IRA-MAR
IMPROVING THE INTEGRATED RESPONSE TO POLLUTION ACCIDENT AT SEA AND CHEMICAL RISK IN PORT

Co-funded by the European Union

D5.2 IRA-MAR Analysis and synthesis report of the survey "Current equipment, practice, needs and experiences in terms of use of drones in coastal/marine pollution response".

WP 5: Studies for the integrated response to pollution accidents: the use of UAS (Unmanned Aircraft System) in emergency response

Task 5.2*:* Identification of experiences, current good practices and needs in terms of use of drones in maritime emergency

Last update: 31/05/2023

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IRA-MAR project – improving the Integrated Response to pollution Accident at sea and chemical risk in port

Project co-financed by European Commission – Directorate General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)

Project number:101048435

Call: UCPM-2021-PP

Topic: UCPM-2021-PP-MARIPOL

D5.2 IRA-MAR Analysis and synthesis report of the survey "Current equipment, practice, needs and experiences in terms of use of drones in coastal/marine pollution response".

https://wwz.cedre.fr/en/Projects/2022/IRA-MAR-2022

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This Deliverable will be updated periodically and published only in digital form on the ISPRA and IRA-MAR websites.

Disclaimer

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Glossary

- AGL Above Ground Level
- AI Artificial Intelligence
- BLOS Beyond Line Of Sight
- BVLOS Beyond Visual Line of Sight
- CBRN Chemical, Biological, Radiological, Nuclear
- CCC Command and Control Centre
- ConOps Concept of Operations
- CP Contingency Plan
- EASA European Union Aviation Safety Agency
- EVLOS Extended Line of Sight
- EMSA European Maritime Safety Agency
- FTP File Transfer Protocol
- Gimbal Device that permits a camera to incline freely in any direction
- GPS Global Positioning System
- HNS Hazardous and Noxious Substances
- HTOL Horizontal Take-Off and Landing
- IR Infra Red
- LiDAR Light Detection and Ranging
- LMRA Last Minute Risk Analysis
- LOS Line of Sight
- LWIR LongWave InfraRed
- MTOM Maximum Take-Off Mass
- NAA National Aviation Authority
- NAS Network Attached Storage
- NCP National Contingency Plan
- NIR Near InfraRed
- Notam Notice to airmen
- RGB Red, Green and Blue
- RPAS Remotely Piloted Aircraft Systems Service
- SCAT Shoreline Monitoring and Assessment Technique
- SLAR Side-Looking Airborne Radar
- Small Drones Drones having a total weight less than 20 Kg
- SORA Specific Operations Risk Assessment

- SOPs Standard Operating Procedures
- SWIR Short Wave InfraRed
- TFR Temporary Flight Restriction
- TIR Thermal Infrared
- UAS Unmanned Aerial System
- UAV Unmanned Aerial Vehicle
- USAR Urban Search and Rescue
- VIS VISible
- VLOS Visual Line-Of-Sight
- WebGIS Web Geographic Information System

Introduction and objectives

The aim of this deliverable is to gather information and knowledge on the use of drones in coastal/marine pollution response. In particular, the authors wanted to collect information on the current equipment, practice, needs and experiences of the institutions that usually intervene during a maritime environmental emergency.

The following chapters report the main results of the survey "Current equipment, practice, needs and experiences in terms of use of drones in coastal/marine pollution response".

The survey is part of the IRA-MAR project (*Improving the Integrated Response to Pollution Accident at Sea and Chemical Risk in Port*). IRA-MAR is a project co-funded by DG-ECHO, which aims to help countries in the Western Mediterranean and Atlantic regions (France, Italy, Malta, Morocco, Portugal, Spain and Tunisia) to improve their preparedness for marine pollution incidents through an integrated approach to response at sea, on the coast and in ports. It will also help the beneficiary countries to better plan and prepare for chemical risks in ports (http://wwz.cedre.fr/en/Projects/2022/IRA-MAR-2022). This integrated approach can also be achieved through the use of drones, which are the subject of Work Package 5 "Studies for the integrated response to pollution accidents: the use of UAS (Unmanned Aircraft System) in emergency response"; the study is part of WP5 (Task 5.2). Indeed, the use of drones in maritime emergency response aims at improving an integrated approach with the following objectives:

- improve response capacity to marine pollution incidents by standardising UAS-based surveys;
- facilitate the inspection of remote areas, reducing the risk of exposure to pollutants;
- provide guidance for the production of geo-referenced thematic cartography for use by authorities;
- develop synergies and information sharing between maritime authorities and civil protection for the use of UAS in coastal areas;
- Facilitate the taking of evidence in case of illegal spill, making available photographic and video evidence;
- notify, inform, and reassure the public about the development of an emergency response, enabling better communication.

This task represents the second step of the activities planned in wp5. Together with the activities carried out in task 5.1 “*Preliminary bibliographic research on the Best Available Technologies for the use of drones in maritime emergency response surveys*”, it represents the basic knowledge needed to carry out field trials (tasks 5.3 and 5.4) and to implement the guidelines “*Best Available Technologies in the use of UAS to carry out surveys in emergency in response*” (task 5.5).

The questionnaire is aimed at institutions that have teams within their organisation specialising in the use of drones in environmental emergencies, such as:

- European Civil Protection Services;
- Maritime Authorities;
- Port Authorities;
- Private entities as oil and gas companies and contractors operating offshore.

The survey was distributed to key stakeholders who were contacted through the following channels:

- DG-ECHO - Directorate General for European Civil Protection and Humanitarian Aid Operations of European Commission;
- Focal Points of three regional seas: REMPEC - Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea, HELCOM - Helsinki Commission, OSPAR – Oslo - Paris Convention;
- EMSA – European Maritime Safety Agency;
- IAPH - International Association of Ports and Harbours.

1 Survey structure

The survey is organised considering the main aspects that emerged from the best technology survey carried out in Task 5.1 “Preliminary bibliographic research on the Best Available Technologies for the use of drones in maritime emergency response surveys”. The questions were then organised around the following themes:

- type of institution to which the survey was addressed;
- main scenarios in which drones are used;
- type of drones and sensors employed;
- data management;
- procedures and licenses used for drones;
- inclusion of use of drones in Contingency Plans, exercises and training;
- key needs to improve the use of drones.

Annex I shows the 32 questions asked. Where possible, an attempt has been made to formulate the questions in such a way as to provide a statistical result for comment.

The main results of the survey are presented in the following pages; for each topic, the results are described and commented on and, where possible, statistical results are provided. The chapter "Conclusions and Summary of Results" comments on the overall results obtained and describes how they will be considered in the second part of the project, which will mainly focus on the implementation of two field trials (Tasks 5.3 and 5.4) and the development of guidelines. *Best Available Technologies in the use of UAS to carry out surveys in emergency in response*” (task 5.5).

2 Institutions providing feedback

Seventeen (17) institutions, mainly European, responded to the survey, the list of which is given below (*Table 2-1*). Representatives of all categories addressed by the questionnaire responded, namely: 5 European Maritime Authorities; 5 Private Entities on oil spill response; 4 European Civil Protections organisations and 3 European Port Authorities. This provided a broad picture of the current use of drones in environmental emergencies.

Table 2-1. List of Institutions providing feedback (alphabetical order)

Country	Institution	Role
Belgium	Port of Antwerp-Bruges	Port Authorities
Bulgaria	Emergency and Rescue Activity Directorate General - Bulgarian Maritime Administration	Maritime Authority
Cyprus	Cyprus Civil Defence	Civil Protection Service
Denmark	Royal Danish Navy Command (RDNC)	Maritime Authority
Estonia	Estonian Rescue Board	Civil Protection Service
Germany	Central Command for Maritime Emergencies	Maritime Authority
Germany	Hamburg Port Authority AöR	Port Authorities
United Kingdom	Oil Spill Response Limited	Private Entity on oil spill response
Italy	Castalia S.C.p.A. on behalf of Italian Ministry of Environment	Private Entity on oil spill response
Italy	italian fire service	Civil Protection Service
Italy	Port Network Authority Eastern Adriatic Sea - port of Trieste and port of Monfalcone	Port Authorities
Norway	Norwegian Coastal Administration	Maritime Authority
Portugal	European Maritime Safety Agency	Maritime Authority
Singapore	ITOPF – International Tanker Owners Pollution Federation Limited	Private Entity on oil spill response
Singapore	Resolve Marine	Private Entity on oil spill response
Slovenija	Administration for Civil Protection and Disaster Relief	Civil Protection Service
United States	Marine Spill Response Corporation	Private Entity on oil spill response

A random ID was assigned to each respondent (Response ID: 16, 25, 30, 33, 34, 44, 45, 61, 64, 68, 74, 79, 85, 90, 91, 96, 102).

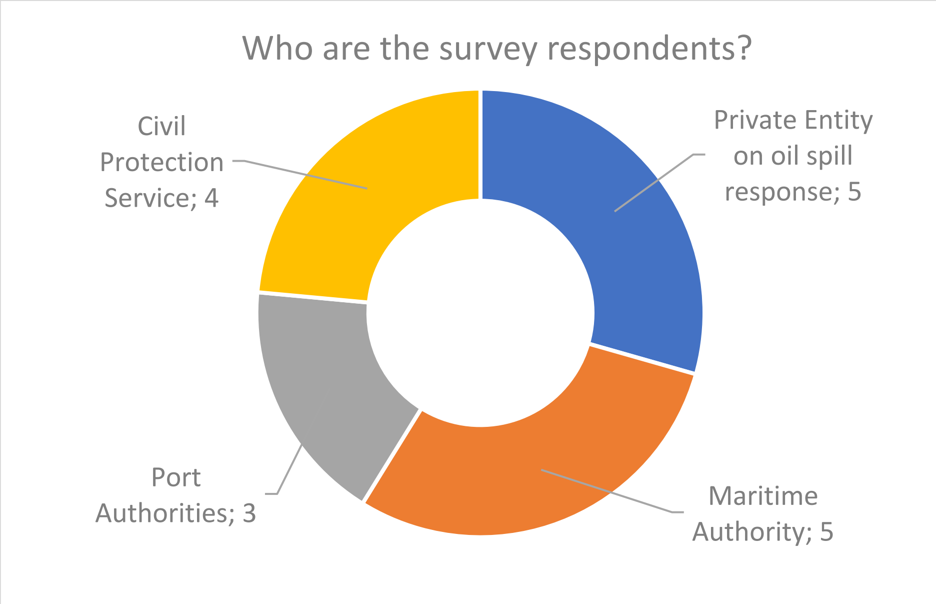


Figure 2-1 – Typology of respondents to the survey

The map in the *Figure 2-2* shows their location; the 3 non-European bodies that responded are private bodies involved in oil pollution response.

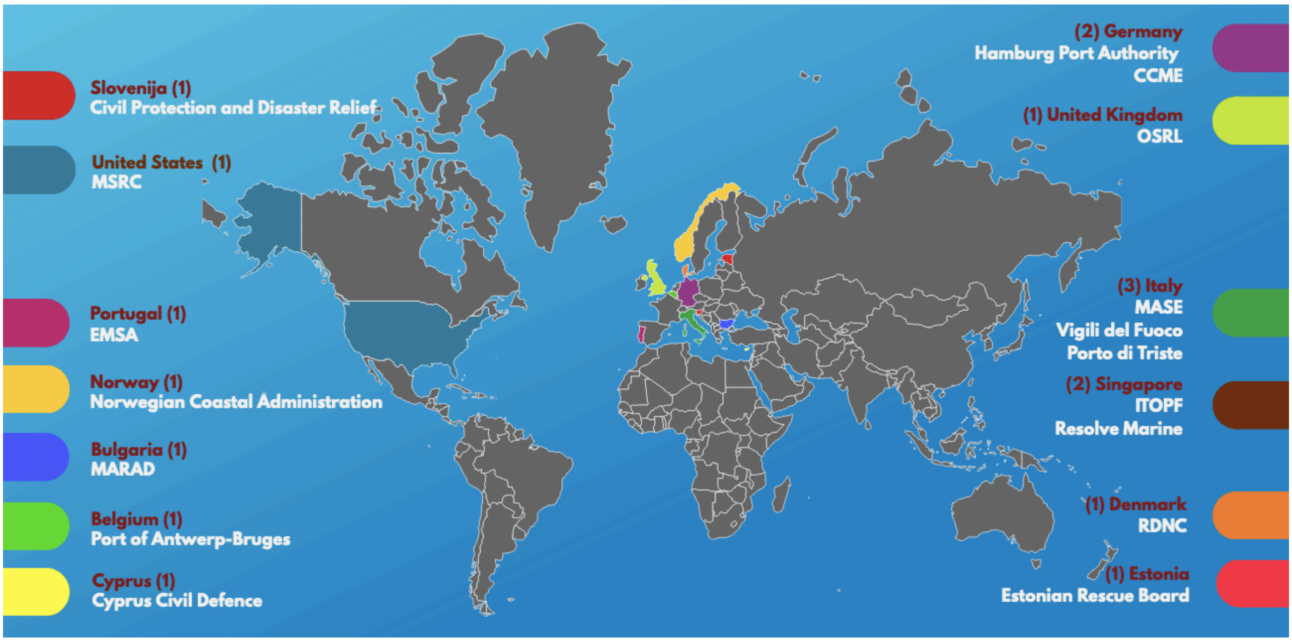


Figure 2-2. Location of organisation responding to questionnaire

In many cases, the institutions involved provided contact details of other organisations that could be contacted because they were involved in the use of drones in their activities. In addition, many were willing to be interviewed in order to elaborate on the answers given in the survey.

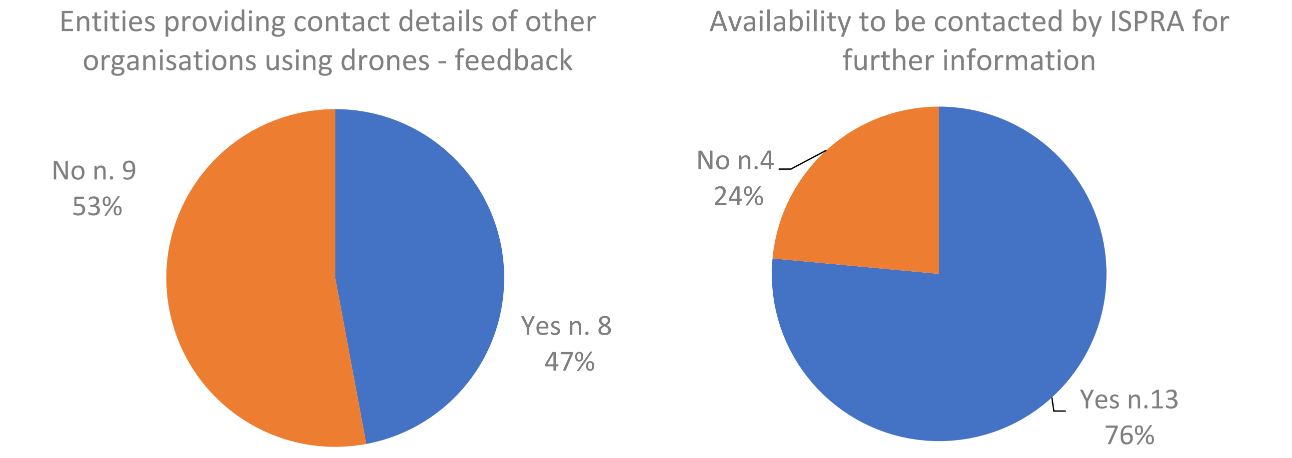


Figure 2-3 Respondents who provided contact details of other organisations and were available for further interviews.

2.1 Drone teams' organisation

It is interesting to note that the institutions contacted have two possible approaches to managing the drone fleet:

1. the competent authority establishes a branch (UAS service) with the task of acquiring a fleet of drones, with appropriate sensors and software, training personnel and distributing the equipment throughout the territory;
2. the management of the fleet of drones is entrusted to one or more private companies (UAV providers), which are activated in the event of an environmental emergency.

The first option is mainly considered by organisations whose main task is aerial surveillance (e.g. fire brigades); the second is mainly considered by organisations operating at a global or European level (EMSA, OSRL, ITOPF).

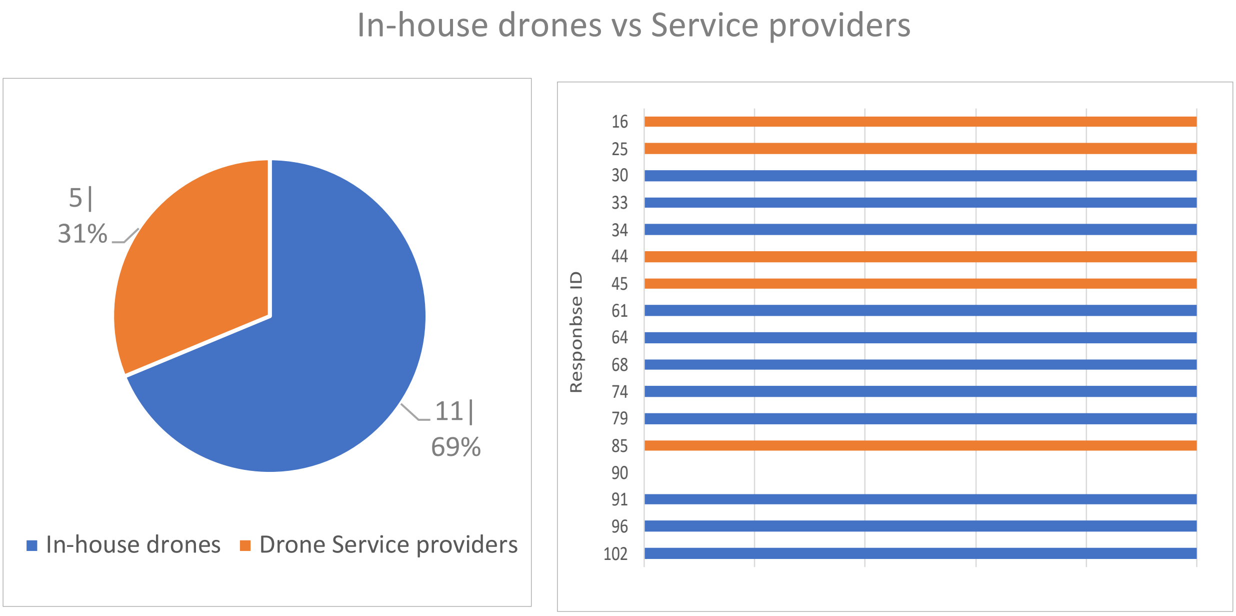


Figure 2-4 In-house drones vs service providers (%). The right-hand graph shows the answers given by each respondent.

The two different approaches are reflected in the organisation of the department's structure, which is focused on the use of drones. There are two types of organisation:

- "Drone office" which is part of a broader structure, called e.g. "Aviation department" or "Monitoring and Surveillance office", with the objective to coordinate the employment of drone systems offered by UAV providers;
- "Drone Department" where both the operational set-up, the training and the approvals of the operation take place. This department coordinates the technical and ground infrastructure and, with the support of relevant specialist departments, develops the required operational concepts.

3 Main scenarios application of drones' system

Drones are used mainly in the following scenarios:

- surveillance and monitoring;
- measurement and quantification;
- supporting marine pollution response;
- searching for missing persons;
- survey of coastal areas.

As can be seen in *Figure 3-1*, the scenarios which drones are commonly used are almost equally considered by respondents, and in many cases more than one scenario is considered.

Surveillance and monitoring are considered in case of: forest fire development, flood spread, fire on ships (heat profile compartments affected), position and condition of the vessel/cargo in distress, locating/guiding of response teams.

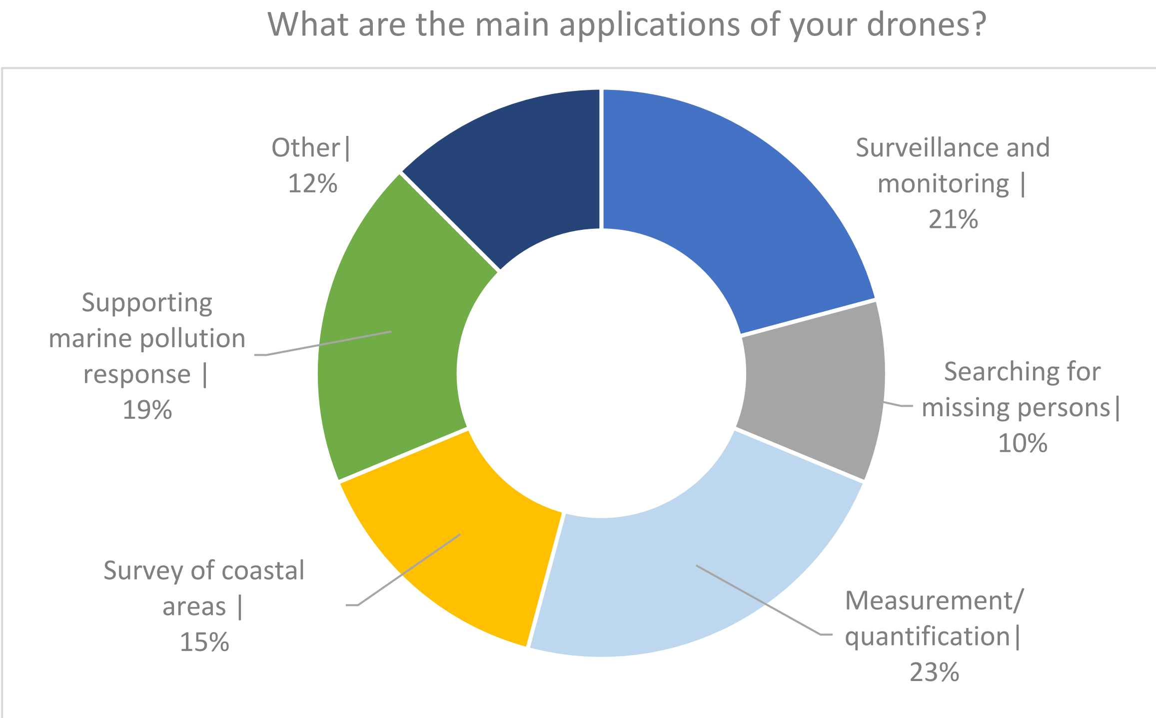
Measurement and quantification include: oil volume quantification; measurement of areas affected by pollution; volume of debris or mounds of soil to be removed; sulphur and other gases and finally wildlife measures.

Supporting the marine pollution response consider: guiding the ship to support the tactical response of anti-pollution vessels equipped with oil recovery tools (oil booms, skimmers, dispersants); monitoring the polluted areas; mapping the extent of the oil pollution.

Searching for missing persons consider also searching of animals/aircraft/cars/phone and the Urban Search and Rescue (USAR).

Survey of coastal areas includes scenarios at sea, on the coast and in ports: spreading and documentation of oil spills; identification of coastal areas affected by pollution; survey at sea, on the coast and in ports for oil or solid pollutants (coal, litter, garbage).

In some cases, other scenarios have been reported, such as: metric information on buildings or other three-dimensional objects; construction and progress control; concession survey.



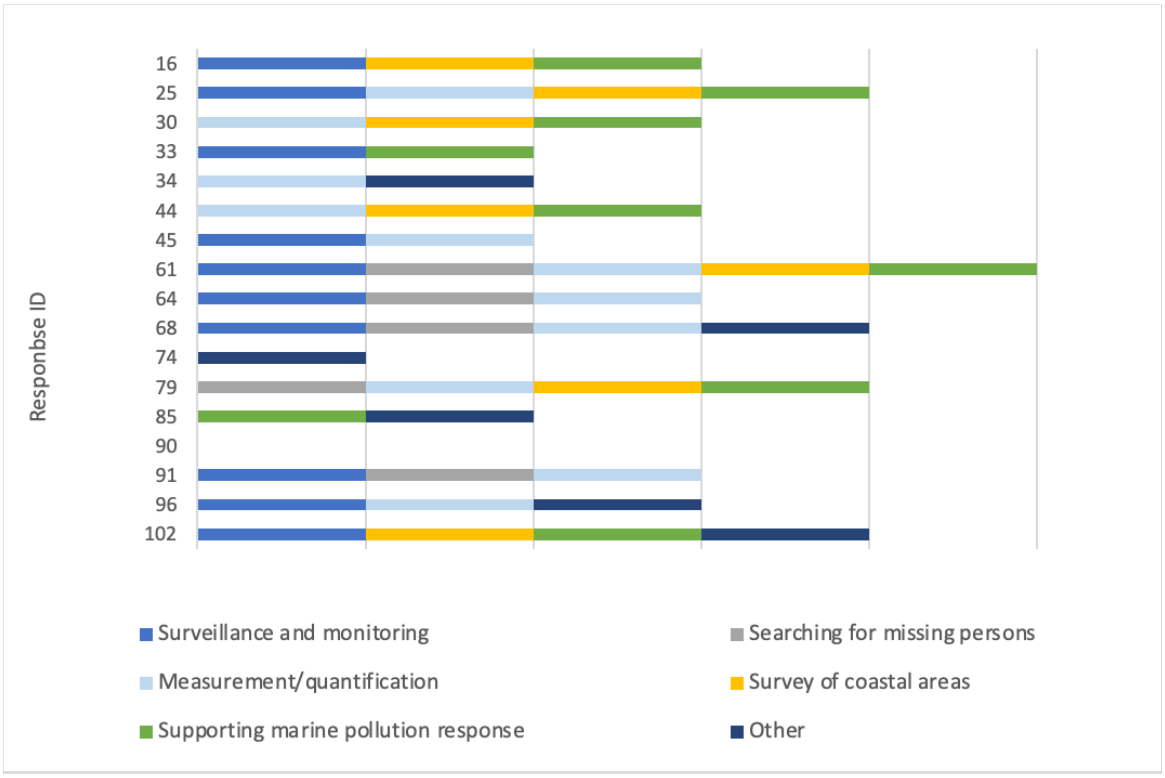


Figure 3-1. Main scenarios where drones are employed. The lower graph shows the answers given by each respondent.

3.1 Past experiences on use of drones during oil or HNS incidents

Most of the institutions (11) used drones in incidents involving oil or HNS spills. These were mainly oil spills; *Table 3-1* shows the name of the incident, the location and the type of scenario for which the drone was used.

Table 3-1. Oil or HNS incidents where drones have been employed

Country	Incident and year	Scenario
Germany	Kiel canal oil spill from a pipeline - 2022	• Surveillance and monitoring
Sri Lanka	Spill of nurdles from container ship X-PRESS PEARL - 2021	• Survey of coastal areas
Gibraltar	Oil spill from cargo ship OS35 - 2022	• Surveillance and monitoring • Supporting pollution response
Malaysia	Oil spill off Penang from cargo ship - 2016	• Surveillance and monitoring
Italy	Island of Montecristo - Sinking of Fishing vessel Bora Bora - 2019	• Surveillance and monitoring
California	Pipeline oil leak off the coast of California - 2021	• Surveillance and monitoring • Survey of coastal areas
Greece	Oil tanker Agia Zoni II spill - 2017	• Surveillance and monitoring • Survey of coastal areas
Solomon Islands	M/V Solomon Trader oil spill - 2019	• Surveillance and monitoring • Supporting pollution response
Spain	M/V Cheshire Ammonium nitrate cargo decomposition - 2017	• Surveillance and monitoring
Danemark	Åbenrå Fjord oil spill from a power plant	• Surveillance and monitoring
Italy	Fire in chemical plant Nitrolchimica - 2022	• Surveillance and monitoring • Measurement / quantification
Belgium	Incidents in the Port of Antwerp-Bruges – 2020 -2022	• Survey of port area

4 Current equipment employed

Data will be reported on the equipment used in terms of: type of drones and sensors; software used to manage the data collected.

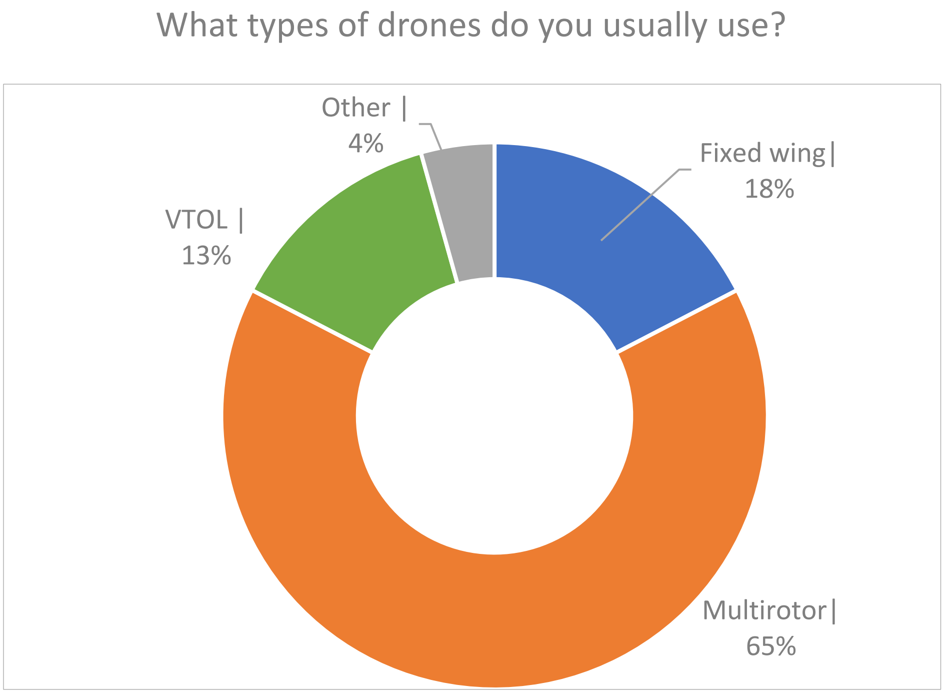
4.1 Type of drones

From the responses received turns out that the following types of drones are used: rotary - wing (multirotor) and fixed - wing. All reported rotary - wing drones are quadcopters, i.e. equipped with four rotors (*Table 2-1*). The most commonly used drones are rotary - wing (multi-rotor) drones (65%). Only in 4 cases are fixed-wing drones used and in these cases they are part of a fleet that also includes rotary - wing drones (*Figure 4-1*).

Table 4-1. List of typologies of available drones

Brand	Model	Type	Takeoff Weigh (Kg)	Payload (Kg)
Flylogix	Fx-2	fixed – wing	42,00	5,00
Sensefly	EBEE X	fixed – wing	1,60	0,70
DJI	PHANTOM PRO 4	rotary – wing quadcopter	1,28	1,37
DJI	Mavic Enterprise	rotary – wing quadcopter	0,750	0.80
DJI	Mavic 2	rotary – wing quadcopter	0,900	0.80
DJI	Mavic 3 Thermal	rotary – wing quadcopter	0,900	0,90
DJI	MATRICE 30	rotary – wing quadcopter	3,770	0,68
DJI	MATRICE 210	rotary – wing quadcopter	3,840	2.30
DJI	M300 RTK	rotary – wing quadcopter	6,300	2.70
Teledyne FLIR	Skyranger R70	rotary – wing quadcopter	5,000	3,50

In some cases, the type of drone was not specified as it was described as 'multiple brands and models'. Where the type of drone was reported, the majority of drones reported fell into the category of "Small Drones", i.e. those weighing less than 20 kg.



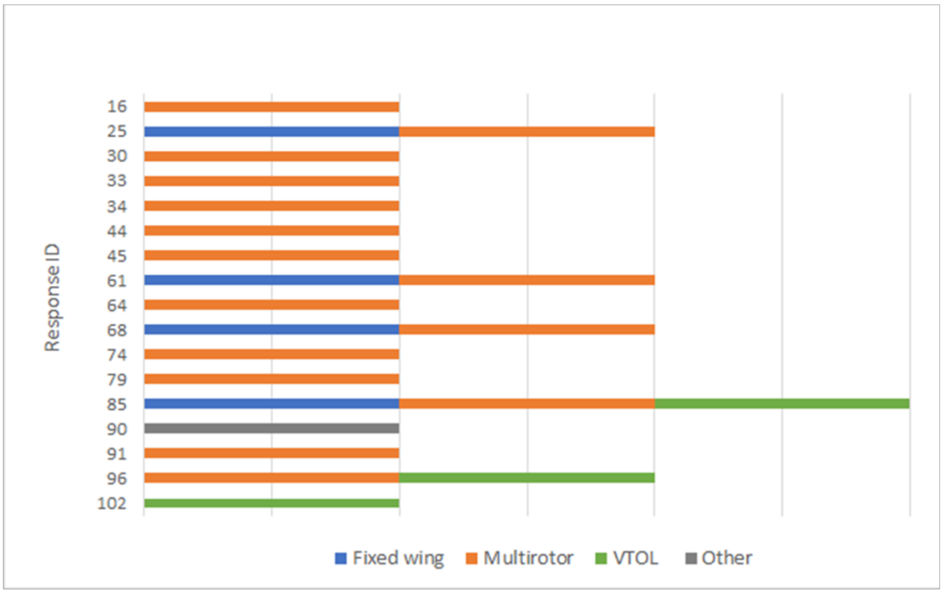


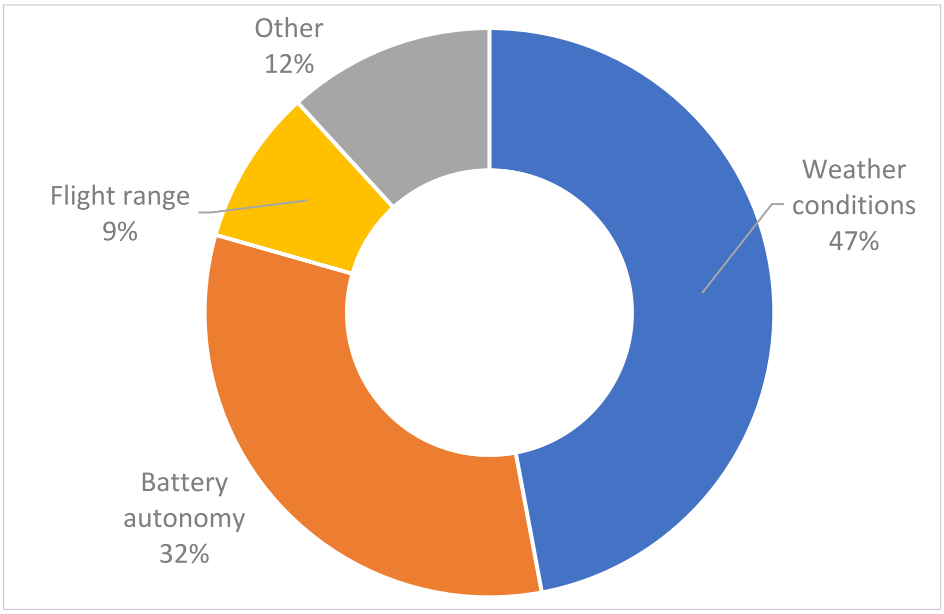
Figure 4-1. Typology of drones used. 5 out of 17 respondents use more than one type of drone. The types of drones used by each respondent are also shown.

4.1.1 Limitations

The main limitations reported in the use of drones are related to:

- weather conditions;
- battery autonomy;
- distance that can be covered.

What operational limits have you encountered on the field?



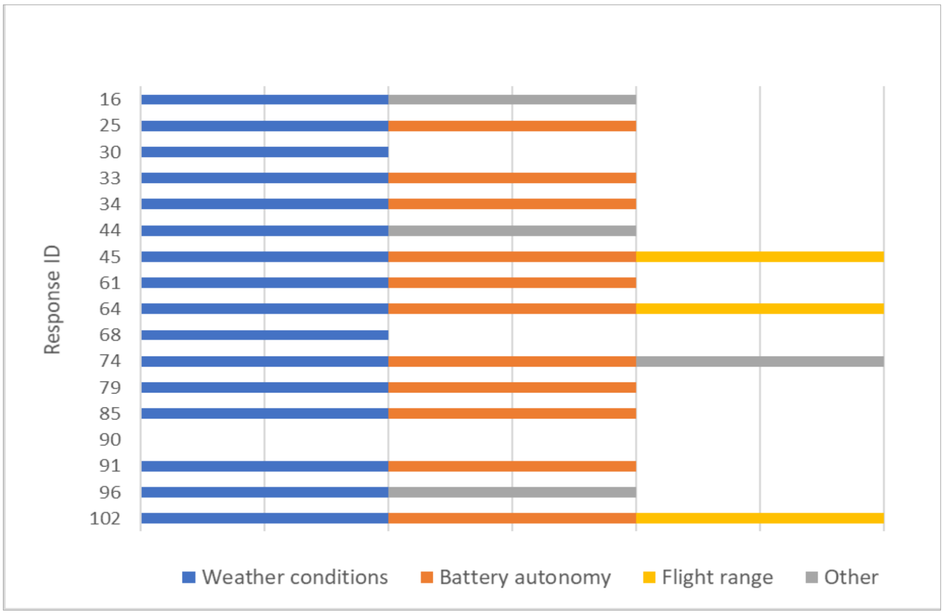


Figure 4-2. Limitations in the use of drones. The lower graph shows the answers given by each respondent.

The weather conditions that most affect the use of drones are: wind speed, rain, temperature and visibility. In general, drones will not be used if the wind speed exceeds a certain limit, which can vary between 35 and 50 km/h. If it is raining, in some cases drones will not be used anyway, in others only if the rain is heavy. Flying is often prohibited in sub-zero temperatures. Visibility is a limitation when flying in visual line-of-sight (VLOS).

Battery autonomy is a clear limitation of drone use; "Small Drones" have an autonomy of between 20 and 45 minutes, depending on size, battery type and payload.

The distance they can fly is directly dependent on the battery range but is also affected if the type of flight is VLOS. For “Small Drones”, the range is generally up to 2 km.

Other limitations include:

- difficulties in taking off and landing from ships. Ship movements and technical equipment cause problems with the drone’s positioning system;
- interference from seagulls.

4.2 Type of sensors

RGB (Red, Green and Blue) and thermal sensors are the ones most commonly used by the respondents. In many cases, respondents have drones equipped with more than one type of sensor (*Figure 4-3*).

The feedbacks from Institutions allowed the quantification of more than 10 different RGB camera models mounted on a UAV platform. The models listed represent both standard RGB cameras provided by drone manufacturers and custom RGB cameras. Some camera models allow to capture images in both visible (RGB) and thermal radiometric intervals (multispectral cameras). Gimbal, the device that allows the camera to tilt freely in any direction, is available on some camera models. The resolution of the sensors is between 10 and 25 MP and the payload weight is between 0.4 and 0.9 kg, which makes them compatible with UAV vehicles of the “Small Drones” type.

The thermal models represent both single-band thermal cameras and hybrid camera models that allow to acquire images in both visible (RGB) and thermal radiometric intervals (multispectral). The thermal radiometric interval sensed is in the LongWave InfraRed (LWIR) range (7 - 14 µm). Gimbal is available for some camera models.

In some cases the use of LiDAR sensors is reported. Other than morphology of investigated area, LiDAR can measure the intensity of the backscattered signal, which can differ between water and pollutants.

No other specific pollutant-capable sensors (e.g. fluorosensors, SLAR, sniffers) are reported. Similarly, no samplers specifically adapted to be mounted on drones are reported. In most cases, sensors are used to detect an oil spill and the type of pollutant. Apart from the use of classic optical RGB video/cameras, multispectral and thermal sensors are often used for this purpose. No one reported the use of sensors for HNS spill detection.

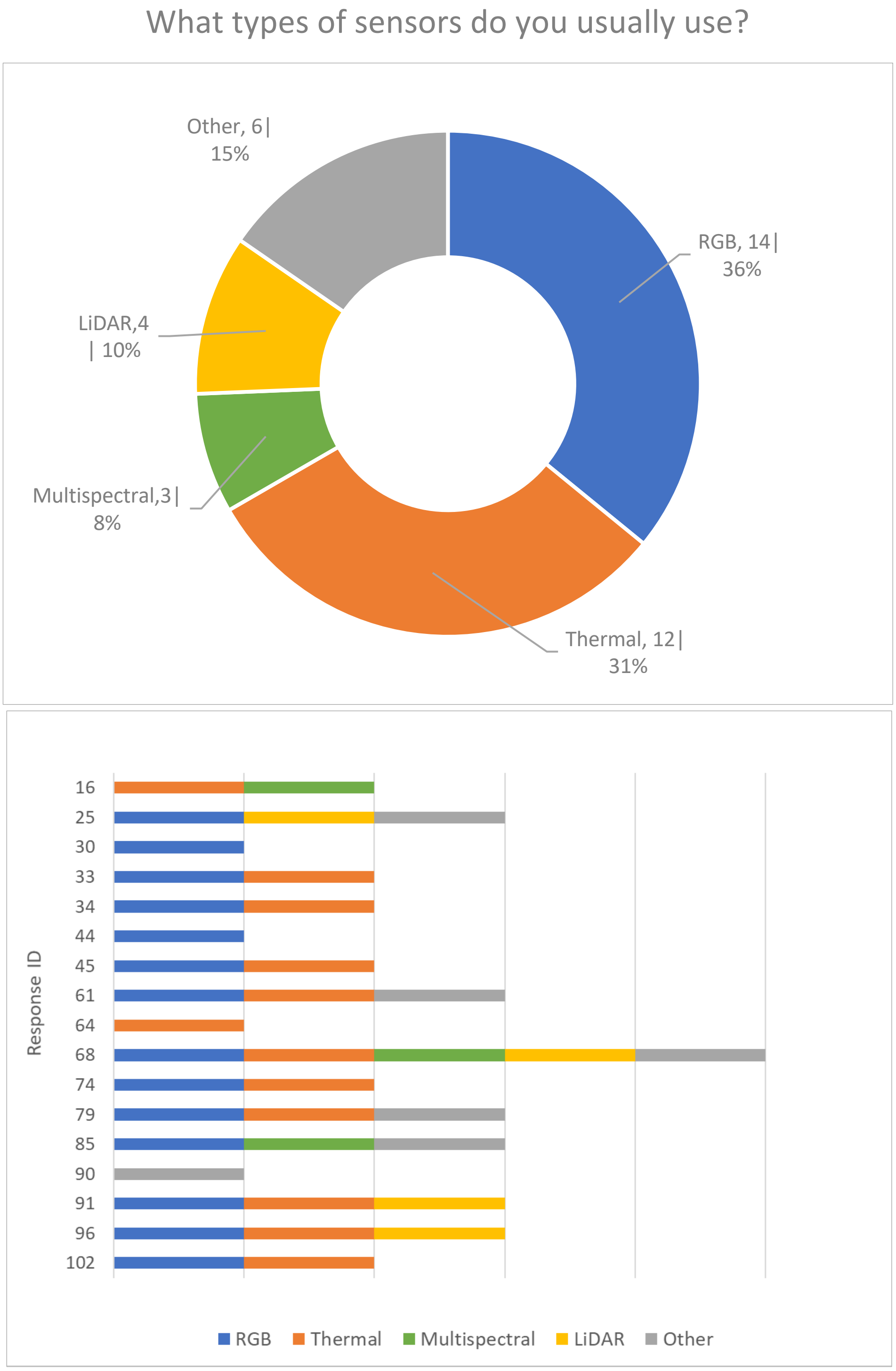


Figure 4-3 Type of sensors used by respondents (%). The lower graph shows the answers given by each respondent.

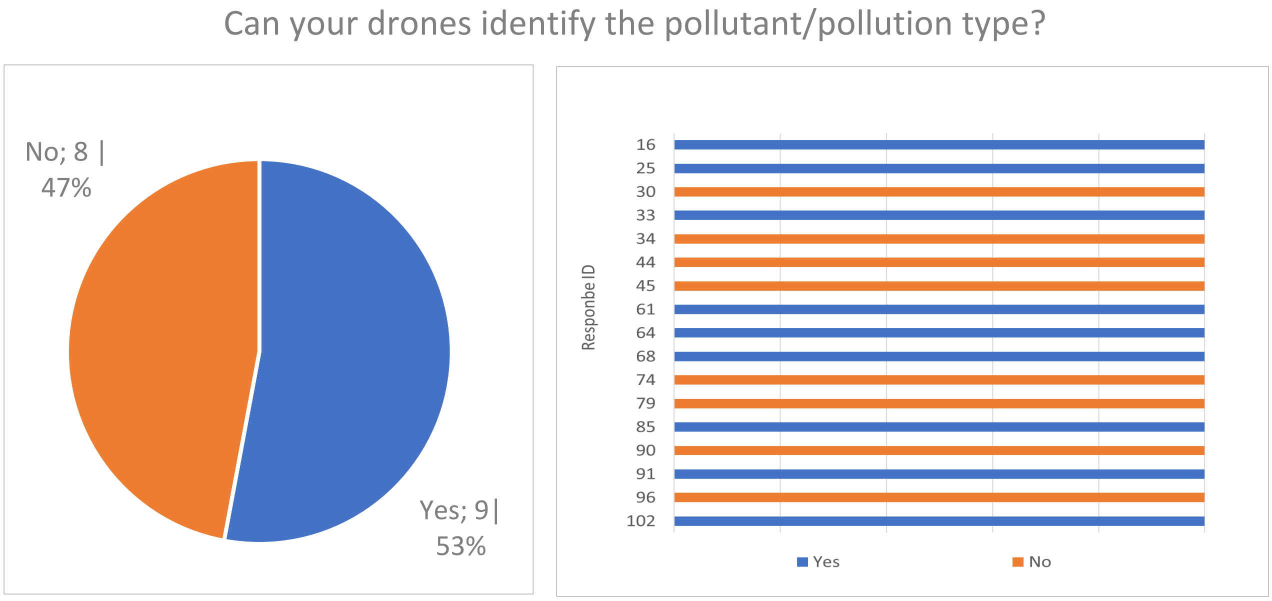


Figure 4-4 Identification capacity of pollutpollution of respondents. The right-hand graph shows the responses of each individual respondent

4.3 Data Management

Data processing is the manipulation of digital data to produce meaningful information.

Respondents provided information on software used in real time, software used during the flight of the drone, and software used to process the data collected. The software can be proprietary or open source.

Real-time software is mainly used for command and control of the drone (e.g., DJI Pilot, DJI Flight Hub), gathering information about problems and malfunctions (e.g. Airdata), wireless transmission and management via Wi-Fi (e.g. FLIR Thermal Studio). Post-processing: includes methods and algorithms for analysis, identification, classification, and characterisation of the pre-processed data.

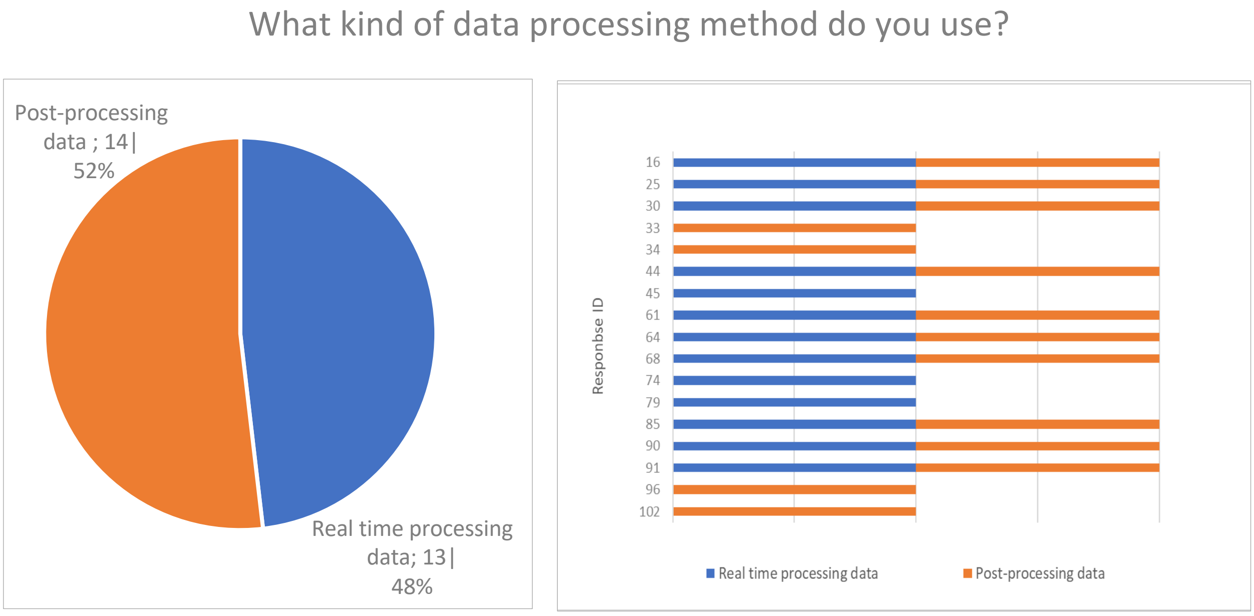


Figure 4-5 UAS data processing methods used by respondents. The right-hand graph shows the responses of each individual respondent.

Processing software includes photogrammetric processing steps such as radiometric calibration, geometric calibration, georeferencing and mosaicking. This software can then produce a photomosaic and a 3D representation of the area. Below is a list of the software mentioned:

- Pix4D Mapper;
- DroneDeploy;
- Agisoft Metashape;
- ArcGIS;
- Reality Capture.

In other cases, video and colour analysis software (e.g. LOC8) was reported.

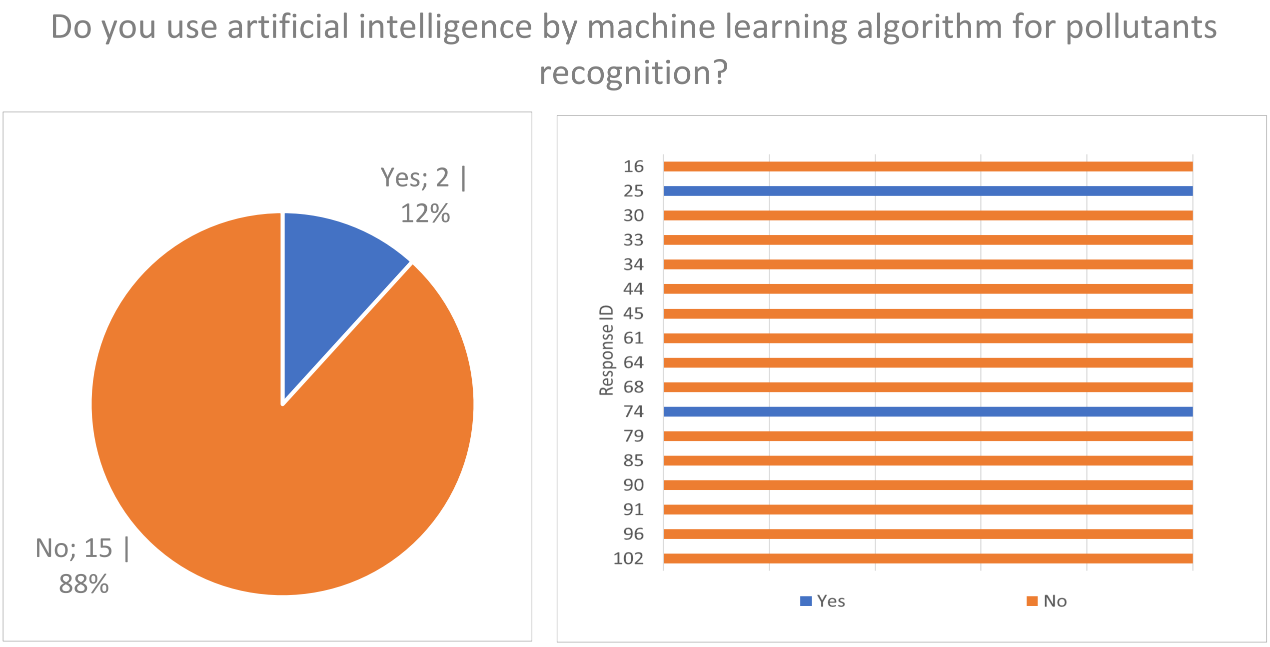


Figure 4-6 - Use of artificial intelligence through machine learning algorithms to detect pollutants among respondents. Left-hand graph: percentage data; right-hand graph: the respondent's individual answers

13 respondents (76%) transmit acquired data to the Command and Control Centre (CCC), typically via online data storage. Data shared includes: live video that can be streamed; fire image maps; oil classification maps.

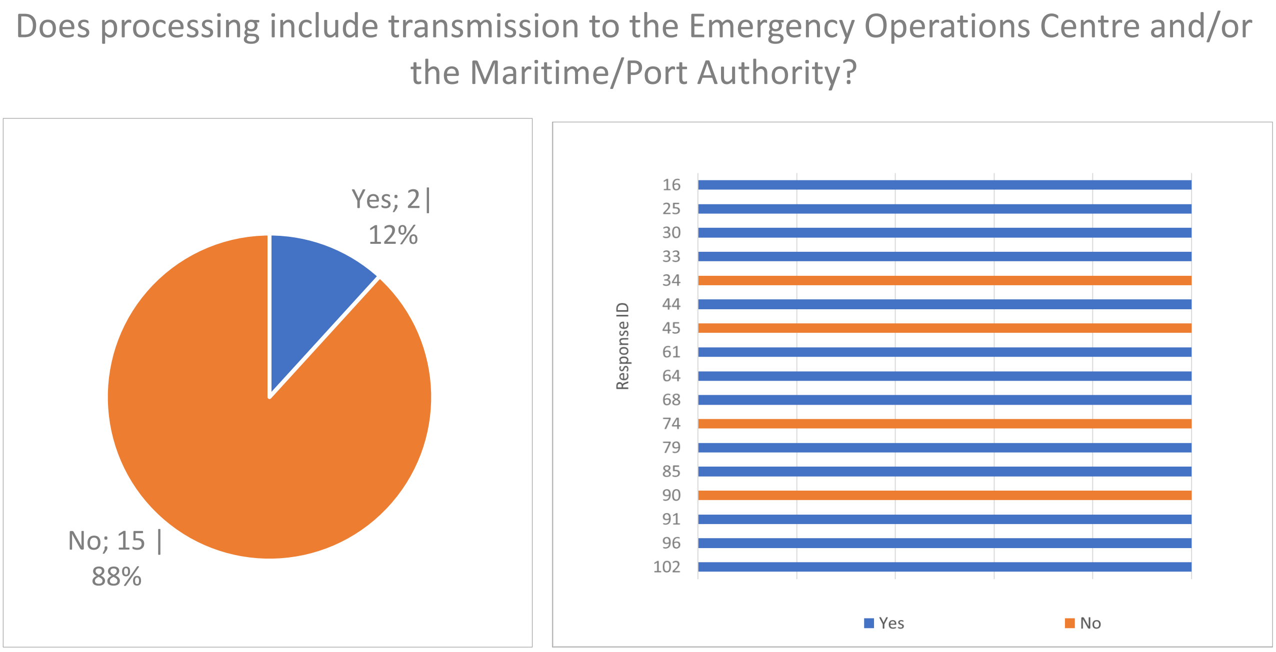


Figure 4-7 – Transmission of UAS data to the emergency operations center. Left-hand graph: percentage data; right-hand graph: the respondent's individual answers

From the CCC, the data could then be made available to other authorised users. In fact, 10 respondents (59%) share their data between agencies involved in the operation, mainly using an internet cloud, such as Microsoft Sharepoint Extranet; File Transfer Protocol (FTP) to share Geotiff and Jpeg files; custom software.

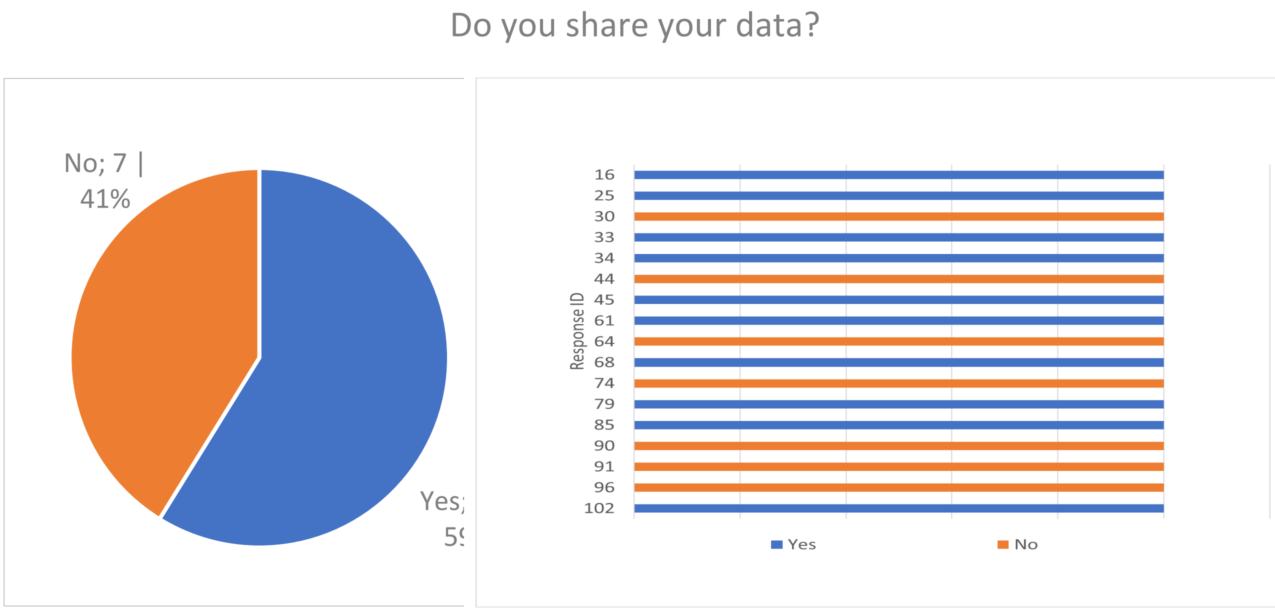


Figure 4-8- Sharing data acquired by UAS. Left-hand graph: percentage data; right-hand graph: the respondent's individual answers

In most cases, data is stored on local storage and network attached storage (NAS), such as Microsoft Sharepoint. The responsibility for storage lies with the requesting authority.

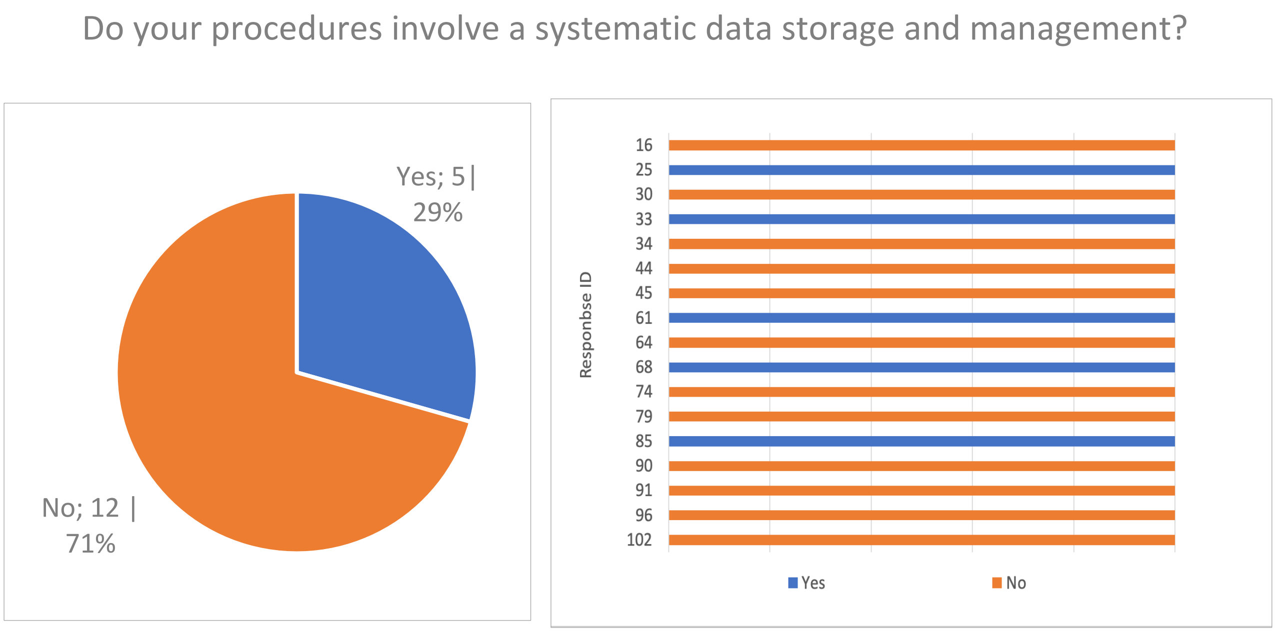


Figure 4-9 Systematic data management procedures among respondents. Left-hand graph: percentage data; right-hand graph: the respondent's individual answers

5 Drones procedures and licenses

The Regulation of drone flights is an ever-evolving discipline that seeks to follow the rapid technological evolution of UAS. Three different aspects can be considered in order to understand how this discipline is evolving:

- risk assessment;
- certification requirements;
- authorization and flight procedures.

These aspects are summarised in the Annex II Drones fly regulations, based on bibliographic research carried out by the authors. Instead, the following paragraphs summaries the results of the feedback given by the respondents on this subject.

5.1 Risk assessment

The risk assessment of UAS operations reflects the level of safety associated with the UAS during the operational period. Currently, the new regulations indicate that the operational risk assessment can be based on SORA (Specific Operations Risk Assessment) developed by the European Union Aviation Safety Agency (EASA). The new basic regulation covers all drones regardless of their size and weight.

70% of respondents (12) say that they carry out a risk assessment *(Figure 5-1)*; of these, 8 use the SORA methodology. Some respondents adopt the SORA including verification of the operator's license and certification, in other specific cases the SORA risk analysis is also used in a simplified form.

Where SORA risk analysis is not used, institutions reported using the following methodological approaches:

- ✓ Toolbox meeting, Method statement;
- ✓ Due to remoteness, other operations and potential risks (including potential flammability) are ad-hoc
- ✓ special operating procedures according to special agreements;
- ✓ operational risk assessment versus mission target;
- ✓ Last Minute Risk Analysis (LMRA)

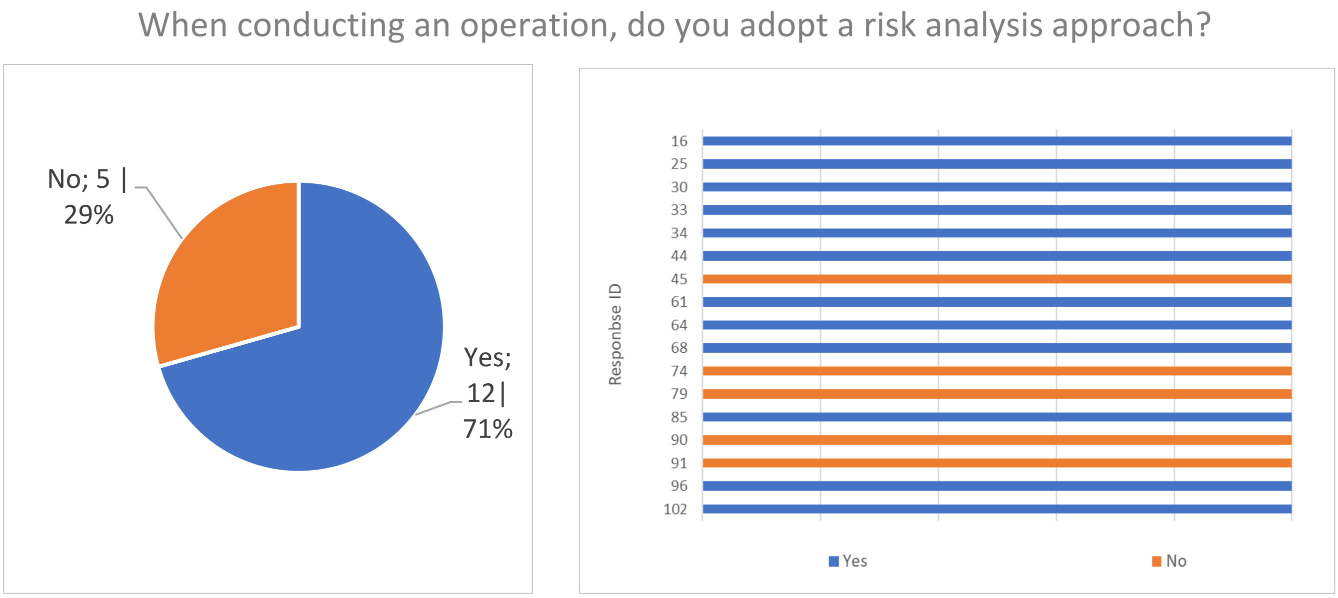
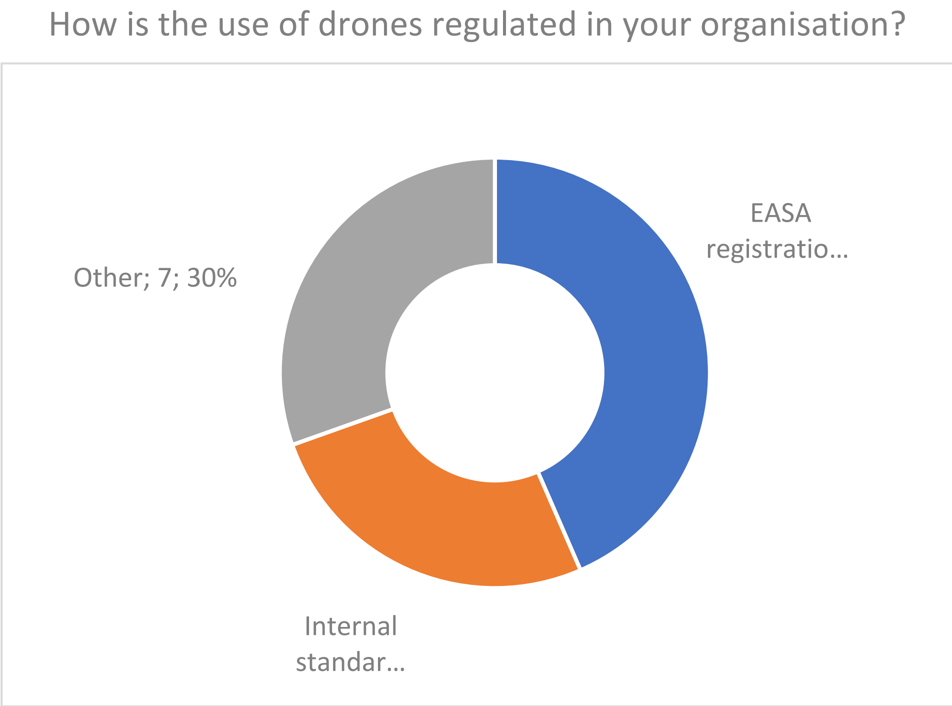


Figure 5-1. Respondents that apply a risk analysis approach. Graph on the left: percentage data; graph on the right: the individual respondent responses

5.2 Certifications needed

The registration of operators and drones (see Annex II Drones fly regulations) is carried out through two different mechanisms:

- National registry for the operators and by issuing a QR code for drone recognition, labelling the drone with the operator's identification. Registration will then take place according to EASA regulations (10 respondents);
- Internal registration through standardised procedures governing pilot training and drone management (5 respondents).



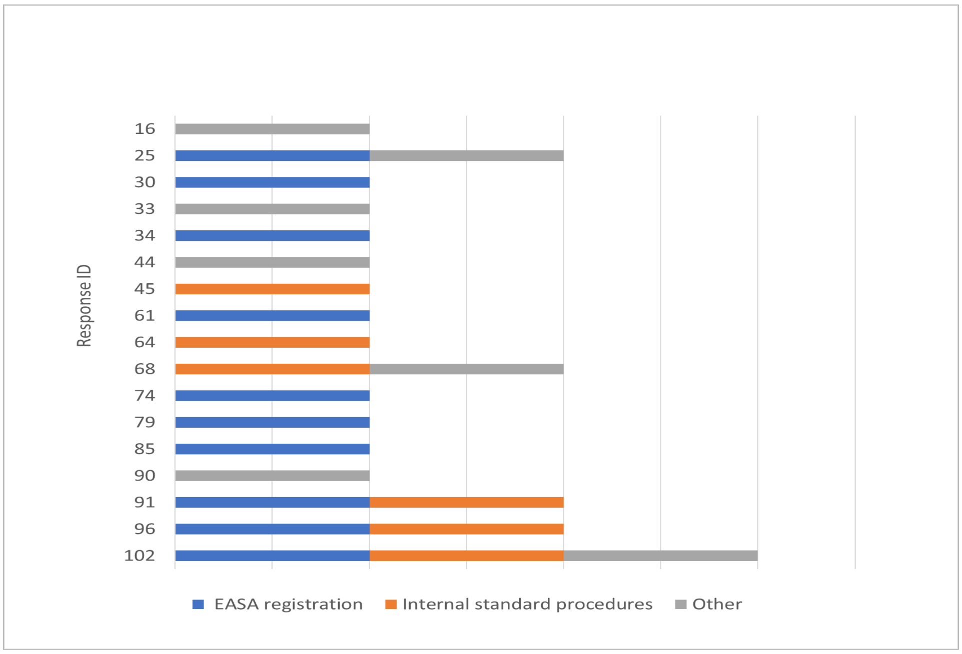
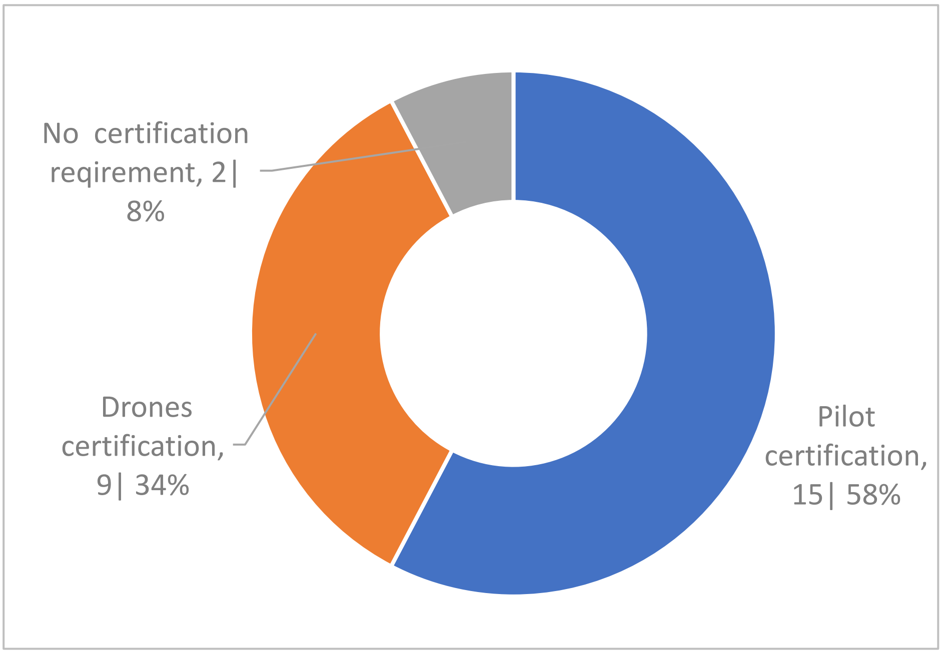


Figure 5-2 Certification procedures adopted by respondents. The lower graph shows the answers given by each respondent.

In cases where the management of the drone fleet is entrusted to one or more UAV providers, the responsibility for registration lies with the companies operating the drone on behalf of the respondent. Port authorities have a specific internal registry in their own geo-zone management portal.

Certification requirement



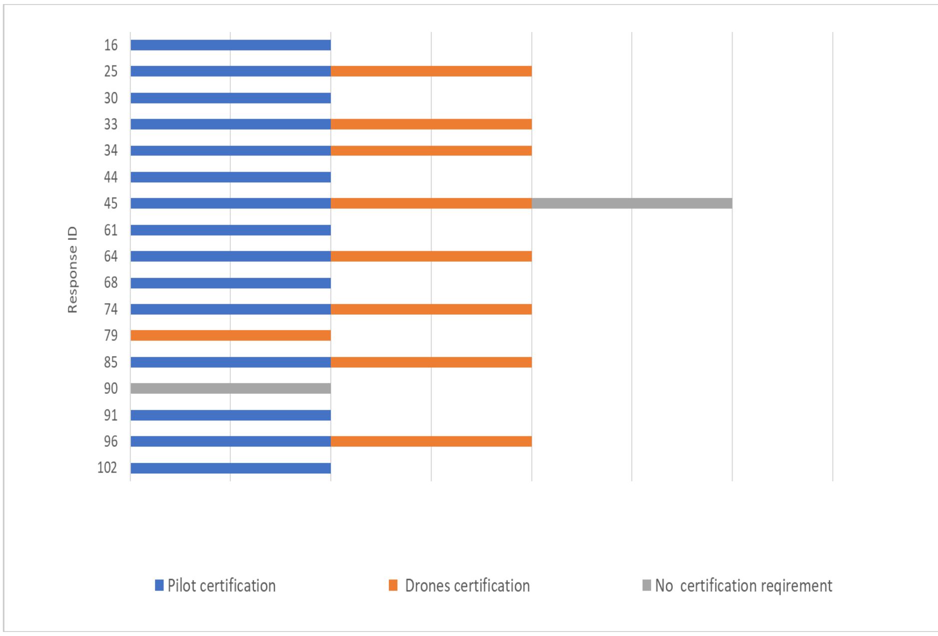


Figure 5-3 Respondents whit operator and drone licenses (%). The lower graph shows the answers given by each respondent.

Drone operator certificates are usually issued by the National Aviation Authority (NAA) in accordance with EASA regulations. The drone operator must obtain a UA Pilot Licence (UAPL) and register for a Civil Aviation Personnel Licensing System (CAPELS) account to obtain a unique CAPELS Personal Identification Number (PID). In most cases, drone operator licenses are open category A1/A3 and A2.

Table 5-1 – Type of certifications required for pilots and drones.

ID Respondent	Pilot certifications	Drone certifications	No certification required – the reasons_
16	A1, A2, A3		
25	Singapore - UA Pilot Licence (UAPL).	SG-Register drone if the total weight exceeds 250g and purchase a registration label	
30	Drone Pilots must be Certified under EASA guidelines		
33	Part 107	Must be resistered with the FAA	
34	According to existing laws.	According to existing laws.	
44	Typically operators must be nationally registered		
45	country depending	Country depending	Light drone, unrestricted locations
61	Drone operator certificate issued by National Competent Authority_according to EASA regulations		
64	+	+	
68	EASA and internal certifications		
74	open category A1/A3 and A2 category	CAA - Civil aviation Agency Slovenia	
79		RO3 certification - BELOS + Darkness + over 120m	
85	this is the responsibility of the service providers.	this is the responsibility of the service providers.	
90			No information
91	A1-3, A2		
96	A1 / A3 & A2	Insurance and operator registration	
102	OPEN A1/A3 + A2 and depending on type of flight SPECIFIC with SORA		

5.3 Authorisation and fly procedures

The airspace management and separation procedures to be followed prior to an operation vary slightly between respondents. In some cases (8) there is a request to the National Aviation Authority (NAA) and waiting for authorisation to operate; in others (12) it is sufficient to send information about the operation to the NAA. In general, the answers vary according to the airspace in which the drones are used:

- no restricted areas;
- airspace with some restrictions (standard clearance for low level flying);
- controlled airspace such as military installations, prisons and airports where permission is required from the NAA.

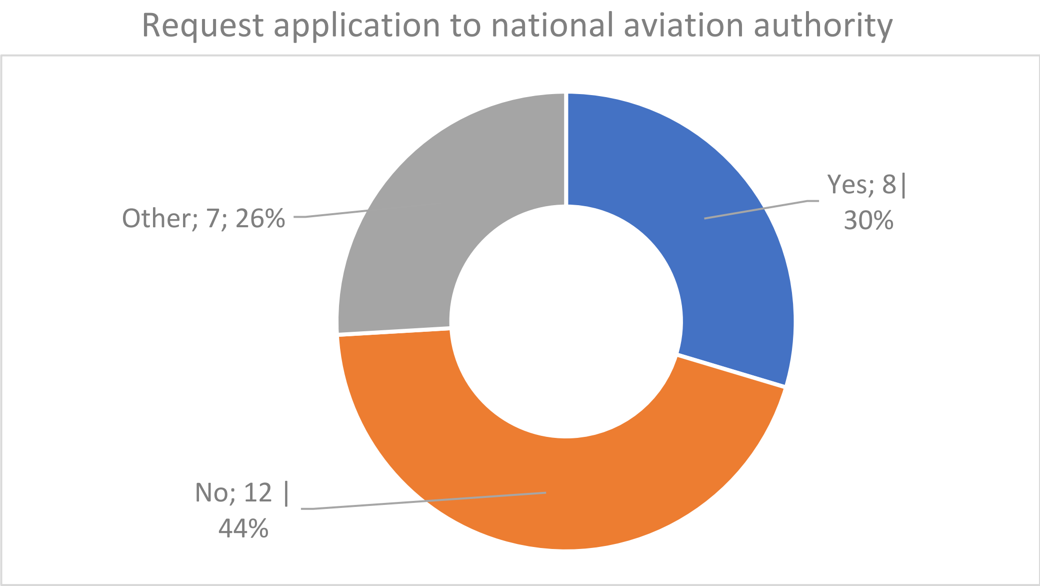


Figure 5-4 Request to National Aviation Authority/Wait for authorization/Operation. The lower graph shows the answers given by each respondent.

In most cases, pilots must be licensed, and drones must be registered. Port authorities have their own management of their geo-zones.

10 respondents (59%) stated that they use standard operating procedures (SOPs) for UAS assets and sensors, using an operations' manual. They have developed general internal procedures that cover the mobilisation of UAVs and the standard outputs required during a UAV mission for specific tasks such as shoreline support, offshore support, etc. The operational manual includes pre- and post-flight checklists. In some cases, a certain number of scenarios are customised and ad hoc procedures/checklists are developed as a result.

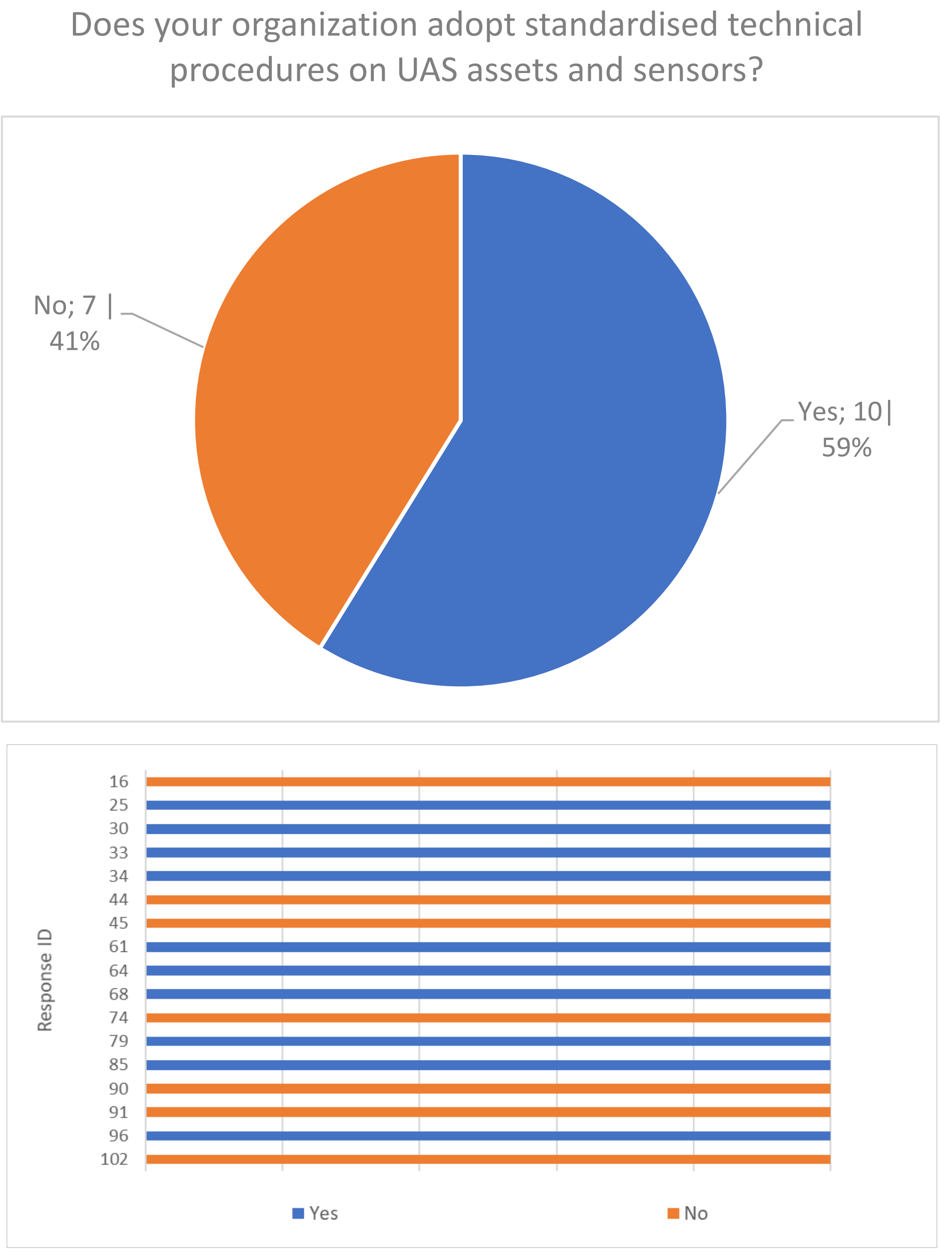


Figure 5-5 – Use of technical procedures by organization. The lower graph shows the answers given by each respondent.

7 respondents (41%) operate Beyond Visual Line Of Sight (BVLOS), i.e. the drone can fly in areas where it is not directly visible to the pilot. This type of flight has both advantages and disadvantages. Benefits highlighted by respondents included:

- large survey area coverage;
- access to remote/inaccessible locations (mangroves, rocky coastlines);
- Allowing mobility of the vessel to detect and track pollution plumes in the open sea.

The reported disadvantages are:

- intermittent signal loss could increase difficulties in returning the drone to its home base;
- more difficult to determine the exact location of the drone, reducing the level of system control;
- effective battery life is relatively short to cover longer distance range;
- increased risks.

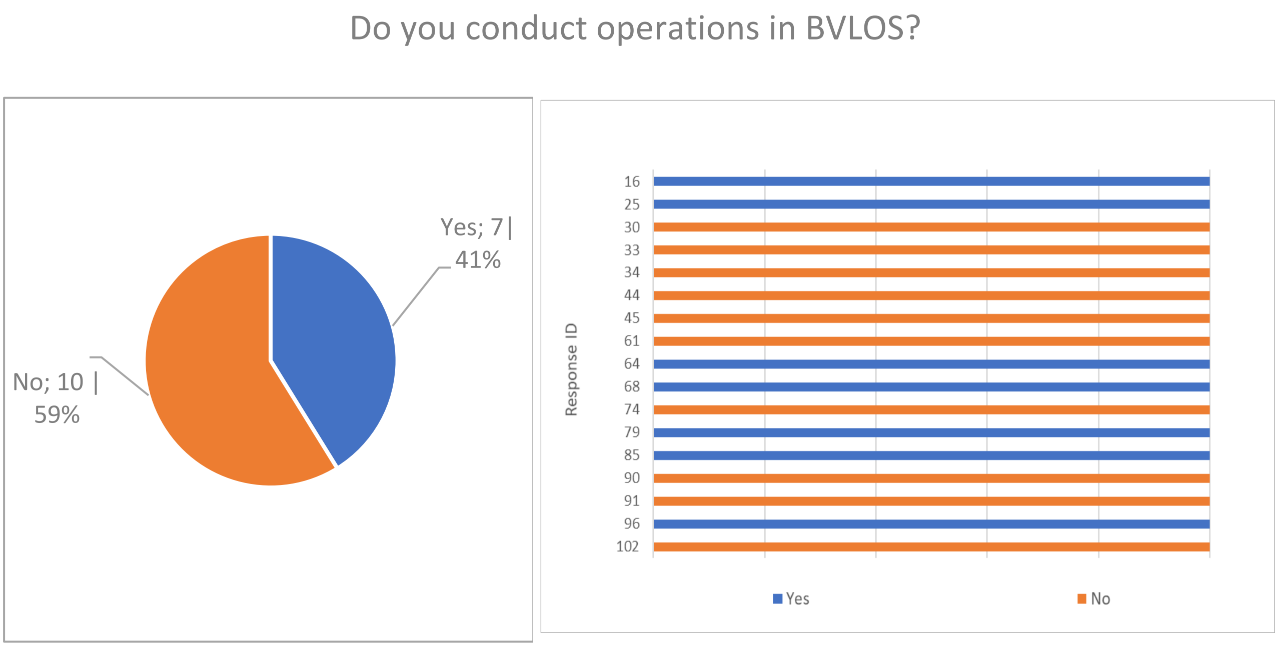


Figure 5-6 Respondents that conduct drone operations in Beyond Visual Line Of Sight. The right-hand graph shows the answers given by each respondent.

5.3.1 Authorisation and fly procedures in emergency

In some cases (5), in the event of an emergency, airspace management and separation procedures are different, and several "exceptions" are observed:

- the flight must be authorised by the on-scene commander;
- Special procedures with airspace managers and the national rules for operational flying are being prepared;
- Request to issue a Notam (Notice to airmen);

- Flights performed as (light) STATE aircraft.

Typically during an emergency a Temporary Flight Restriction (TFR) is established and Command and Control Centre (CCC) manage the air space above the impacted area.

The majority of respondents stated that activation of UAV services, as all other response services, would come by a Command and Control Centre (CCC) through an availability 24hr/365 day, usually activation happen through telephone line.

Activation time varies between 5 minutes and 2 hours, depending on the broader protocol for activating different functions in an emergency. Mobilisation time depends on the distance to travel to reach the area affected.

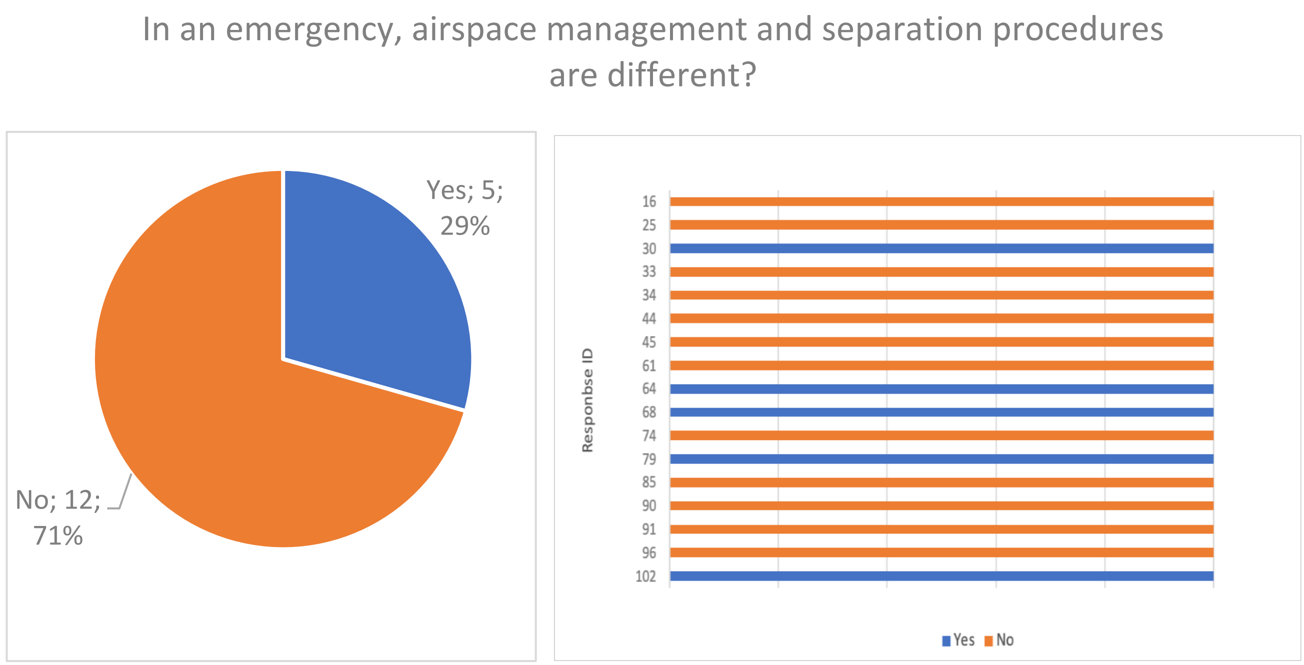


Figure 5-7 – Presence of procedures for the management of airspace in the event of an emergency

6 Inclusion of use of drones in a Contingency plan

Among interviewed, none stated that they consider the use of drones in their Contingency Plan (CP). In some cases, they report the intention to include in CP this technology in the future and develop a drone strategy. The authors of this paper consider this crucial to allow the use of drone technology to be effective and of real support to an environmental emergency response.

12 respondents (74%) include the use of drones in occasional, periodic and International/Regional training/exercises, to test UAV providers response times, safety procedures and sensor capabilities (*Figure 6-1*).

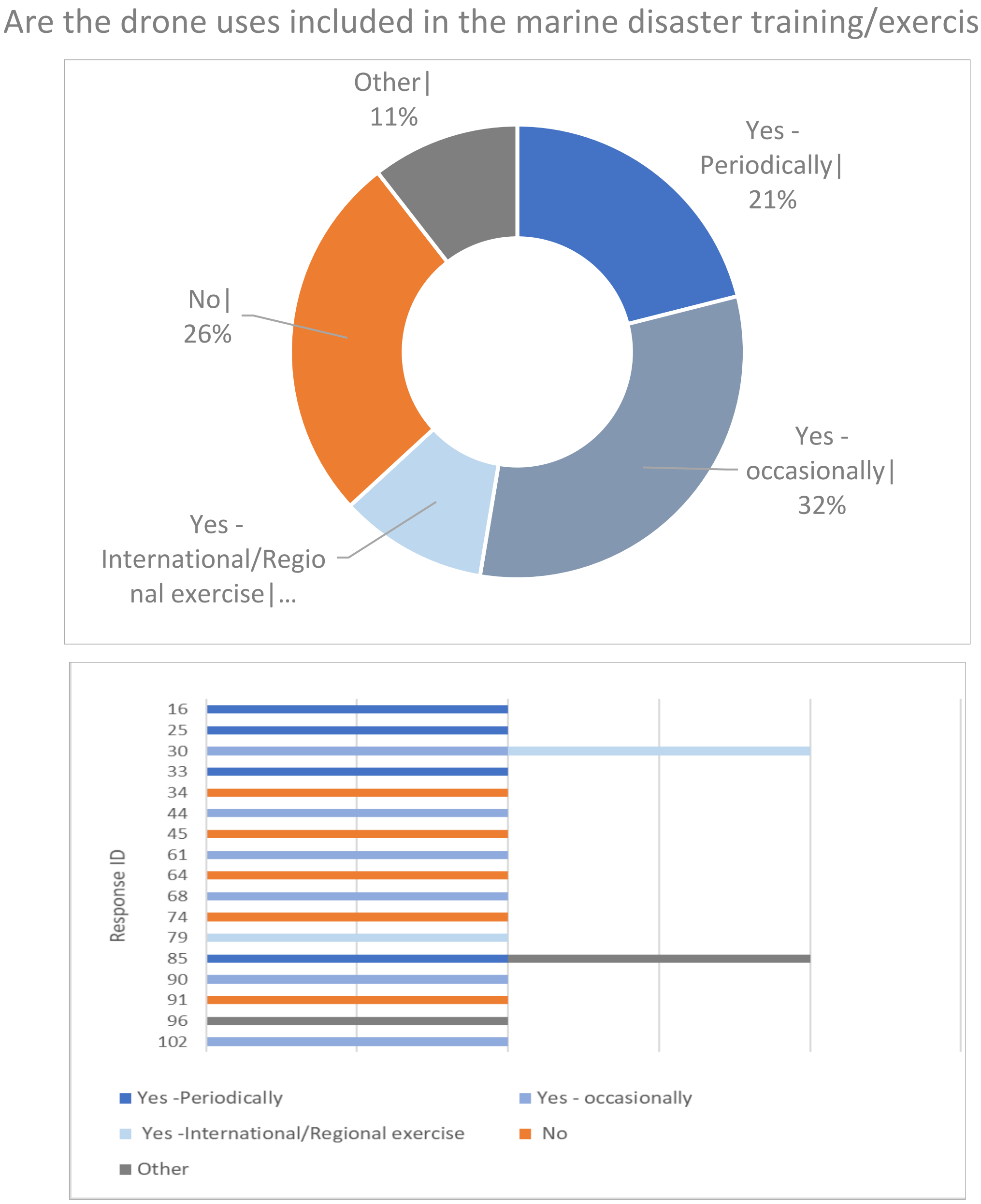


Figure 6-1 Respondents that include use of drones in marine disaster training/exercises

7 Main needs to improve the use of drones

Each respondent then indicate what are from their point of view main needs to improve the use of drones. These indications can be summarised as reported hereinafter.

Authorisations

- Bureaucracy for the use of official drones must be simplified;
- Standardisation of airspace management protocols;
- Difficulty of importing drones and having difficulty flying in countries where they are not registered.

Procedures

- Operational procedures and guidelines must be standardised and refined;
- Facilitate procedure for reserving portions of airspace for drones of public services involved in emergency;
- Establish the rules and create procedures for using drones in case of different scenarios;
- Improve during an emergency procedure for coordination with manned aviation (e.g. helicopters)

Technology development of drones

- Longer battery autonomy;
- Longer Range, developing hybrid drones;
- Light weight drones able to carry more than one sensor/multisensory.

Technology development of sensors.

- Improve knowledge about sensors capabilities, developing use of new sensors (thermal/Infrared);
- Development of radioactive sensors for CBRN (Chemical, Biological, Radiological, Nuclear) detection capability.

Technology development of software

- Development of capability to have live stream;
- Datalink able to process live data feed at long distance (more than 100 km at sea);
- Integrate the output into the common operating picture of the oil spill management system;
- Reduce risks coming from starting and landing drones on a ship;
- Integrate with AI technologies working with UAV providers and AI companies in exercises for different scenario (shoreline, offshore).

Training of personnel

- Implement the use of automated BVLOS drones;
- Improve operational readiness for VLOS drones by continued education for personnel;
- Improve use-cases and expand the use of drones as a daily operational tool.

8 Conclusions and summary of results

The survey "Current equipment, practice, needs and experiences in terms of use of drones in coastal/marine pollution response" made it possible to verify that the use of drones in coastal/marine environmental emergencies is at an early stage of development. At present, the enormous potential of the systematic use of this technology is appreciated, but at the same time gaps are clearly evident and topics where challenges need to be focused have been identified.

Seventeen (17) institutions, mainly European, responded to the survey. Representatives of all categories addressed by the questionnaire responded, namely: 5 European Maritime Authorities; 5 Private Entities on oil spill response; 4 European Civil Protections organisations and 3 European Port Authorities. This provided a broad picture of the current use of drones in environmental emergencies.

It is interesting to note that the institutions contacted have two possible approaches to managing the drone fleet:

1. the competent authority establishes a branch (UAS service) with the task of acquiring a fleet of drones, with appropriate sensors and software, training personnel and distributing the equipment throughout the territory;
2. the management of the fleet of drones is entrusted to one or more private companies (UAV providers), which are activated in the event of an environmental emergency.

The first option is mainly considered by organisations whose main task is aerial surveillance (e.g. fire brigades); the second is mainly considered by organisations operating at a global or European level (EMSA, OSRL, ITOPF).

Most of the institutions used drones in incidents involving oil (mainly) or HNS spills. Drones are used mainly in the following scenarios:

- surveillance and monitoring. Forest fire development, flood spread, position and condition of the vessel/cargo in distress, locating/guiding of response teams;
- measurement and quantification. Measurement of areas affected by pollution; volume of debris or mounds of soil to be removed; sulphur and other gases and finally wildlife measures;
- supporting marine pollution response. Guiding the ship to support the tactical response of anti-pollution vessels equipped with oil recovery tools (oil booms, skimmers, dispersants); monitoring the polluted areas; mapping the extent of the oil pollution;
- searching for missing persons.

- survey of coastal areas. Spreading and documentation of oil spills; identification of coastal areas affected by pollution; survey at sea, on the coast and in ports for oil or solid pollutants (coal, litter, garbage)

The most commonly used drones are rotary - wing (multi-rotor) drones; in some case fixed-wing drones. The majority of drones reported fell into the category of "Small Drones", i.e. those weighing less than 20 kg.

The survey points out that main limitations in the use of drones are:

- weather conditions: wind speed, rain, temperature and visibility;
- battery autonomy, especially in the case of "Small Drones";
- distance that can be covered, also affected if the type of flight is visual line-of-sight (VLOS);
- difficulties in taking off and landing from ships.

RGB (Red, Green and Blue) and thermal sensors are the ones most commonly used. In most cases, sensors are used to detect an oil spill. Many of those interviewed emphasised the need to improve knowledge about sensors capabilities, in particular to highlight the presence of a pollutant at sea.

Respondents provided information on software used in real time, during the flight of the drone as well as to process the data collected. The software can be proprietary or open source. It is pointed out that data management needs improvement, in particular on:

- Development of capability to have live stream;
- Datalink able to process live data feed at long distance (e.g. more than 100 km at sea);
- Integration the output into the common operating picture of the oil spill management system;
- Reducing risks coming from starting and landing drones on a ship;
- Integration with AI technologies working with UAV providers and AI companies in exercises for different scenario (shoreline, offshore).

The survey revealed that there is no common approach among respondents in the administrative procedures for obtaining drone and pilot certifications as well as for flight authorisations.

The Regulation of drone flights is an ever-evolving discipline that seeks to follow the rapid technological evolution of UAS. Three different aspects can be considered in order to understand how this discipline is evolving:

- risk assessment;
- certification requirements;
- authorization and flight procedures.

These aspects are summarised in the Annex II Drones fly regulations. The analysis of the responses highlighted the need to tackle following challenges:

- Bureaucracy for the use of official drones must be simplified;
- Standardisation of airspace management protocols;
- Difficulty of importing drones and having difficulty flying in countries where they are not registered.
- Operational procedures and guidelines must be standardised and refined;
- Facilitate procedure for reserving portions of airspace for drones of public services involved in emergency;
- Establishment of rules and creation of procedures for using drones in case of different scenarios;
- Improvement of procedure, during an emergency, for coordination with manned aviation (e.g. helicopters).

It is interesting to observe that none of respondents consider the use of drones in their Contingency Plan (CP). In some cases, they report the intention to include in CP this technology in the future and develop a drone strategy. In the authors' opinion, it is necessary to promote the inclusion of drone use in a CP; this could allow to improve the response capacity in order to: facilitate the inspection of remote areas; develop synergies and the exchange of information between authorities; inform and reassure the public about the development of an emergency response.

Survey highlight a series of gaps and challenges related to several topics: administrative procedures to obtain certifications as well as flight authorisations; technology development of drones, sensors and software; inclusion of use of drones in Contingency Plan and training/Exercises. All these aspects emerge from this survey and from the bibliographic research conducted in Task 5.1"*Preliminary bibliographic research on the Best Available Technologies for the use of drones in maritime emergency response surveys*". It represents the basic knowledge needed to carry out field trials (tasks 5.3 and 5.4) and to implement the guidelines "*Best Available Technologies in the use of UAS to carry out surveys in emergency in response*" (task 5.5).

I. Annex I Questionnaire

Current equipment, practices, needs and experiences in terms of use of drones in coastal/marine pollution response

<u>Section I - YOUR INSTITUTION</u>

<u>Information about the compiler and the Institution</u>

Name: Surname:

Email: Phone:

Position:

Institution:

Address:

Country:

Website:

<u>Section II - YOUR OPERATIONS</u>

1. What types of drones do you usually use? <u>(multiple answers/choices possible)</u>
   - Fixed wing\brand ______________________
   - Multirotor\brand ______________________
   - VTOL (Vertical Take-off and Landing)\brand ______________________
   - Other, please specify ______________________

2. Which sensors are used in your drone(s)? Please, specify the target(s) of their use (i.e., oil patches, injured fauna, …) <u>(multiple answers/choices possible)</u>
   - RGB\model\use ______________________
   - Termic\ model\use ______________________
   - Multispectral\ model\use ______________________
   - LiDAR\model\use ______________________
   - Other, please specify: ______________________

3. What are the main applications of your drones? <u>(multiple answers/choices possible)</u>
   - Surveillance and monitoring of fire/floods/other. Please, specify: ___________________
   - Searches for missing persons. Please, specify: ___________________
   - Measurements/quantifications/estimations. Please, specify: ___________________

- Photogrammetry. Please, specify: _________________
- Survey of coastal areas affected by pollution (SCAT). Please, specify: _________________
- Assistance/support of marine pollution response operations (e.g., deploying booms). Please, specify: _______________
- Other, please specify: ____________________

4. Have you experienced any use of drones in oil or HNS spill accident?
   - Yes
   - No
   - If so, please, indicate name of incident and pollutant(s): ____________________
   - Report the bibliographic reference and/or a link, if applicable: ____________________

5. What operational limits have you encountered on the field? <u>(multiple answers possible)</u>
   - Weather conditions. Please, specify e.g., wind speed (km/h), visibility range (m), etc.):____________________
   - Battery autonomy. Please, specify max duration in minutes: ____________________
   - Flight on sight. Please, specify distance in meters: ____________________
   - Other, please specify: ____________________

6. When conducting an operation, do you adopt a risk analysis approach ?
   - Yes
   - No
   - If so, Please, specify:
     - applying SORA methodology (Specific Operation Risk Assessment) _______________
     - applying other methodology ____________________

7. Do you conduct operations in Beyond Visual Line Of Sight (BVLOS)?
   - Yes
   - No
   - If so, Please, specify:
     - Advantages ____________________
     - Disadvantages ____________________

8. Does your organization adopt standardised technical procedures on UAS assets and sensors (e.g., by using an operation manual)?
   - Yes
   - No
   - If so, Please, specify: ____________________

9. What are the procedures for airspace management and segregation to follow before an operation?
   - Request to National Aviation Authority/Wait for authorization/Operation
   - Information to National Aviation Authority/Operation/
   - Other, please specify: ____________________

10. During an emergency, procedures for airspace management and segregation are different?
    - Yes
    - No
    - If so, Please, specify: ____________________

11. What are your needs and how do you plan to improve your use of drones in the future?
    - Please, describe briefly: ____________________

Section III - YOUR DATA

12. Which method is applied in the processing data collected by the drones? (multiple answers possible)
    - In Real time. With what software? ____________________
    - Post processing. With what software? ____________________

13. Does data processing include the transmission to the crisis management center and/or to maritime/port authorities?
    - Yes
    - No
    - If so, Please, specify: ____________________

14. Do you share your data?
    - Yes
    - No
    - If so, with what tool and with whom? Please, specify: ____________________

15. Do your procedures involve a systematic data storage and management?
    - Yes
    - No
    - If so, Please, specify: ____________________

16. Do you use artificial intelligence machine learning algorithm for pollutants recognition? With what softwares?
    - Yes.
    - No
    - If so, Please, specify: ____________________

17. Is the recognition of the pollutant/pollution type possible using your drones (we refer both HC and HNS)?
    - Yes.
    - No
    - If so, Please, specify: ____________________

Section IV - YOUR DRONES PROCEDURES AND LICENCES

18. What procedures are adopted for drone registration?
    - National registry for the operators and by issuing a QR code for drones recognition
    - Internal registry
    - Other, please specify: ____________________

19. How is the use of drones regulated in your institution?
    - Drone operators are registered under European EASA (European Union Aviation Safety Agency) regulations

- Through internal standardise procedures that regulates the pilot training and drone management
- Other, please specify: ____________________

20. What certifications are required by your National Aviation Authority?
    - For Pilots. Please, specify: ____________________
    - For Drones. Please, specify: ____________________
    - No certifications required. Please, specify: ____________________

21. Is there a specific Working Group that deals with the management of drones and personnel involved in their use?
    - Please, briefly describe structure and organizational chart: ____________________

22. What alerting protocols do you adopt?
    - Please, briefly describe how activation takes place and who are activated: ____________________

23. What is your response time?
    - Please, briefly describe the timing and logistical organization: ____________________

24. Is the fleet available at local or at national level?
    - National level
    - Local level with a coordination at national (or central) level
    - Local level without any central (or national) coordination
    - Other, please specify: ____________________

25. What are your national regulatory limits for fleet use in emergency?
    - Please, briefly describe: ____________________

26. Are there any exceptions to the regulatory limits, that you have taken in advantage?
    - Yes
    - No
    - If so, Please, specify: ____________________

27. Does your national/regional emergency response plan include drone(s) deployment?
   - ○ Yes
   - ○ No
   - ○ Other, please specify: ____________________

28. Are the drones uses considered in the marine disaster training/exercises?
   - ○ Yes periodic ____________________
   - ○ Yes occasionally ____________________
   - ○ Yes transboundary ____________________
   - ○ No
   - ○ Other, please specify: ____________________

Section V – MORE INFORMATIONS

29. What other authority/contact person would you recommend for providing us with further details concerning the use of drones in your Country? (please, provide us the contact details)
   - ○ Name _________________
   - ○ Authority _________________
   - ○ Email _________________
   - ○ Telephone _________________

30. Would you agree to being contacted by ISPRA for a short interview?
   - ○ Yes
   - ○ No

31. Any other information you would like to share with us:

____

____

II. Annex II Drones fly regulations

Over the past 15 years, much effort has gone into preparing legislation to regulate unmanned aircraft systems (UAS). Initially, since the mid-2000s, attention has been focused on the military use of this technology. However, the use of drones in the civil sector has expanded significantly (*Pagallo et al., 2020*). When considering the regulation of UAS on a global scale, it is important to provide a brief background on the International Civil Aviation Organisation ICAO (**www.icao.int**). ICAO was established under the Chicago Convention of 1944 and is now governed by 193 national governments to support and manage transport issues. During ICAO's second informal meeting on UAS (January 2007), it was concluded that ICAO should act as a focal point for global interoperability and harmonisation in terms of (1) developing a regulatory approach, (2) coordinating the development of UAS Standards and Recommended Practices (SARPs), (3) contributing to the development of technical specifications by other bodies, and (4) identifying reporting requirements for UAS activities. However, UAS activity is constantly increasing and therefore UAS operators are a rapidly growing group of airspace users who require larger volumes of airspace for their operations. From this perspective, the 40th ICAO Assembly in September 2019 discussed the safe and efficient integration of UAS into the global airspace. As a result, it highlighted the importance of reviewing and improving the operational framework for UAS in technical, economic and legal areas (https://www.iata.org). From a regulatory perspective, efforts by national and international legislators have focused mainly on safety and security issues to improve current air traffic management systems to ensure that UAS can progressively share this airspace with conventional aircraft without risk. In Europe, UAS regulations have changed significantly over the past few years, with major differences in flight permit requirements evolving with the emerging technology, and UAS operations are therefore constantly evolving with respect to the needs and laws of EU member states. From this perspective, some national and international EU aviation authorities and organisations have started to update and modernise the first wave of regulations adopted in 2017, focusing on: (a) keeping pace with recent technological developments and new UAS capabilities, (b) trying to meet user requirements, and (c) increasing the level of safety in the conduct of flight operations. In this context, a recent outcome of the modernisation is the entry into force of new EU regulations on drones as of 1 January 2021, which is seen as a positive step towards the harmonisation of UAS rules in Europe (Pagallo *et al.*, 2020).

EASA drones regulations

In the European Union (EU), Regulation (EU) 2018/1139 establishes a common set of rules in the field of civil aviation. The new regulation, which repeals the previous Regulation (EU) 2008/216, reduces the powers and responsibilities of Member States and national authorities in the field of drone operations and transfers most of the relevant regulatory powers to the European Commission and the European Aviation Safety Agency (EASA).

Regulation (EU) 2018/1139 thus establishes common rules in the field of civil aviation, the so-called 'new basic regulation'. For a better understanding of the state of UAS regulation in the EU, here is a brief overview of the state of the regulations and the key issues that were decided before the new EU regulations were adopted on 1 January 2021. (Alamouri *et al*., 2021).

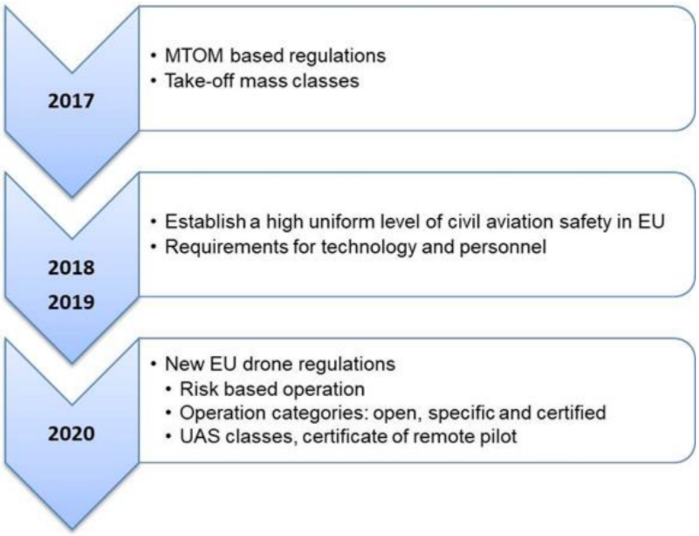


Figure I. Important updates on EU drone regulations from 2017 to 2020. From Alamouri et al., 2021

As of March 2017, the European Aviation Safety Agency EASA (www.easa.europa.eu) introduced the first major wave of regulations, which focused on air traffic management and navigation services. This wave of regulations classified UAS into different categories based on the maximum take-off mass MTOM allowed for UAS. A distinction was made between systems with MTOM < 5 kg, between 5-25 kg and over 25 kg, as the risk was considered to be significantly related to the potential and kinetic energy of UAS. In the same year, a new concept of basic regulation was proposed and discussed between the European Council, the European Commission and the European Parliament, to regulate all UAS regardless of their MTOM (EASA, 2017). Accordingly, standards for the operation of UAS and requirements for technology and personnel, including the involvement of remote pilots (EASA), will be adopted at EU level in 2019.

At a later stage, in December 2020, EASA established the new UAS regulations, which introduce an in-depth overview of two main parts: the implementing regulations IR, (operations of UAS - EU Regulation 2019/947) and the delegated regulations DR, (technical requirements for the design and manufacture of UAS - EU Regulation 2019/945). The implementing regulations, which are the main focus of this document, provide detailed rules for the operation of UAS. They provide rules for personnel and organisations involved in such operations. In this context, and for a safe UAS operations, the IRs propose three categories of UAS operations based on the risk posed by the operation poses to third parties. The three categories of UAS operations are: open, specific and certified (*Figure II*).

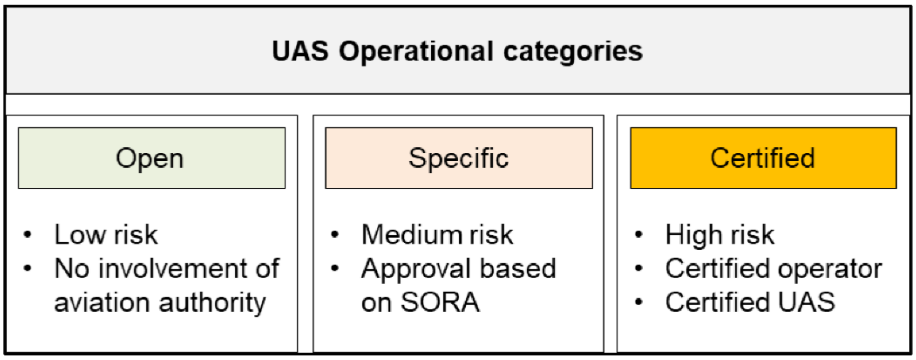


Figure II. UAS operational categories. From Alamouri et al., 2021

UAS'open' operational category

The open category is considered as low-risk for UAS activities. The main advantage id therefore the possibility to fly without an operating licence, which is required for other categories and requires some effort to obtain. According to Article 4 - IR EU 2019/947, "UAS operations are classified in the open category only if the following requirements are met (EASA):

- the UAS has a class defined in the EU RD 2019/945;
- the maximum take-off mass of the UAS must be less than 25 kg;
- the UAS operation is conducted in the VLOS line of sight and the UAS is kept at a safety distance of at least 1.5 km from populated areas, airports and sensitive areas and at least 100 m from infrastructure such as motorways, hospitals, power plants, etc.;
- during an operation, UAS do not carry dangerous goods and do not drop any material;
- flight altitude is limited to 120 m above the ground.

From an operational point of view, the new rules divide the open category into three sub-categories: A1, A2 and A3, depending on the operational distance from people, with different restrictions on UAS weight and pilot certification. Classification is based on the UAS Class Identification, which describes the technical characteristics of the UAS and the operational requirements to be considered during operations. According to this classification, UAS are divided into seven classes, C0 to C6 (*Table I*).

In sub-category A1, UAS operators are not required to obtain an operating licence or submit an operating declaration before commencing operations when flying C0 class. In addition, A1 UAS operations may not be conducted over open-air gatherings of people. On the other hand, remote operation, flying in C1 class, requires remote pilots to be familiar with the UAS user manual and to have completed an online training course. The main difference between C0 and C1 is the MTOM, which is a maximum of 250g compared to 900g.

For sub-category A2, remote pilots must be familiar with the UAS user manual and hold a remote pilot certificate. In addition, UAS operations must always be conducted above and at a safe distance from bystanders. A high level of safety, privacy and environmental protection is essential.

Table I UAS classes (C0-C6) according to technical characteristics and operational requirements. Source: EU Delegated Regulation 2020/1058. From Alamouri et al., 2021

Subcategory	Class	MTOM Incl. Payload	Velocity	Max. AGL	Proof of Knowledge
A1 Fly over people	C0	<250 g	max 19 m/s	120 m	Familiar with operation instructions
	C1	<900 g	max 19 m/s	120 m	Familiar with operation instructions Online training and test
A2 Fly close to people	C2	<4 kg	-	120 m	Familiar with operation instructions Online training and test Certificate "proof of knowledge" (according to German rules)
A3 Fly far from people	C3	<25 kg <Diameter 3m	-	120 m	Familiar with operation instructions Online training and test
	C4	<25 kg	-	-	
-	C5	No max. MTOM defined	-	-	
-	C6		max 50 m/s	-	

Finally, for flights in subcategory A3 - flying away from people - remote pilots must also be familiar with the UAS user manual. However, UAS operations must take place in an area where the remote pilot can reasonably expect that no bystander will be endangered within the area in which the UAS is being used. Within this scenario, UAS pilots must maintain a horizontal safety distance from public services and residential, industrial or recreational areas.

The technical characteristics and operational requirements did not define a maximum Above Ground Level (AGL) for classes C4, C5 and C6, but mentioned that "during flight, provide the remote pilot must be provided with clear and concise information on the height of the UAS above the surface or take-off point" (EASA).

However, if at least one of the above requirements is not met, the operation is no longer in the open category. For example, when a UAS is operated beyond visual line of sight. Another example is the use of a 15 kg UAS near a gathering of people; in this case, within A2, this is limited to a maximum MTOM of 4 kg.

UAS 'specific' operational category

If, for some reason, one or more of the standards of the open category cannot be met, the specific category comes into force, as a medium risk can be expected. From this point of view, the specific category has established rules for UAS operations that present a higher risk during flight, for which a thorough assessment should be carried out to indicate what measures are necessary to make the operation as safe as possible. In such cases, an operating licence is required or a prior declaration must be made. To obtain an operating licence, a risk assessment must be carried out and reviewed by the competent authority. This is much more extensive than a simple declaration. According to IR EU 2019/947 - Article 11, an operational risk assessment includes, but is not limited to: "(a) description of the UAS operation, (b) proposal to maintain operational safety, (c) identification of ground and airborne hazards, e.g. uninvolved persons, objects, etc., (d) risk mitigation measures, (e) technical characteristics of the UAS, and (f) personnel competencies".

UAS 'certified' operational category

According to IR EU 2019/947 - Article 6, UAS operations are considered to be in the category of certified operations if the UAS is certified in accordance with Article 40 of DR EU 2019/945. UAS certification covers the design, manufacture and maintenance of the UAS. It is definitely required if the UAS meets one of the following conditions: (a) the size of the UAS is at least 3 m and it is designed for use on assemblies of people, (b) it is designed for the transport of people, and (c) it is designed for the transport of dangerous goods and requires a high level of robustness to mitigate risks to third parties in the event of an accident. The certified category includes, in addition to the certification of the UAS itself, the certification of the entire operation, i.e. the operating company, remote pilots, UAS maintenance, Continuing Airworthiness Management Organisation (CAMO) maintenance oversight.

Impact of the new regulations on the operation of UAS

The new UAS regulations in Europe are seen as an important step towards the harmonisation of rules and better adaptation of UAS operations. Unfortunately, the regulations are still under development and may be subject to continuous change, which will lead to instability in the legal framework for the operation of UASs on the one hand, and to confusion in the implementation of administrative and bureaucratic processes on the other. As an example, the registration of UAS operators and certified UAS procedures are reported below. According to Article 14 of the EU Drone Regulation, EU Member States shall establish a system for the registration of UAS and users for "UAS whose design is subject to certification and for UAS operators whose operation may pose a risk to safety, security, privacy and the protection of personal data or the environment". It follows from this statement that the registration process depends on the design and risks of the UAS, which are the main factors considered when defining the operating categories of UAS. This means that the intended registration system depends, among other things, on the category of operation in which the UAS is to be used. For example, according to Article 14, when flying in the open category, registration is required if the UAS meets one of the following conditions: (a) MTOM is 250 g or more, (b) UAS is integrated with a payload such as a sensor that could be used to collect personal data. On the other hand, when it comes to flying in the specific category, the registration of UAS is mandatory. To this end, the rules have clearly addressed who should register and when, but the practical implementation of this registration system remains a key challenge. This is due to the fact that each EU Member State has to create an online platform for the registration process, which does not yet exist in many EU countries. As a result, interoperability, mutual access and exchange of registration information could be compromised.

Another issue to be considered is the protection of personal data. As part of the registration process, personal information such as full name, date of birth, addresses of UAS operators, etc., has to be provided. In many EU countries, data protection laws are strictly enforced and therefore data interoperability and mutual access at EU level is currently unrealistic or at least requires further efforts to develop adequate registration systems that allow data exchange with a high level of security. This, of course, requires databases to document, manage and analyse the data collected. This will require close cooperation between the experts, operators and managers involved to define the parameters and issues that need to be addressed in the design of the database.

Limits of visibility and range

The main criteria of most UAS regulations revolve around the limits of UAS operations and relate to flight mission restrictions (Stoecker *et al.*, 2017). This refers to visibility and range restrictions in terms of height levels and horizontal distances allowed during UAS operations; i.e. the operation of UAS under visual/beyond line-of-sight (VLOS/BVLOS) conditions (Figure III). According to the latest EU regulations, UAS operations classified in the open category are only allowed under VLOS conditions with a remote pilot. Within this scenario, pilots must maintain continuous visual contact with the UAS. VLOS is specifically interpreted as up to 500 m horizontally and 120 m vertically (Davies et al., 2018), but for large and highly visible systems (conspicuous paint, position lights), altitudes up to 1000 or even 1500 m and a radius of 1.5 km around the operator have been accepted as VLOS (Altstadter, 2015 and 2018; Platis *et al*., 2015). In practice, UAS are sometimes used beyond the above distance limits as Extended Line of Sight (EVLOS). In EVLOS-based operations, pilots require additional observers or remote pilots to maintain continuous visual contact with the UAS. Under these conditions, and as far as the economic feasibility of UAS-based applications is concerned, both VLOS and EVLOS scenarios are not the best option for the commercial UAS sector, where flight missions beyond line-of-sight (BVLOS) are extremely valuable due to the fact that they allow UAS to cover long distances and large areas beyond the visual range of the remote pilot; especially when obstacles such as buildings and mountains may be encountered during VLOS flight missions.

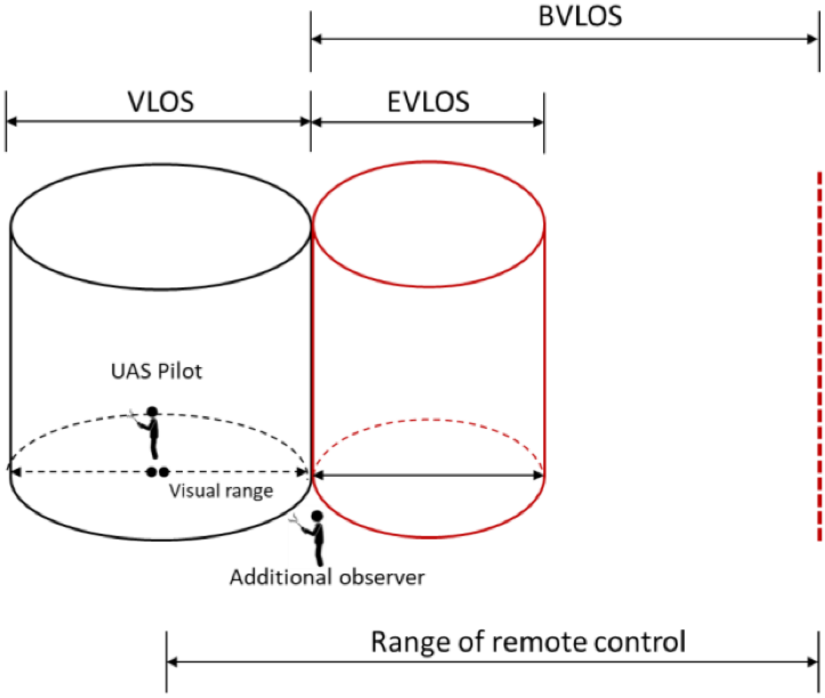


Figure III. Illustration of VLOS and BVLOS - Source Stoecker et al., 2017

A better understanding of the potential of BVLOS can be achieved by comparing typical applications for VLOS and BVLOS (*Figure* IV). In the UAS markets, it can be observed that manufacturers/users are adopting the BVLOS technology to enhance UAS functionality and open up new business opportunities, e.g. first responders, package delivery (already tested by Amazon), inspections, atmospheric science, etc. On the other hand, the benefits of using drones in BVLOS mode are intuitable in the case of intervention during a maritime environmental emergency.

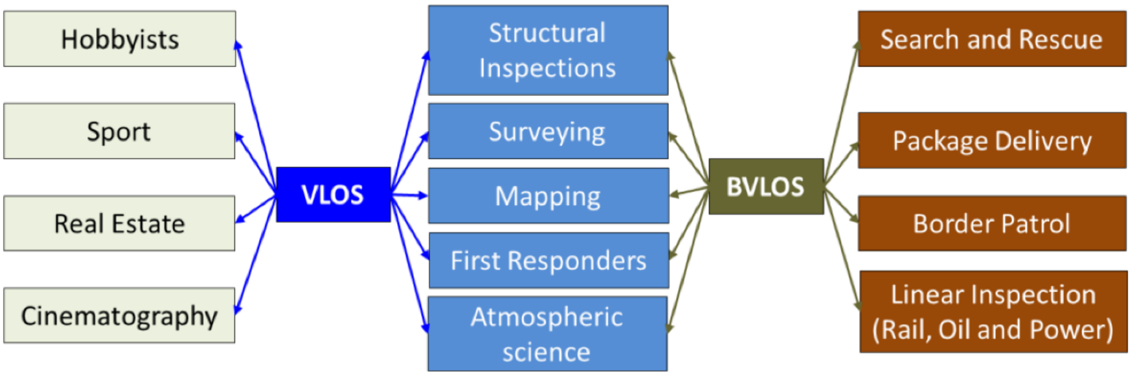


Figure IV. Typical applications based on VLOS and BVLOS, modified from Davies et al., 2018.

Operational Risk Assessment

The risk assessment of UAS operations reflects the level of safety associated with the UAS during the operational period. A reflection of the level of safety must make safety risks measurable so that risks can be assessed and controlled. The new EU drone regulations have adopted risk assessment as a fundamental issue required for flights in the 'specific' and 'certified' categories (Clothier *et al*., 2014). The collection and characterisation of risks that may occur during UAS operations must describe both the environment in which the UAS is used and the nature of the risk, such as ground risk (e.g. damage to third parties on the ground) or airborne risk (e.g. flying in prohibited areas). It requires sufficient information, data and resources, which are not always available and/or outdated. Currently, the new regulations indicate that the operational risk assessment can be carried out on the basis of SORA (Specific Operations Risk Assessment) developed by the Joint Unmanned Systems Regulatory Authority (EASA). The paradigm implemented in SORA is to minimise the impact of a possible drone risk, i.e. damage to third parties on the ground or in the air, but this classification is only made on the basis of general rules and is estimated by the characteristics of the type of UAS used for the mission, the type of airspace and the population of the area in which it operates.

The key elements of the SORA classification are 'risk' and 'robustness'. Risk' is defined in SAE ARP 4754A/EUROCAE ED-79A as 'the combination of the frequency (probability) of an event and the severity associated with it'. The term risk is applied only to damaging events. "Robustness defines the requirements for the operation of UAS for different risk classes. The level of robustness can be low, medium or high. Operations with higher risks require higher levels of robustness.

For a SORA classification, the first step is to define the concept of operations (ConOps), including technical details, missions, checklists, and safety aspects. The technical details include information on the UAS (dimensions, MTOM, loads, subsystems such as hydraulic systems, sensors), performance characteristics (maximum flight altitude, rate of climb and descent, maximum airspeed, precipitation, turbulence and other parameters), propulsion system (type and number of engines, engine power, maximum current of the electrical system), control system (flaps, pitch, elevator, rudder), and sensors, control system (flaps, pitch, elevator, aileron), sensors for operation, payload (power supply, effect on flight parameters), navigation, autopilot, flight control, ground control station, detection and avoidance system, compliance with geo-fencing, take-off and landing equipment and implemented functions such as flight termination system or automatic recovery system.

Risk is divided into 'ground risk' and 'air risk'. The Ground Risk Class (GRC) defines the risk not people not involved on the ground in the event of loss of control of the UAS. According to SORA, there are five different scenarios that determine the ground risk:

- VLOS or BVLOS in controlled areas (such as military zones);
- VLOS in sparsely populated areas;
- BVLOS in sparsely populated areas;
- VLOS in populated areas;
- BVLOS in populated areas.

Therefore, the location and operating area, the so-called operating volume, must be well defined in advance. Airspeed, mass and wingspan are also important. The ground risk class can be determined on the basis of technical specifications (*Table II)*.

Table II. Determination of the ground risk class according to SORA. This table is taken from the JARUS Guidelines on Risk Assessment of Specific Operations (SORA), 2019. Source Alamouri et al., 2021 DA TRADURRE IN INGLESE

Classe di rischio terrestre UAS intrinseco				
Dimensione massima delle caratteristiche UAS	1 metri	3 metri	8 metri	>8 m
Tipica energia cinetica attesa	<700 J	<34 kJ	<1084 kJ	>1084 kJ
Scenari operativi				
VLOS/BVLOS su area terrestre controllata	1	2	3	4
VLOS in ambiente scarsamente popolato	2	3	4	5
BVLOS in ambiente scarsamente popolato	3	4	5	6
VLOS in ambiente popolato	4	5	6	8
BVLOS in ambiente popolato	5	6	8	10
VLOS sull'assembramento di persone	7			
BVLOS sul raduno di persone	8			

In summary, the new EU regulations provide detailed guidance on how to define operations, identify risks and analyse situations before deploying UAS. Extensive documentation is required, depending on the risk and robustness of the planned operation, the UAS and the operator. Safety measures include technical documentation and controls, as well as crew training and situational analysis of the operation. For complex missions, the move towards standardised procedures and documentation, such as those used in manned aviation, helps to obtain flight permissions from the relevant authorities.

In order to ensure certainty, harmonisation and clarification of the rules for drones, the new 2018 EU Regulation establishes a centralised, top-down framework, delegating key regulatory powers to both the European Commission and the European Aviation Safety Agency (EASA). The new basic regulation covers all drones, regardless of their size and weight. Member states can set specific national standards for UAS by granting specific exemptions from certain European requirements or by amending the Commission's delegated and implementing acts in accordance with Articles 56(8) and 71 of the regulation (Bassi, 2019).

Unfortunately, there is a clear heterogeneity between national regulations, despite the common goal of ensuring security and protecting the privacy of citizens and property. As a result, UAS service providers need to obtain pilot licences and special operating permits when deploying UAS in different countries (Stöcker *et al*., 2017).

In summary, the new EU regulations provide detailed guidance on how to define operations, identify risks and analyse situations before deploying UAS. Extensive documentation is required, depending on the risk and robustness of the planned operation, the UAS and the operator. Safety measures include technical documentation and controls, as well as crew training and situational analysis of the operation. For complex missions, the move towards standardised procedures and documentation such as those used in manned aviation, helps to obtain flight permits from the relevant authorities.

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