the ROV is configured in a safe state for the divers and he/she has to report to their attention any known defects or weaknesses of the vehicle, in order to make them aware of possible “unconsidered” hazards. Moreover, the ROV supervisor is responsible for ensuring that pilots employed are suitably qualified and experienced to be able to safely drive the ROV in an environment occupied by divers as well.

In the second case (operations performed without divers), the ROV supervisor has to authorize the start and the end of the tasks even if in some cases, linked to possible hazards or safety reasons, the vessel officer (whose responsibility is to ensure the safeness of the vessel and its occupants) might require stopping the activity [11]. Supervisors have to ensure that either themselves and other personnel involved are enough qualified to carry out the activities required of them. Besides that, they have also to ensure that all the tools used are adequate, safe and properly certified and maintained, documenting their performances and characteristics periodically. ROV supervisor should keep audio and, if possible, visual communications with any personnel under their supervision during the whole duration of the task.

ROV pilots, as any other personnel, should act following supervisor’s instructions and adhere to any relevant procedures defined by the company. They should immediately bring to the supervisor's attention any doubts or concerns, in case there’s any, caused by their inability to conduct the task they were requested to. Moreover, they should inform the ROV supervisor and, whenever present, the diving supervisor, in case of any defect, failure or alarm of the ROV and also in case the ROV location becomes uncertain or it is lost.

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3.5. Operational requirements and procedures

Operational procedures regarding planning, preparations and execution of the operations should be reported in detail and explained to the personnel involved. Relevant rules and regulations, namely related to the safe execution of the operations, shall be updated in the documentation required and be easily accessible at the work-site [9]. Risk assessment, performed according to recognized methods, are a pivotal tool for the preparation of the operations. Meetings shall be held, before the beginning of the operations, to ensure that all the personnel is aware of the work-site conditions, status of the work, any incidents in previous tasks as well as any other relevant information pertinent to the safe and efficient performance of the work [9].

The briefing should treat issues such as [14]: project safety requirements and goals, medical evacuation contingencies, drug and alcohol policy, PPE requirements, medical treatment requirements, tropical storms or inclement weather procedures, project procedures, fire extinguishment equipment and requirements.

The superintendent/supervisor is bound to take responsibility/supervision of the operations, ensuring that they are performed in accordance with all the applicable rules, regulations and operational procedures. The meet of the technical requirements regarding the interfaces between platform/vessel and ROV systems falls under the platform/vessel chief responsibility. Electrical equipment needs to be monitored by the platform/vessel electrician, whose responsibility is to ensure that it is well maintained and certified and that all the personnel working on it is qualified [9]. Supervisor/superintendent has to accept or not any further tool installed in the ROV system by third party or client, and he/she is also responsible for the compatibility between ROV systems and the tools at issue.

The ROV operation might be characterized by four different phases [15].

Surface preparation [15]: the surrounding area might be surveyed by multibeam sonar, if the ship is equipped with it, or alternatively the ROV itself can be used to survey the area by using its own scanning sonars and other equipment able to detect obstacles. This inspection must be complemented by pre-dive checks performed by ROV pilots/technicians through a visual and physical inspection, a check of command controls and vehicle response as well as data displays and auxiliary tools responses.

Deployment [15]: deployment and recovery may be manual in case of small ROV (such as Class I and smaller Class II) or via ships through cranes. The ROV supervisor is responsible for the deployment. The ROV shall be launched and recovered mid-ship where possible: in order to ensure a stable deployment, the ship can be held, in case of shallow waters, using two-point anchoring. In case of deeper waters or when the anchoring must be avoided (e.g. not to impact on the habitats), the boat can drift or can motor slowly into the current or wind (to balance their effects). Once the ROV is lifted and softly lowered into the water, the pilot should fly it a short-distance away from the ship and make it dive using its thrusters. At 20 m far from the mother-ship, the acoustic positioning system as well as other features must be checked to verify that they are working properly.

Task execution: once completely dived into the water, the ROV driven by the pilot can reach its working area where it has to perform the planned tasks. In the scope of ATLANTIS, ROVs can be used either to clean surfaces (such as submerged substructures) and to help divers and workers while performing their activities. Specific functions will be attributed during the development of the project and are defined in *Deliverable D2.1 "Requirements of the Scenarios"*.

Recovery [15]: as for the deployment, even for the recovery phase, the vessel should be kept steady by anchoring it or drifting it against the sea current: even in this case the ROV supervisor has to give the green light for the recovery. Good practice is to surface the ROV away from the vessel (quite far from the vessel

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propellers) and then manually (or using cranes or other lifting tools) recover it. ROV recovery is strictly dependent on its class and type.

Stowage [15]: before being stowed and the samples being processed, in accordance to specific requirements, all the equipment should be cleaned with freshwater. ROV logs, data and video should be downloaded in a folder to record the mission's information for later archiving. The download of data should be done the earliest possible in order to prevent samples' deterioration or loss.

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4. ASV

The ASV (Autonomous Surface Vehicle), as well as other kind of unmanned marine vehicles, are becoming increasingly popular, but in spite of that there is still a deep gap between technological development and existing legal frameworks. The difficulties in ratifying specific laws for this kind of technologies are due to several aspects, such as their autonomy level (if fully autonomous or remotely controlled), the unmanned nature of the vehicle (this leads to some uncertainties in the matter of liability issues) and the variety of applications (military, civil, commercial, etc.). The scope of this section is to try and frame ASVs into existing regulations and guidelines.

Autonomous Ships are now a very promising technology and currently several projects are working on both legal and technical challenges. The interest of the shipping industry on this topic cannot dispense from stronger and clearer legal rules and for this reason international organizations, namely IMO (International Maritime Organization), have started taking appropriate measures to regulate and ensure safety during the operations of Maritime Autonomous Surface Ships[19] (MASS).

In this chapter several maritime rules related to both international and national regulations, as well as treaties governing ASV, are described, considering obligations and responsibilities of operators and owners of unmanned autonomous vessels. The scope of this work is to assess the current legal framework for marine vehicles, by trying to fit it into the application of unmanned and autonomous vessels involved in O&M activities for offshore wind.

To have a better understanding of the legal aspects that apply to ASVs, it is worth to provide a clarification on the different terminologies used when discussing about MAVs (Maritime Autonomous Vehicles). By using the term “unmanned” it is possible to go further the autonomy degree of the crewless vessels. In particular, six levels of autonomy have been identified by Lloyd’s Register [16], ranging from decision support on board to a fully autonomous vessel. In the regulatory context, autonomy degrees can be grouped into four categories [16]:

- (M) Manual navigation with automated decision support;
- (R) Remotely-controlled vessel with crew on board;
- (RU) Remotely-controlled vessel without crew on board;
- (A) Autonomous vessel.

The adoption of the term “unmanned” may be helpful to encompass the different degrees of autonomy of the vessel, by going over the classified distinctions. In this report this approach has been chosen (following the guidelines of IMO), and, where necessary, regulations applicable for only “fully autonomous” vessels have been distinguished.

The first part of this chapter concerns international laws and standards, providing a set of the existing regulations for maritime vehicles and how they can be applied to unmanned vehicles.

The second part focuses on national laws, with a focus on the Portuguese framework. The core of this subsection is a set of national regulations concerning ocean-related activities, with insights on insurance, liability in case of collision, registration, duties of the operators and dispute settlement in national courts. Special emphasis is reserved to the United Kingdom legal framework, since the UK stands as the market

[19] Discover more info about IMO’s initiative regarding MASS at: http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-99th-session.aspx

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with the highest potential for offshore wind[20] and at the same time is a pioneer in the development of autonomous vessels.

It is worth to mention that, wherever applicable, commonly used design standards should be applied to ASVs, provided that the manned requirement is not binding. For instance, the International Code of Safety for High-Speed Craft (HSC code), which defines mandatory requirements for high-speed crafts (either cargo or passenger crafts, capable of operating at planning speed), might be applied to ASVs as well (most likely scenario is that ASVs should comply with cargo crafts' requirements). More difficult is the appliance of the Code of Safety for Special Purpose Ships (SPS Code) for which the presence of the crew onboard seems to be a binding requirement.

4.1.International standards and regulations

The most important rules governing sea activities are amended by the IMO[21] and they focus on environmental, health and safety issues, collisions avoidance, legal matters, technical co-operation, thus covering everything that affects the overall efficiency of shipping. The main goal of these treaties is to define guidelines and standards which should be transposed in laws and applied by the State parties. International conventions (such as UNCLOS, COLREGs and SOLAS, described in detail below) have been drafted for vessels with a crew on-board: removing the crew most of the requirements defined in the conventions are no longer valid. This leads to three different scenarios: (1) the unmanned ships don't comply with the existing regulations and hence are illegal, (2) the legal framework cannot be applied to unmanned vehicles because of their nature, (3) responsibilities and duties must be addressed to shore-based personnel. The last approach is the most common in the literature: in MUNIN[22] (EU funded project) project for example, the participants have identified in the Shore Control Centre (SCC) the liable legal subject [17].

In this section the main existing instruments governing the operations and navigation at sea are described, moreover ASV's compliance with these instruments and rules is analysed.

4.1.1. UNCLOS

The UNCLOS, also known as "Constitution for the Ocean", is the international law of the sea (contracted by 168 parties) aiming at promoting and ensuring a peaceful use of the oceans and seas. The UNCLOS was ratified and adhered by 167 countries and by the European Union (EU). UNCLOS lays down the rules to establish and delimitate marine zones and it indicates contracting States' rights and obligations, which are different for each zone. It regulates commercial vessels and marine vehicles used for MSR (Marine Scientific Research): in this section both domains and how ASVs can fit these regulations is described.

UNCLOS specifies universally recognized rules governing all uses of the oceans, their resources and the activities undertaken therein, as well as the definition of the flag and coastal States' roles and their rights and obligations[23]. The UNCLOS framework was adopted among the member States through several

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[20]UK in 2019 was the country with highest OW installed capacity (around 10 GW) followed by Germany (7.5 GW) and Denmark (1.7 GW). See Wind Europe's wind market statistics at:
https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2019.pdf

[21] The International Maritime Organization (IMO) is a specialized agency of the United Nations that is responsible for measures to improve the safety of international shipping and to prevent marine pollution from ships. See Website: http://www.imo.org

[22] Research Project, funded by EU, MUNIN is the abbreviation for ´Maritime Unmanned Navigation through Intelligence in Networks´ highlighting the project's aim to develop technology for an unmanned and autonomous vessel. For more details see: http://www.unmanned-ship.org/munin/about/

[23] The full UNCLOS convention can be found at:
https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

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international conventions and it doesn't recognize and regulate directly the Unmanned Maritime Vehicles (UMV). It's a matter of fact that UMVs and more specifically autonomous ships, being a new reality, raise new legal challenges which have to be faced and tackled by international laws. Considering that UNCLOS doesn't introduce any exception for unmanned embarkations, it might be possible to include crewless vehicles in the regulatory framework applied for conventional ships and vessels as far as possible, as it has been done for the UAVs, which are not excluded from the legal regime pertinent to aircraft[24].

The UNCLOS splits the ocean waters in five different zones where different legal regimes are applied:

1. *Internal waters:* they include ports, rivers, inlets and other marine spaces landward of the baseline. The port State has jurisdiction to enforce its regulations;
2. *Territorial Sea:* located12 nautical miles from the baseline, the coastal State has unlimited jurisdiction over all activities, unless some restrictions are imposed by law.
3. *Contiguous Zone:* is the intermediary zone between territorial sea and high seas which extends up to 24 nautical miles from the baseline. The coastal state has jurisdiction in matter of preventing or punishing violation of customs, fiscal, immigration or sanitary legislation.
4. *Exclusive Economic Zone (EEZ):* it extends from the territorial sea to the high sea, up to200 nautical miles from the baseline. In this zone the coastal State has exclusive sovereignty and it can therefore take actions aiming at exploring, exploiting and conserving natural resources.
5. *High Seas:* beyond 200 nautical miles from the shore, are open and freely available to everyone. On the High Seas, no State can act or interfere with justified and equal interest of other States.

The first fundamental question is to understand whether unmanned vehicles can be classified as "ships" or "vessels" given the definition drafted by the convention (the two terms are used interchangeably in the UNCLOS). Furthermore, it would be unjustified that two ships, one manned and the other one unmanned, performing the same activities with the same dangers associated, would not be subjected to the same rules addressed to mitigate those dangers.

The UNCLOS doesn't provide a unique definition of vessels, but it indicates some guidelines to group them according to their purpose and public or private function performed. The UNCLOS defines States' vessels or any kind of ship navigating for non-commercial purposes (such as research surveys, rescues at sea, etc.) as warships, and thus military or political instrument of the State. Merchant ships are not officially defined in the UNCLOS and neither in other customary regulation, but it is a common practice to identify them as private sea-going vessels which are not either government ships or warships operating for non-commercial purposes (as are fishing vessels, passenger boats, oil tankers, cargo ships and research vessels not operating by the government). Nowadays merchant ships are subjected to international laws and maritime conventions applied to different areas, which lay down technical requirements and indicate their own definitions of vessel or ship.

It's important to identify which definition ASVs belong to, in order to understand if they have to stick or not to the existing standards.

4.1.1.1 UNCLOS for USV

Assuming that unmanned vehicles and ships comply with "ships" and "vessels" definition within the UNCLOS, we can consider that they are subjected to the same rules as any ordinary crewed ship. The hypothesis of considering an ASV as a vessel or a ship is assumed in this section: eventual issues related to the unmanned nature of the craft are also addressed.

[24] For more details see: I Henderson and B Cavanagh, 'Unmanned Aerial Vehicles: Do They Pose Legal Challenges?' in H Nasu, R McLaughlin (eds), New Technologies and the Law of Armed Conflict (Springer, Canberra, 2014), 193-212, at p. 197.

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Technical requirements- Registration: Article 94 of the UNCLOS imposes to the flag State[25] to create and maintain a registration of the vessels flying its flag, in accordance to Article 91(1) (which requires a genuine link between the flag State and the registered vessel) and Article 92(1) (which imposes that a vessel should fly under the flag of one State only). By applying these rules to the unmanned vessels, each State shall be free to determine the criteria and procedures necessary to attribute its nationality to the unmanned ships.

Due to the different nature of unmanned vehicles compared to regular ones, the adoption of a specific database for unmanned vessels might be necessary, or alternatively a clear statement of their nature. In addition to the information required for regular vessels (such as size, ownership, port of registry, identification number, etc.) technical and specific features shall be registered (such as the technology involved for the navigation, the distance from the control centre, the endurance, etc.).

There are some exceptions for ships to be registered by the flag States, as stated in Article 94(2)(a): ships that are excluded from generally accepted international regulations, due to their small size, have the nationality of the owner by default. The UNCLOS adopted this strategy to avoid and exclude from onerous requirements of registration small local vessels that would normally navigate just within the costal States' waters. It is worth to notice that the UNCLOS doesn't require the area where vessels should sail in order for them to be registered. It is also important to mention that the Article 94(2)(a) doesn't indicate the exemption from the registration as mandatory: States can still impose the registration for these small vessels and unmanned vessels that are excluded from GAIRS (Generally Accepted International Rules and Standards) because of their small size.

The ASVs deployed for offshore wind farm inspections may be part of this category, since most of the time power plants are placed within national waters.

Legal regime of flagged unmanned vessels: the unmanned vessel registered at national level acquires the right to fly the flag of the registering State, the right to receive documents attesting such registration and the right to enjoy diplomatic protection [18]. The right of diplomatic protection means that only the flag State may legally represent the vessel before other entities such as State, international organization, courts and tribunal.

Some concerns arise for unmanned vessel regarding this topic, especially on how the diplomatic protection works in case of shore-based control. For manned ships, the physical presence of the crew leads to consider it as a part of the vessel and hence it is subjected to the diplomatic protection of the flag State. The physical link doesn't exist in the case of unmanned vessels, for which the SCC and hence the distance-based master may be able to monitor and control the vehicles from another country. The exclusive jurisdiction of the flag State doesn't exonerate a third State to affirm its jurisdiction over its national borders, hence as long as a legal solution is not found, the shore-based master and the crew can always be subjected to the jurisdiction of the State of nationality [18].

Being the unmanned vessels subjected to the sovereignty of the Coastal State in both territorial and internal waters, the incompliance enables the coastal State to take actions to stop a certain conduct, requiring an immediate withdrawal and even boarding and expelling the unmanned vessel from the territorial sea [19]. In the EEZ the unmanned vessels may be subjected to the jurisdiction of third States rather than the flag State, as a result of specific treaties. As indicated in Articles 210(3), 220(5) and (6), the coastal State, within the EEZ, may exert its sovereignty over unmanned vessels if they are involved in activities that may contaminate or jeopardize the marine environment.

[25] The 'flag state' of a merchant vessel is the jurisdiction under whose laws the vessel is registered or licensed and is deemed the nationality of the vessel.

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The flag State shall ensure that each ship is governed by a master who owns appropriate qualifications, as stated in Article 94(4)(b) of the UNCLOS, also in case of unmanned vessels.

4.1.1.2 UNCLOS and UMV for MSR

Besides "ships" and "vessels", in the UNCLOS other terminologies ASVs may be placed within are used, such as "structures", "platforms", "artificial islands", "installations" and "equipment". As indicated in [18] UMV, ASVs can be classified as "equipment" (the definition is given in Articles: 1(5)(b)(i), 21(2), 62(4)(a), 94(3)(a), 94(4)(a), 129, 194(3)(c)(d), 202(a)(iii),211(6)(c), 217(2), 226(1)(a)(i), 248(b), 249(1)(g), 274(b), 275(2)). The same term is described in the UNCLOS as 'a device or instrument of quick deployment and removal, normally not fixed or anchored to the ocean floor'.

In *Section IV part XII* the UNCLOS lays down the rules for UMVs used for MSR activities, which can be considered as a landmark to discuss the legal framework for UMV, and hence ASV used for other purposes. It's worth to cite that in the UNCLOS is also provided a difference between "pure" and "applied" MSR activities.

Pure research (mentioned in Article 246(3)) is the activity carried out for peaceful purposes, aiming at increasing human knowledge about the marine environment without resulting in economic benefits.

Applied research (mentioned in Article 249(2)) is also performed for peaceful purposes, aiming at exploiting living and non-living marine resources. This kind of research is driven by economic reasons and benefits that either individuals and/or companies may earn from the sea exploration.

The use of ASVs in offshore wind farms would better fit the "applied research" rather than the "pure research" as it results in economic benefits for companies, but it can also be exploited to have a better understanding of the marine environment and its processes.

Technical requirements- Registration

Article 262 does not oblige to register UMVs used in MSR activities, but it prescribes that the equipment deployed in the marine environment for MSR purposes should bear identification indicating their purpose and identifying the State or the International organization they belong to.

Same approach might be used for ASVs implied in offshore wind farms: in this case the vehicles might be logged in national registers or otherwise have labels reporting their owner (SCC or the third party involved in IMR activities) and purpose (surveillance, monitoring, etc.). The absence of registration leads to some problems, due to:

- impossibility of the coastal State to identify and confirm the device;
- uncertainty of liability in case of accidents at sea, such as collision. The absence of registry may create additional constraints regarding the identification of the liable State or organization.

Technical requirements- Warning signals

To ensure safety at sea, the Article 262 of the UNCLOS imposes to have adequate warning signals agreed at international level. Warning signals, as pointed by the IMO resolution 671(16) [26], may include lights, sound signals, radar watch, listening for warning vessels on VHF channel or other appropriate frequencies and means for permanent visual out-look. The adoption of warning signals would facilitate the identification of

[26] See preamble of the IMO Assembly Resolution No. 671(16), Safety Zones and Safety of Navigation Around Offshore Installations and Structures, (19 October 1989), Annex 1(1), available at: http://www.imo.org/blast/blastDataHelper.asp?data_id=22502&filename=A671.pdf

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ASVs among other similar devices avoiding collision, fostering safe navigation and finally it would prevent ASVs' interference with other legitimate activities and uses of the sea (such as fishing).

Technical requirements- Physical deployment

Article 258 of the UNCLOS set out the conditions for the deployment of UMVs for MSR in the sea, adopting a zone-based approach: requirements and permitting may vary from zone to zone and case by case. As offshore wind farms are usually deployed from 20 to 40 km far from the coast, the deployment of ASVs would interest both territorial seas and EEZ. In both cases the physical deployment is allowed under expressed consent from the Coastal State, even if the vehicle is drifted into the selected area from other zones or if it is launched by an aircraft.

The deployment of an UMV in the EEZ is subjected to the coastal State's consent, however Article 246(3) limits the power of the Coastal State and define compulsory consents in specific cases.

Article 246(5)(c) allows optional consent from the Coastal States when the deployment of the UMVs is implied in the construction, operation or use of artificial islands, installations (as it might be in case of OWFs), and structures mentioned in Article 60 and 56 of the UNCLOS (in which energy power plant are included). In the scope of ATLANTIS, the deployment of ASV (if considered as UMV for MSR applied activities) for IMR activities in Offshore Wind Farm would need to face the optional consents of the Coastal State.

4.1.2. COLREGs

The International Regulations for Preventing Collisions at Sea (COLREG) was ratified by 169 contracting parties in 1972 with the scope to prevent collisions at sea. It is applied to all vessels or water crafts used as means of transportation in high water sea, as indicated in Rule 3a of Part A of the convention. In the scope of ATLANTIS, the ASV might be intended as a mean of transportation for the presence of sensors and tools on-board, as well as for its capability to transport and deploy any other kind of robot in the place where its operation is needed.

The convention is composed by 38 rules and divided in 5 parts:

I. Part A – General Rules (Rules 1-3);
II. Part B – Steering and Sailing (Rules 4-19);
III. Part C – Light and Shapes (Rules 20-31);
IV. Part D – Sound and Light Signals (Rules 32-37);
V. Part E – Exemptions (Rule 38).

Besides the five parts, it also includes 4 annexes regarding technical details and requirements for lights and sound signals.

Whilst the majority of the rules refers directly to the vessel itself, *Rule 2(a)* places the responsibility to comply with the rules on the owner, master or crew. According to this rule a mariner should act as "the ordinary practice of seaman", which stands for a normal behaviour dictated by the circumstances, experience, knowledge and perception. It needs to be noted that, being an ASV driven by a computer, it is very hard to assign the ordinary practice of a seaman to a computer. For this reason, clear and specific regulations for autonomous marine vehicles need to be ratified, especially to solve issues related to liability and responsibility, which represent the major concern that ASVs have to face and which may slow down the deployment of autonomous robots in the offshore sector.

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The main goals of COLREG are related to collision avoidance, which is mitigated by establishing navigation standards and safety requirements. The convention covers decision-making and situation awareness including look-out, which is defined by *Rule 5* as follows:

"Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision".

According to the rules, the term look-out, rather than strictly implying a person, represents in a general way an adopted system capable of collecting information. The look-out rule aims at making whoever controls the ship aware about what is ongoing in the surrounding area of the ship, making them informed about the decisions and actions which have to be undertaken in order to avoid collisions. The matter is to understand if the *Rule 5* can authorise the replacement of human look-out by several technologies such as cameras, radar and others. This issue can be solved, and the replacement accepted, if the equipment is able to provide to the controller an adequate overview of the circumstances, allowing him to take appropriate actions as promptly as, if not even better, a real controller on-board.

In case of collision among remotely-controlled vehicles, the SCC and the owner might be considered liable for not complying with the COLREGs. The scenario is different if the ship is driven by Artificial Intelligence (AI): in this case the manufacturer, who understands the decision-making process, might be the only one liable because of SCC's lack of knowledge. Even though human operators placed in the SCC monitor the ASVs, it might happen that the AI makes a decision that breaches the COLREGs faster than a human operator, and hence might not be possible to avoid the created danger: in this case the owner or the producer of the ASV should be liable.

Rule 6 is about safety speed, which has to be managed according to several factors, such as visibility, traffic density, wind, current, manoeuvrability and other characteristics of the vessel. ASVs might not interfere with this rule as long as they respect all the factors mentioned.

Rule 18 is applied to vessels in sight of one another, and since they need to be able to observe each other only by means of sensors and not visually, this would mean that they can't comply with this rule, unless the reconstruction of the surrounding areas with the assistance of sensors able to identify obstacles may be compared to visibility. If not, *Rule 19,* which regards vessels in conditions of restricted visibility, may be applied. The term "restricted visibility" is defined by Rule 3 as "any condition in which the visibility is jeopardized due to fog, snow, rainstorms and other causes". If the assumption that vessels can't comply with Rule 18 is taken, other possibilities might be considering ASV as "not under command" or "restricted in ability to manoeuvre". These assumptions arise some concerns, because ASVs are designed to work and behave as manned vessels. Furthermore, a vessel "not under command", as defined in Rule 3, is a vessel that under exceptional circumstances is unable to manoeuvre as required and since the vessel is supposed to be unmanned all the time it can't be considered as exceptional circumstance.

Part C & D define detailed requirements for the signals which must be used to communicate with other sea users. The technical requirements are specified in the Annexes I-IV, but it is worth to say that the ASV should be equipped with very sophisticated systems as it needs to be able to detect signals coming from other vessels. Furthermore, making the communication system as resilient as possible to ordinary and likely failures will be the first step to demonstrate safety credentials of ASVs and thus increasing their acceptance.

In the four Annexes, as already mentioned, the COLREGs define some technical requirements, which have to be taken into account by the ASC manufacturer, related to shape and sensors positioning, sound and distress signals.

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4.1.3. SOLAS

The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime treaty ratified in 1974 by 164 contracting parties. It sets minimum safety requirements for the construction, equipment and operation of ships and it is articulated along 14 articles and one annex spread in 12 chapters. For the aim of this assessment, the SOLAS will be evaluated considering regulations concerning construction, fire protection, life rescue, radiocommunications, navigation and safety measures.

The SOLAS presents a wide flexibility, since the contracting government may exempt the vessels from the compliance with some provisions, if research and development are jeopardized by the application of the said provisions. In that sense, ASV may stand to benefit from this dispensation, but much depends on the attitude of the domestic regulators.

Construction (Chapter II)

In chapter II ships' structure, subdivision and stability, machinery and electrical installation are defined. As explained in Regulation 5-1, it is requested that the ship master has to be supplied with all the information necessaries to make him/her aware about the operating conditions. The chapter also highlights the need of alarm signals, and following the spirit of the regulations, ASVs should be equipped with alarm signals to help the crew on the SCC to take command of the vehicle when a danger is approaching.

Fire protection (Chapter II)

Structural requirements aiming at ensuring the safety from fire are prescribed in Chapter II. Besides technical requirements for the alarm systems, Regulations 15 and 16 also prescribe onboard training and drills, with the scope of boosting personnel skills in terms of fire containment and extinction. For ASVs these requirements make no longer sense and according to Regulation 4-1, which establish the exemption for individual ships from these requirements if considered "unnecessary or unreasonable" and the ship navigates within 20 miles from the shore. Because of either the unmanned nature of ASVs and their "usual" navigating distance, in the scope of ATLANTIS, ASVs might be exempted by fire protection requirements.

Radiocommunication (Chapter IV)

Radiocommunications requirements and transmission capabilities are prescribed in Chapter IV. Whilst Regulation 16 of the chapter requires that every ship should carry personnel qualified for distress and safety radiocommunications, in the context of ASVs the prescribed capabilities should be delegated to the SCC.

Navigation (Chapter V)

Regulation 14 of Chapter V requires that all ships must be sufficiently and efficiently manned, from a safety perspective, but the regulation does not explicitly require that at least one member should be on board at any time. Regulation 15 prescribes principles in order to "facilitate the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation". In case of ASV these requirements might be fulfilled by a qualified individual that monitor the vehicle from the SCC and who can take remote-control of the ship immediately. This means that an ASV not monitored and which cannot be remotely-operated does not comply with the regulation. Regulation 33 remarks the obligation for the master of the ship to provide assistance to a person in distress at sea, whatever possible and within his/her possibilities. In the unmanned context, the duty may be charged to the SCC, whose tasks and actions would not concern the physical rescue of the person but rather the obligation to alert rescue authorities. A remote controller of an ASV that, having received the distress signals, does not undertake any action to save the person in

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danger, would imply that he is breaching the spirit of the duty. As a result of this misbehaviour, the integration of ASV into the conventional maritime community would get more difficult.

Safety management (Chapter IX)

Principally, the chapter requires to the ship to comply with the International Safety Management (ISM) code. Well-defined and specific guidelines are needed in case of ASVs, especially regarding the requirements and the identification of the master's responsibilities, the overall procedures, shipboard operations and documentation.

Safety measures (Chapter XI 1 & 2)

This chapter defines additional measures to enhance safety and security of ships. The main concern which arises with ASVs is related to cyber infiltration. According to Regulation 6, the ships should have an alert system which communicates to the designated authorities its position and that its security is under threat. In case of an ASV, a similar system might be used to alert the SCC that the vehicle is under a physical or cyber-security threat.

4.1.4. EP Guidelines on Civil Law Rules on robotics

The work conducted within the funded European project FP7 called RoboLaw[27], whose aim was to study the application of law to robotic technologies, has inspired the European Commission (EC) which has drawn up a report about recommendations on Civil Law Rules on Robotics,[28] then approved by the European Parliament (EP) in 2017. This report addresses ethical, social and technical issues for the use of autonomous cars and healthcare robotics; it doesn't cover specific issues related to the marine domain, nevertheless some guidelines may fit into the use of ASVs. Whilst autonomous cars and healthcare robots have a strong interaction and influence on human operators, since they could replace some of the work that humans perform, the concept is a bit different when referring to ASVs, because they will not necessarily reduce human jobs, but they might increase safety in some operations. For this reason, not all the topics reported in the EP Guidelines might be suitable for ASVs: the most important ones are related to classification, liability, standardization, safety and security, and will be discussed in this section.

Before describing the guidelines, it is worth to explain some concerns raised by the EP at some points. At point 1 the EP has requested the EC to provide a detailed description of autonomous robots with references to autonomy degree, adaptive behaviour, self-learning and physical support. The EP also asked to the EC to foster standardization for data protection, privacy and risk assessment, to define criteria to identify areas where robotics experiments are allowed. Very relevant concerns are those related to liability issues: at Point 27 it is suggested to apply strict liability as a rule, meaning that it must be proved that the damage has been caused by a harmful behaviour of the robot, mindless of the fault. Liability should be proportional to the degree of autonomy, as indicated at Point 28, while at Point 29 the motion proposes a mandatory insurance scheme to be taken out by the producer [20]. A compensatory fund, complementary to the mandatory insurance, might be used to defray cases not covered by commercial insurance.

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[27] RoboLaw (Regulating Emerging Robotic Technologies in Europe: Robotics facing Law and Ethics) is an EU funded project, ended in 2014. The main objective of the RoboLaw project was to understand the legal and ethical implications of emerging robotic technologies and to uncover (1) whether existing legal frameworks are adequate and workable in light of the advent and rapid proliferation of robotics technologies, and (2) in which ways developments in the field of robotics affect norms, values and social processes. More info about the project can be found at:

http://www.robolaw.eu/projectdetails.htm

[28]The full report can be found at:

https://www.europarl.europa.eu/RegData/etudes/STUD/2016/571379/IPOL_STU(2016)571379_EN.pdf

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Classification

As mentioned before, the report highlights the need to define a detailed and clear definition for autonomous robots according to several aspects. The adversity in classifying an ASV as a vessel makes the application of the current regulation very hard, and this is an issue that must to be solved. Other guidelines as [21] and [12] have already provided a classification of ASVs considering mainly their size and degree of autonomy.

Registration

The EP requested the EC to ratify a registration system at European Level, based on classification criteria and managed by a future EU Agency for Robots and Artificial Intelligence. Even though in the UK the first ASV has been registered in the UK Shipping Registry[29], it is highly inadvisableto have individual country-based registries with different classification criteria. For this reason, European Registers or even better an International Register, promoted by the IMO, would be the best option, helping manufacturers, owners and users and also enhancing legal certainty [20].

Risk and safety

An important issue highlighted by the EP in the report is the need for risk assessment and code sharing, in order to investigate liability and bugs in case of accidents. The major risk an ASV has to face is that of collision, so it is important that proper countermeasures are taken to avoid (or at least mitigate) this risk. Even though several technologies might be helpful (such as radar sensors, cameras, LIDAR, etc.) to build up a collision avoidance algorithm, this might not be enough to foresee the dynamical behaviour of other vessels: for this reason, dedicated sea lanes can be helpful to avoid collisions. COLREGs relies on human control in navigation, which heavily depends on the type of vessel, its tonnage and navigation's circumstances: for an ASV it might be tough to recognize automatically and rapidly all the possible variants. The report also highlights the need for access to the source code and interoperability to investigate accidents. The access to the source code might raise Intellectual Property (IP) issues, resulting in a chilling effect on the market development, because manufacturers might not be willing to give access to their code and share their intellectual properties. This issue might be solved by accessing data logs [20] through standardized black box, which would make the investigation easier and less time expensive.

Liability and Insurance

One of the most relevant issues related to the use of autonomous robots, ASVs in this case, deals with liability and responsibility in case of accident or damage to third party. The EP suggests using strict liability as a rule, indicating that liability should be proportional to the degree of autonomy. For other philosophy of thoughts[30], as ASVs are a product, the product liability regime should be applied: this makes the producer responsible for damages caused by the user to third parties. Liability rules, besides identifying the responsible in case of damage to third party, also define proper compensation methodologies for the harmed party. The most common way is to have an insurance policy. The EP has proposed a mandatory insurance scheme, similar to the one that applies to cars, to be subscribed by the producers, and it also recommends complementing it with a compensatory fund for all cases not covered by the basic insurance, which is mandatory. Itis worth to mention that even though ROVs and AUVs have specific insurance

[29] For more information about the first ASV registered in the UK Ship Registry see article at: https://www.ukshipregister.co.uk/news/uk-ship-register-signs-its-first-unmanned-vessel/

[30] ASV are robots, hence being a product should be subjected to "product liability" according to: A. Bertolini, P. Salvini, T. Pagliai, A. Morachioli, G. Acerbi, L. Trieste, F. Cavallo, G. Turchetti, and P. Dario, "On robots and insurance". It can be found online at: https://link.springer.com/article/10.1007/s12369-016-0345-z

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policies, well defined and already commercialized, the same cannot be said for UMVs, even though the market is already looking for a solution.

4.1.5. Liability issues for ASV

Due to the increased use of ASVs, future accidents will rise caused by technical defects, while the weight of the human error will be reduced or moved elsewhere. Current laws don't identify liable subjects for autonomous operations. Several actors could be liable for accidents provoked by autonomous systems: the responsibility might fall on the owner/operator of the USV (Unmanned Surface Vehicles) or even on the manufacturer who created the defective vehicle.

In case of collision, the "ship" is liable without any mention to the person actually behind the collision, while environmental rules address the responsibility to the registered ship owner [22].

Damages and accidents caused by a ROV should be similarly treated as errors committed by on-board crew: in this case instead, as mentioned in MUNIN project [17] , the SCC is liable in case of accidents. The situation is different for autonomous vehicles. For instance, the operator (hence the SCC) might be responsible in case of failure or fault in the software of the autonomous vehicle, but in case of the connection between the USV and the SCC is cut-off is less obvious that the owner/operator is liable, as the vehicle has to rely only on its autonomous system (without the possibility to be monitored and blocked remotely). The use of USVs arises some issues related to liability and responsibility in case of incidents and collisions. Liability issues are different according to the size and the degree of autonomy of the UMV. Before analysing the possible liability regime it is worth to provide a classification of the UMVs (and hence ASVs) based on their size and degree of autonomy. A brief description of the liability regime is then provided. In the classification, only the ASVs deployed in OWFs have been considered.

There are many ways of classifying USVs according to different criteria such as size, speed, intended use, potential hazards, etc. The EDA (European Defence Agency) through SARUMS (Safety and Regulation for European Unmanned Maritime Systems) group has detailed the best practices for Unmanned Maritime Systems handling, operations, design and regulation by publishing a document [21] in 2012, then updated in 2015. They identified categories are:

- *Length:* small (up to 12 meters), medium (from 12 to 24m) and large (over 24 m);
- *Distance of operation:* low end (less than 100 nautical miles) and high end (more than 100 nautical miles);
- *Speed:* low end (less than 30 knots) and high end (more than 30 knots).

In the Code of Practice [12], the UK Maritime Autonomous Systems Regulatory Working Group (MASRWG) focuses on USVs up to 24 meters and provides a classification considering both length and speed.

Both document [21] and [12] provide a further classification based on the autonomy degree of the USVs, organized on six levels (level 0 refers to manned vehicles) , as follows:

1. *Remote Controlled:* vehicle movement and actions are directly controlled by the operator who takes all decisions;
2. *Directed:* the vehicle can suggest actions, but the operator has the authority to take decisions;
3. *Delegated:* the vehicle can request to perform actions, but it needs the operator's consensus;
4. *Monitored:* the USV invokes functions and the operator's consensus is not necessary;
5. *Autonomous:* the USV, by sensing the surrounding environment, defines actions to be performed without warning the operator but only reporting to him/her.

In this work the same categorization illustrated in [23] is used, based on lengths. The adopted classification is:

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- ***Light***: overall length < 1.4m;
- ***Small***: 1.4m ≤ overall length < 12m;
- ***Medium***: 12m ≤ overall length < 24m;
- ***Large***: overall length ≥ 24m.

As suggested in [23] other parameters should be considered, such as the intended used and who the operator is.

Assessing the existing liability regime in the tort law, it would make sense to consider only responsibility deriving from damages to third-parties, without taking into account criminal regimes. A brief description of the different regimes considered appropriate in case of USVs is provided down here.

1. Liability with fault: requires the human intention to damage something/someone. It makes sense to apply it to ROV where the human action might represent the intention to produce a fault, whilst in case of an ASV it would be very hard to assign the intention to the vehicle itself.
2. Strict liability (without fault) and Absolute liability: the damaged party (claimant) needs to prove that the tort occurred because of the liable person’s fault. The defendant can prove due diligence and can raise a defence of absence of fault. The claimant has to prove the defect in the robot and the causal relationship between the damage and the defect, as indicated in Directive 85/374/EEC [23]. Absolute liability is similar to strict liability, except for the fact that the due diligence cannot be used as a defence.
3. *Product liability:* it is related to defects in a product.
4. *Vicarious liability:* this liability arises when a superior is responsible for the conduct of a subordinate. This might be an important approach in case of USVs for which normally more people are involved in the operations. The USV might be seen as the employee and the operators as the principal.
5. *Abnormally dangerous activities liability:* it derives from abnormally dangerous activities. The party conducting these activities is liable unless it can prove due diligence.

In this assessment the absence of the intention to damage a third party has been assumed, both for the USV and the person driving/monitoring the vehicle. In case of cyber-attack, the hacker takes control of the USV and might cause damage to a third party: in this case the liable person might be the one controlling/monitoring the vehicle, even though the manufacture might be liable as well for not protecting the USV against cyberthreats.

In case the USV is not used in its normal operating conditions (thus without fulfilling the manufacturer’s indications), in case of damage, the liable subject should be whoever has decided to launch the USV at sea or the one who commanded that action. In the following cases it is assumed that the USV is used respecting the limits imposed by the manufacturer (thus in its normal operating conditions).

In case of *light USVs*, as they can cause minimum damages to other vessels, they can be exempted from insurance, as usually happen for drones. Besides insurance exemption they can still require authorization to operate, which can be either implicit (as in case of commercial products) or explicit (in case of modified prototypes). As suggested by the EP Resolution (2015/2013(INL)) at Point 59b, as long as the damage is minimum no person is liable, and a compensation fund might be enough to reimburse the damaged third party [23].

In case of *small*, *medium* or *large USVs* for level 4 and 5 (hence in the ASV case), the strict liability might not be the best option as in this case the vehicle operates autonomously, and the human operator can only supervise its actions. In this circumstance the absolute liability should be applied for the producer/manufacturer. Even though the operator might be guilty for not properly monitoring the USV, the biggest share of liability should be assigned to the producer, who has deployed into the market a

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vehicle which is supposed to operate by itself with no need of intervention [23]. In case of modified USV the liability falls upon the ones who modified it as their modification may alter the vehicle behaviour.

4.2. National Framework

In this chapter both Portuguese and British national laws governing the use of ASVs are reported. Particularly, Section 4.2.1 presents how Portuguese laws deal with ASVs' requirements concerning: the registration of the vehicle, the documentation required and insurance and liability issues. In regard of the British legal framework are discussed topics such as: ASVs' registration, personnel competences and requirements, design and vehicles standards and requirements, ASV deployment's approval and SCC's requirements.

4.2.1. Legal Portuguese context

In this section the Portuguese legal framework and its appliance to ASVs is presented, starting from the subdivision of the Portuguese waters and later assessing all the requirements that operator, users and manufacturer must fulfil. Article 5 of the Constitution of the Portuguese Republic (CRP) establishes as "territory of Portugal" the European mainland (historically defined as Portuguese) together with the Azores and Madeira archipelagos. According to Law No. 34/2006 of 28 July, Portugal exercises jurisdiction or sovereignty over international waters, territorial seas, contiguous zone, EEZ and the continental shelf in line with the UNCLOS. In accordance with the UNCLOS, territorial sea extends up to 12 nautical miles from the shore, whilst contiguous zones extend up to 24 nautical miles from the baseline and the EEZ up to 200 nautical miles from the shore. Law No. 34/2006 divides Portuguese EEZ in three sub areas (shown in Figure 4.1):

- Mainland sub-area: whose extension covers 287 521 km^2;
- Madeira sub-area: which covers 442 248 km^2;
- Azores sub-area: which covers 930 687 km^2.

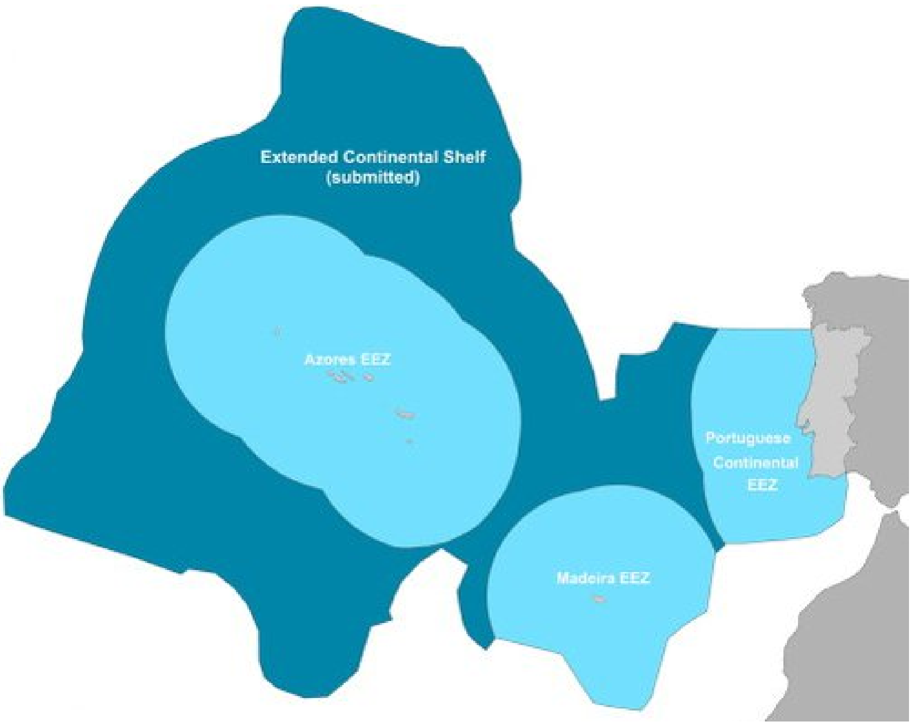

Figure 4.1: Subdivision of Portuguese waters.

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Article 14 of the Decree-Law 34/2006 establishes that the jurisdiction over Portuguese maritime zones is exercised by the System of the Maritime Authority (SAM), by the Navy and by the Air Force.

SAM is an organization which includes transversal institutions such as military and civil entities, technical bodies and police authorities [18]. According to Article 7 Decree-Law No. 43/2002, other entities are allowed to exercise maritime authority:

- AMN – Autoridade Marítima Nacional;
- Maritime Police – Polícia Marítima;
- National Republican Guard – Guarda Nacional Republicana;
- Public Security Police – Polícia de Segurança Pública;
- Portuguese Criminal Police – Polícia Judiciária;
- Immigration and Border Service – Serviço de Estrangeiros e Fronteiras;
- General Fisheries Inspectorate – Inspeção Geral de Pescas;
- Water Institute – Instituto da Água;
- Maritime and Port Institute - Instituto Marítimo-Portuário;
- Port Authorities – Autoridades Portuárias;
- General Directorate for Health – Direção Geral de Saúde.

Port captaincy (Capitania do Porto) exercises maritime authority at local level and it is integrated in the AMN.

DEFINITIONS

Different definitions for ships and vessel, respectively translated from "navio" and "embarcação", can be found in the Portuguese legal framework: below definitions present in some of the laws applicable to ASVs involved in offshore activities are reported.

Decree-Law No 201/90 of 10 July regulates the necessary conditions to grant the Portuguese flag to the vessels and it defines a ship as "any floating device intended for water navigation", including onboard equipment and auxiliary machines.

Ships are defined as floating devices for navigation purposes in *Decree-Law No 202/98* of 10 July, which sets out liability regimes for ship owners.

Law No. 34/2006 of 28 July defines the maritime zones under Portuguese sovereignty, without mentioning the term "ships" but rather using the expression "other floating devices".

A wide explanation has been provided for vessels and ships and adopted in the legal framework, and it is worth to notice that nowhere the manned nature of the vehicles is considered: it seems that manning is not a constitutive requirement for a vessel to exist in legal terms. This does not directly imply that an ASV has to comply with the regulations, because most of them have been ratified and conceived based on the idea that vessels are usually manned.

Decree-Law No. 265/72 of 31 July approved the General Regulation of Captaincies and provided some guidelines for classifying the vessels based on the activities performed.

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Among all the definitions (such as State vessels, fishing vessels, research vessels, commercial vessels, auxiliary vessels, merchant vessels, tugboats and recreational vessels) the two categories where an ASV involved in the offshore activities might belong to are:

- ***Commercial vessels***: used for the transportation of people or goods (in that case sensors might be considered as goods). They are also categorized by considering the area they operate in. UMVs might perfectly fit the definition because it does not consider the manning as compulsory.
- ***Auxiliary vessels***: are vehicles used in other activities rather than fishing, commercial, recreational, MSR activities.

REGISTRATION

In accordance with Article 94 of the UNCLOS, the Portuguese law requires that vessels must be registered to be legitimated to fly the Portuguese flag. This registration is mandatory for any type of vessels, with some exemptions: this is the case of small vessels on board, like ASVs transported and deployed by larger vessels. Decree-Law No.43/2018 of 18 June led to the creation of BMAR, an electronic registration system for vessels. The registration must be required by the shipowner or by any entity on his behalf. Specific information related to ASVs should be integrated in the near future, such as distance navigation, activation of safety procedures in case of emergency and information related to the distance-based master and crew [18].

Madeira's International Shipping Registry (MAR) is the Portuguese international registry which provides registration for all acts and contracts related to vessels. It also ensures compliances with safety standards required by the Portuguese authorities. Inspections of ships, vessels' certificates, providing names and numbers, are MAR's responsibilities. The definition of vessel provided by MAR is very expansive and it includes any fixed or floating platform, commercial or recreational craft. For this reason, MAR would allow the registration of UMVs as the manning requirement is not explicitly mentioned in the definition.

Specific information reporting the number of the registration, the name of the vessel, an indication of the tonnage, a letter identifying the type as well as the acronym 'PT', should be marked for vessels registered in Portugal. These signals, which are mandatory for regular vessels, must be observed by UMVs. Besides traditional marks, for ASVs some signals indicating the unmanned nature of the vehicle might be necessary, in order to facilitate its identification and avoid collisions at sea.

Several certificates should be released before allowing the vessel to legally operate under Portuguese jurisdiction. These certifications are mainly related to safe navigation and pollution prevention.

DOCUMENTATION

Portuguese legislation requires commercial vessels to keep on board several documents (listed in Article 121 of Decree-Law No. 265/72 of 31 July) which should be held by the master or by the responsible of the craft. These documents must be presented to the authorities upon request: non-compliance with this regulation will result in the payment of a fine between 25,00 to 500,00 euros. If specific regulations will not be emended for ASVs, unmanned vessels will have to comply with the existing regulations: this means that itis important to understand how UMVs are going to have the documents on board. By now an electronic system might be used, as suggested by Article 18(2) of Decree-Law No.92/2018 of 1 November.

LIABILITY ISSUES

Collision involving vessels flying with the Portuguese flag is subjected to Portuguese laws, independently of the maritime area. In the Portuguese legal framework, the term "collision" is not cited, whilst the term "sea event" is commonly used, for example in *Decree-Law No. 384/99* of 23 September, which regulates the legal regime for a ship's crew. A "sea event" is defined as an exceptional situation which has caused or

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is likely to cause damages to ship, floating devices (floating offshore wind farm may be included), people or transported goods.

Ordinary legislation, Civil Code (CC) and Commercial Code regulate liability in case of collision [18] and, as they do not directly refer to the manning on board, they could be applied also to ASVs. From article 664 to Article 675 of the Commercial Code, reimbursement compensations are defined for four type of collision:

- *Collision caused by one ship:* the defaulting vessel is in charge to pay a compensation fund to the damaged party;
- *Collision caused by both ships:* each vessel should refund the other in accordance and in proportion to the gravity of the damage;
- *Collision without fault:* it's not required any compensation, it happens when the damage has been caused by actions undertaken by force majeure;
- *Collision in case of doubt:* both vessels are in charge to pay a compensation.

Even though Article 4 Decree-Law No. 202/98 set as default liability on the shipowner in case of collision and damage to third parties, the Commercial Code does not prejudice the liability of those who are actually responsible for the collision, like the master and the pilot.

Article 500 of the CC regulates, generally, liability that individuals hold when they make use of others to perform their responsibilities, and it places the liability on those individuals, even for acts and damages they may cause to a third party. According to this regime, shipowners are liable for damages and acts caused by masters or a pilot, even when they are remotely in charge of the vessel [18]. The idea is that third parties affected such as floating devices, artificial islands etc. are compensated by the owner of the craft that has caused the collision. The liability regime is strict liability, as it exists even when the shipowner has no fault. The shipowner, by the way, has the right to be reimbursed by those that were actually liable for the collision, if some requirements of Article 500 of the CC are fulfilled:

- Distance-based master and shipowner must have a commissioning in place, intended as any service allowing one person to carry out an activity under the direction of another person. Distance-based master would act under the direction of the shipowner.
- The activity performed should be done in the interest of the entity that exercises the direction (shipowner) and the damages caused must be produced during the exercise of these functions.
- It is necessary that the distance-based operator is liable too, under the regime of fault liability, as indicated in Article 483 of the CC.

Article 483 of the CC set out some requirements which should be observed to consider a certain vessel liable, in particular it should be verified that an unlawful conduct has been adopted. Unlawful conduct is held when rights of other persons are breached or when legal provisions aiming at protecting interests of others are violated. Duty of care and good seamanship are the behaves to undertake in order to ensure and protect the interest of others. These two topics arise some concerns when talking about ASVs, in particular their application to this kind of vessels and also on how they bind the distance-based master and the crew (which may be identified in the SCC). In order to overcome these barriers and establish a clear liable regime, guidelines, manuals and legal principles have to be elaborated with the scope to reduce the risk of collisions and facilitate clarifications in case of non-compliance with the regulations.

Moreover, Article 493(2) of the CC indicates that damages caused to third parties resulting from dangerous activities should be compensated by those causing the damages, unless they prove that they have used due diligence to avoid the damages. Technical discussions are still in place to understand if the employment of ASVs can be considered as dangerous activity.

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MARITIME INSURANCE

Most of the maritime accidents are caused by human errors[31] but this does not imply that the use of ASVs will reduce the amount of marine accidents, mainly because human decisions will be moved from on board the craft to land-based stations (SCC). The Commercial Code, in the Portuguese legal system, establishes the legal regime applied to marine insurance through Article 595 and Article 615. The formal requirements which have to be fulfilled in order to consider the insurance policy valid are defined by the Commercial Code, which has to include the name of the captain, the duration of his contract and the perils covered by the contract.

The Commercial Code specifies the dangers that can be covered by the contract and none of these intrinsically imply the manned nature of the craft. In fact, Article 604 lists some perils for which the insurance company is liable such as damages arising from storms, collisions, fires, explosions, floods, wreckages, groundings, unlawful violence and other sea fortunes. It is worth to notice that in case of ASVs other specific perils related to the operation of the craft should be considered, namely [18]:

- *Technological peril:* like software failures, cyber-attack and other events that may prejudge and corrupt the remote control and monitoring from the SCC;
- *Technical and mechanical malfunctions:* any failures that may interfere with the voyage and require immediate human intervention.
- *System failure:* any event that can jeopardize the navigational system or the communication network;
- *Perils arising from collision:* even though collision can be avoided with the adoption of algorithms and technologies, likely perils should be assessed.

Owners of ASVs should require insurance companies to include specific perils in the insurance contracts, because if such dangers are not covered the insurance companies might refuse to compensate them.

The fault of the master and their assessment is also relevant for the insurance, in fact Article 604(1) of the Commercial Code excludes the liability of the insurance company when the damage occurs due to "*barataria*" [18] , which represents an act of the master made with negligence or guilt. The same can be applied to ASVs which are remotely monitored and controlled, whilst totally autonomous craft not monitored by the SCC should be subjected to a specific framework which regulates the failures of this technology.

It is worth to notice that when referring to UMVs, which are crafts much smaller than vessels (which can be deployed in the scope of ATLANTIS) the Commercial Code does not require an insurance contract. However, when UMVs are employed in activities which require an insurance, it might be necessary that the insurance policies cover also the eventual damages caused by the UMVs involved [18]. This might be the case of offshore activities such as IMR inspections for offshore wind farms.

4.2.2. United Kingdom: legal status for ASV

The UK is one of the pioneers of autonomous vessels and one of the more active countries in dealing with legal issues in this context. Important guidelines have been redacted from both the UK Maritime Authority

[31] See, the *AGCS Safety & Shipping Review 2018*, at p. 18, available at: https://www.agcs.allianz.com/content/dam/onemarketing/agcs/agcs/reports/AGCS-Safety-Shipping-Review-2018.pdf.

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and the UK Marine Alliance[32] in order to frame and define legal issues related to ASVs, allowing their fast deployment.

The UK Maritime Authority has published a report named "*Being a Responsible Industry: Maritime Autonomous Surface Ships (MASS) UK Industry Conduct Principles and Code of Practice*" [12], which aims at setting out initial standards and best practices for those who design, manufacture, own, operate and control MASS less than 24 meters in length. It also defines nine "Industry Principles" trying to demonstrate and ensure safety and responsible operations of ASVs, assuring compliance with all the existing applicable regulations.

As stated in *Principle 1*, industries have to adhere to several principles aiming at ensuring health and safety and preventing accidents. They also have to understand the risks present at the workplace during the whole lifecycle of the ASV (design, manufacture, maintenance and operation) and mitigate them.

Principle 2 of the Code of Conduct deals with environment impact of the ASV as a product during its whole lifecycle. Industry has to consider and adopt techniques able to reduce and minimize their impact in order to preserve the environment by, for instance, adopting a recyclable design.

ASVs have to comply with both law and safety policies, for this reason in *Principle 3* it is stated that the Industry and the customer need to agree the level of safety required for each product throughout its life. They have to pinpoint any modifications to mitigate, where possible, eventually identified risks.

Customer data privacy and confidentiality of the information have to be handled in accordance with the specific regulations, policies and processes as declared in *Principle 4*.

Principle 5 sets responsibilities in terms of assurance and authorizations. ISO9001:2015 certification has to be held by manufacturer and operators, in order to put in place rigorous quality systems aiming at ensuring design, test, build and operational quality standards.

Principle 6 states that when exporting or importing products, services and information, the Industry must comply with all the existing related regulation.

Principle 7 asserts that operations must comply with local rules and regulations concerning safe operations at sea and eventual environmental issues. Any local controlling authority will approve or not the operations of ASVs based on the result of the risk assessment applied to the ASV.

All the applicable regulations, at both national and international level, have to be complied in order to avoid collisions and incidents at sea, injury and damage to the environment in accordance to *Principle 8*.

Principle 9 deals with the human element: the best practices for the operation of ASVs have to be shared, as well as certification and training held to ensure the appropriate operation for all ASV operators.

In order to classify and define the several types of ASVs and their operation, some definition have been made.

Based on the navigation distance, six categories for **"Area of Operations"** have been defined as shown in Table 4.1. It might be relevant, in the scope of ATLANTIS, to consider as realistic areas of operations those from Category 4 to Category 2, as most of the offshore wind farms are placed 20-60 miles far from the shore.

[32] It is an association that gathers all the stakeholders of the UK marine sector. Its scope is to help and sustain the industry to flourish. Find more at:
https://www.maritimeindustries.org/

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Table 4.1: Categories for Area of Operations.

Area of Operations	
Category	**Definition**
Area Category 6	Within 3 miles from a nominated departure point and never more than 3 miles from land, in favourable weather and daylight
Area Category 5	Within 3 miles of land and not more than 3 miles radium from the point of departure or the boundary of protected waters
Area Category 4	Up to 20 miles from a safe have, in favourable weather and in daylight
Area Category 3	Up to 20 miles from a safe haven
Area Category 2	Up to 60 miles from a safe haven
Area Category 1	Up to 150 miles from a safe haven
Area Category 0	Unrestricted service

Another classification has been made according to the "**Degrees of Autonomy**", as already reported in Section 2.1.1. The classification, shown in Table 4.2, has been established by the IMO for their Regulatory Scoping Exercise in IMO MSC Circular 1604. For what is intended as ASV in the scope of ATLANTIS, Degree of Autonomy equal to four is considered.

Table 4.2: Degrees of Autonomy for crafts.

Degree of Autonomy	
Degree	**Definition**
1	**Ship with automated processes and decision support:** crew is on board and it is supported by "digital systems". Some operations may be automated but seafarers on board can take the control in case of malfunctions.
2	**Remotely controlled ship with seafarers on board:** the craft is remotely controlled and operated from another location. Crew is on board and can take the control in case of malfunctions.
3	**Remotely controlled ship without seafarers on board:** the crewless craft is controlled and driven by another location.
4	**Fully autonomous ship:** the operating system of the ship is able to make decisions and undertake actions by itself. It can be remotely monitored or not.

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Table 4.3: Level of Control for ASV.

Level of Control		
Level	**Name**	**Definition**
0	**Manned**	The crew on board controls the ASV.
1	**Operated**	The operator takes all the decisions, controls all vehicle's functions and undertakes the due actions. All cognitive functionalities are within the human operator, who has direct contact with the vehicle through radio communication or cables.
2	**Directed**	The operator has the authority to make decisions. The vehicle can sense the environment and suggest actions, but it will act only under the operator's consensus.
3	**Delegated**	The vehicle can execute independently some functions. The operator has the right of veto on those actions to be exercised within a certain time. The decision-making is shared between the operator and the vehicle.
4	**Monitored**	The vehicle defines, undertakes and reports the actions to the operator, who can monitor the events.
5	**Autonomous**	The vehicle can undertake actions without reporting and notifying them to the operator. A maximum degree of independence, in accordance to the operation, may be defined.

The "**Level of Control**", together with the degree of autonomy, is essential to identify the specific type of ASV involved. Table 4.3 shows the different Levels of Control defined in the report, in accordance to the European Defence Agency's SARUMS group. In the scope of ATLANTIS, ASV with level of control from 3 to 5 are considered.

A further classification has been made according to the size of the vehicle. For what is relevant in the scope of ASVs involved in ATLANTIS, only vessels up to 24 meters length are considered. They are grouped as following:

- *Ultra-light:* overall length less than 7 meters;
- *Light:* overall length between 7 meters and 12 meters;
- *Small:* overall length between 12 meters and 24 meters.

APPROVAL DEPLOYMENT

[12] Several Waterspace Authorities have to be consulted, based on the area of operation and the tasks involved, to ensure a successful, authorised and approved ASV deployment. The principal contacts are the Harbour Masters (HM) and the Inner Harbour Authorities, the MCA local Office, Marine Scotland and eventually other UK Government Departments; when sensors and transmitter operating licenses are needed the MMO (Marine Management Organisation) needs to be consulted.

Other authorities and operators should be consulted during the planning phase, such as fishermen, offshore operators, local sport leisure clubs and any other stakeholders with economic, environmental or safety interests in the intended location.

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HSE documentation needs to be provided to assure the approving authorities that full consideration to the safety and risk management has been paid. This documentation may include launch and recovery risk assessment, HSE plan, emergency recovery plan and procedures.

Maritime UK provides a template to be filled with all the information needed, in order to facilitate the contact between ownership and approval authorities. Information regarding operating and launch areas, insurance company, policy number and information of the contact person have to be indicated. In the mentioned template location area and timing schedule of the activities need to be provided. Details of the unmanned craft and information regarding the SCC, such as location and licenses, need to be added to the document.

SAFETY MANAGEMENT

[12] The safety Management System (SMS) needs to be implemented to ensure safety at sea, prevention of human injury or loss of life and avoidance of damage to the marine environment. It is operators' responsibility to implement this system, which may include some functional requirements:

- procedures to prepare and respond to emergency situations or to report accidents and non-conformities with some provisions;
- instructions and procedures to ensure safe operations of ASVs and protection of the environment, complying with Flag State regulations;
- a safety and environmental-protection policy;
- defines levels of authority and lines of communication among ASVs and SCC personnel;
- mission data recording may be needed for further analysis.

The Code identifies some standards which have to be followed to properly work on the risks' assessment, which is a key tool to identify potential hazards and their probabilities of occurrence. ISO/IEC 21010 (risks' assessment techniques) and ISO/IEC 27005 (information security risk management and techniques) are the most suitable methodologies to be applied to ASVs' risk assessment.

Risk assessment should identify potential failures like collision with fixed or floating structures, grounding, leakages of noxious substances could become an obstruction or hazard to other traffic crafts. It should be taken into account the probability of a failure occurring per 10.000 hours of operations, the magnitude of the collision (which is strictly related to the craft's kinetic energy or mass) and the pollution which may be produced if the ASV carries significant quantities of dangerous substances [12]. Failures assessment should consider also malfunctions of proper systems such as propulsion, connectors, data quality and others.

Clear and detailed lines of communication both in normal and emergency situations must be established and the responsibilities of each employee clarified.

As a result of the risks' assessment, safe systems and procedures have to be developed to mitigate the hazards. When a signal is not received by the ASV for a critical time period, that has to be deemed as an emergency situation. The appropriate authorities must be informed as soon as the SCC recognizes the emergency situation. Emergency situations may include but are not limited to [12]:

- Loss of control/monitoring of the ASV for a critical time period;
- Fire;
- Collision;
- Grounding;
- Flood;
- Violent act;
- Main propulsion or steering failure.

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Roles, acts and responsibilities of each employee should be defined and recorded when an emergency situation occurs.

It is operator's responsibility to provide appropriate training sessions to each employee, to ensure them awareness regarding their duties and tasks.

A Maintenance Management System (MMS) is a vital part of the SMS. The operator, to ensure conformity to ASVs requirements, has to guarantee that: inspections are performed at appropriate time intervals, any non-conformity is reported together with the cause that produced it (when possible), and corrective actions to be undertaken and recorded. The equipment should be checked and tested in accordance with the defined schedules and procedures defined by the Original Equipment Manufacturer (OEM).

DESIGN AND MANUFACTURING STANDARDS

[12] The Code provides some guidelines for ships designers and manufacturers in terms of structure requirements and it also pays attention to the software and its resilience to cyber-attacks. The ASV should be designed, constructed and maintained according to standards and requirements defined by classification societies recognised by the Flag State, or in accordance with applicable standards of the Flag Administration (for example UK MCA Workboat Code[33]). The vehicles should be designed to withstand foreseeable and reasonable operating conditions, to minimise the risk and spread of fire and explosions, and it should allow and facilitate maintenance and repair activities.

The structure should be designed and constructed with a level of integrity sufficient to guarantee safe operations for the vehicle under all the foreseeable and reasonable operating conditions. Buoyancy and watertight integrity should be such as to enable ASV stability according to classification body requirements.

High attention needs to be paid in respect of the software and its integrity: a fail-safe approach has to be used when the software is developed, in particular software failures should not provoke hazardous events, compromise the mitigation of such hazards or, even worse, the recovery from a hazard.

The software should be protected against cyber-attack, as well as software manipulation by additional devices or unauthorised users.

Failure Mode Effects and Criticality Analysis (FMECA) may be carried out to identify risks or safety critical software elements. The configuration status of the software on each platform should be captured and recorded, and the record maintained up-to-date for the life of the platform.

Both internal and external sensors should be carefully selected: the first ones to assess the status of the crafts (which is normally assessed by on-board crew) such as structural damages, fuel level, vibration, shocks and others. External sensors should be capable to sense the surrounding environment and navigational data. Appropriate sensors may be position sensors (satellite and GPS measurements), anemometer, radar, sea state sensors and others. [12]

NAVIGATION LIGHTS AND SOUND SIGNALS

[12] The Code indicates that vessels should comply with COLREGS in terms of lights and sound signals, according to Part C and Part D of the convention. In the regard of Part C, an ASV that navigates just between sunrise and sunset and in favourable weather conditions is not required to be equipped with

[33] It is a Code applied to small workboats that operate to sea, and to pilot boats of any size operating either at sea or in categorised (i.e. inland) waters. It applies to such vessels that are United Kingdom (UK) vessels wherever they may be, and to non-United Kingdom vessels in UK waters or operating from UK ports. This Code sets out some requirements which vessels shall comply with.

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lights signals as long as it can be demonstrated that the craft won't navigate in areas with restricted visibility. Table 4.4 summarizes requirements based on the craft overall length.

Table 4.4: Lights and Sound Signals Requirements.

<table>
<tr><th rowspan="2">Overall length</th><th colspan="3">Navigation Lights</th><th>Sound signals</th></tr>
<tr><th>During Navigation</th><th>At Anchor</th><th>Not under command</th><th>During Navigation</th></tr>
<tr><td>< 7 m</td><td>All round with, 1 mile + side-lights</td><td>Required</td><td>Not required</td><td rowspan="2">A vessel of less than 12 metres in length should not be obliged to carry sound signalling appliances, as prescribed in Part D, Rule 32 (a), but in that case it should be equipped with other means to produce an efficient sound signal where feasible and practicable.</td></tr>
<tr><td>≥7m - < 12m</td><td>All round white + side lights
Or
a masthead light, 2 miles;
a sidelight, 1 mile;
a stern light, 2 miles;
a towing light, 2 miles
a white, red, green or yellow all-round light, 2 miles.
OR
(if lights have to be offset from centreline) combined lantern sidelights plus either all round white or masthead and stern light.</td><td>Required</td><td>Two all-round red lights in a vertical line where they can best be seen;</td></tr>
<tr><td>≥12m - < 50m</td><td>a masthead light, 5 miles;
a sidelight, 2 miles;
a stern light, 2 miles;
a towing light, 2 miles;
a white, red, green or yellow all-round light, 2 miles.</td><td>Required</td><td>Two all-round red lights in a vertical line where they can best be seen;</td><td>A vessel whose length is between 12 and 20 metres should be equipped with a whistle.

A vessel of 20 metres or more in length should be equipped with a bell in addition to a whistle.</td></tr>
</table>

COMUNICATIONS SYSTEMS

[12] Communication systems requirements are suggested by the Code in accordance with IMO instruments. Radio communications systems include GMDSS and control system monitoring and input. Whilst SOLAS convention, at Chapter IV, indicates compulsory requirements for radio communication systems for craft from 300 tonnage upwards, there are no mandatory requirements for lighter crafts. However, any craft which uses GMDSS frequencies is bound to follow the ITU Radio Regulation[34] requirement. Even though radio requirements are strictly related to ASVs' capabilities and areas of operation, the Code indicates recommended (R) radio equipment for ASVs according to the area of

[34] The ITU Radio Regulations regulates on law of nations scale radiocommunication services and the utilisation of radio frequencies.

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navigation: these requirements are listed in Table 4.5, where only distances up to 60 miles are considered suitable and applicable for offshore wind farms.

Table 4.5: Communications Systems Requirements.

Communications Systems			
Equipment	Up to 3 nm	Up to 20 nm	Up to 60 nm
VHF radio installation with DSC	R	R	R
MF radio installation with DSC	R	R	R
NAVTEX receiver			R
EPIRB			R
Search and Rescue locating device		R	R

Back-up power supplies have to be provided for systems exercising emergency stop functionality and control functionalities (according to the specific level of control). These power supplies have to be considered in the risk assessment. In case of a wider system failure, a fail-safe communication system is necessary to ensure compliance with COLREG requirements.

REMOTE CONTROL CENTRE

[12] The remote-control centre, named SCC hereinafter according to ATLANTIS structure, is the set of control units and equipment needed to monitor and control the operation of the ASVs. The tasks in which the SCC is involved are mainly related to the planning, control, monitoring and post-analysis of the operations.

The *Operation Planning* includes: determination of the operational area, allocation of the notification and permissions from the maritime authorities, notice to mariners, environmental assessment, RF licenses, route planning, infrastructure and description of incidents handling procedures.

The *Operation* itself needs to be monitored by the SCC. It starts from the deployment of the craft by rail, road, sea or air, with each phase described and planned in detail. The craft is then launched from the mother ship or the shore, and before transiting to the operation point the equipment (including propulsion system and steering, communication link, emergency procedure and fail-safe devices) has to be tested into the water. The operations start once the craft has passed all the pre-tests and moved towards the operating point: at this stage the craft carries out all the tasks assigned under the SCC oversight. During the operations, the craft can be replenished of fuel or some equipment be replaced. Once all the tasks have been fulfilled the craft can be berthed to mother ship or to the shore. Finally, it is shut down in accordance with the specific procedure.

Post Operation Analysis includes: analysis of data capture, evaluation and reporting of failures, errors and safety-related issues, evaluation of the success of the operation and reporting of events to authorities (maritime authorities and environmental monitoring agencies) as required.

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A clear understanding of the responsibilities of the SCC personnel involved in the mission should be clarified: at this purpose the Code provides a hierarchy for operations carried out by ROVs.

Even though several levels of control have been considered, the SCC should be designed to allow the SCC operator to take control of the ASV at any time, this means that the ability to switch level of control or shut down the craft should also be implemented. The SCC operator should be able to assess and monitor the behaviour of the ASV at all times with a very accurate level of data available, in order to react and take actions necessary in case of emergency situations.

OPERATORS STANDARDS AND TRAINING

[12] Operators should demonstrate a clear understanding and awareness of relevant IMO instruments, such as COLREGs and SOLAS. The Code recommends the owner or the operator to produce a "Safe Manning Guide" similar to the one published by the MCA called "A Master's Guide to the UK Flag".

The Industry has the responsibility to offer trainings for the operator and personnel using ASVs. The owner/operator has to ensure that all MASS operators are adequately trained by dispensing safe practices during ASVs operations, continuously improving safety management skills by complying with mandatory rules and regulations and ensuring the appliance of the Code, guidelines and standards recommended by IMO, Flag States and Classification Societies.

The code also suggests performing Hazard and Operability (HAZOP) to assess the level of knowledge of the operators in relation with possible hazards and their resolution. Figure 4.2 shows a possible flow chart to conduct this assessment.

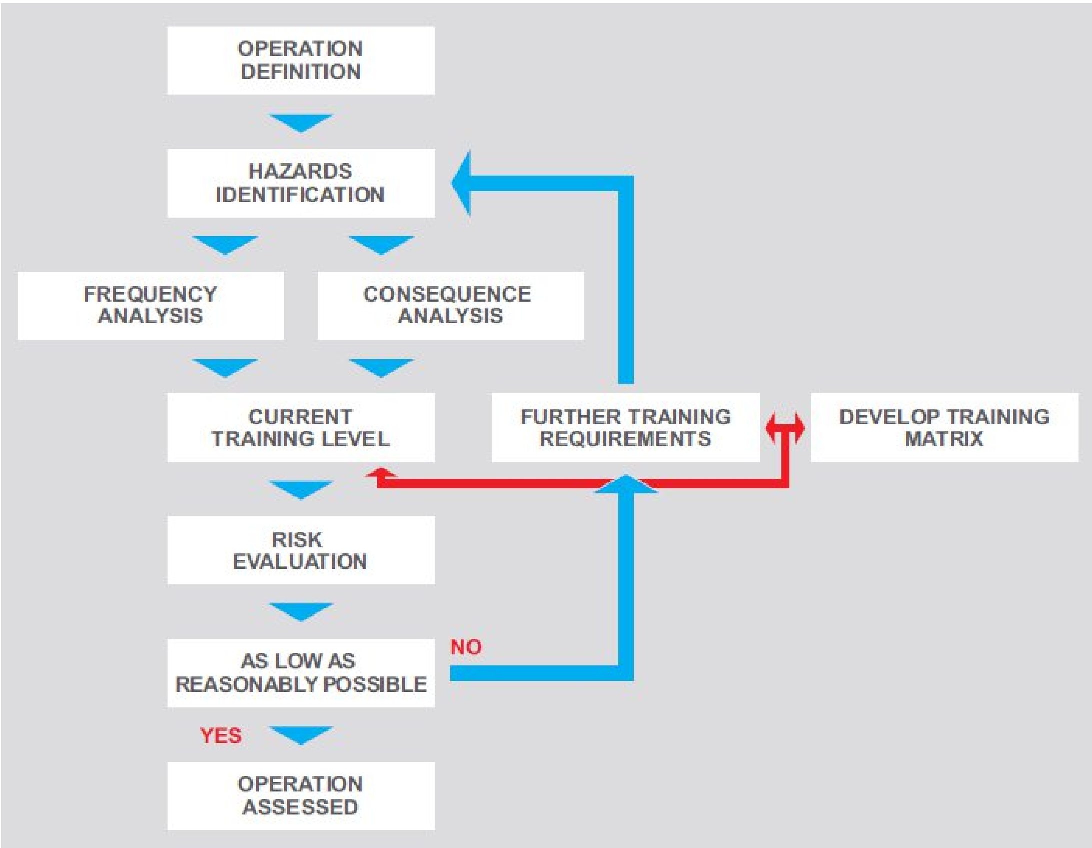

Figure 4.2: Flow diagram to determine level of knowledge of Operators [12].

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Moreover, the Code identifies some training areas, and wherever possible existing applicable standards from the MNTB (Merchant Navy Training Board), which might be needed for ASV operators which are shown in Table 4.6.

Table 4.6: Training needs and applicable MNTB standards [12].

Key Training Areas	Explanation	MNTB Occupational Standard (if applicable)
Principles of Autonomous Systems	Understanding of levels of automation and, specifically, the level of interaction between the operator and the MASS	N/A
Mass Regulations, permissions, notifications, requirements	Understanding and producing the required notifications, permissions and requirements for the operation of MASS in the given area	MNTB NOS Series A: A35
MASS Safety Principles including Machine Application of Regulations	Understanding the safe operation of the MASS and any limitations in the application of regulations within the system	
MASS Command Control and Communications to include Security	Operating and controlling communications with the MASS, awareness of security aspects (e.g. cyber) and responses when communications are lost	MNTB NOS Series C:C12, C13, C14, C23, C45
MASS Deployment and Recovery	Controlling the launch and recovery of vessels from land or other vessels	MNTB Series A: A41
MASS Responsibilities (Owner, operator, insurer, accreditor, certifier)	Understanding the responsibilities of all parties involved with a MASS operation	
MASS operations risk assessment	Conducting risk assessment for MASS operations including deployment and recovery	
MASS Vessel Specifics	Controlling the specific MASS and understanding all the operational requirements according to the MASS vessel in operation	Manufacturers' training courses
System Maintenance & Checks	Training on the servicing, repairing (including fault finding), maintenance, pre-launch checks & overhaul of all the appropriate components of the whole system	Manufacturers' training courses
Operator Facilities and Interactions	Understanding all vessels' controls and interactions available to the operator and awareness of the specifics of operating a vessel at distance	Manufacturers' training courses
Limits of Operation	Understanding the limitations of the vessel	
Sea Awareness and Handling	Demonstrating the awareness of the performance of the MASS under different conditions and any specific handling limitations	
Operations	Controlling all MASS system operations, maintaining safety at all times and meeting all regulatory requirements	MNTB Series B: B02, B04, B13, B14
Emergencies, Contingencies and Faults	Controlling the vessel or taking appropriate actions in case of emergencies, including loss of communications with the MASS	MNTB Series B: B11, B12 Series C: C42, C43, C44, C45
Mission Planning	Conducting mission planning for the MASS operation according to the area, type and vessel solutions	MNTB Series B: B03, B15

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REGISTRATION

[12] ASVs, as traditional crafts, need to be identified through the adoption of a number. The most used is the IMO identification scheme, which is currently compulsory only for cargo ships of 300GT. An alternative identification scheme, for craft less than 24 m in length, is pointed in EN ISO 10087:2006, which meets the requirements of the Merchant Shipping Act of 1995. The identification number, better known as Watercraft Identification Number (WIN) may be applied directly by the manufacturer. An official number will be provided for crafts registered in the UK Ship Register and it will be reported on the ASV together with the ASV name and the port of registry. The official number will appear on the Registry Certificate and it is different from the IMO number, which will remain with the ASV throughout its life. The level of control should be included and indicated in the identification tag of the ASV.

The Code suggests identification requirements according to the craft's size: for ultralight ASVs the WIM would ideally be the best solution, otherwise it should at least display a label reporting the owner and contact details. With regard to light and small ASVs, they should have as a minimum the WIM, complemented with the IMO identification number.

Registration is the process which establishes a genuine link between the Flag State and the ASV flying its flag. British ships' registry is filled through the UK Ship Register, which indicates rules and steps to be followed in "UK Ship Register – A Guide to Registration". ASVs with a level of control between 3 and 5 have to be registered and dispose of identification tags, as mentioned before. An important step forward regarding ASVs was made in 2017 in UK, when the first Unmanned Vessel was registered into the UK Ship Registry[35].

Before being registered, each ASV has to be inspected by either the MCA or MCA approved Class surveyors, and it has to comply with international standards and UK regulations.

[35] For more information about the first ASV registered in the UK Ship Registry see article at:

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

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5. AUV

In this section regulatory requirements for AUVs are illustrated by assessing standard guidelines and well-accepted practices.

In particular, topics such as classifications, administrative requirements, personnel qualifications and responsibilities and insurance issues are discussed.

AUVs share a lot of similarities with both ROVs and ASVs, thus many requirements applied to those vehicles (and already discussed in the previous sections), are valid for AUVs too.

As for ASVs, currently there are not yet specific regulations governing AUVs. Thus, well-accepted guidelines and regulation concerning maritime manned vehicles are applied to AUVs as well. In this section all these aspects are discussed and wherever possible and necessary, given the unmanned nature of AUVs, more detailed discussions are articulated.

5.1.Classifications

An Autonomous Underwater Vehicle (AUV) is an unmanned underwater robot, electrically powered by batteries that can operate, independently of the surface sustaining the vessel, for a few hours to several days. These vehicles are used for underwater surveys, as they can collect geophysical, biological and oceanographic data from the seafloor. AUVs can follow a totally pre-defined survey plan or a combination of pre-planning and re-planning during the operation. The data collected is downloaded when the AUV surfaces [24].

According to the NORSOK STANDARD in the "*Remotely operated vehicle (ROV) services*" [9] classification, AUVs are classified in CLASS V, as special–purpose vehicles which do not fit into the other classes or prototypes under development (*see above paragraph 3.1*).

[24] proposes a more specific classification for AUVs, based mostly on their size and therefore on their capabilities. Two broad classes of AUVs can be defined [24]:

- Small AUV Class (< 3m): it is the smallest AUV class, with scale of operation Meso – Broad (>25m^2 <1km^2)
- Large AUV Class (>3m): larger AUV models, with scale operation broad (>25m^2<1km^2)

Both AUV types can collect still images of species and habitats, environmental data (including temperature, salinity, depth, oxygen, etc.), vehicle telemetry (pitch, roll, heading, altitude, etc.), acoustic data (used to produce bathymetric and, if data validation is available, habitat maps) [24].

As described, AUVs can be categorized depending on their size, and therefore on their weight, ability and power, meaning that the choice of the type of AUV to be deployed is determined by the objectives of each operation and the data the operator need to collect [24].

Manually deployed *small AUVS* have lots of capabilities in terms of data collecting and are mostly used in shallow waters (1-2m depth) [24]. Their length varies from 1.8 to 4.5m and their weight between 50 and130 Kg. Their operations involve one or two engineers / operators [24].

Large AUVs have longer endurance capabilities and deeper diving capacities (>150km missions, 48h battery life), their length can reach 6.4m and their weight 1,800Kg (a 5.5m-long vehicle). Staff involved during the operations is typically composed by two or three engineers/operators.

Apart from the abovementioned categorization, there are also four subclasses of AUV [24]:

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- *Gliders*: they are buoyancy driven systems that are not used for benthic monitoring [24]. They use buoyancy changes and wings to ascend or descend through the water column and can carry a wide range of sensors [24]. They are cost-effective for long term monitoring of hydrography and pelagic ecosystems [24].
- *Hover AUV:* their main advantage is that they can be used in complex and high-relief habitats [24]. The *SeaBED* AUV is widely used for biological monitoring, as it can travel slowly or hover over the seafloor and perform low altitude surveys (2.5 meters) above the seafloor. Unlike cruising AUVs, the *SeaBED* AUV can be used in complex terrains [24].
- *Hybrid AUV/ROVs*: are specialized AUVs, as they can switch between AUV and ROV (tethered and manually operated) mode [24].
- *Benthic Crawlers*: are specialized AUVs used for habitat surveys and include a rover about the size of a small car [24]. They are designed for long deployment (several weeks) and can move slowly across the seafloor on tracks. They can carry a wide range of equipment [24].

5.2.Administrative requirements

The planning of all the documentation starts during the design phase. The manufacturer has to transmit to the Certification Society all the necessary documents for approval before the production of the AUV. The kind of documents needed depends on the type and the equipment of the system.

For the contracting and operation phases, the contractor is responsible for the documentation. According to NORSOK STANDARD in [9] “Contractors should establish and maintain matrices to be reviewed by the clients, such as compliance to: relevant regulations and standards, project's specifications and personnel's qualifications”. Information on compliance issues shall be evaluated by the contractors and forwarded to the clients for acceptance. Eventual qualified alternative solutions may be proposed.

Quality standards should be taken into consideration by the contractor, who shall establish routines to document that the quality management meets ISO 9001 requirements [9].

Similarly with ROVs, before mobilisation, the contractor shall define, document and make available: a mobilisation plan, a list of services required from the work-site, a structure plan for system acceptance test, a procedure for normal and emergency operations of the equipment, procedures for maintenance of all equipment under services, a minimum list for spare parts and the personnel competency matrix for the allocated personnel [9].

As far as the document availability on the worksite is concerned, the contractor shall make sure the following updated editions of plans/manuals are available [9]: a quality assurance manual / plan, a HES plan for the work-site, operational manuals, a contingency plan, procedures for all activities pertaining to the relevant contract, a risk analysis, a log to document operational activities, maintenance programmes and records for last 12 months.

NORSOK Standards pay special attention to reporting issues. Contractors shall provide the client with data so as to meet regulatory, administration and internal requirements [9].

On a daily basis, a brief summary of the last 24h events shall be handed to the client representative, signed by both parties. This report should contain information regarding:

- Date, reference to contract, job;
- name of installation/vessel;
- name of personnel involved in the activities;
- arrival/departure of the personnel;
- timing and description of the activities;

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- summary of hours in: water, standby, maintenance and breakdown;
- list of additional equipment;
- a plan for the next 24h.

The maintenance report shall contain a full description of maintenance work carried out in accordance with the established maintenance plan, and it shall be available to the client upon request [9].

System's failures should be registered and tracked by the contractors in accordance with ISO 9001:2000 clause 8.

Undesired events such as accidents, non-conformances and near-misses with potential damage to personnel and/or equipment should be registered in a ***Report of undesired events*** [9].

Contractors should also create an ***experience report***, by the end of the year or 30 days after the mission, with evaluations of the operation, procedures and equipment involved [9].

5.3.Personnel qualifications and responsibilities

According to [24], missions with small AUV systems need one or two engineers/operators, whereas missions with larger AUV systems need two or three engineers/operators.
The leading role is the Survey Manager who is responsible for the survey planning, making sure that all the operational stages are planned and safely executed [24]. He/she should be skilled and experienced in planning, management and risk assessment, and have experience in seagoing surveys with similar vehicles, vessels and operations. It is strongly recommended that the Survey Manager and a fully briefed scientific staff are ready to advise and modify plans when it is considered necessary to do so [24].
For larger AUVs, staff requirements for longer missions can reach the number of three people to cover different skill sets. These guidelines [24] point out that there is not any formal qualifications scheme for the supporting staff, but manufacturers may provide staff with training courses for their systems. Generally, AUVs staff should be selected based on experience and scientific competences, as AUV systems are equipped with lots of subsystems (sensors, actuators, communication systems etc.) and therefore all the staff should be skilled enough to support these marine instruments [24].
According to the NORSOK STANDARD in [9], AUVs are classified into CLASS V as special–purpose vehicles which do not fit into other classes or prototypes under development (*see above paragraph 3.1*). This means that "Personnel Qualifications" described in NORSOK STANDARD are valid for Autonomous Underwater Vehicles as well.

Just like in paragraph 3.3, the three main roles involved in AUVs' operations are: superintendent, supervisor and pilot (the role of trainee will not be discussed). Following, the specific requirements for each role are described as pointed out in [10].

AUV superintendent and supervisor are requested to have experience in planning and management of offshore activities. They should be fully aware of safety issues, and they are also responsible for the risk assessment and risks' mitigation [10]. They shall urge their subordinates to report incidents and always comply with safety measures and rules [10]. They should be able to tackle emergency situations effectively and coordinate their team in a proper way so as to keep safe both personnel and equipment [10]. They should also assess and ensure training and skills' development for all their supporting staff, using a competence assessment and organising training courses (*Performance Management*) [10]. *Supervisory skills* are needed so as to manage the team and at the same time to make sure that the mission will be conducted in a safe, cost-effective and timely way, respecting the procedures [10]. To conclude, in order to achieve a satisfactory result in a project, it is necessary that the superintendent and the supervisor are competent and experienced, with respect towards the project's requirements and the equipment. Reporting, project planning and management are also their responsibility [10]. An AUV/ROV

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superintendent must have at least 2 years' experience as AUV/ROV supervisor and an AUV/ROV supervisor shall have as a minimum the same qualifications and experience as ROV/AUV Pilot [9].

Even though AUVs are autonomous vehicles, the figure of the pilot may be necessary especially in case of emergency. In that case, the pilot should be able to take the command of the vehicle and avoid as far as possible emergency situations (e.g. by avoiding collision with other vehicles and/or structures).

AUV Pilots

IMCA Guidelines [10] describe three subcategories of pilots based on their competences and experience: Senior Pilot, Pilot Grade I, Pilot Grade II.

Senior Pilot' roles:

- He/she should be fully aware of safety issues and relative legislations/guidance, and should always respect report procedures, especially about accidents, incidents and near misses. He/she should be able to manage the safety of the team [10].
- Effective emergency response is a necessary skill which entails excellent knowledge of emergency procedures and efficient management of the team during an emergency [10].
- Interpersonal and communication skills are also necessary, as Senior Pilots must: communicate effectively with all team, recognise their abilities/limitations, offer assistance/guidance and explain or instruct subordinates as far as equipment issues are concerned [10].
- Pilots can also supervise the team when the supervisor is absent [10].
- Thorough knowledge and familiarity with AUVs' subsystems are considered a must for taking care of preventive maintenance and fault finding which might require modifications to the equipment [10].
- Skilfulness regarding the determination of weather and current conditions that might affect an operation is also necessary [10].
- Administrative tasks such as reporting, briefing, log completion by subordinates, are part of the Senior Pilot's role [10].
- Technical understanding is also needed so as Senior Pilots can provide instructions and supervision to less experienced personnel [10].
- They should be able to discuss the scope of work with clients and all the people involved, suggesting improvements if required [10].
- Project planning understanding is a key skill, so as they can respect the pre-defined planning of each project [10].

Pilot Grade I's roles:

- He/she should be fully aware of safety legislations/guidance, always respect report procedures and be also aware of the company's safety management system [10].
- They should have excellent knowledge of emergency procedures, good knowledge of other team members' roles and responsibilities and knowledge of the company's emergency procedures documents and where to find them [10].
- Good knowledge of English is required, so as they can deal with oral and written communication without problems and assist other team members during the missions [10].
- They should be able to assist during preventative maintenance by identifying possible hazards and help mitigating the risks: fault finding, and diagnosis skills are essential [10].
- They should be able to pilot the AUV under various circumstances, identifying the environmental conditions that might be dangerous. They should be able to understand worksite's constraints and manipulator functions [10].

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- They have to carry out administrative tasks, such as video log or other information as per the company or the clients' requirements, ensuring compliance with quality assurance policies of the company [10].
- Technical knowledge of the tools, the equipment, electrical and mechanical specifications is required so that they can test and inspect the installed specialist equipment and perform correct maintenance services [10].

AUV Pilot Grade II's duties are similar to the ones of the Pilot Grade I (regarding safety, emergency, communication, technical competencies, administration), but with less responsibilities.

The IMCA Guideline [11] discusses both team size and working hours that each mission should have, so as safety is always ensured. AUVs are sophisticated systems with high end technology, so personnel should be carefully chosen to always ensure safe and efficient operations for both humans and equipment.

The safety of the team is of paramount importance, so the contractor should provide a well-balanced and competent team. Team size depend on several factors, such as AUV type and tasks and the duration of the mission.

Accidents are more likely when people work long hours, so long working times should be exceptional and limited wherever strictly necessary [11]. Therefore, work should be planned in a way that each person is normally asked to work for a maximum of 12 continuous hours, while under normal circumstances an AUV pilot should not go beyond 6 hours in every 24-hour period, even though non-piloting work may be included up to the 12-hour maximum [11].

Special reference should be made to the *Responsibilities* and liabilities of the main roles working for an AUV.

Contractors are the ones who must define in writing the management structure of the AUV operation [11]. In case of a clear handover of supervision at a certain stage of the mission, this should also be defined in writing [11]. The contractor is also responsible for the meal breaks of the team, which shall be offered at least one meal break in a 12-hour shift, as well as toilet and snack breaks, either by using substitutes or simply organizing the work in such a way that breaks can be taken when a team member is not required for the mission [11].

Contractors are also responsible for the following [11]:

- risk assessment and preventive actions to be taken;
- making sure the worksite is suitable and safe;
- ensuring the professional competences of the team and the team size;
- suitable, certified and properly maintained equipment is supplied;
- a suitable plan is pre-defined, including emergency and contingency plans;
- records regarding project's details are kept;
- first aid and medical treatment of personnel is ensured;
- clear written reporting and responsibilities;
- compliance with all related regulations.

Supervisors are responsible for the operation and in case they need to hand over the control, this should be defined in writing through a procedure/logbook [11]. The supervisor is also the only person who can decide the beginning of an AUV mission, even though other relevant roles such as the captain of the supporting vessel, or the installation manager, can ask the supervisor to end his work for safety or operational reasons [11]. When the supervisor has to cooperate with a supporting vessel, then he/she must know that the vessel's captain is liable for everybody's safety [11].

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The supervisor can only give direct instructions regarding health and safety to any person involved in the AUV operation, even to the client's representative [11]. For instance, the supervisor might decide to instruct the team to leave the control area or to operate the equipment. Such instructions are beyond any company's structure of hierarchy [11].

The following issues should be taken into serious consideration by the supervisors in order to ensure safety [11]:

- The supervisors should be competent to perform all tasks, they must have clear picture of the areas and the levels of their responsibility and who is in charge for any other area. All responsibilities should be explicitly written into the operation's documentation;
- Their team should be competent enough to perform the work required of them;
- They need to check/control that the equipment to be used is adequate, safe, properly certified and maintained. All these checks need to be proved through checklists and records/logs kept.
- If for a mission potentially dangerous equipment is planned to be used, then possible perils should be assessed properly, and all team should fully understand possible dangers through a special training. This preventive action is part of the risk assessment and should be documented.
- Supervisors should also make sure that all the involved parties get aware that an operation is about to start or continue. Any necessary permission before starting or continuing the mission must be taken as the procedures define it.
- Supervisors should have clear audible and visual communication with all the personnel under their supervision to ensure safety.

As for the other AUV team staff, it is imperative that they all have in mind safety issues and that they should always act in a responsible way, respect supervisor's instructions and adhere to the company's applicable procedures [11]. In case any of the team members identifies that a task is unsafe, then it is their responsibility to ask the supervisor to stop it [11].

5.4. Insurance

The increasing use of AUVs all over the world, the eventual risks they deal with coming from their particular nature and from the delicate environment they operate in, created the need for insurances. Even though, generally speaking, accidents are usually caused by human factors, it is undeniable that the unmanned nature of this kind of vehicles does not mean that they do not face risks. This is valid because, first of all, the operators may not work onboard these vehicles, but they do work onboard an accompanying vessel or on land. It is also worth mentioning one more factor: the technology itself and the technical failures that often arise. On top of that, over the recent years, the number of the AUVs that got sold to operators increased significantly, and similarly accidents involving equipment loss, damage or expensive retrieval increased too. So, AUV insurance attracted the insurances market.

The article "*Insurance for Autonomous Underwater Vehicles*" [25] discusses insurance issues regarding AUVs in a very specific way within UK.

Client, broker and underwriter: it is important to understand these three roles and the business relationships that elapse between them. These relationship may also be different from country to country [25].

The *client* is the purchaser of the insurance the AUV's owner who might look for an insurance coverage going directly to the *underwriter* (the insurance company), but this way the client is likely not to find the best value [25]. This problem is solved with the interference of the *insurance broker*. The broker is fully aware of the insurance market and can give the client some advice regarding the types of cover, what exactly is covered and in case of a claim the broker can represent the client's interest [25]. To achieve this

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successfully, the professional insurance broker needs to understand the client's AUV missions, procedures and risks, so that he can offer a good advice for the right insurance coverage, as well as to represent the client's interests in an effective way if needed [25].

The text of the contract is essential for a good insurance coverage. As explained, the particular nature and the delicate environment where AUVs operate form rather dangerous conditions. So, the wording of the contact for an AUV should be structured in a way that provides the coverage the client needs [25]. Apart from the obvious risks of damage and loss, the client should be also protected from [25]:

- the on-land storage and if the vehicle is launched and recovered from the shore;
- the transportation to the worksite (by land, sea or air);
- maintenance, modification or upgrade works;
- mission, launch, recovery, monitored transit and unattended surveys;

The wording can only be effective for the client's requirements if the underwriter gets a clear understanding of the client's business, operations and risks. Therefore, the underwriter may meet with the client for this first-hand understanding, take a look at the documentation, the procedures and the risks AUV operations face [25].

Apart from the equipment insurance coverage described above, other coverages might include:

- Third party liability: as extensively described in the ASV section above (see paragraph 4.1.5), the legal framework for the autonomous vehicles contains lots of grey areas. Therefore, the statutory requirements for third party liability and how courts deal with incidents are taken on a case by case basis [25].
- Consequential damages: it is the coverage for the financial loss coming from the failure to operate or the interruption of the mission due to an accident [25]. This coverage is rather difficult to be provided because of the nature of AUVs [25].
- Claims: conflicts often arise when there are incidents. For example, if a vehicle gets lost, a time and money limit have to be set on its searching [25]. Another example for claim could be when a client asks for a high value on data retrieving, while the data is not insured properly or the cost to repeat the survey is not covered [25].

At this point, a new figure should participate: the *adjuster*. The underwriter asks for the adjuster's contribution to settle the arisen conflict of interests [25]. This new role's task is to investigate the incident and get the information needed for the insurance company in order to decide the actual value the underwriter has to pay for the claim discussed. For example, in case of a damage, the adjuster will survey the AUV and check if the claim is actually within the scope of the insurance coverage [25]. The expenses for the adjustor's services are on the underwriter.

After the claim submission, the insurance company makes a list with the total costs of the claim, including all fees [25]. If the client is not interested in repairing the AUV but prefers receiving money from the underwriter, the claim becomes an "unrepaired damage" case [25]. Unrepaired damage claims are not compensated at 100%, therefore the returned value is significantly lower than the full value of the AUV [25].

Insurance cost

Special reference should made on what can affect the cost of insurance for an AUV [25]:

- personnel experience, training, track records of all people involved in an AUV operation;
- experience and track records of the operators involved in launch and recovery procedures, as well as the particularities of the accompanying vessel;

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- clear evidence of the risk assessment and respect of the procedures;
- proofs for mitigation measures;
- details for the worksite and the existing risks;
- the extent of co-insurance between the insurance company and the client;

It is worth paying attention also to how Portugal tackles insurance issues, as described in [18] [26]. This paper discusses issues regarding all "Unmanned Vessels", obviously including the AUVs.

As already extensively explained in paragraph 4.2.1, it is the Commercial Code that defines the legal regime to be applied to marine insurance, as it actually regulates the formal requirements that should be observed on a valid insurance contact, such as: the name of the Master, the extent of the object of the contract, the duration, the beginning and the termination of the perils [18].

Commercial Code is mostly about maritime insurance in general, but it can be applicable to insurance contracts for an unmanned vehicle, even though the specific risks such vehicles face should be discussed. Article 604 of the Commercial Code mentions a list of risks that can cause damage, for which an insurance company must provide coverage, such as storms, wreckage, grounding, collision, forced change of route, travel, dumping, fire, unlawful violence, explosion, flood, plunder, supervenient quarantine, and generally all other sea fortunes [26].

This list does not include any special risks an AUV can face because of its unmanned nature. In addition, it is difficult to conclude for which specific perils an underwriter is obliged to offer insurance coverage, without having a complete picture on how autonomous underwater vehicles operate from a technical, administrative and operational perspective [26] [18]. Here are some expected risks related to the operations of unmanned vehicles [18]:

- Technological risk: information leaking, software failures, cyber-attack, or other technical issues that might arise either with the remote control by the shore-based operator or other issues related with the pre-programmed route;
- Technical & mechanical malfunctions: any technical problem that might affect the voyage and require human intervention;
- System failure caused by a fire or other technical issues that might affect the navigational system or the communications system;
- Risks related to collision: technology can surely help avoiding collision, but this is still a risk which requires insurance coverage.

Clients / owners can ask underwriters for insurance contracts which cover the mentioned risks or any other danger identified as relevant, until the legal framework is amended accordingly [18]. Obviously, if a peril is not explicitly covered by the contract, then the underwriter may refuse to compensate for it. Therefore, until the Portuguese Commercial Code is amended accordingly, the involved parties (AUV owners and the insurance company), should assess the risks properly and include detailed clauses in the insurance contract on what is covered and what is not [18].

An important point in insurance contracts is the assessment of the fault of the Master [18]: Article 604(1) of the Portuguese Commercial Code excludes the liability of the insurance company when the damages result from a Master's fault or negligence that violates the Master's duties [18]. In such a case, the insurance company can compensate the client only if a specific and explicit clause in the contract imposes this compensation [18]. Unmanned vehicles do not have an onboard Master, but still there is an operator who totally controls thr operation using technological methods, so it seems that the Master's liability is maintained [26] [18]. It is surely difficult to prove that the distance-based captain has not performed his/her duties properly, unless a code of conduct applies [18]. For AUVs, which are totally pre-

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programmed without any distance-based master, the relative legal framework should be amended, so that technological failures can be regulated [18].

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6. UAV

The aim of this section is to provide a comprehensive overview about Unmanned Aerial Vehicles' (UAVs) regulation in terms of both device and operator's requirements. A special focus is put on European laws and guidelines to ensure safe and robust operations, with a dedicated window on the Portuguese context.

European regulations such as EU 2019/947[36] and EU 2019/945[37] amended by EASA[38] (European Union Aviation Safety Agency) can be considered as the holy grail that governs the use of UAVs within the European airspace. Rules and regulations are set out to make sure that unmanned aircraft operate preserving the safety of people on the ground and other airspace users.

EU 2019/947 lays down the requirements for the use of UAVs outdoor (the use of drones indoor is not subjected to this regulation), while EU 2019/945 establishes the minimum requirements for design and manufacture of UAVs. In the following sections these two regulations are described in detail together with their relevance with ATLANTIS.

6.1.UAV's classes and requirements

According to EU 2019/945, four classes of UAVs can be identified. Both technical requirements and specifications characterizing each specific class are reported.

UAVs ***class C0*** must fulfil the following requirements [26]:

1. Having a maximum take-off mass (MTOM) lower than 250 g;
2. Having a maximum speed of 19 m/s;
3. Having a maximum attainable flying height limited to 120 m;
4. Being safely controllable in terms of stability, manoeuvrability and performance by a remote pilot who has to follow the instructions provided by the manufacturer.
5. Being designed and constructed in a manner that injuries to people during the operation are minimised (e.g. sharp edge should be avoided as far as possible).
6. Being supplied with electricity with a nominal voltage not higher than 24 V DC or the equivalent alternating AC voltage. UAV's parts accessible by the user must not exceed 24 V DC or the equivalent AC, unless it is ensured that the voltage level does not cause electrical shock to the user even when the UAV is damaged.
7. If equipped with a follow-me mode, when this function is enabled, the UAV should be in a range of50 m from the remote pilot.
8. Being available on the market with a user manual providing: UAV's characteristics (class, mass, equipment, software, etc.), clear operational procedures, operational limitations (meteorological conditions, day/night operations), list of likely risks.
9. Include an information notice published by EASA providing applicable limitations and obligations, in accordance with EU 2019/947.

UAVs ***class C1*** should comply with the following requirements [26]:

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[36] The full directive can be found at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0947&from=EN

[37] The full directive can be found at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0945&from=EN

[38] The European Union Aviation Safety Agency (EASA) is an agency of the European Union (EU) whose responsibility is to ensure civil aviation safety. It is in charge of certification, regulation and standardisation of aerial vehicles and also performs investigation and monitoring.

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1. Having a MTOM lower than 900 g or being made of materials such as to ensure that in case of impact with a human head the energy transmitted in less than 80 J.
2. Having a maximum speed of 19 m/s.
3. Having a maximum attainable flying height limited to 120m or being equipped with systems able to limit it to that value. Moreover, it can be equipped with systems able to limit the flying height according to values selectable by the user: in this case clear instructions and precise information about the UAV should be provided in real time to the user.
4. Being safely controllable in terms of stability, manoeuvrability and performance by a remote pilot who has to follow the instructions provided by the manufacturer.
5. Having mechanical strength and stability to withstand any stress the vehicle may be subjected to during its operation.
6. Being designed and constructed in a manner that injuries to people during the operation are minimised (e.g. sharp edge should be avoided as far as possible).
7. In case of loss of data link, it should have a reliable and predictable method to recover that link and allow to terminate the flight in a safe way, reducing risk of injury to third parties in the air or on the ground.
8. Having a maximum sound level as defined in Part 15 of the regulation, varying from 81 to 85 dB throughout the years.
9. Unless it is a fixed-wing UAV, it should indicate the sound power level.
10. Being supplied with electricity with a nominal voltage not higher than 24 V DC or the equivalent alternating AC voltage. UAV's parts accessible by the user must not exceed 24 V DC or the equivalent AC, unless it is ensured that the voltage level does not cause electrical shock to the user even when the UAV is damaged.
11. Having a unique serial number with standard ANSI/CTA-2063.
12. Having a remote identification system that: allows to upload the UAS' operator registration number in accordance with Article 14 of the Regulation (EU) 2019/947, ensuring to track in real time the UAV's operator number and position, the UAV's serial number and the position of the vehicle.
13. Being equipped with a geo-awareness system, providing: information regarding airspace limitations, alerts to the pilot when a potential breach of airspace limitations is detected and information and/or warnings to the pilot when the navigation system cannot ensure the proper functioning of the geo-awareness system.
14. If the UAV is equipped with a function that limits its access to certain airspace areas, this should work smoothly and in cooperation with the flight control system.
15. Providing the pilot a clear warning and understanding about the battery status, so that he/she has sufficient time to safely land the UAV when the battery level is low.
16. Being equipped with lights to increase the controllability of the vehicle as well as to allow people on the ground to distinguish it from a manned aircraft.
17. If equipped with a follow-me mode, when this function is enabled, the UAV should be in a range of 50 m from the remote pilot.
18. Being available on the market with a user manual providing: information about UAV's characteristics (class, MTOM, equipment, sound power level, description of the behaviour in case of loss of data link), clear operational instructions, procedures to upload airspace limitations, maintenance instructions, troubleshooting procedures, operational limitations and a list of likely risks and hazards.
19. Include an information notice published by EASA providing applicable limitations and obligations under EU law.

The requirements to be fulfilled by UAVs ***class C2*** are the following [26]:

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1. Having a MTOM lower than 4 kg;
2. Having a maximum attainable flying height of 120m or being equipped with systems able to limit it to that value. Moreover, it can be equipped with systems able to limit the flying height according to values selectable by the user: in this case clear instruction and precise information about the UAV should be provided in real time to the user.
3. Being safely controllable in terms of stability, manoeuvrability and performance by a remote pilot who has to follow the instructions provided by the manufacturer.
4. Having mechanical strength and stability to withstand any stress the vehicle may be subjected to during its operation.
5. In the case of tethered UAV, it must have a tensile length of the tether lower than 50 m and a mechanical strength not lower than 10 times the weight of the vehicle (in case of heavier than air aircraft) or 4 times the force, due to the combination between the maximum static thrust and the aerodynamic force at the maximum allowed wind speed in flight (in case of lighter than air aircraft).
6. Being designed and constructed in a manner that injuries to people during the operation are minimised (e.g. sharp edge should be avoided as far as possible).
7. Unless tethered, in case of loss of data link, it should have a reliable and predictable method to recover that link and allow to terminate the flight in a safe way that reduce risk of injury to third parties in the air or on the ground.
8. Unless tethered, it has to be equipped with a data link protection against unauthorised access to command and control functions.
9. Being equipped, unless it is a fixed-wing AUV, with a low-speed mode selectable by the remote pilot which limits the maximum cruising speed to no more than 3 m/s.
10. Unless it is a fixed-wing, it must have a maximum sound level as defined in Part 15 of the regulation and depending on the mass. It can vary from 81 to 85 dB throughout the years for a 900g UAV, while it varies from 93 and 97 dB for a 4 kg UAV.
11. Unless it is a fixed-wing, it must show the sound level.
12. Being supplied with electricity with a nominal voltage not higher than 48V DC or the equivalent alternating AC voltage. UAV's parts accessible by the user must not exceed 48 V DC or the equivalent AC, unless it is ensured that the voltage level does not cause electrical shock to the user even when the UAV is damaged.
13. Having a unique serial number according to standard ANSI/CTA-2063.
14. Unless tethered, having a remote identification system that: allows to upload the UAS' operator registration number in accordance with Article 14 of the Regulation (EU) 2019/947, ensures to track in real time the UAV's operator number and position, the UAV's serial number, the position of the vehicle.
15. Being equipped with a geo-awareness system providing: information regarding airspace limitations, alerts to the pilot when a potential breach of airspace limitations is detected and information and/or warnings to the pilot when the navigation system cannot ensure the proper functioning of the geo-awareness system.
16. If the UAV is equipped with a function that limits its access to certain airspace areas, this should work smoothly and in cooperation with the flight control system.
17. Providing the pilot a clear warning and understanding about the battery status, so that he/she has sufficient time to safely land the UAV when the battery level is low.
18. Being equipped with lights to increase the controllability of the vehicle as well as to allow people on ground to distinguish it from a manned aircraft.
19. Being available on the market, with a user manual providing: characteristics of the UAV (class, MTOM, interfaces, equipment & software, transmission protocol, sound power level and the description of UAV's behaviour in case of loss of data link), clear operation instructions,

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procedures to upload airspace limitations, maintenance instructions, troubleshooting procedures, operational limitations and list of likely risks.

20. Including an information notice published by EASA providing applicable limitations and obligations under EU law.

UAV ***class C3*** are vehicles whose MTOM is lower than 25 kg, with a maximum dimension of less than 3 m [26]. For this kind of UAVs are applied the same requirements for class C2 described in points 2,3,5,7 and from 10 to 20.

Class C4 UAVs have to comply with the following requirements [26]:

1. Having a MTOM lower than 25 kg;
2. Being safely controllable in terms of stability, manoeuvrability and performance by a remote pilot who has to follow the instructions provided by the manufacturer.
3. Not being capable of flying in autonomous mode, except for flight stabilisation assistance with no effect on the trajectory and lost data link.
4. Being available on the market, with a user manual providing: characteristics of the UAV (class, MTOM, interfaces, equipment & software, transmission protocol, sound power level and the description of UAV's behaviour in case of loss of data link), clear operation instructions, procedures to upload airspace limitations, maintenance instructions, troubleshooting procedures, operational limitations and list of likely risks.
5. Including an information notice published by EASA providing applicable limitations and obligations under EU law.

6.2.Operational requirements

The operations of UAVs are divided into three categories [26], according to the risk level, the take-off mass of the vehicle, the flying height, the CE marking of the product, the pilot certification and the identification of the vehicle. The categories are the following:

***Open Category*:** in this category we can find the operations that present the lowest risk: the Unmanned Aerial Systems (UAS) are not subjected to standard aeronautical compliance procedures but should follow what is defined by the Commission Delegated Regulation (EU) 2019/945. The main requirements are the following:

1. The remote pilot must keep the unmanned vehicle in Visual Line of Sight (VLOS) all the time, not exceeding 500 m.
2. MTOM of the unmanned aircraft should be under 25 kg.
3. The maximum flying height should not exceed 120 m from the closest point of the ground. In case of obstacles taller than 105 m, the flying height can be increased by 15 m upon request presented to the owner of the man-made obstacle, as stated in the Annex A of the EU 2019/947 [26]. Moreover, if the Member State has defined a lower attainable height, the operator must always comply with it.
4. The unmanned vehicle should have the CE marking.
5. The operator of the drone should be registered, and the pilot must be certified.
6. The unmanned aircraft should have a QR identification code.

The ***Open Category*** itself can be divided into three further subcategories, based on the flying zone of the UAV: in particular, whether or not it involves crowed areas or uninvolved people is considered. The regulation sets out the requirements for both vehicles and the pilot. In this chapter only technical

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requirements are discussed, while pilot's competences and requirements are analysed in a dedicated section. The three subcategories are:

- *Subcategory A1:* the UAV flies over assemblies of people and it is a C0 or C1 drone class. The regulation sets out technical requirements for both the drone and the operator. Pilot's requirements are described in the dedicated section, while technical requirements imposed by the regulation are related to the maximum speed (19m/s) and height (as per point c).
- *Subcategory A2:* the UAV's trajectory is performed in proximity of people (for a significant portion of the flight) with a C2 drone class. According to Annex A of the EU 2019/947 regulations, the operator must keep a safe horizontal distance not lower than the flight height. Finally, the drone must be equipped with an electronic ID reporting its serial number.
- *Subcategory A3:* the UAV, either C3 or C4 drone class (MTOM lower than 25 kg), flies in uncrowded areas. In this case the operator shall ensure a safety distance of 150m from commercial, industrial or recreational areas [26]. If uninvolved people enter into the flight area, the pilot should adjust the trajectory of the UAV in order to ensure their safety and/or stop the operation if necessary. In this case a minimum horizontal distance not lower than 30 m or the flight height must be kept [26].

Specific Category*:** For this category, there are special authorizations assessed on a case by case basis by the competent bodies. Before starting the operation, the operator should be legitimated by national authorities: this authorization must be updated every time significant changes in the operation happen [26]. Operations that fall into this category present a higher risk than the ones in the ***Open Category. This is why a thorough risk assessment must be done to indicate the necessary requirements for a safe operation. The method recommended by EASA is the "Specific Operations Risk Assessment" (SORA), developed by JARUS. This is a new method which, through a holistic approach, guarantees that all possible risks are considered, and it proposes mitigation measures to keep them under control.

The main requirements that must be fulfilled are the following:

1. The remote pilot can keep the unmanned vehicle also Beyond Visual Line of Sight (BVLOS).
2. The MTOM should be under 25 Kg.
3. The risk level should be defined through a thorough risk assessment procedure.
4. The unmanned vehicle should have the CE marking.
5. The operator of the drone should be registered, and the pilot must be certified.
6. The unmanned aircraft should have a QR identification code.

***Certified category*:** Operations associated with high risks fall into this category and therefore they are subjected to rules regarding: the certification of the operator, the licensing of remote pilots, the certifications of the aircraft.

More specifically, based on the risk assessment conducted, an operation conducted with the help of a UAS belongs to the certified category when:

1. The operations are conducted over assemblies of people.
2. The operations involve transport of people.
3. The operations involve the carriage of dangerous goods, that may result in a high risk for third parties in case of accident.

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6.3. Personnel requirements and responsibilities

The EU directive 2019/947 sets out minimum requirements for remote pilots of UAVs in terms of age, competences and specific responsibilities.

Before analysing in detail the competencies required, it is worth to make a distinction between the two main figures involved in UAV's operations, which are:

- *Operators*: intended as the legal entity (person, organisation or enterprise) that is engaged or offers services implying UAVs' operations. Operators must be registered with the Civil Aviation Agency of the EU nation they operate in.
- *Remote pilot*: is the person that manually takes control of the UAV and operates it. Operators may rely on the remote pilot to provide and perform their services.

As stated in Article 9 of such directive, the minimum age for remote pilots operating an UAV in "open" or "specific" category should be 16 years. Although, no minimum age is required when: the remote pilot operates with an UAV in subcategory A1 with a vehicle of class C0, with a privately-built UAV with a MTOM lower than 250 g or when they operate under the supervision of a remote pilot who complies with such age requirements. Member States can lower that age requirement by up to 4 years if operating in the "open" category or up to 2 years if operating in the "specific" category.

6.3.1. Personnel's duties in "open" category operations

Part A of the Annex of the directive establishes the competency requirements that both operators and remote pilots shall comply with, when operating an UAV in the "open" category. They are reported below.

Operators

UAV's operators should fulfil some requirements and tasks whose aim is to ensure the safeness of the operations. In particular, they have to develop "ad-hoc" operational procedures based on the type of operation and its associated risks. However, written procedures should not be necessary if the operator itself is the remote pilot [26]. If the operator employs more than one remote pilot, he/she has the duty to develop procedures aiming at coordinating the activities between his/her employees and establish and keep a list of duties assigned to the personnel.

For what concerns the data link between the pilot and the UAV, it is a responsibility of the operator to ensure that the radio spectrum used does not produce harmful interferences. Operators have to designate the most suitable remote pilots, who are the ones that own the experience and all the competences needed for specific tasks [26]. Moreover, the operators have to ensure that the remote pilot is familiar with both the UAV manual and the operational procedures.

Operators have the responsibility to update the information into the geo-awareness system: they should download the latest version of the geographical data and make them available to the remote pilot so he/she can upload it to the geo-awareness system [26]. In case of UAV operating in subcategories A2 and A3, the operators have the duty to inform all people involved in the operating area about the actual risks, and those people have to explicitly agree to participate in the operations [26].

Remote pilots

Remote pilots have different duties that must be fulfilled either before and during UAV operation.

Before starting the mission the remote pilot has to be aware of any flight restrictions published by the Member State, like zones with limited accessibility or no-fly zones [26]. The pilot has to check the working environment as well as any condition that might affect UAV's operation (presence of people, obstacles,

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critical infrastructures, etc.) or that might arise hazards to the safety of the mission. Other obstacles that might alter the UAV's behaviour are represented by possible electromagnetic interference sources). Remote pilots should check if weather conditions are bearable by the UAV either at the beginning and during the operation [26]. It is a responsibility of the remote pilot to ensure safety conditons throughout the UAV's mission by fulfilling several tasks. Firstly, he/she has to update the geo-awareness system of the vehicle and be sure that the conditions of the mission fall within the limitations and instructions provided by the manufacturer. If equipped with further tools, the remote pilot have to verify that the MTOM is not exceeded. He/she has also to assure that the charge of the battery is enough to perform the intended operation (considering either the planned route and the need of extra energy in case of unpredictable events). If the vehicle is equipped with loss-of-data-link recovery function, the remote pilot has to ensure that it allows a safe recovery of the UAV [26].

Table 6.1: Remote pilot competences in the different scenarios for the "open" category.

Subcategory	Class	MTOM	Remote pilot competences
A1	*Privately built* *C0*	<250 g	*Read owner manual*
	C1	<900 g	• *Read owner manual* • *Perform online training* • *Pass online test*
A2	*C2*	< 4 kg	• *Read owner manual* • *Perform online training* • *Pass online test* • *Pass a theoretical test in a centre recognised by the aviation authority (necessary if UAV flights close to involved people)*
A3	*C3* *C4* *Privately built*	<25 kg	• *Read owner manual* • *Perform online training* • *Pass online test*

During the flight the remote pilot must not make use of alcohol or drugs; he/she must not serve when injured or sick [26]. The pilot should keep the UAV within the VLOS such he/she can always clearly see the vehicle and evaluate the distance from other obstacles. The maximum distance depends on the size of the vehicle, environmental conditions and characteristic of the area (visibility, presence of obstacles, etc).

Keeping visual contact with the UAV is necessary to avoid any collision with manned aircraft, parachutes or other sky users. It is a responsibility of the remote to avoid collisions, as other users might not be able to see the UAV due to its reduced size. Operations can continue if the other sky users are quite far from the UAV, otherwise they have to be stopped. If the remote pilot operates the UAV from a moving vehicle (either on ground or in the water), the speed of that vehicle should be reduced enough to allow the remote pilot to maintain a VLOS of the UAV [26]. Autonomous flights are not allowed in the ***Open Category***, hence the remote pilot has to keep the control of the UAV during the whole duration of the operations, unless in case of loss of data link.

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Remote pilot's competences are different based on UAV class, subcategory and MTOM: Table 6.1 reports the required skills in the different cases.

The remote pilot's online theoretical competency and his/her competency certificate are valid for 5 years [26].

6.3.2. Personnel's duties in "specific" category operations

Part B of the Annex of the EU 2019/947 sets out the minimum requirements, competences and responsibilities that both operators and remote pilots, operating in the "specific" category, must comply with. In this chapter these requirements and responsibilities are described.

Operators

Operators belonging to the "specific" category, as already said, need to get the authorisation from the Civil Aviation Authority (of the EU nation they operate in) to perform their services. The Civil Aviation Authority, if satisfied (requirements to be met are described in the Part C of the Annex of the EU 2019/947 directive), releases either the permission or a Light UAS Operator Certificate (LUC) to the operator. In the first case, the operator needs to get an authorisation every time he/she needs to perform an activity, while in the second case the LUC confers to the operator the privilege of self-authorizing operation without applying for an authorization to the competent authority every time an operation has to be performed.

A UAV operator has the duty to establish the procedures and the limitations adapted to the type of operation and the risks involved. Operational procedures are set out to ensure safety of the operations, as required by the standard scenario or by the operational authorization [26], and also in accordance with the indications of the manufacturer. If there are more than one remote pilot activities need to be coordinated, and employees and their assigned duties listed. It is a responsibility of the operator to take measures against unlawful interference and unauthorised access as well as define guidelines for the remote pilot with the purpose to minimise nuisances (e.g. noise) to people and animals [26]. Operators must undertake procedures with the scope of complying with any applicable European or national laws particularly concerning privacy, data protection, liability, insurance, security and environmental protection [26].

Operators designate remote pilots for each operation ensuring that, during all phases, responsibilities and tasks are properly allocated. Operators must ensure that during the operation a suitable radio spectrum is adopted in order to avoid any harmful interference [26].

As the ***Specific Category*** covers a wide range of operations, with different levels of risk, UAV operators are required to identify the competencies necessary for either the remote pilot and all the personnel involved in accordance with the outcome of the risk assessment. Hence, operators have the duty to ensure that remote pilots' competences are in line with those provided by all applicable training identified by the operational authorisation. They have to ensure pilots are aware about UAV operations manual, risk assessment and established operational procedures [26].

Operators must also ensure that the operations are carried out within their limitations as defined in the operational authorisation. Furthermore, UAVs used shall be designed in such a manner that possible failures do not cause fatalities or lead the UAV to fly outside the operation area. In addition, Man Machine Interfaces should minimise the risk of errors committed by the pilot and not provoke unreasonable fatigue. UAV should be maintained in a good status by carrying out maintenance activities according to the manufacturer's indications, by employing adequately trained maintenance staff [26].

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Finally, operators operating in the ***Specific Category*** should keep record of the UAV's operations. Records should be stored for 2 years, generated in electronic or paper format [26]. The recorded information should comply with the ones indicated in the operational authorisation, and may include [26]:

- the identification of the UAV (e.g. serial number);
- the date, time and location of the take-off and the landing;
- the duration of the flight;
- the name of the remote pilot responsible;
- the activities performed;
- any possible incident occurred during the mission;
- a completed pre-flight inspection;
- any defects and rectifications;
- any repairs and/or changes to the UAV configuration.

Remote pilots

The remote pilot must not perform his/her duties under the influence of alcohol or other psychoactive substances or when he/she is unsuited to serve due to injury, fatigue, medication, sickness or other causes. Moreover, the remote pilot must have the appropriate competences as defined by the LUC or the operational authorization [26].

Before starting the mission, the remote pilot must ensure that the operating environment is compatible with the authorised and/or declared limitations and conditions (such as meteorological condition, presence of people, obstacles, etc.) reported in the UAV's user manual. The remote pilot should get surveys to become familiar with the environment and eventually be able to identify possible electromagnetic interference sources. The remote pilot has to check and be sure that the UAV is in good conditions to complete the mission. Finally, the pilot has to assure that the information about the operation has been made available to the relevant Air Traffic Service (ATS) and other airspace users, as requested by the operational authorisation or conditions imposed by the Member State [26].

During the mission the pilot must avoid any risk of collision with manned aircraft or stop the flight when continuing it may represent a risk to other aircraft, people, animals, environment or property. remote pilots must stick to the procedures defined by the operator: for example, they must not fly close to or inside areas where an emergency response effort is ongoing, unless they have the permission to do that [26].

6.4. Insurance and Liability

The issue of liability is fundamental to drone manufacturers, operators, pilots and owners as they can be the source (and thus liable) of several kind of damages.

Bodily injury is defined as a harm to a person's body and can occur directly when a drone injures a person through a direct collision, or indirectly when, for instance in case of collision between other sky/ground users [27].

Property damage is defined as a damage caused by the drone directly (e.g. when it hits and breaks a blade) or by an event triggered by the drone (e.g. when it hits a power line resulting in a fire that burns buildings, structures, etc.) [27].

These two liabilities are likely to be the largest source of liability claims, hence a registration to identify the owners/operators is indispensable in order to offer an adequate compensatory framework [28], even though in case of heavy collision the drone might be completely destroyed and hence its identification through the registration details could be useless. To overcome this weakness drones might be equipped

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with a “black box” to allow investigators to gather the information causing the incident (as already done for manned aerial vehicles) [28].

Personal injury, in addition to bodily injury, it includes the invasion of privacy by, for instance, taking unauthorised pictures of people, buildings, structures etc. Concerns arise in regard of how these data/images are treated, collected, stored and deleted [28].Commercial drones, like the ones in the scope of ATLANTIS, capture and send back anything in their view: this might make arise privacy concerns and issues. In fact, the images they capture might be used to accidentally or deliberately survey employees, which might have serious labour law implications [27]. Other issues arise in case of loss of the drone: in this eventuality data gathered are lost too, and this creates a liability risk. This risk has to be considered and mitigated through an IT security plan via countermeasures such as encryption (in line with the EU General Data Protection Regulation 2016/679 GPDR) [28]. Moreover, drones can be under cyber-attack threats and hence they should be designed in order to be resilient to those threats [28].

Third-Party Liability is the most likely liability applicable to drones, which means that the service provider (the drone operator) is the liable part. Regulation 785/2004, which regulates insurance obligation for aircraft, requires all commercial operators to purchase third-party liability insurance. The regulation contains limitation for the minimum amount of third-party liability insurance based on the MTOM of the aircraft. Drones that weigh less than 20 kg are not subjected to compulsory insurance requirements [28].

It is not always straightforward who should be considered liable in case of drone incident: applying the general principles of civil liability, cases where liability falls on the pilot in command, the drone operator or, if applicable, the drone’s owner (in case it is owned by another party) can be distinguished.

Generally, the pilot is liable in case of non-compliance with public law obligations such as pilot licenses, certificates, etc. [28].

Liability for other obligations, whether contractual or extra-contractual, falls on the operator [28]. According to Article 2 of the *Rome Convention of 1952*[39], the operator is liable for damages caused by the flying vehicle on the surface [28]. Operator’s liability is a form of strict liability, based on the inherent risk of flying a drone: this means that it does not depend on his personal responsibility and the damage must be compensated even in case of accident beyond the operator’s control [28].

Drones manufacturers can also be liable for damages caused by defects in their products. Directive 85/374/EEC considers a product defective when it does not offer the safety which is expected from it: the producer has strict liability for defective products. The damaged party, if it can be shown that the incident has been caused by a defect in the product itself, can assume the producer liable without proving any fault: it is up to the producer to show that the defect was not present at the time when the product was put into circulation, but it has been caused by someone else (e.g. drone operator or pilot) [28].

6.5.Portuguese framework

In this chapter the Portuguese regulation governing drones’ operations within the Portuguese airspace is analysed. The regulation 1093/2016[40], emended by the national aviation authority (Autoridade Nacional da Aviaçao Civil, ANAC), sets out the requirements and the operating procedures that must be followed by

[39] The Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface, signed in Rome on 7 October 1952 (“Rome Convention”) might be equally applied to incidents caused by drones or unmanned aircraft. The Rome Convention prescribes a strict liability (no-fault liability) regime for operators of aircraft, which entails that the operator of the aircraft will be liable for the damage caused to third parties by his aircraft, even without proof of the operator’s intent or negligence.
[40] The full regulation can be found at:
https://dre.pt/application/conteudo/105367104

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both the remote pilot and the drones' operators. The guidelines defined by this regulation are in line with the European directives 2019/947 and 2019/945.

The regulation is applied to an aircraft system remotely piloted and are excluded either aircraft systems owned by the Portuguese State and UAV operating in closed or covered spaces (*Article 1*).

The *Article 3* lays down general requirements for the UAV's operations:

- UAV's flying height is limited to 120 m in case of VLOS operations during the day, while toys UAVs are allowed to fly at maximum 30 m.
- UAV's operations should be executed in a manner that risks for people, goods and other aircraft are minimised.
- Remote pilots must ensure that the UAV keeps a safety distance from other people and objects as well as leave fly priority to manned aircraft.
- Remote pilots must not exercise their role under the effect of psychoactive substances or in case of sickness.
- Remote pilots shall ensure, before starting the mission, that the UAV and other task-related equipment are in a good status through a pre-flight inspection.
- During VLOS operations, the remote pilot cannot drive two or more UAVs simultaneously.
- The UAV must have a signalling light always on, whether during daily or night flights.

As stated in the *Article 10* of the regulation, in some cases UAV's operations need to be authorised by ANAC. Night flights as well as BVLOS operations and flights above 120 m must be expressly authorised by the aviation authority. BVLOS operations performed by a UAV whose weight is lower than 1kg do not need to be to be authorised if present the following requirements:

- The flight does not exceed 5m.
- The UAV is equipped with First-Person-View (FPV) system (the remote pilot can monitor the UAV through a video camera installed on it).
- The flight extends over 100 m with the pilot at the centre of the trajectory.
- The flight is realized in confined spaces where the risk of collision is reduced.
- The UAV flies away from people and objects.

Operations performed by drones whose weight is higher than 25 kg need to be authorised by ANAC. The authorisation must be requested at least 12 days prior the mission, by compiling an electronic form provided by ANAC which includes the following information:

- UAV's and RPS (Remote Pilot Station: where the pilot drives the UAV from) characteristics.
- Tasks performed and the exact location (expressed in geographic coordinates) including: altitude, date, schedule, duration, operational procedures, routes and action ray.
- Information of the operator and the remote pilot: personal data, license, etc.
- Other relevant information related to the mission.

Article 11 defines areas where UAVs cannot fly over. They are:

- Airports (explicitly reported in the Annex of the regulation), unless the flight is performed by the airport's responsible or by the air-traffic services' provider or it is expressly authorised by ANAC.
- Open spaces with concentration of people (more than 12), unless expressly authorised by ANAC.
- Accident areas where rescues and/or aid operation are taking place.
- Military installations, embassies, prisons, consulates, educational centres, unless expressly authorised by ANAC.

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Drone insurance is not mandatory but ANAC recommends that civil liability insurance is contracted to cover any damage that may arise from the use of UAVs.

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7. Legal framework of the ATLANTIS' method

In this section a possible structure for the SCC's personnel hierarchy is described as well as all the necessary measures to ensure a safe use of robotic technologies, taking into account all the requirements described in the previous sections. The first part deals with robot-related technical and administrative requirements that must be fulfilled before the deployment of robotic technologies. The second part focuses on a possible hierarchy structure, in terms of roles, responsibilities and competences, that might be applied to the personnel operating at the SCC. It is worth to mention that all the operations carried out within ATLANTIS should be planned and organized according to the existing standards, such as ISO 29400-2015. This ISO standard sets out the minimum requirements and operational procedures that have to be considered during both the installation and the operation (thus O&M activities) of OWFs. As this standard is commonly applied in OWFs, and big differences are not foreseen due to the unmanned nature of the ATLANTIS' assets, it is not described in this document.

7.1. ATLANTIS robots' requirements

As explained before, in this section robot-related requirements that are applicable to the ATLANTIS method are summarized for completeness. Figure 7.1 summarizes the main requirements, either technical and administrative, that one must cope with when the specific robotic technology is used. Beside technical requirements which are strictly related to the nature of the device (e.g. collision avoidance systems for ASVs and AUVs), all the technologies shall present common requirements such as: fire protection systems, radio communication standards and cyber-attack defence systems.

	Technical Requirements	Administrative Requirements	Insurance & Liability
ROV	• Variable according to ROV class • Met Standards such as NORSOK U-102 or DNVGL-RU-UWT Pt.5 Ch.7	• Certified by certification Society • Operational and emergency procedures • Maintenance plan • Risk assessment • Daily report • Undesired event report	• Coverage for third-party liability (recommended): a thorough risk assessment shall be conducted in order to identify all probable accidents to be covered by the insurance policy. • In case of accident provoked by a defect, "product liability" shall be applied.
ASV	• Collision avoidance system (in line with UNCLOS) • Warning and navigation signals (lights, sound signals, radar watch or other systems) • Fire protection systems • Radiocommunication standards • Cyber-attack defence system	• Registration to Coastal State registry • Label indicating the owner of the ASV • Authorization by the Coastal if the deployment occurs in the territorial seas or in the EEZ	• Coverage for third-party liability (recommended): a thorough risk assessment shall be conducted in order to identify all probable accidents to be covered by the insurance policy. • In case of accident provoked by a defect, "product liability" shall be applied.
AUV	• Collision avoidance system (in line with UNCLOS) • Warning and navigation signals (lights, sound signals, radar watch or other systems) • Fire protection systems • Radiocommunication standards • Cyber-attack defence system	• Operational and emergency procedures • Maintenance plan • Risk assessment • Daily report • Undesired event report	• Coverage for third-party liability (recommended): a thorough risk assessment shall be conducted in order to identify all probable accidents to be covered by the insurance policy. • In case of accident provoked by a defect, "product liability" shall be applied.
UAV	• Lights to signal the presence of the UAV. • Power supply requirements variable with the category (24V-48V DC or equivalent AC voltage) • Data-privacy protection • Cyber-attack defence system	• CE marking • Authorization by the national Aviation Authority when operating in the "specified" category or in BVLOS (in PT by ANAC) • QR identification code • Remote pilot training and test	• Coverage for third-party liability (recommended): a thorough risk assessment shall be conducted in order to identify all probable accidents to be covered by the insurance policy. • In case of accident provoked by a defect, "product liability" shall be applied.

Figure 7.1: Robot-related requirements.

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Protection towards cyber-threats is paramount for robotic technologies. These protection systems should ensure that:

1. robots are resilient to cyber-attacks from a data-privacy perspective. In fact, these technologies collect a lot of data, most of which are sensitive for users: cryptography is one of the most used technique to protect robots from cyber-attack;
2. hackers may be interested in taking control of robotic technologies to perform terroristic attacks towards people, structures or communities. Thus, robots should be capable of recognizing possible threats and, at the same time, being able to reject these attacks.

Where requested, robots should be signed into registries of the specific authorities. If this is not compulsory, they should be equipped with labels or other kind of systems (e.g. QR code) to be properly identified. Moreover, documents like maintenance plan, operational/emergency procedures, daily report, risk assessment and a list of undesired events must be updated frequently and made available to OWFs' operators/owners (which are clients of robotic services' providers).

For what concerns the insurance, nowadays there are not yet regulations or laws which impose the insurance coverage for these technologies. However, it is recommended to sign insurance policies covering third-parties' liability. Most of the time (it is not the case of UAVs where commercial policies already exist) these policies are stipulated on a case by case basis: through a thorough risk assessment, both insurance providers and clients identify which kind of accidents and incidents should be covered by the insurance. In some cases, the manufacture is responsible for accidents and damages to third parties, particularly when the event has been caused by a defect in the product.

7.2. SCC organizational structure

In this paragraph a possible hierarchy structure for all the personnel involved in O&M activities in the scope of ATLANTIS is presented, either they work from the SCC or in the "field": this model is shown in Figure 7.2. This hierarchy structure has been developed taking into account roles, responsibilities and competences required to personnel involved in robot-based operations. The roles are:

- *Commanding officer*: he/she is at the top of the pyramid and he/she is in charge of all the decisions and authorises the mission plan.
- *SCC watch officer*: he/she supervises each operation performed by the robots and has to report any possible hazard that might jeopardize robot personnel operating in the field. He/she is also in charge of authorizing the start and the end (with some exceptions as explained after) of the mission.
- *ASV operator*: he/she operates from the SCC and is responsible of the supervision of the tasks performed by the ASVs. In case of emergency he/she has to take control of the ASV and pilot it in order to avoid accidents/incidents. When the ASV is used to deploy other robots, the ASV operator is also responsible of the transportation, launch and recovery of the device.
- *Vessel officer*: he/she is involved when the robots are deployed from a vessel. The vessel officer has to ensure the safeness of the vessel and its occupants, thus in some case he/she can require stopping the activity if this safeness is jeopardized: in this case the vessel officer has more power than the SCC watch officer.
- *Ship Crane operator*: he/she is involved when the robots are deployed from a vessel. The Ship Crane Operator is responsible for lifting and lowering the robot to/from water and for deploying the vehicle in the operating area.
- *Robot operator*: each robotic technology has its own specialized operator, who monitors (in case of autonomous vehicles such as AUVs and ASVs) and/or pilots (in case of ROVs or UAVs) the vehicle either from the SCC (in this case we talk about SCC operator, if the deployment occurs

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from an ASV) or on deck of the ship (in this case we refer to on deck operator, if the vessel is used to deploy the robot). Skills and competences are different according to each technology and are described in detail in the dedicated sections.

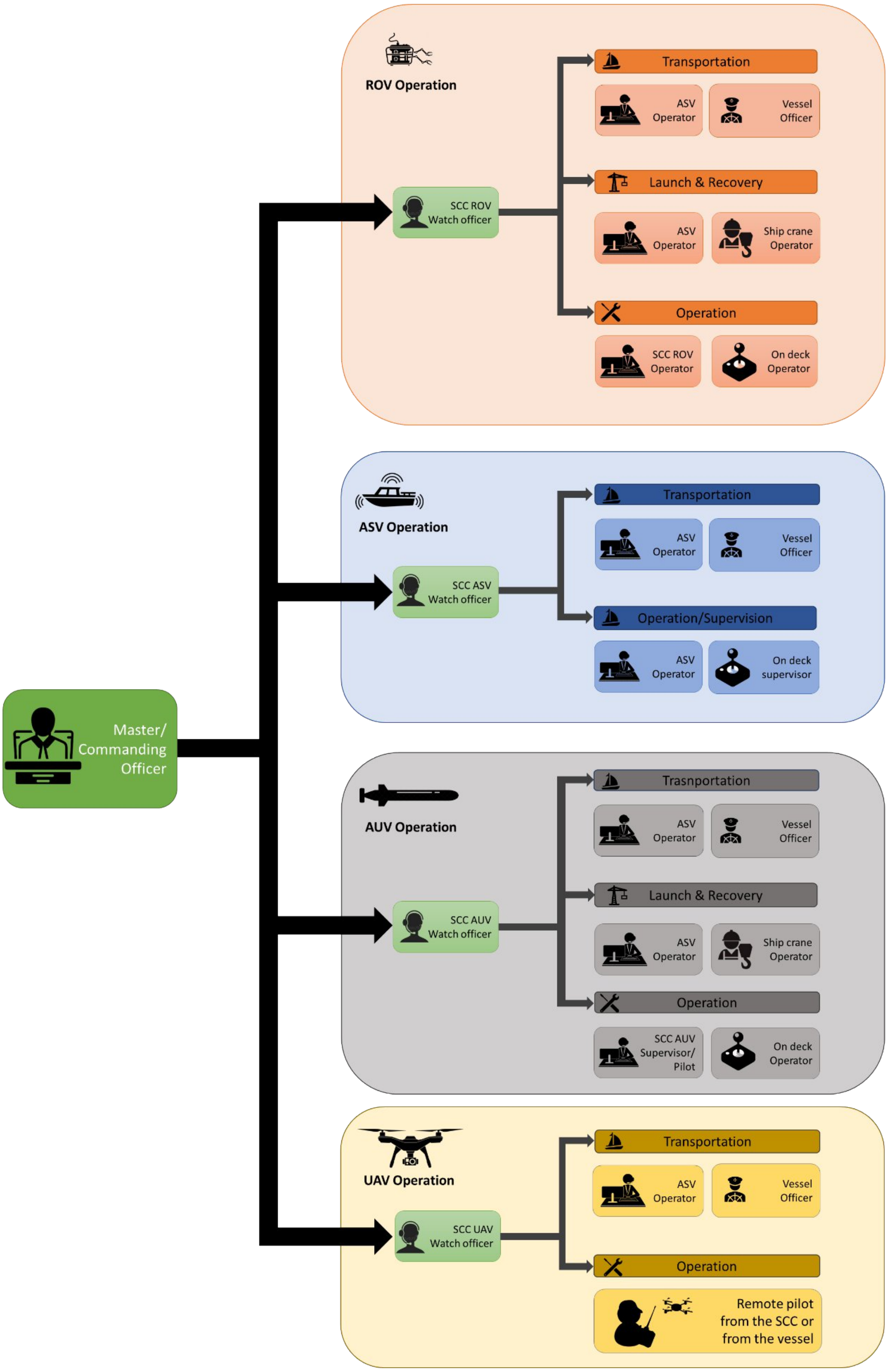

Figure 7.2: ATLANTIS' SCC hierarchy structure.

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8. Conclusions

The use of robotic technologies will pave the way to innovative methods to operate O&M activities for OWFs. Operations carried out more frequently at a lower cost will make the LCOE of this plant closer to the targeted values which are imposed by the Energy Market, resulting in more competitive energy plants.

Even though, robotic technologies represent the point of arrival in the path towards automation of O&M activities, the lack of clear and ad-hoc regulations may be a break for the deployment of these technologies in OWFs.

Some of these technologies (ROVs and UAVs) benefit from a long experience in the OW sector and thus are already framed in clear regulations. If the existing regulations do not cover all the specific use cases, however there are well-established practises emended by recognized certification bodies, which can help the user to overcome issues they may face.

For less tested-technologies (AUVs and ASVs) there is not yet a clear picture in terms of regulations to be followed: it is a common practise to fit these technologies into the existing legal instruments.

It is desirable that in the near future the gap between technological development and the correspondent legal framework will be filled, in order to protect end users from all risks connected to their application.

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