DR 8.3: Guidelines for Robot-Assisted Disaster Response

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Guidelines constitute a basis for setting a homogeneous behavior and modus operandi; to this purpose, guidelines do not represent mandatory procedures, but they tend to incorporate the best practices, that is the distillate of available knowledge and best operating methods in the literature to perform specific activities. Designing guidelines for Robot-Assisted Disaster Response, taking into consideration operational procedures already present in a emergency response system, is a great challenge. The work presented here is the achievement of this goal by TRADR end users after working groups stating what robots, specifically UAVs, could perform in an emergency or monitoring activity under specific rules and guidelines.

Executive Summary

This report presents the guidelines for Robot-Assisted in disaster response, taking into consideration past EU project (e.g. NIFTi) when robots, for the first time, were deployed in specific scenarios. Actually, the Italian Fire Corps is going to regulate robots employment in specific cases from monitoring, surveillance, assessment operations to emergency situations with proper *modus operandi*. Considering levels of risk first responders have to face, there are cases where a specific emergency contingency plan is necessary and where robots could fit into specific positions, roles in order to give the Incident Command System (ICS) a wider knowledge of the scenario and risks on it. Robots, in short, are an added value, a further capacity, like dogs in a search scenario, that can report hidden or future hazards in a damaged scenario to an established Command and Control chain. Robots could represent a further tool to prevent risks in first responders, but also a way to plan strategy when, for instance, they can monitor and survey a sensitive area subjected to natural risks, like floods, landslide, etc…

The purpose of a Robot-Assisted Disaster Response guidelines, besides handling procedures, way to communicate an on-going situation, to report data and others is, above all, to build a joint team composed of humans and robots in compliance with the Chain of Command and Control established in the aftermath of a disaster.

Role of Guidelines for Robot-Assisted Disaster Response in TRADR

The experiences on the field performed during the period of NIFti EU project, the activity in an earthquake scenario (post earthquake damage assessment) in Mirandola, Modena province (Italy, 2012) and joint exercises held, for instance, in Calambrone, Pisa (Italy, 2014) gave TRADR end-users a great opportunity to test limitations and functionality of robots deployed.

Furthermore, activities at home using robots in training and demos helped to draw a draft guidelines. This to give some clarity and a role to robots, that in TRADR project are going to cover more and more specific positions in a defined Command and Control structure and a specific aid in a decision making process.

In the following paragraphs, specific scenarios have been taken into account where robots can fit in emergency scenarios. Their roles could be as support (Surveillance, Reconnaissance and Monitoring) or crucial (Search). But, in any cases, they represent an useful instrument for data reporting. A more detailed document is presented as annex.

1 Introduction

1.1 Field of Application, objectives

The field of application of these Guidelines is mainly focused in activities performed by first responders using robots, principally drones (UAVs). These are:

- Search;

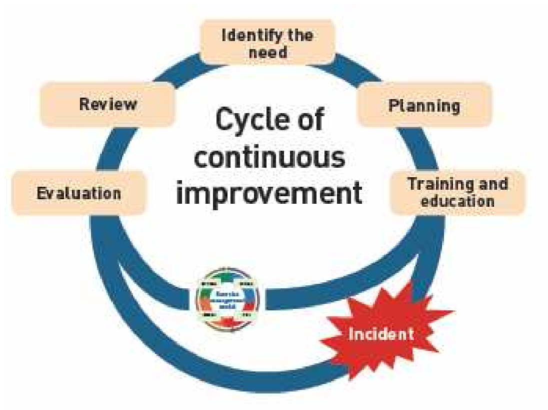
- Surveillance, Reconnaissance and Monitoring;

- Video/Image documentation for forensic activity, training, Media;

- Integration with existing communication (e.g. mobile ACP – Advanced Command Post), existing GIS software and data reporting system.

Scenarios like search of missing people, floods, earthquake, fire-forest and CBRN- Hazmat emergency were taken into consideration and were thought to be suitable to deploy robots together with first responders.

These Guidelines aim to discipline roles of robots in scenarios before mentioned. A scenario changes and never resembles to another, that’s why these guidelines may suffer from periodic amendments according the cycle below.



The diagram before represents a planning cycle where our guidelines are used. It begins at the top by identifying a need to plan; for example, a community is located on a floodplain and therefore a risk exists.

The community plan for the hazard and adopt our guidelines, conduct training of emergency services and deliver community education. On the outer circle the community is impacted by the hazard and respond to the incident: the response is evaluated and plans, policies and procedures, guidelines reviewed accordingly. Exercises and tests are essential and vital, in peacetime, and simulated events are conducted and substituted for a real event.

These Guidelines used in real events and tested in simulated scenarios, start from needs to be identified among first responder and aim to facilitate and overcome specific gaps in disaster management.

1.2 Review and Update

These Guidelines are subjected to periodic review and update in case of:

- Changing in end users Organizations with a substantial impact on safety and health of operators;

- Important changes in rescue techniques;

- Innovative precautions to mitigate risks;

- Severe injuries where the principal origin derives from lacks in the safety management system adopted.

1.3 Policy on health and safety at work

Health and safety safeguard of first responders represents a strategic commitment for end users organizations and is also a fundamental necessity to perform rescue. In compliance with this principle, Guidelines here presented have to main goal to safeguard operators safety and conclude rescue operations, in partnership with robots, successfully.

2 Activity description

UAVs and UGVs could give a good support in preparation of rescuing people or other event. Static and haz-mat assessment to define site access for first responders in the early stages of a scenario evaluation can be performed by robots. This would help operators to avoid exposures to possible hazards due to further collapses in buildings already damaged.

Without robots, first responders could get exposed to risks. Robots would offer the chance to investigate parts not easily accessible for height and/or other unstable, risky conditions. Robots would avoid using means much more challenging and sometimes impossible to deploy. Use of drones (UAVs) is also important to have an integral vision and a better overview from above of damaged areas and surrounding conditions. This would avoid deploying helicopters that can modify the emergency scenario and provoking further collapses in buildings that have precarious stability conditions.

Use of drones would also limit operational costs during rescue.

(Another use could be to follow and track dogs during a search when the conditions do not allow handlers to follow their dogs during search operations).

UGVs, despite having a considerable volume, could offer great opportunity of use especially to assess potentially hazardous areas and not immediately accessible, for instance industrial facilities damaged. They are useful to define positions where hazardous materials are present, inspect collapsed sites, verify cracks without accessing into them directly. The possibility to apply chemical and radiological detectors make also robots undoubtedly a valuable aid in high residual risk conditions.

2.1 UAV and UGV. Robotic and Architecture system

UGVs made by BlueBotics, patent PCT/EP2011/060937 were used. Robots have a payload format mainly of a 3D laser sensor that has internally a 2D laser rotating, a room PT GREY LadyBug3 for spherical vision with a visual field of 360 °, an inertial platform IMU / GPS-X-sense MTIg, a sensor for locomotion and a sensor for the batteries. The robot, shown in Figure 2, combines an active and passive structure that allows to switch from an active control, for particularly complex situations such as climbing stairs, to a passive configuration which allows the robot to adapt the tracks (equipped with differential lock) and pinball to the ground. However, there are in study models of adaptive function to ensure autonomous behavior even in soils with very complex morphology. In fact, the robot is able to climb stairs with steps of 30 cm, 20 cm or with an inclination of 40°, is able to overcome a gap in the ground of 40 cm amplitude, can climb walls of 30 cm and other obstacles which make it one of the more flexible existing robots, in terms of adaptability to terrain difficult.

Last NIFTI architecture used two robotic operating systems: ROS and CAST. ROS (Robot Operating System) is commonly used by advanced robotic systems, because 'offers several features for basic low-level control, from the calculation of a path between two specified positions, from the construction of a 2D map to the integration of different robot components for the communication management. CAST is a system based on dislocated memory cells of work that allows you to manage the cognitive capabilities of the robot, such as the planning of what to do on the basis of various inputs and stimuli, functional maps that interpret 2D/3D maps metrics in terms of relationships as near or far above or below, or qualitative properties that do not require a spatial extent but a spatial relationship and the recognition of specific elements in the environment.

2.2 Operational capacity

In order to fulfill requirements during Robot-Assisted Disaster Response operations, features to match would be the followings:

- Easily to be deployed (not to long to boot);
- to be easily and safely carried or transported in a trail, van, aircraft;
- to resist in corrosive environments and jets from chemical compounds with different pH (at least in the points of contact with the terrain or with objects that the robot wants to pick and analyze);
- do not interfere with electromagnetic fields coming from other devices;
- resistance to maximum external temperature of 60 °C and smoke derived from fires;
- to operate in presence of water generated by water guns in our fire trucks (engines IP 65);
- to be easily decontaminated and degreased , so regular shapes and dimensions are required; (remember, a robot will be operating in areas soaked by sewage, bodily fluids from victims, chemical compounds or radioactive dusts)
- to operate and work in explosive atmosphere (robots intrinsically safer in explosive environment).

- Autonomy (in terms of time): 100 minutes in maximum power/energy consumption; maximum time to recharge batteries 45 minutes.

2.3 Competences and Abilities

UAVs and UGVs aid in making crucial decisions about resource allocation quickly. Emergency responders use UAVs instead of traditional aircraft in disaster recovery for several reasons, including their lower cost, reduced need for refueling, and their ability to stream night-vision or infrared footage to people in safer positions on the ground. UAVs also avoid operator fatigue, and can sustain flight for much longer periods of time.

The benefit of using UAVs is to have the capacity to enter environments that are unreachable or potentially hazardous to first responders. Additionally, there are being deployed to locate survivors and those in distress, and communicate their whereabouts responders on the ground or those coordinating emergency response

As for the specific field of applications presented before, here some pictures are presented where, especially, UAVs are taken into consideration for specific scenarios and tasks.

UAV surveillance after evacuation to allow the deactivation of a 2 tons bomb from the 2nd World War (Vicenza Province, 2014)

Monitoring of cracks in a bell tower limiting rope rescuers intervention.

Aerial view of a wide area hit by snow and followed by snow slides. They can also be used to fly over disaster-impacted areas, help determine which buildings and roads have been or could be impacted, helping emergency responders prioritize which area to assist first and help emergency vehicles determine which transportation routes to use, helping them avoid roadways that are blocked with debris

On the other hand, the benefits of using UGVs could be to enter environments that potentially hazardous to first responders, especially when dealing with CBRN agents. Additionally, there are being deployed to locate those agents and take samples without exposing first responders to radiations or dangerous substances in general.

They can communicate their locations and record data when entering an HAZMAT scenario, for instance. The possibility to drive a UGV over slopes, rubble, harsh terrain conditions allows first responders to explore inaccessible areas. The possible use of an arm plugged into the UGV give the first responders the chance to perform sampling, use detectors for CBRN, use further tools to help the decision making process.

Genoa Harbour – Containers Terminal (2011). Routine radioactive controls detected gamma activity from a container. A Cobalt 60 source was detected by gamma spectrometry. The Container was isolated from the others in the terminal (in contact 600 mSv/h). A C-shape of 9 container (3 levels/lines) was built to make further operations safer. First two container lines (from the bottom to the top) filled inside with 50% of concrete (shielding). Level of radiation out of the bunker is under safety limits. No danger for the population and operators.

Necessary to open the container like a metal can and then look and analyze its content. An excavator with specific tools and a UGV robot with cameras and "small tools" to search and pick up the source were needed. These two remotely controlled. To this purpose a Command and Control Room was set-up.

Regarding this radiological scenario, a specific contingency plan and a SOP – Standard Operating Procedures were designed taking into consideration also joint human-robot tasks. This to stress that plans are designed on a case by case situation depending on specific conditions.

Actions were divided into the following steps:

Preparatory step: ICS - Incident tasks division and control room set up; radioactivity – excavator – robot remote network set up; TVCC system,…);

Internal zone analysis: hole in the container via a steel wedge as a tool in the excavator, air monitoring for further chemical and radiological analysis;

Visual analysis of the inside: Robot in action over the roof; HD micro camera on its arm; bomb experts from Police to investigate if any suspicious explosive materials were hidden – “dirty bomb”;

Opening from the top: A blade as a tool in the excavator started cutting the container;

Removal of copper “rubbish”: grab as a tool; radiological detectors inside the C-shape at work; grabbed material no containing the source into a trailer;

Fishing for and recovery of the R-source: robot at work – a joint HR cooperation in action; A sealed lead container was read to host the radiological source; After the source was gathered by the UGV through his arm a safe transport was realized to get the source as waste in a safe place.

A sealed lead container hosting the radiological source. A safe transport, escorted by police, was realized to get the source as waste in a safe place

A Base of Operation was established at the Harbour of Genoa. A Command and Control unit was set-up to follow all the operations and control remotely the excavator and the UGV.

3 General Aspects

3.1 Command and Control structure

Command and Control structure is organized in such a way as to expand and contract as needed by the incident scope, resources and hazards. Command is established in a top-down fashion, with the most important and authoritative positions established first.

For example, Incident Command is established by the first arriving unit. Only positions that are required at the time should be established. In most cases, very few positions within the command structure will need to be activated. For example, a single fire truck at a dumpster fire will have the officer filling the role of IC – Incident Commander, with no other roles required. As more trucks get added to a larger incident, more roles will be delegated to other officers and the Incident Commander (IC) role will probably be handed to a more-senior officer.

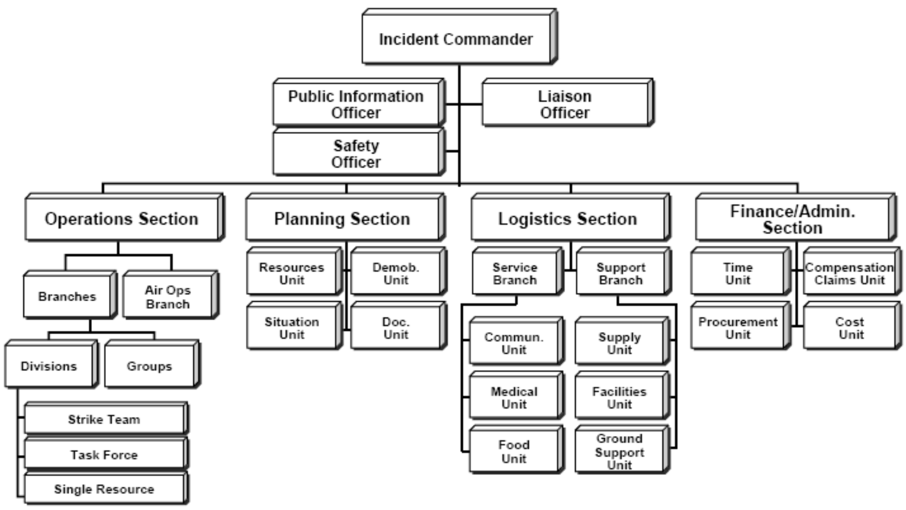
Only in the largest and most complex operations would the full ICS organization be staffed. Conversely, as an incident scales down, roles will be merged back up the tree until there is just the IC role remaining.

ICS consists of a standard management hierarchy and procedures for managing temporary incident(s) of any size. ICS procedures should be pre-established and sanctioned by participating authorities, and personnel should be well-trained prior to an incident.

ICS includes procedures to select and form temporary management hierarchies to control funds, personnel, facilities, equipment, and communications. Personnel are assigned according to established standards and procedures previously sanctioned by participating authorities. ICS is a system designed to be used or applied from the time an incident occurs until the requirement for management and operations no longer exist.

ICS is interdisciplinary and organizationally flexible to meet the following management challenges:

- Meets the needs of a jurisdiction to cope with incidents of any kind or complexity (i.e. it expands or contracts as needed).
- Allows personnel from a wide variety of agencies to meld rapidly into a common management structure with common terminology.
- Provide logistical and administrative support to operational staff.
- Be cost effective by avoiding duplication of efforts, and continuing overhead.
- Provide a unified, centrally authorized emergency organization.

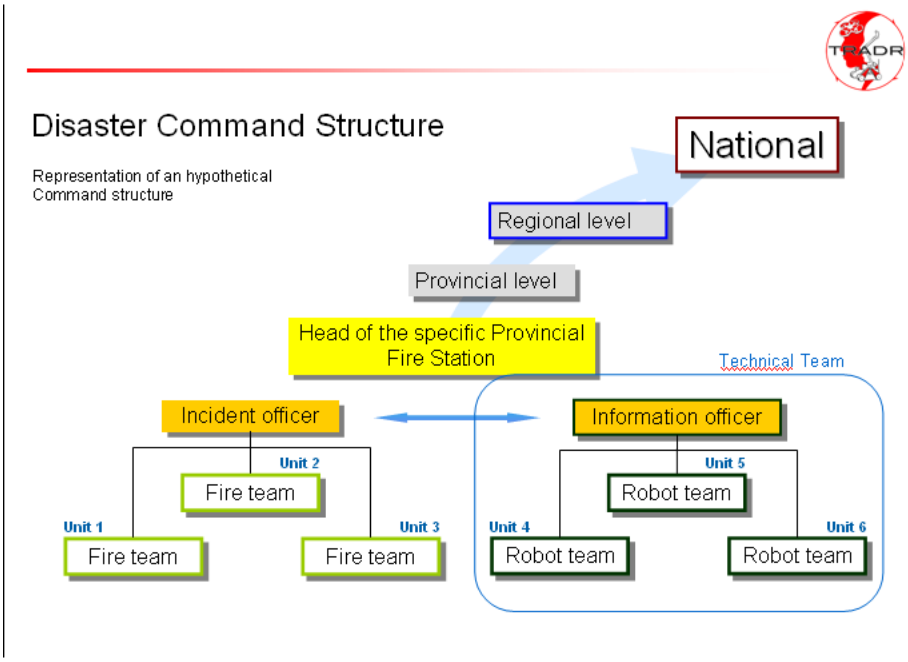


3.2 Joint human-robot team tasks

Regarding the robots deployment in a designed ICS structure, a joint human-robot team has been identified and put in a the chain of command. This cell fitted and staffed in a structured ICS will cover the role of Information Officer. This position horizontally (without a defined hierarchy) to an IC figure, would provide elements of interests during an incident timelines. Tasks of this cell would be presented in the specific SOPs for that scenario, previously fitted into a specific contingency plan. The Information Officer role would be to gather information not only by robots and their drivers but also from other "impersonal" devices (detectors, stand-off devices, remote cameras, etc…) placed on-site and interrogated from time to time to get an overview of the on-going situations.

All these pieces of information would be collected in a platform and would enhance the decision making process of the IC in charge. The Information Officer would cover a role and participate in the specific sections like operations, planning, logistics and administration.

With the information gathered, the Information Officer would address new elements for the Operations cell, would enhance the planning of an emergency (using forecast software) and avoid specific logistics needs like using ladders or helicopters to survey an hit area, so to reduce administrative costs.



4 Guidelines and SOP design

4.1 The design process

The main purpose of these guidelines is to create a common basis on how to handle with robots, mode of use of them and start writing Standard Operating Procedures (SOP) for specific scenarios of study. The future Standard Operating Procedures should contain all predictable procedures during the whole deployment cycle of robots, but should also introduce the user into the general and technical context of the respective joint human-robot team ("Unit") philosophy.

A 'table of contents', which was developed, should be used and respected for drafting of all SOPs adaptable to each chosen scenario.

Table of contents to build a SOP

SOP Part	**Short Description**	**Remarks**
Introduction	*The introduction should contain a short and very brief written summary of the SOP, including its scope and validity period. The user group of the SOP should also be mentioned.*	
Purpose/objective of the Unit	*A short description of the purpose, aims and objectives of the module should appear under this point. The unit fact sheet should be attached (as Annex).*	
Tasks of personnel	*A brief overview over all functions and the functions descriptions should appear under this point. The descriptions could also be attached as an annex.*	
List of required qualifications/certifications	*List of required qualifications, certifications, which are needed (pilots, …)*	
Structure of the Unit	*The personnel structure, containing the command structure should appear here. A graphical approach for visualizing the structures, e.g. a tree diagram or a flow chart,*	

	should be preferred.	
Equipment of the Unit	*This item should contain a short overview of the equipment carried along with the Unit during all phases of the operation. The overview should include all information necessary for transportation (consider all different modes of transport) of the equipment – its weight, size, volume, floor space, hazardous material, value, special requirements (sanitary, legal, etc.).* *The explicit content lists should be printed down in the Technical Handbook/Technical Manual (it covers all checklists of the equipment and all additional manufacturers' manuals").*	
Communication	*This part should provide description of communication lines and list all communication equipment (service mobile phones, radios, sat phones) including their numbers, call signs and types.*	
Safety and Security	*This part is to raise the awareness of the personnel for safety and security issues, including specific rules depending on the Unit's equipment. Safety rules, including fire safety and safety notes of the manufactures should*	

	be adopted under this headline. *The security related part should list all predictable major threats, contingency and evacuation plans, including emergency communication. Radio frequencies, sat phone and mobile phone numbers, call signs, etc to be in Annex.*	
Preparedness of the Unit:		
Training	*It should list types and levels of national and international (EU, UN) training allocated to each team function (team leader, deputy team leader, etc.).* *It should also set up a training program of the Unit and procedures for testing of the Unit's activation.*	
Maintenance of equipment	*It should list basic rules/requirements for storing and maintaining the Unit's equipment. If storage costs are estimated, the way of cost accounting should also be described.*	
Administrative issues (health, insurance, contracts, passport, etc)	*List all predictable expenses that Unit team's members / operation of the Unit may encounter during the mission. The team leader should appoint someone to be in*	If applicable

	charge of financial issues.	
Transport and border crossing planning	*Preliminary information regarding the transport of the Unit. Preliminary data/data sheets to be filled in which can be requested for customs formalities and cargo.*	If applicable
Financial elements (optional)	*Estimated deployment cost: 1. basic cost for deployment 2. cost for road transport 3. cost for air transport 4. operational cost per 24h 5. personal cost (man/day)*	
Procedures		
Alerting	*It is necessary to have common and efficient way of alerting the Unit's staff (team members, support staff, etc…)* *The alerting structures should appear in flow chart to create a proper overview.*	
Pre-deployment phase	*Description of all necessary procedures should be described and explained here. Each staff member has his/her own tasks during the pre-deployment. The tasks during a deployment should be listed here.* *A graphical approach, such as a flowchart, could be useful.*	

Deployment phase - description of specific roles of key team members	*Description of all necessary procedures should be described and explained here with a special focus on transport planning and preparation. Each staff member has his/her own tasks during the operation on-site. The tasks during a deployment should be listed here.*	
Operational phase		
Setting-up the Unit	*All procedures concerning the establishment of the module in the field appear here, from very basic issues, such as the first assessment, or camp-building (if necessary) up to technical start-up-procedures and security issues.*	
Running of the Unit	*After setting up the Unit on-site, the operations should begin and should be carried along properly.*	
On-site Command, Control and Coordination structure	*In an emergency various command, control and coordination structures can be established depending on the severity of the disaster, national emergency management structure of the affected country and its capacity to cope with the emergency management.* *This chapter aims to describe in a simplified way the most important parts of the command, control and coordination structure at the*	

	operational level during operations	
Reporting/Information Exchange	*This point aims to describe in a simplified way the most important lines of reporting and ex-change of information and reports amongst the main actors at the operational level during operations.*	
End of mission	*All necessary steps regarding the end of the mission should be mentioned here. If possible, a checklist or a flowchart should be published.*	
After-deployment (debriefing, medical issues, psycho-sociologic support, equipment)	*Examples and checklists should be laid down under this item to provide an overview of possible activities, which occur at the end of a deployment.* *The proper treatment of both personnel and equipment should be mentioned here, assisted by checklists, contact details of psycho-social support teams,….*	If applicable
Additional issues	*Any additional issues not covered by any of the previous chapters should be mentioned here, e.g. any special or own terms of the deploying organization, etc.*	
Annexes	*Unit information - Description of the personnel tasks - Structure of the Unit (diagram) -*	

	List of communication means - Costs (basic, transport, operational, etc.) (optional)	

4.2 Dissemination plan

From the radiological scenario happened in Genoa last 2011 to training activities within past NIFTi project, the TRADR end-users have disseminate their specific competences within their Organizations via web portal, symposiums and exhibitions.

The purpose of end-users is to give an homogenous structure of a joint Human-Robot team and produce shared SOPs for analyzed and tested scenarios. Once issued these SOPs, the goal is to apply them also in ordinary scenarios so to further raise up a robot cultural awareness within skeptical first responders. TRADR, being an EU project, has got the power to cross-check SOPs built in Italy, for instance, and get them tried and tested in Germany or in the Netherlands.

This activity would head the TRADR project for an European consistency and homogeneity to the new EU Countries, beginners into this field and so to start building a “code of conduct” in using robots in disaster response.

To conclude, Italy has issued SOPs for drones deployment piloted by qualified/certified pilots working at Helicopter Units. To this purpose, a working group worked last 2014 to produce a document taking into consideration all the scenarios where UAVs were used and give some rules to have their deployment regulated.

In designing these regulations, operating personnel at different levels (from operators to fire commanders) and different abilities and skills (pilots, CBRN, Rope Rescuers, etc…) were tasked to put their competences and past experiences in realizing a comprehensive work. Different topics were taken into account, for instance, FAA (Federal Aviation Administration) data incident drones; safety objectives risks analysis and qualifications/certifications needed to pilot drones.