TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 15
Number 1
March 2021
DOI: 10.12716/1001.15.01.14

Certification of Unmanned Aircraft (UA)

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ABSTRACT: PRS (Polish Register of Shipping) is an expert institution acting on the international market, that - by conducting business for the benefit of the community - through the formulation of the requirements, survey and issue of the appropriate documents, assists State Administrations, Underwriters and customers in ensuring the safety of people, floating objects, land undertakings, carried cargo and the natural environment. PRS is a body accredited for certification of management systems, as well as a notified body in the European Commission for conducting product conformity assessment procedures with EU directives and regulations, and certify of personnel and processes. Subject and scope of the Publication The Publication defines requirements and procedures of conformity assessment process of Unmanned Aircraft (UA) and the technical possibilities of their use in the maritime economy segment. Purpose of the publication: Defining technical and formal requirements for design, construction and operation of the Unmanned Aircraft (UA), Determining the scope and methodology of conformity assessment process of Unmanned Aircraft (UA), Determining the technical possibilities of using Unmanned Aircraft (UA) in the maritime economy segment. The publication includes the following issues: basic principles and design requirements as well as technical regulations that ensure the design of the Unmanned Aircraft (UA), as a safe product in operation; the scope and methodology of conformity assessment of Unmanned Aircraft (UA); principles and scope of technical supervision over the Unmanned Aircraft (UA), requirements set by PRS in using Unmanned Aircraft (UA) on sea-going ships. The conclusions of the paper: indication of the way to obtain BSP certification, the basis for launching the procedure for developing the NO defence standard for the certification of ships and naval auxiliary units for cooperation with Unmanned Aircraft (UA).

1 INTRODUCTION

Since the 1980s, the rapid development of remotely operated aircraft has been dated. However, the progress in miniaturization over the past 15 years has triggered a truly rapid development of unmanned aerial vehicles (different classes). They are used in many fields, ranging from military aspects, through commercial and scientific applications, and ending with entertainment. In this article, the term "unmanned aerial vehicle" will be used interchangeably with the term "drone" to mean an aerial robot.

Increasingly, Unmanned Aerial Vehicles (UAVs) are successfully replacing airplanes and helicopters, performing their tasks. They can constitute a tool supporting human activity and be used as a means of providing information and knowledge about the surrounding environment, perform work in difficult and often inaccessible conditions, as well as deadly, carrying various types of weapons and armament.

In order to standardize the terms used in this article, it has been assumed that:

- unmanned aerial vehicle (UAV / RPAS - Remotely Piloted Aircraft Systems) generic name of the type of aircraft (mainly aerodines) moving in the airspace without flying personnel (i.e. pilot) performing aviation activities (including flight);
- Unmanned Aircraft System (SBSP, UAS / RPAS - Remotely Piloted Aircraft System) is a set of all elements necessary to perform a flight by an unmanned aerial vehicle. The essential elements of SBSP are:
  - Ground Control Station (GCS): is a station used to control an (unmanned) aircraft, consisting of both configured hardware and control software. Such stations have a set of switches and control devices, as well as a screen on which information about the UAV status is displayed.
  - Unmanned Aerial Vehicle or an aerial platform: it is an element of the SBSP that moves through the air. It is an exact unmanned aerial vehicle
  - Pilot of an unmanned aircraft - a person who has control over an unmanned aircraft by direct control or by exercising supervision over the course of the flight in an automated mode.
  - Radio link (communication): a dedicated ground-air-ground radio direction used to transmit (ground-to-air) commands and (air-to-ground) reports between UAV and GCS. The executive elements of radio communication are antenna assemblies. As a rule, antenna assemblies are a component of GCS, however, solutions are used to arrange the antenna assemblies separately like transmitters (in order to increase the UAV's range).

The above list includes the most important elements of UAV systems. Additionally, the UAV systems elements are ground protection elements, such as: catapults or other launch aids, chargers, fuel pumps, diagnostic equipment, starters, consumables, etc.

2 USE OF UNMANNED AERIAL VEHICLES

Currently, drones are used by state institutions, the military, scientific and research centers, companies conducting commercial activities and private individuals. The operation of drones is more effective, cheaper, more secretive and safer for pilots than the use of manned aircraft. The large-scale use of drones during the war between Armenia and Azerbaijan in September 2020 showed that precise combat operations can be conducted far beyond the front lines without exposing pilots to the risk of being shot down. The use of circulating ammunition released from BSP containers on a massive scale effectively destroyed groupings of troops along with military technology. The area of application of drones is constantly expanding. Drones are used for launching satellites into orbits around the Earth, transporting contaminated medical samples and medicines to laboratories and hospitals, inspections, geodesy, protection of people and property, photography and counting the number of animals. With the simultaneous use of thousands of drones (swarms), outdoor shows are organized with complex inscriptions and spatial drawings that affect human imagination.

The maritime industry is also opening up to the use of drones. Big players in maritime and aviation business (Wilhelmsen and Airbus) joined their forces to offer a parcel service to vessels, which is executed by drones [3]. The first commercial long range drone delivery to vessel took place in Singapore on 29th of April 2020 [4]. Only 7 months later World's First Night-time Drone Delivery From Shore to Ship took place in Singapore [5]. A short time between those two actions shows how fast is the progress in the drone technology.

There are also known uses of drones on the domestic market. On October 5, 2020, an unmanned aerial vehicle was handed over for use of the Port of Gdynia Authority S.A., dedicated and designed for the needs of the port. As part of the research and development project called "Aviation Monitoring System", a reliable multirotor platform in the X8 system was created, adapted to work in very difficult port conditions: strong wind, high air salinity and disturbances in drone-operator communication [6]. The use of Hydrodron, developed by the Polish company Marine Technology, for hydrographic works was also tested at the Port of Gdynia [7].

Another project that somehow integrates unmanned marine and air solutions is AVAL [8]. Autonomous Vessel with an Air Look is co-financed by National Centre of Research and Development. The project consists of three integrated technologies, i.e.: UAVs, developed by Bialystok University of Technology (project's leader), Object's Recognition and Classification Awareness (ORCA) System, developed by UpLogic sp. z o.o. and Autonomous Navigation System, developed by Sup4Nav Co. ltd. [1]. All components have been tested [2] in The Ship Handling Research and Training Centre at Ilawa owned by the Foundation for Safety of Navigation and Environment Protection [9]. Finally, they were successfully tested in real conditions on Unity Line ferries m/f Wolin and m/f Gryf, in September 2020.

The NAVDEC system [10], which was the ancestor of the mentioned Autonomous Navigation System, was certified in 2015 and recertified in 2020 by Polish Register of Shipping. Preparations are currently underway for the certification of all three components of the AVAL system.

There are two types of drones delivered in the AVAL project. The first is Hybrid Unmanned Aerial Vehicle. It has a fixed wing platform with vertical take-off and landing (VTOL) function. The maximum speed is over 100 km/h on a forward marching engine in horizontal flight. The maximum flight range is about 200 km, while the maximum flight time is up to 2 hours. It is dedicated to recognize the objects at the greater distance. The second one is Multirotor Helicopter in six-arm configuration. The power supply and data transmission is provided by the 50 meters long dedicated cable, which makes the flight time practically unlimited. It has ability to fly in wind condition up to 60 km/h and is dedicated to recognize the objects at the shorter distance.

Reliability of such systems has obviously to be assessed and validation methods have to be developed.

2.1 *Application of cameras and object identification process - ORCA System*

COLREG clearly states in the Regulation 7 that all available means should be employed to determine if the risk of collision exists and highlights in paragraph 7 (c) that OOW should not make assumptions on the basis of scanty information, especially scanty radar information. This shows how important for the safety of navigation is that all objects in the ship's vicinity are properly identified.

The ORCA system uses a state-of-the-art detection system based on an artificial neural network. As soon as it detects an object, estimation of the location of the object is made and the information about the class of the object as well as its geographical coordinates are sent to the autonomous navigation system.

ORCA monitors the area around the vessel (up to 10 Nm) using a custom-built camera vision system. The images are analysed in real-time by an AI-based algorithm which detects, classifies and geolocates potentially hazardous objects. There are many image recognition and classification systems on the market for objects as diverse as diseases and cars. Unlike those, images form in the marine environment present specific and very complex challenges. These challenges can be grouped in four blocks: a) horizon detection when the camera is installed on a mobile platform (ship); b) registration - the situation where different frames in a scene correspond to the same physical scene with matching coordinates; c) water background subtraction which is continuously dynamic both in spatial and temporal dimensions due to waves, wakes, foams, and specular reflections which are inferred as foreground by typical background detection method; d) foreground object detection - since general dynamic background subtraction and foreground tracking problems do not require the detection of static objects, no integrated approaches exist that can simultaneously detect the stationary and mobile foreground objects. This is an open challenge for the maritime scenario. Current research on object detection in images may be applied for detection of objects in individual images, thus catering for both static and mobile objects. However, the complicated maritime environment with the potential of occlusion, orientation, scale, and variety of objects make it computationally challenging.

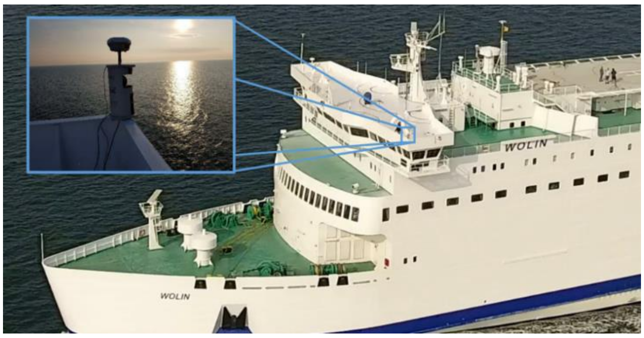

Figure 1. The first ORCA prototype installed on m/f Wolin.

The following table shows the main features of the ORCA technology and navigational challenges that are solved by image processing algorithms collected by the vision device.

The cameras used in ORCA system can be mounted on ship's superstructure. Both drones i.e. VTOL and multirotor, can be also equipped with ORCA system

ORCA functions	Problem solved
Detection of static and dynamic objects, 20 m long** and placed within 10* nautical miles (Nm) from a ship or yacht. objects.	The system continuously monitors the surroundings of a vessel and simultaneously detects, classifies, and locates visible
	This improves the navigator's ability to identify hazardous objects around the ship and make decisions regarding appropriate anti-collision manoeuvre options.
Classification** of detected objects within 5 Nm into the following categories: ship, yacht, iceberg, whale, container.	Determine the risk of collision with a specific object based on its category and location. Verification of the navigator's ability to see and identify all objects through binoculars.
Geolocation of the detected objects within 2 Nm*.	Provision of accurate data about the category and geographical coordinates of the object to the anti-collision algorithm, which automatically generates an anti-collision manoeuvre or anti-collision trajectory.
Self-tuning of the image recognition algorithm	Self-tuning improves the efficiency of detection, geolocation, and classification of the objects. Self-tuning is applicable for repetitive routes - for example in the case of ferries.
Data fusion with AIS, ARPA (radar) and digital maps real-	Enhancement of maritime navigation systems with ORCA's
	time data can reduce the need for the navigator's eye observation - the key function of autonomous ships in the future.

*Ranges for a vision sensor mounted 24 m above sea level (observation deck on ferry Wolin - see Fig.2.)
**The ability to detect and classify an object depends on its size and distance from the ship or yacht. The value of the parameter is calculated under the assumption that the measured dimension of the object is parallel to the camera's projection plane.

2.2 *Limitations of unmanned aerial vehicles and collision avoidance issues*

The law that has been imposed on unmanned aerial vehicles requires that they always give way to the manned ship. The operator - now called the pilot controlling manually or only supervising automatic flight, is responsible for this duty. It does not matter if sensors, cameras, transponders are used - the pilot is obliged to make the right maneuver if necessary to give way. The right of way in aviation is regulated by the Convention on International Civil Aviation, signed in Chicago on December 7, 1944 - Chicago Convention (Journal of Laws of 1959, No. 35, item 212, as amended) - Annex 2: Rules of the Air.

The same convention (Article 8 – Pilotless aircraft) states that "Each contracting State undertakes to ensure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft" .

Until now, it was regulated in the regulation of the Minister of Infrastructure on the exclusion of the application of certain provisions of the Act - Aviation Law to certain types of aircraft and determining the conditions and requirements for the use of these aircraft.

In the Commission Implementing Regulation (EU) 2019/947, it is the responsibility of the pilot to inform that the pilot stops the flight if the operation poses a threat to other aircraft and to impose on the operator of the unmanned aircraft the obligation to avoid collisions with the manned aircraft.

3 USE OF UNMANNED AERIAL VEHICLES

Drones with specific characteristics can be used for specific tasks. The division of drones may result from their construction, purpose, energy source used, level of autonomy, weight, range and operating time, operating altitude, load capacity in the form of equipment, wingspan, possibility of cooperation with other aircraft, method of take-off and landing, and many other criteria.

Due to their construction, drones are divided into rotor (single- or multi-rotor) and airframes.

It is worth familiarizing yourself with the advantages and disadvantages of these two types with regard to maritime use / ship and naval operations.

1. Airframes:
   - Advantages
     - longer flight time than rotors (in the same UAV class)
     - higher lifting capacity (in the same UAV class)
     - higher speeds
     - faster finding of the airframe beyond the outline of the ship / naval ship during take-off. This reduces the risk of catching on elements of the ship's infrastructure during take-off
     - possibility of a gliding flight
   - Disadvantages
     - Necessity to use start assist devices (launchers)
     - Necessity to use landing aids (nets, rope clamps)
     - The need to consider pulling the airframe out of the water after its landing

Figure 2. Photo showing the launch of the Scan Eagle UAV from the deck of the ship. In the foreground you can see an aircraft launcher. The use of airframe (UAV) on board ships requires taking into account the presence of such devices on board. Source: https://www.navy.gov.au

Figure 3. The Camcopter 100 drone in front of the GCS and antenna unit. Operation of the UAV from the deck must take into account the need to deploy these elements on the ship / naval ship. Source: https://penaviation.com

Figure 4. Scan Eagle landing sequence on board. Visible mast for intercepting the plane. After folding, the mast must find a place on the ship's deck. Source: https://www.navaltoday.com

2. Rotors
   - Advantages
     - Vertical take-off and landing
     - Precise navigating ability to fly past obstacles
     - Possibility to use wired power for specific types of missions
     - Ability to hover
   - Disadvantages
     - Shorter flight time (in the same UAV class)
     - Lower lifting capacity (same UAV class)
     - Lower cruising speeds (in the same UAV class)

Figure 5. Camcopter 100 rotor aboard a vessel. Source: https://dronebelow.com

Figure 6. Sample VTOL airframe drone. Source: https://test.threod.com

Figure 7. VTOL developed within the AVAL project. Source: avalproject.pl

The solution may be VTOL (Vertical Take off and Landing) airframes. These are structures that combine the features of a rotor and airframe. They have wings used for flights and rotors for take-off and landing. In this case, the disadvantage is the need to use inferior-lighter sensors due to the allocation of a part of the load capacity to VTOL elements.

As you can see, there is no rule as to what UAVs should be used for operation from the deck of ships and naval ships. One solution is that carrying out tasks for ships and naval ships does not have to require operating from their decks. The length of the UAV flight and the possibility of changing the crew during the flight make it possible to cooperate with vessels. However, this requires adapting the vessels to such cooperation by installing transmitting and receiving devices or only receiving devices. In addition, rules for such cooperation must be established.

4 POSSIBILITIES OF USING UAVS

Operations with UAVs are already standard in operations both on land and on the sea. Performing tasks over water requires cooperation with vessels. In order for this cooperation to be established, both the UAV and the ships and naval ships must meet the requirements for its undertaking. On the watercraft, there are limitations related, on the one hand, to the size of the deck area intended for air operations, as well as to a large impact of hydrometeorological conditions on the conduct of take-off and landing operations.

For this reason, rotor drones and planes with vertical take-off and landing capabilities (VTOL - Vertical Take Off and Landing) are used on board naval ships. On naval ships, it is possible to pick up wing drones from the water immediately after a drone landed on a parachute near the ship. Another way to take over a winged drone is to intercept it using flexible nets on board. In order to use such a UAV which is dependent on the ship's crew in picking it up from the water or for spreading the net for its landing, a man is needed for handling it onboard. Is it possible to use UAV on autonomous units, where the role of a human being is slim or none?

4.1 *Application of unmanned aerial vehicles*

The scope of UAV's tasks based on naval ships depends on the technical capabilities of the installed devices, sensors and transferred armament. Ship drones can do:
- reconnaissance, tracking, escorting, patrolling, surveillance, guidance;
- conducting search and rescue operations;
- transfer of light loads between naval ships and the shore;
- detection of electromagnetic radiation and destruction of detected radar stations;
- conducting radio-electronic warfare;
- detection of chemical, biological and radioactive contamination;
- detection of submarines using the drop-down sonar station;
- determining the effects of an attack by own and enemy forces;

- laser highlighting of detected and identified objects for destruction;
- destroying detected targets with high accuracy using precision weapons (e.g. circulating ammunition, gliding bombs, etc.);
- inspection of damage to hulls and tanks, archiving photos;
- training for the anti-aircraft forces in the fight against air targets and at the same time being phantom targets;
- terrain scanning and mapping.

4.2 *Technical requirements*

On the basis of the scope of tasks that the UAV would be assigned, relevant technical requirements will be set to be complied with. They concern, inter alia:
- requirements for the structure and strength (degree of resistance to weather conditions, mechanical strength and degree of resistance to water and moisture in salinity conditions);
- adequate battery capacity (ensuring the ability to complete the task in a specified time);
- suited camera equipped with matrices, ensuring perfect visibility in the worst lighting conditions;
- requirements for lighting installations and equipment used in operations (lighting characteristics and lighting sectors);
- requirements for systems and equipment supporting operations (related to communication and equipment);
- additional requirements depending on the later application and tasks to be performed by UAV.

At this point, the disadvantages of drones should also be mentioned. And they include:
- Lack of a pilot on board and, consequently, much more complicated way of organizing the flight than in the case of manned aircraft (MAC);
- The need to ensure a stable radio link;
- Signal transmission delays resulting in inaccurate pilot situational awareness. Delays in the signal circulation from the command by the pilot (enabling the option on the GCS screen) to the receipt of information about the reaction of the air platform mean that the information displayed on the GCS screen is always delayed in relation to the current state of the air platform;
- Limiting the number of stimuli / information about the state of the air platform that reach the UAV pilot. The UAV pilot receives information about the state of the platform only visually, while the manned aircraft (MAC) pilot receives information also with other senses (e.g. eyesight - instrument panel, hearing - engine operation rhythm, smell - unusual smells, e.g. smoke, touch - non-standard vibrations of the platform or control sticks / yokes);
- A complicated spatial orientation of the UAV pilot. The MAC pilot takes a position in the aircraft axis facing the direction of flight. This allows to keep to the basic rules governing human behavior and activities of the aircraft operator. For example: the right side of the aircraft is also the right side of the pilot. On the other hand, the UAV pilot takes the place of the above-mentioned GCS and takes place in front of the screens. On the other hand, the GCS does not need to be oriented in the direction of flight. An additional difficulty is the fact that the UAV is used to perform tasks related mainly to directing the observation instruments towards the ground, not to the flight. One solution to this issue is mounting cameras in the noses of the UAV. However, this solution necessitates additional image transmission at the expense of the main transmission and necessitates an increase in the number of crew members.

The key problem of the ship's cooperation with the UAV is the lack of a pilot on board the aircraft, with all the related legal, organizational and technical consequences. Depending on the degree of autonomy of the UAV, its activities are supervised by a pilot-operator with appropriate knowledge, skills and experience.

4.3 *Levels of autonomy*

At the first level, when we are dealing with partial autonomy, the pilot-operator has the ability to remotely control the aircraft using data provided by sensors installed on the aircraft. Complex military systems to support UAVs require the cooperation of a team of people. Most often, the pilot-operator is responsible for the correct UAV flight, and the sensor operator is responsible for collecting information from sensors, using armament and transferring the developed data to the ship's command and communication systems. In the case of small and medium drones, their activity within the range of visual visibility can be supervised directly from the ship's deck.

A typical ship's unmanned aerial vehicle system consists of:
- ship platform (the UAV system carrier);
- a separate UAV take-off and landing area on board the carrier (take-off and landing area, the location of the launch pad, the location of the intercepting nets, etc.);
- naval aviation infrastructure related to UAV service;
- ship's UAV control and guidance station;
- unmanned aerial vehicle systems;
- communication system between the ship's control and guidance station and UAV.

The elements of the UAV system may be combined or may be adapted to the carried or planned for cooperation aircraft.

The size and purpose of the UAV determines the parameters of the carrier capabilities. UAVs can be placed on surface ships and submarines. In the case of submarines, the use of UAVs is limited. Re-use of the drone depends on the possibility of its seizure after the mission has been completed and its launch in the area of the submarine's operation. It is connected with the necessity of surfacing, and thus: the possibility of losing the hidden operation of the naval ship. The larger the vessel, the greater the range of UAV selection (in terms of size, weight, wingspan, propulsion type) and its number. Compared to airplanes and helicopters performing typical tasks at sea, the size and weight of the UAV is smaller, which gives the possibility of embarkation of a greater number of the UAV and their use on a larger scale. At present, a subclass of the aircraft carrier class is being created, in which UAVs play a significant role. Most of the naval ships of the destroyer, frigate, corvette and patrol ship classes currently being built have a ship aviation infrastructure adapted to conducting air operations with the use of helicopters, hence the adaptation of naval ships of these classes to cooperation with UAVs is easier.

4.4 *Autonomous ships*

Autonomous vehicles are already state-of-the-art in many land-based transport modes. There exist several examples of automated subways, self-driving intralogistics vehicles or automated guided vehicles (AGV) on modern container terminals. There are also very wide-ranging approaches of autonomous control concepts in modern aviation. Consequently, autonomy is also seen as a possibility for maritime transport to meet today's and tomorrow's competitiveness, safety and sustainability challenges. On the most advanced version of the watercraft, the decision-making and control functions are performed by intelligent systems operating on the basis of data from various sensors and data acquisition systems, installed on board or operating outside the vessel. Examples of the levels of ship autonomy are given in the figure.

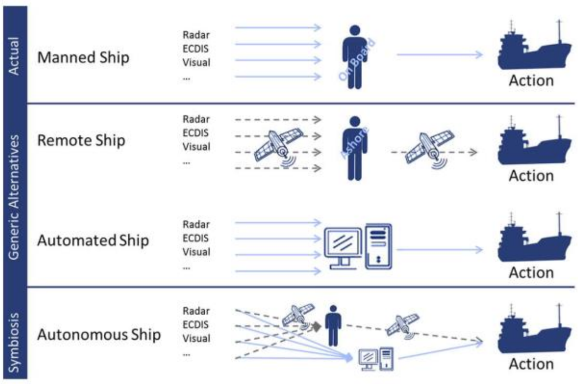

Figure 8: Source: www.unmanned-ship.org/munin/about/the-autonomus-ship

The use of UAVs on autonomous units should be determined by the level of ship autonomy. Based on the autonomy degrees, it is possible to determine appropriate tasks and adjust the procedures that the UAV and the crew (if any) should fulfill.

Degrees of autonomy (IMO):

1. Ship with automated processes and decision support - seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated),
2. Remotely controlled ship with seafarers on board - the ship is controlled and operated from another location, but seafarers are on board,
3. Remotely controlled ship without seafarers on board - the ship is controlled and operated from another location. There are no seafarers on board,
4. Fully autonomous ship - the operating system of the ship is able to make decisions and determine actions by itself.

The above division is not hierarchical. It should be assumed that during a single voyage a ship can navigate with more than one degree of autonomy. In this case, the Unmanned Aerial Vehicle should be adapted to the autonomy levels that will be applied during the voyage.

4.5 *Certification and the role of Classification Societies*

The current classification regulations do not apply to autonomous ships, but we are aware of that this classification process will begin soon. Guidelines from classification societies are available. These documents allow for certification to the extent agreed with the client, which allows the certification and release to service procedures to be carried out in agreement with the Administration.

The Polish Register of Shipping plans to introduce a special additional mark of the DOCK DRON class into the classification regulations, for ships that intend to use the unmanned aerial vehicles for navigation. At the request of the Shipowner, PRS will be able to assign a class to a newly built or existing ship. The assigning of an additional symbol will be confirmed by an appropriate entry in the Certificate of Class. Additional marks in the symbol of class define the ship type, obligatory requirements or limitations resulting from the ship type or its seaworthiness, and define additional features of the ship's structure or adaptation. Additional marks are placed in the symbol of class after fulfilling the requirements specified in the relevant parts of the Rules. In the case of an additional DOCK DRON class mark, special requirements will be created for the ship and for the device itself.

The requirements for the DOCK DRON class will be divided based on the type of ship and the type of drone that would be used on the vessel. The regulations applicable to a given UAV will be adjusted to the tasks to be performed by UAV.

Basic requirements to be met by a unit:

– requirements for the location of the flight deck surface, specifying safe heights and distances to obstacles when cooperating with UAVs, landing deck marking and arrangement of deck lights;
– requirements for lighting installations and equipment used in aircraft operations;
– requirements for the structure and strength of the flight deck and its security;
– requirements for equipment and facilities supporting on-board operations;
– system requirements, depending on the purpose of the UAV;
– requirements for fastening equipment;
– requirements for means of communication and landing site control equipment adapted to the operated UAV
– requirements for the navigational equipment of the ship;
– and many others.

The proposed DOCK DRON class mark will contain additional symbols, characterizing a specific unit as well as tasks that can be performed using BSP.

It is worth mentioning that autonomous units, depending on their autonomy level, will have the option of receiving an additional DOCK DRON class mark. The requirements will be adapted to the autonomy of the unil. A ship with a limited number of crew will require a qualified person with appropriate knowledge, skills and experience. Adapting the UAV to the unit will be essential because there are aircrafts that require human presence in order to use the launch pad or to deploy the landing net.

In autonomous units, such an Unmanned Aerial Vehicle operated from shore by a pilot makes it possible to provide additional safety for both the ship and its surroundings. The ship equipment systems itself, do not ensure location of every object detected by the system. Having an UAV onboard, we are able to quickly identify an object, e.g. an iceberg or a small yacht, thus getting the chance to avoid a collision and reduce the risk of danger.

4.6 *Adaptation of the existing infrastructure to receiving drones*

Having a flight deck, ships can manage vertical take off and landing of drones. The development of technology, increasing the efficiency of processors and gathering experience from the operation of existing drones contribute to their miniaturization (reduction in dimensions and weight). The use of more efficient energy sources increases the operational range of the UAV and extends the duration of missions and flights. The development of this dynamically developing industrial sector enables the use of UAVs on units smaller than the corvette class.

Problems with using drones from the board of surface ships include a number of technical issues. They include:

– the need to allocate space on board the unit for storing the drone.
– the need to provide logistic infrastructure, including maintenance and repair infrastructure
– the need to modernize the vessel if the use of ATOL (Automatic Take off And Landing) systems is planned
– the need to provide fuel or power energy infrastructure appropriate for UAVs that may land on board the a vessel

Organizational and staffing problems should be added to the above problem areas, such as:

– the need to train crew members in the use of UAVs
– the need to train UAV pilots for take-off and landing operations on / from the decks of vessels
– the need to take into account new crew specialties or the need to provide UAV maintenance personnel on board the vessel
– the need to provide UAV pilots on board the vessel and the related organizational and technical problems

The BSP (rotor) landing operation on board may serve as an example of difficult operating UAVs from the deck of a ship / naval ship. As indicated above, the BSP pilot receives information about the platform condition (including its position) with a delay. The landing area moves with the movements of the ship's hull. The UAV pilot has access to the control station screen only (if he is outside the ship). Thus, traditional landing aids are of limited use. The use of ATOL systems requires a trained person who can interrupt landing in case of problems. This solution requires the UAV to start landing again and repeat the procedure.

In the case of placing a pilot onboard a ship, assigning one person from the UAV personnel for the duration of the voyage is necessary. In the case of systems with more persons, the decision results in separating at least two persons(pilot and sensor operator).

4.7 *Technical capabilities of drones*

It is fairly common to believe that commercially available drones are suitable for tasks at the seaside. In the case of these drones, there are two basic limitations that make that the use of such drones, although incidentally possible, fails to fulfil expectations.

Those are:

– Very low flight duration (approx. 30 min.). This is catalog parameter. In the case of actual use, approx. 10 - 15% of the time (% battery charge) should be deducted for take-off and landing operations. Effective use is then about 20 minutes. From this time, one should deduct the time needed to get to the place of the mission. This time varies depending on the distance to the mission area from the launch site. Taking into account the speed typical for this class of drones, it should be assumed that for a mission at a distance of approx. 1 - 1.5 km from the launch site, the effective time for its execution at the site will vary between 10 - 15 minutes. The above calculation does not take into account the influence of wind. Considering that the pilot must allocate some time to find out in the place where the task is to be performed, we can see that this type of drones can only be used in missions aimed at confirming information (e.g. taking a photo of a signal buoy), and not obtaining it (searching).
– Meteorological limitations covering both wind and weather phenomena. Wind and weather affect all aircrafts, however, commercial drones require near-perfect weather conditions for take-off, flight and landing, i.e. wind of 3-5 m/s , i.e. 2 or 3 degrees in the Beaufort scale.
– Design limitations. Commercial drones are not designed to be used on board ships. It manifests itself in several areas, the most important of which is the control logic. In this logic, the place (Home Position) to which the drone is to return in case of loss of communication is automatically programmed (Return To Home). The difference is that the ship is moving, while the drone control logic usually does not take this into account. In the worst situation, the drone may return to a place where the ship is not present. If we add that this happens when the drone battery is low, the result will be the loss of the drone.

Technical requirements for ships other than aircraft carriers cooperating with helicopters have been specified, inter alia, in NATO publications, e.g. MPP-02, VOLUME AND HELICOPTER OPERATIONS FROM SHIPS OTHER THAN AIRCRAFT CARRIERS

(HOSTAC), as well as in the Polish defense standard NO-19-A206: 2009 "Ships and auxiliary naval vessels. Ship aviation infrastructure. Requirements".

Figure 8. Part of the protection elements for the Skeldar drone. Please note that drones with internal combustion engines will require a fuel storage infrastructure with fire, explosion protection devices, etc. Source: https://umsskeldar.aero

4.8 *Infrastructure requirement depending on drone operating conditions*

Adapting the requirements of the defense standard to the use of UAVs should not be difficult. In accordance with the provisions of the standard, it is possible to clearly define the capabilities of the host ship to conduct air operations, specifying the level and class of possible air operations. According to the defense standard, three levels of the ship's aviation infrastructure have been established, defining the possibilities of helicopter operations depending on the environmental conditions. We can apply a similar criterion to UAV.

- Level I means the ability to conduct flight operations in night conditions, without visibility.
- Level II stipulates that the ship's equipment is adapted to the performance of air operations both during the day and at night, in conditions for flights with visibility.
- Level III means that it is possible to perform flight operations in daylight conditions only with visibility.

4.9 *Helicopter Operation Classes*

At each helicopter operation level, there are seven classes of helicopter operations.

- Class 1 means that the ship has a landing surface and ground handling equipment and aircraft maintenance equipment.
- Class 2 means that the ship has a landing surface and ground handling equipment and maintenance equipment for selected aircrafts only.
- Class 3 means that the ship has a landing surface and the on-board service and maintenance of the aircraft equipment is not available.
- Class 4 and 5 means that the ship has a surface for carrying cargo suspended from the outer hook of the aircraft and it is dependent on the safe height of obstacles for the helicopter rotor and the safe distance to the hull and landing gear of the helicopter.
- Class 6 means that the ship is equipped for refueling operations by a hovering helicopter.
- Class 7 means that the ship is equipped to carry people and light loads to the board of the helicopter and vice versa using the helicopter's on-board winch.

From the above-mentioned classes, in the case of air operations with the use of UAVs, we can directly adapt classes 1, 2, 3, 4 and 5.

In order to describe the ship's aviation infrastructure for cooperation with aircraft, the equipment and fittings have been classified into the infrastructure branches. There are ten branches in the ship's aviation infrastructure (OIL).

Compliance with the requirements of the defense standard by the host ship (aircraft carrier) is confirmed by the issue of a Certificate of Compliance of the Naval Aviation Infrastructure with the Defense Standard by an independent certifying body (classification society). The certificate is issued for a period of five years and remains valid subject to annual inspections. As part of the inspections, the technical condition of the ship's systems, devices and equipment is assessed. The completeness of the equipment and the validity of certificates are checked.

Compliance with the requirements of NO-19-A206: 2009 contributes to increasing the safety of joint operations of ships and aircraft and may constitute the basis for determining the requirements for the ship's aviation infrastructure in cooperation with unmanned aerial vehicles.

5 CERTIFICATION OF UNMANNED AERIAL VEHICLES

The Classification Society, allowing the use of the Unmanned Aerial Vehicle, will require a Product Type Approval from the interested party. To obtain a given document, it will be necessary to submit to PRS:

- material / product documentation;
- confirmation that the product manufacturer has an Approval Certificate;
- confirmation that material manufacturer has an Approval Certificate;
- technical conditions are to be fulfilled, documents relating to the material shall be agreed with PRS.

Requirements for the commencement of supervision over a product or material in production must be met, in the case of UAV certification, the below factors shall be considered:

- fail safe function - procedure for dealing with dangerous events, e.g. low battery / fuel level, loss of GNSS signal, loss of communication with the control station;
- determination of e the weather minima, mainly wind, but also aspects such as magnetic interference from the sun, the so-called Kp index affecting compass and GNSS navigation;
- determination of the degree of resistance to water / moisture;

- definition of the time and scope of inspections and replacement of electromechanical parts (servos / motors) in the context of wear in salinity conditions - long-term tests should be performed;
- verification of long-term flight capability - tests should be performed;
- determination of mechanical strength - gusty sea weather may have a negative effect in the long-term use;
- checking the stability of electrical and mechanical connections - plugs / sockets, screw connections;
- flight preparation procedures, periodic checking of parameters during the flight and the so-called post-flight "minor inspection" - sending the results to PRS.

The Classification Society completes information and performs test and research programs - if applicable, or agrees them with the manufacturer, on the basis of the presented documentation that should be delivered.

6 CONFORMITY ASSESSMENT OF UNMANNED AERIAL VEHICLES

On 1 July, 2019, the European Commission published the Commission Delegated Regulation (EU) 2019/945 on unmanned aircraft systems (UAS) and on third-country operators of unmanned aircraft systems. Regulation 2019/945 regulates matters related to the introduction of UAS on the market and the requirements that must be met by designers, manufacturers, importers and distributors in order to obtain conformity markings and in terms of safety and interest in its competitiveness.

The second published document is the Commission Implementing Regulation (EU) 2019/947 of May 24, 2019 on the rules and procedures for the operation of unmanned aircraft by pilots and operators, specifying the categories of use and the requirements for their use.

These are:

- Open category - the UAS belongs to one of the classes set out in Delegated Regulation (EU) 2019/945. Operations not requiring approval / authorization, drones weighing less than 25 kg and flights up to height above the take-off point limited to 120 m, where the risk to third parties is close to zero. This category includes 3 additional flight subcategories: A1, A2 and A3.
- Special category - operations performed with a statement of compliance with standard scenarios or requiring authorization from the competent authority due to the expected higher risk for outsiders compared to the open category. The authorization may refer to both a single operation and a group of operations.
- Certified category - includes operations that require UAS certification under Regulation (EU) 2019/945 and operator certification and, if applicable, obtaining a license by a UAV pilot. The Certified category includes high-risk operations for third parties - comparable to the risk of flying with manned aircraft.

Both of the regulations 2019/945 and 2019/947 define the classes of unmanned aerial vehicles and the categories of their use.

Regulation 2019/945 sets out the requirements for the design and production of UAVs. It also deals with UAV commercialization requirements for the open category in Chapter II, including systems or accessories that they must have. Chapter III applies to Unmanned Aerial Systems (UAS) for a special category and certified category, specifying its requirements for design, production, maintenance and use as intended. Chapter IV concerns operations performed by operators from third countries outside the territory of the European Union.

One of the most important parts of Regulation 2019/945 is Annex I, which establishes the UAS classes. Depending on the maximum take-off weight, the following classes are established:

- Class C0 with the maximum take-off weight of the drone to 0.25 kg and the maximum flight speed below 19 m / s with the limitation of the maximum flight altitude to 120 m. Class C0 drones can fly in all subcategories of the Open Category.
- Class C1 with a maximum increase of the take-off weight of the drone to 0.9 kg, or those which, in case of a collision with a human, generate kinetic energy lower than 80 J. Maximum flight speed and height limitation are the same as in class C0. Class C1 drones can also fly in all subcategories of Open Category.
- Class C2 with a maximum take-off weight of the drone to 4 kg, which have a free flight mode activated from the apparatus and limited to a speed of less than 3 m/s horizontally, with a height limitation also to 120 m. C2 class drones can fly in subcategories A2 (in close proximity to people, from 5 m to 30 m) and A3 (away from people) Open Category.
- Class C3 with a maximum take-off weight of the drone up to 25 kg, which can fly in various automatic modes and have a flight altitude limitation of 120 m. C3 class drones are approved only for subcategory A3 (far from people) of the Open Category.
- Class C4 with a maximum increase in the take-off weight of the drone to 25 kg without automatic modes, except for standard flight stabilization.

Each class has a number of requirements for its production and obtaining the CE mark, necessary for approval in the European Union. It is worth to pay attention to the following requirements:

- The maximum achievable height at the starting point is limited to 120 m above the ground. If the altitude can be selected by the pilot, the system must have an altitude reading at all times in order not to exceed the limit mentioned above.
- A direct identification system that class C1 aircraft should have. The system must allow for the entire duration of the flight an unambiguous periodic emission identifying a given UAV in real time using an open and documented transmission protocol, including a unique registration number and operator data.
- UAV class C1 or higher should be able to be equipped with the function of limited access to specific areas or regions of the airspace. In

addition, the UAV pilot should receive a clear signal when the system algorithm blocks entry into a given area or region of the airspace
- UAV should be provided in operating instructions, which should be used from class C1.

Technical requirements for the AVS classes											
Class	Class symbol	Mass	Maximum flight speed	Maximum flight altitude	Power supply	Remote identification	Geo-awareness	Lighting	Battery warning	Other requirements	Using in the open category
C0	0	<0,25kg	<19m/s	<120m *	Up to 24V DC or equivalent AC voltage	-	-	-	-	-	All categories
C1	1	<0,9kg	<19m/s	<120m **	Up to 24V DC or equivalent AC voltage	YES	YES	YES	YES	Energy transmitted to the human less than 80J	All categories
C2	2	<4kg	-	<120m **	Up to 48V DC or equivalent AC voltage	YES	YES	YES	YES	Low-speed mode selectable by the remote pilot and limiting the maximum cruising speed <3m/s	A2 and A3
C3	3	<25kg	-	<120m **	Up to 48V DC or equivalent AC voltage	YES	YES	YES	YES		Maximum typical dimension must be less than 3 m
C4	4	<25kg	-	-	-	-	-	-	-	-	No automatic modes except for flight stabilization

In the case of an open and certified category, the manufacturer has to perform a UAS conformity assessment under one of the modules:
- module A - Internal production control,
- module B - EU-type examination together with module
- C - Conformity to type based on internal production control or
- module H - Full quality assurance.

In the case of modules B and H, the conformity assessment requires the participation of a notified body, which after a successful assessment process issues a certificate for module B for a period of five years, and for module H for a period of one year. Module A may be used by the manufacturer provided that he has applied the harmonized standards, published in the Official Journal of the European Union, for all requirements for which such standards exist in relation to class C0 and C4 UAVs and elements used for unambiguous remote identification. However, taking into account the lack of publication of harmonized standards to Regulation 2019/945, manufacturers will have to use modules, where it is a prerequisite for conformity assessment to be carried out by notified bodies.

Taking into account the distant perspective of the publication of harmonized standards, manufacturers will have to use modules requiring the participation of notified bodies.

There are currently few safety standards that can be applied to UAVs. However, this is about to change, and intensive work is currently underway to develop requirements.

Basically, all drone components, such as batteries, MEMS and other sensors are based on International Standards developed by IEC Committees:
- IEC / TC 47 Semiconductor devices and IEC / SC 47F Micro electromechanical systems. These Committees are responsible for the preparation of International Standards for semiconductor devices used in sensors and MEMS necessary for safe flights of drones,
- IEC / TC 2 Rotating machinery - prepares International Standards covering the specification of rotating machines,
- IEC / TC 91 Electronic assembly technology - is responsible for standards for electronics assembly technology and its components,
- IEC / SC 21A Secondary cells and batteries containing alkaline or other non-acid electrolytes develops standards for batteries used in mobile applications, but also for high capacity lithium cells and batteries.

The transitional provisions of the new drone law are in force from 31/12/2020 to 01/01/2023. According to the EU Commission Implementing Regulations 2019/945 and 2019/947, drones distributed in the EU must meet certain standards (assigned classes) and have the CE marking. In accordance with the decision of EASA (European Union Aviation Safety Agency), it will be possible to certify drones placed on the market before 01/01/2023 (before the entry into force of the target regulations).

7 SUMMARY, CONCLUSION

The Convention on International Civil Aviation (known as the Chicago Convention) was drawn up on December 7, 1944. This Convention regulates matters in the field of aviation law and covers civil aircraft. On its basis, unmanned aviation regulations are established. The new EU legal regulations that enter into force on December 31, 2020 require the registration of drone operators and the use of certified devices only. Legal regulations apply to drones weighing up to 25 kg with the possibility of flying up to 120 m.

A major problem accompanying rapid technological leaps is the lack of appropriate legal regulations regarding liability for damage related to the use of UAVs. When operating the drone in international waters, there is a risk of damage and loss of an expensive device. In the worst case, it can lead to casualties caused by a drone falling on board and its consequences. Societies need time to adapt to the challenges of modern technology. We can say that UAVs have proved their usefulness and will continue to develop.

REFERENCES

1. Wolejsza, P., Kulbiej, E.: Analysis of Possibilities How Collision between Kraslava and Atlantic Lady Could Have Been Avoided. In: 2018 Baltic Geodetic Congress (BGC Geomatics). pp. 42–45 (2018). https://doi.org/10.1109/BGC-Geomatics.2018.00014.
2. The autonomous navigation system tested in quasi-real condition, https://youtu.be/bvkdpnw_ypk, last accessed 2021/02/28.

3. https://www.wilhelmsen.com/ships-agency/maritime-drone-delivery/, Last accessed 2021/02/27.
4. https://smartmaritimenetwork.com/2020/04/29/first-commercial-long-range-drone-delivery-to-vessel-completed-in-singapore/, Last accessed 2021/02/27.
5. https://www.maritime-executive.com/article/f-drones-completes-world-s-first-nighttime-drone-delivery-to-a-ship, Last accessed 2021/02/27.
6. https://www.port.gdynia.pl/pl/wydarzenia/aktualnosci/1716-dron-zwiekszy-bezpieczenstwo-w-porcie-gdynia, Last accessed 2021/02/27.
7. https://marinetechnology.pl/en/news/hydrodron-during-maneuvers-at-the-port-of-gdynia/, Last accessed 2021/02/28.
8. http://www.avalproject.pl, Last accessed 2021/02/28.
9. https://www.ilawashiphandling.com.pl/about.html, Last accessed 2021/02/28.
10. http://navdec.com/en/, Last accessed 2021/02/28.