COLLaborative network on unmanned **A**e**RI**al **S**ystems

FORESIGHT REPORT

2030 Horizon for Drones in Civil Protection Activities

Background

The COLLARIS project is financed by the European Commission through the DG ECHO Union Civil Protection Knowledge Network. Its goal is to establish a multidisciplinary network focused on Unmanned Aerial Systems (UAS) to connect, share, and grow knowledge among European actors.

The purpose of this report is to provide an overview of the use of drones in rescue and civil protection operations that can become reality before 2030. The report presents a brief description of 22 selected use cases and identifies non-technical enablers required for real operational use of these existing or upcoming capabilities.

Core partners

CBK PAN (PL), Entente Valabre (FR), MSB (SE), DCNA (AT), KIOS (CY)

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List of Abbreviations

ATM	Air Traffic Management
AED	Automated External Defibrillator
AOC	Air Operations Coordinator
BVLOS	Beyond Visual Line of Sight
CI	Critical Infrastructure
eVTOL	Electrical Vertical Take-off and Landing; The acronym is used as an umbrella term for vessels ultimately unmanned (in test mode controlled by a pilot on board) powered by electric motors that can carry passengers or act as ambulance / cab / HEMS unit.
FD	Flight Director
GA	General Aviation
HAZMAT	Hazardous Materials
HEMS	Helicopter Emergency Medical Services
LiDAR	Light Detection and Ranging
NAA	National Aviation Authority
SAR	Search and Rescue
SORA	Specific Operations Risk Assessment method
UAS	Unmanned aerial system
UAV	Unmanned aerial vehicle
VTOL	Vertical Take-off and Landing

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Key findings and recommendations

The rapid development of drone technology represents a fantastic opportunity for first responders and crisis management professionals for better reconnaissance, increased situational awareness, improved coordination of activities as well as growing number of direct, physical actions.

Drones indisputably offer a very substantial potential for increasing efficiency of civil protection activities, however even as technology is developing fast, there is and will be a continuously existing gap between the recently created technical capabilities and the operational practices of civil protection not utilising them yet. Understanding new capabilities, assessing and experiencing their usefulness, identifying the way to optimally utilise them, arranging operational procedures and practices of regular use – these are only some of the challenges faced by civil protection users around the world. At the same time this effort need not to be conducted separately by different institutions – there is a clear added value of sharing experiences and learning from others. This was the underlying assumption for establishing the COLLARIS Network.

During the course of the Network activities various representatives of the civil protection and crisis management community helped to elaborate and clearly endorsed the following general observation.

While there is a high number of drone solutions that has already achieved technical maturity, today only a relatively small fraction of available capabilities is used operationally for rescue and crisis management. Effective use of drones is limited mainly by legal and organisational obstacles and not by pace of technology development. As a significant number of innovative solutions will become available within the coming 5 years, this gap will grow unless those impediments are properly addressed. Finding 1

The purpose of this report is to provide an overview of the use of drones in rescue and civil protection operations that can become reality before 2030. The report presents a brief description of 22 selected use cases and identifies non-technical enablers required for real operational use of these existing or upcoming capabilities.

During the coming 5 years drones will more often be able to conduct longer-range operations (beyond visual control of a pilot) effectively and safely. Their uses will expand from “flying eyes”, which they are mainly today, to “flying robots” capable to conduct variety of different tasks. Increase in automatization and autonomy will decrease effort required from pilot and more often it will be enough to task (define objectives of expected action) and not manually control all activities. Intelligent data analysis, including use of machine learning and AI, will significantly improve efficiency of reconnaissance and monitoring activities.

As a result of maturation of technology a variety of new applications will become possible. The report identifies three main groups of use cases and two supplementary ones.

“First on scene” are situations when drones can reach emergency site before arrival of first teams of responders. They will provide early reconnaissance, will be able to deliver aid equipment and in some cases may warn people about imminent danger.

“First 2 hours” cover drone support for typical response activities. Drones will provide effective information support with minimal effort from early responders and information will be easily and rapidly available in the form of maps and 3D models. Simultaneous flights of multiple drones will be safe and coordinated, including coordination between different responding services.

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"Complex operations" reflect large operations where common information environment will enable efficient analysis and sharing of drone information between all stakeholders involved (if one sees something, all can see it). Efficient coordination of flights will enable simultaneous use of drones and human-operated aviation.

Furthermore, monitoring of threats will be conducted more effectively with drones enabling rapid verification of situation, from a safe distance and with semi-automatic detection of significant information (e.g. presence of water, fire or change detection). Operations ensuring safety of public events will also benefit as drones will be able to fly safely over people providing more effective visual and CBRN monitoring.

As stated before, wide variety of promising applications demonstrate large potential of drone solutions to contribute to increasing efficiency of crisis operations. However, it is not availability of technical solutions but legal and organisational obstacles that represent today the main impediment for wider implementation of drone solutions.

The key enabler is ensuring safety of drone flights, taking into account both safety of people on the ground and avoiding collisions in the air. **Implementation of air traffic management solutions enabling safe drone flights will be the most significant factor increasing their use for rescue and crisis management.** Finding 2

There is a universally recognised necessity for more effective communicating of civil protection needs to SESAR Joint Undertaking and EASA – institutions responsible for definition of current and future air traffic management. Recommendation 1

It is critically important to enable simultaneous flights of both human-operated aviation and drones. Establishment of the universally recognised "blue light flight" status would be highly beneficial. Currently defined future U-space architecture needs to offer specific functionalities for "blue light flights", in particular recognition of their priority, including rapid processing and ensuring optimal trajectories. There is a need for more flexible SORA standards applicable for "blue light flights". There is also a need for universally recognised method of indicating ongoing rescue or crisis operation to third-party VLOS pilots.

Beyond issues related to air traffic management, it is institutional readiness of users that hinders uptake of innovative capabilities into rescue and crisis management operations. **Majority of civil protection stakeholders has insufficient organisational arrangements and know-how for widespread and fully efficient use of drones in their activities.** Finding 3

To ensure efficient use of drone solutions there is a need for establishment of an appropriate organisational ecosystem. It must include standard operational procedures for use of drones. Arrangements for coordination of complex drone operations must be implemented, including cooperation with national air traffic management agencies. There is a need for appropriate training system addressing not only pilots, but also commanders and analytical personnel. An important element is also establishment of GIS systems and appropriate procedures for data processing, sharing between all stakeholders, and their inclusion into analytical and command processes.

Addressing those challenge may be significantly facilitated by cooperation between institutions in exchanging experiences and sharing relevant know-how. For this purpose **establishment of the "Observatory of best practices of use of drones" should be considered.** Recommendation 2

The Observatory would gather and share information about preoperational and operational implementation of drones in specific use cases as well as national practices related to all organisational aspects mentioned above. Additional aspect of the Observatory activities would be promoting European interoperability, in particular related to use of drones and exchange of drone-derived data during operations of UCPM modules.

The efficient introduction of innovative solutions requires demonstrations, technology validations and pilot implementations. Undertaking such activities always represents a significant challenge and it is also the case for uniformed services. Therefore, **there is a high need to establish an ecosystem supporting introduction of innovative uses of drones**, bringing together the scientific community and crisis management practitioners to enable effective transfer of knowledge, sharing experience and peer-to-peer learning. Recommendation 3

The mechanism should include three main forms of support, depending on the needs of users and the level of their technical and organizational capability to absorb innovation. It should be able to: provide the competencies, know-how and knowledge needed for preparation and conduct of pilot activities; organize or help to organize Trials – experiments demonstrating operational usefulness of new solutions, evaluating their benefits and eliminating identified weak points; and support conduct of pilot activities aimed at confirming over longer time systemic benefits of a new solution and/or procedure.

The mechanism should operate in synergy with the Observatory (recommendation 2). It should be flexible enough to support both "pathfinding users" and assist the "second wave" followers. It should also support the uptake of results of EU-funded development activities, in particular Horizon projects.

Figure 0.1. Response to question: "How important would be different support activities for improving effectiveness of use of drones for crisis management?", collected during COLLARIS workshop (18 individual responses, all participants were emergency responders deeply engaged in employing innovative drone utilisation methods, or researchers closely cooperating with such)

Introduction

Following chapters present an overview of a variety of drone use cases that will become possible as a result of technological maturation. Some of them have already achieved technical maturity and most of remaining ones, if not all, will become available before 2030.

The main message of this report is the observation that effective use of drones is limited mainly by legal and organisational obstacles and not by pace of technology development. Therefore, selected use cases have been divided into five groups (three main and two supplementary that have similar systemic and organisational requirements for effective operationalisation. For each group key non-technical enablers for operationalisation are identified as well as key technologies required. The report is comprised of five chapters presenting each group with last chapter presenting general enablers.

The goal of the COLLARIS Network project is to establish a multidisciplinary networking platform focused on UAS by bringing together civil protection and crisis management stakeholders – both individuals and institutions who will share their competences and experience to contribute to building and sharing of knowledge, expertise and skills in the chosen domain. It is in this context that COLLARIS carried out this study on upcoming near-term innovations that will re-shape use of drones in the blue light sector.

Literature overview and desk research were complemented by several individual interviews with experts. The resulting preliminary findings were consulted with a broader community during two online workshops: one for innovation providers and European R&D projects related to the development of drone technologies, the other for practitioners of the emergency management sector. During these workshops, technologies, different use-cases and enablers were discussed and participants shared their valuable knowledge, experience and remarks. The updated document was shared with the members of COLLARIS Strategic Group and associated partners (currently comprising 23 institutions) for their written feedback and discussed during a dedicated summary meeting. These broad and extensive consultations with the representatives of interested communities – both solutions providers and end users – ensured that the presented key findings and recommendations reflect their common opinions and needs.

It is not possible to analyse all possible use cases, but in the opinion of authors and consulted practitioners the presented scope covers the majority of important cases that may have a significant impact on rescue and crisis management operations.

Let us move to year 2030 …

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1. First on scene. Drones before the humans

Flying eyes – gathering of information	Flying robots – other activities
• First reconnaissance (video transmission) • Transmission of emergency information from third-party overflying drones (drone-to-112)	• Delivery of aid equipment: defibrillator, floating device, survival pack, … • Population warning • Two-way audio communication with people in distress

"First on scene" focus on situations when drones can reach emergency site before arrival of first teams of responders. Drones can be rapidly dispatched to location of an emergency to facilitate quick assessment of the situation and provide crucial real-time information, particularly when arrival of first responding teams is delayed due to long distance, heavy traffic or difficult terrain. By being the first on scene, drones can provide early reconnaissance, assess extent of damage, identify potential hazards, locate survivors or deliver first aid equipment (such as AED), all of this significantly enhancing the effectiveness of response efforts and emergency operations.

On the icy road

The accident takes place on the motorway just after a bride crossing a large river. Due to icy conditions a car with a family of four is unable to slow down and hits the vehicle in front of it. Next car hits from behind. Another one is rapidly approaching and tries to slow down…

First 112 call informs the operator about the single accident, but the next caller talks about the multi-vehicle collision. Within a few seconds the operator also receives two eCall alerts with precise geolocation. He immediately dispatches the first wave of emergency vehicles. However, as the scale of the event is not clear he also decides to activate the rapid-reconnaissance drone that is permanently stationed in small hangar on a roof of nearby fire station. Within two minutes, a multi-copter, which is on a long-term stand-by duty, launches and heads directly to the accident coordinates. It arrives on scene after 4 minutes, well before the first emergency vehicles. Video transmission to the 112 centre gives the operator an aerial overview of the situation – he immediately understands that the scope of the event is unfortunately much larger. He decides to send additional emergency units, taking this decision much earlier - not needing to wait for first assessment given by professionals arriving on site.

The operator immediately sends the drone to the end of traffic jam and activates its strong yellow beacon. The drone becomes a warning signal for approaching vehicles – they slow down and the risk of further collisions decreases. The video transmissions provide an overview of the situation at the end of the jam, so the operator would be aware if any additional collision takes place.

However, as the first drone is busy at the end of the jam, the rescue services dispatcher needs to continue observing the front of the accident site and also to assess the situation on the currently-jammed bridge. He activates a special "emergency-requests-for-support" mechanism for third-party drone operators. The air traffic management system transmits a request to all drones in the vicinity and one of transportation drones flying nearby is redirected to circle for a few minutes above the bridge and to provide video transmission to 112 centre.

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This video is also transmitted to the commander of the first responding rescue team, which is still on his way. It gives him a better understanding of the situation and helps to prepare in advance for initial decisions to be taken on arrival.

1.1 Key enablers

The key non-technical enabler for operational implementation of "First on scene" use cases is related to availability of air traffic management (ATM) solutions that will make it possible to conduct of such long-range BVLOS flights.

The obvious precondition is a **legal and operational ability to conduct BVLOS flights**. However, the second factor is an **ability for rapid initiation of such flights offered by ATM systems**. For this purpose, there is a need for introduction and universal recognition of the "blue light flight" priority, which would result in i.a.:

- rapid processing and approval of flight plan requests;
- applying more flexible SORA standards;
- special effort to calculate optimal trajectory;
- redirecting conflicting traffic.

Such functionalities must be available in the final U-space architecture, but they should be also implemented in any intermediate systems that will be created.

It should be noted that "blue light" status should not be considered as synonymous with competence of state aviation. Many flights conducted as part of emergency response are not realised by national services but by entities that are considered private by aviation law.

1.2 Technical solutions

All technical solutions offering basic functionalities required for "First on scene" already exist and initial pilot projects have already been implemented. Mature full-scale operations of that kind are fully feasible within 3 years if requirements of non-technical enablers are met.

The key technical solutions that need to achieve maturity are:

- Ability to conduct remotely-controlled, semi-autonomous drone flights. In particular, GSM-based pilot-drone communication seems the most promising.
- Ability for rapid planning and calculation of trajectories.
- Ability to sustain long-term continuous readiness and then rapid take-off (below 2 minutes).

Solutions that will further enhance "First on scene" capabilities include i.a.:

- Automatic hangars/docking stations that can restore readiness without human intervention.
- Automatic payload exchange systems that will enable single drone to automatically rearm for different missions (multi-mission automatic capability).

1.3 Use cases

Of the following use cases, all are considered by practitioners as having significant positive impact on rescue and crisis management activities. However “first reconnaissance” is judged as the most important – a potential game changer.

First reconnaissance - video transmission

A drone can be used for the purpose of conducting first reconnaissance and transmitting live video feed from its on-board camera. In this use-case, the drone is deployed to survey an area of interest or a specific location, such as a disaster site, a search area, or any remote region. The drone captures high-definition video footage in real-time as it flies over the designated area, providing dispatchers, first responders or decision-makers with valuable visual information. The live video transmission enables immediate observation of the situation from a bird's-eye view, allowing for rapid assessment of the situation, presence of survivors and casualties, terrain conditions and identification of potential hazards.

Figure 1.1. Road accident in Lublin recorded from a drone. Credit: screenshot (00’09”) from a YouTube video published on “Lublin112” account *(Lublin112, 2020)*

Transmission of emergency information from third-party overflying drones (drone-to-112)

This use case in an enhancement of the “first reconnaissance” case, built upon assumption of a growing number of civilian drones that will be used in a few years. Availability of many cameras flying over majority of populated areas represents an important opportunity for improved first assessment of emergency situations – if video can be made available to emergency services.

Firstly, if pilot of overflying UAV observes some kind of recent emergency (e.g. fire of an isolated building apparently not noticed by anyone, a car crash without any person next to it), he can immediately notify 112 about detected threat and transmit short video to illustrate it. In a second scenario 112 operator has been already informed about new emergency and he can request provision of video from pilots of UAVs flying in the vicinity by indicating specific area of interest. In many cases responding to such request will only require directing the camera in a specific direction and transmitting video. Alternatively, minor change of trajectory can be performed.

Cooperation with such service would not be mandatory but it should be considered a service for "public good". From the perspective of 112 operator, receiving an aerial overview of emergency site may significantly enhance understanding of situation and enable faster, more fitting response by emergency services.

Delivery of aid equipment

Rapidly deployed drones can deliver critical life-saving equipment such as AEDs, floatation devices or medical kits to individuals in need or those assisting them, when minutes represent a difference between life and death. This will be important especially in remote or hardly-accessible areas where traditional delivery methods may be hindered, but also in high traffic. In particularly difficult terrain special survival kits can be delivered hours before arrival of rescue teams (e.g. high mountains).

In Trollhattan, Sweden, the deployment of drones for AED delivery marks a ground-breaking advancement in emergency response strategies. This innovative approach aims to significantly reduce response times during cardiac arrest incidents by swiftly delivering AEDs to the scene. Drones can navigate urban and remote areas, overcoming geographical obstacles and ensuring timely access to life-saving devices. As a part of community-based initiatives, these programs collaborate with traditional emergency services, integrating into existing response systems. AED delivery by drone not only enhances survival rates by facilitating early intervention but also contributes to public awareness and education on AED usage. Compliance with aviation regulations, continuous improvement through research, and close coordination with emergency dispatch centres is at the centre of this initiative, highlighting the potential of drone technology to revolutionise life-saving interventions in medical emergencies.

During the pilot implementation, from April 2021 to May 2022, drone-delivered AED arrived on scene before an ambulance 37 times (67% of successful deliveries), with a median lead time of 3 minutes and 14 seconds. In that period 211 suspected out-of-hospital cardiac arrest alerts occurred, and in 72 of those a drone was deployed and an AED was successfully delivered in 58 cases (the major reason for non-delivery was cancellation by dispatch centre).

Figure 1.2. Drone helps save cardiac arrest in Sweden. Credit: Everdrone. (BBC, 2024)

Supplies for trapped tourists

One of the first high-profile delivery action was on 21.01.2022, when Polish TOPR (Tatra Volunteer Mountain Rescue Service), in severe weather conditions, used off-the-shelf professional quadrocopter to find and then supply tourists trapped under the summit of Kopa Kondracka (2005m above sea level, 14 experienced rescuers dispatched had to turn back due to high avalanche danger and poor visibility caused by strong gusty winds and continuous snowfall). Instead of endangering the rescuers, a drone which carried blankets and heaters was used, allowing trapped tourists to survive the night in harsh weather conditions and low temperatures.

Figure 1.3. Departure of a delivery drone in hard meteorological conditions (TOPR, 2022)

Figure 1.4. Harsh conditions are especially dangerous at nights. Credit (TOPR, 2022)

Population warning

Drones arriving on scene before first responders can provide early warning and separation, in particular in case of road accidents and in CBRNe incidents. In case of road accidents that represent a risk of growing into multi-vehicle collision an immediate clear warning from the drone (e.g. yellow strobe light) visible to upcoming cars may stop the "pile-up". Ability to deliver such a warning even before arrival of first rescue personnel may decrease scale of such events.

In case of CBRNe incidents, drones equipped with specialized sensors can rapidly detect and measure hazardous substances. If needed, they can move well in front of hazardous cloud and be used to immediately broadcast audible alerts to the population, providing crucial information about imminent hazard with instructions for evacuation, advising on a safe distance or sheltering in place.

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Two-way audio communication with people in distress

Drones equipped with audio communication systems, such as speakers and microphones, can enable real-time verbal interaction between the drone operator or dispatcher and the individuals in distress. Drones can serve as a remote messaging medium, advising both the more lightly injured victims and those assisting them, gathering first interview or enabling communicating about impending danger.[1] It enhances the effectiveness of emergency response efforts by providing direct and immediate communication capabilities in situations where arrival of rescue teams is delayed.

[1] Such communication may be applicable to virtually any type of incident: can warn of the risk of a multi-stage event (in case of an explosion), advise on self-decontamination, instruct on how to secure a home in the event of a CBRN threat or how to use coloured flags to communicate with rescuers in deluged areas.

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2. First 2 hours. Drones in support of typical response activities

Flying eyes – gathering of information	Flying robots – other activities
• Situation/damage assessment, monitoring of response activities: video transmission (optical and IR), geotagged images • Decision support (and evidence gathering): generation of maps and 3D models, automatic emergency delineation • Search and Rescue operations • Specialised sensors: CBRNE detection and mapping, avalanche search, cell phone detection, …	• Support for operations on site (overhead area lighting, radio retransmitting) • Fire suppression • Transport of specialised equipment • *eVTOL – rapid arrival of first responding personnel / victims' transportation (auxiliary for HEMS)*

"First 2 hours" cover drone operations supporting typical response activities. Drones provide effective information support – they can be deployed to enhance situational awareness from above, by providing real-time footage of the emergency area, generating maps of the area and 3D models, locating survivors. By providing real-time information, they help make informed decisions and prioritise actions. All this requires minimal effort from early responders in first minutes of an operation. Drones also conduct activities beyond information gathering: lighting the scene, radio retransmission, transporting vital equipment or even suppressing fire in difficult-to-reach locations. Simultaneous flights of multiple drones are possible – they are safe and coordinated, including coordination between different responding services.

Fire outbreak in an industrial chemical complex

During a windy night a fire breaks out in a large industrial chemical complex. The Incident Commander immediately dispatches a small drone with a normal camera to obtain the first overview of the area directly affected by the fire and its surroundings. The drone manages to detect a potential additional threat – several HAZMAT containers stored nearby, which have to be removed immediately so as not to catch fire and cause chemical contamination. IC is able to call in specialised chemical units to neutralize the identified threat. They bring their own drones equipped with dedicated sensors to detect if there is any contamination in the area already on fire and if yes, what toxic materials are burning. Drone data combined with a quickly generated 3-D model of the industrial complex and wind force and direction forecast enable the IC to decide which areas have to be evacuated first and where the fire suppression activities have to be concentrated.

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The Air Operations Coordinator arrives to coordinate the aerial part of the response. He informs all relevant aviation authorities and isolates the airvolume out of General Aviation and civilian drones' usage. AOC sets an autonomous flying zone above the incident, so drones can collect photographs to create an up-to-date ortophotomap (that is accurate enough to be used for future investigations). UAVs are also controlling if fire is not crossing firewalls, without the need for the IC to delegate firemen just for this purpose – the rescuers can focus on more needed activities. In one place the situation is too dangerous to send in personnel, so a drone with a fire retardant is used to minimize the risk. At the same time other drones fly to check whether the adjacent construction site has already been evacuated. Unfortunately, they detect 2 people needing urgent medical assistance, so a HEMS helicopter comes to the site to transport casualties. All aircrafts are informed about this and their pilots move them accordingly, to create a safe passage.
This is not the only case when airspaces sometimes change dynamically during a crisis situation - when a USAR team working on a rooftop asked to move a heavy powered tool, which was provided by a heavy octocopter, all other UAVs moved a few hundred meters for the duration of heavy lift mission.
When a powered hang glider unintentionally invaded the space, flying on rooftops, all low-flying drones made an immediate landing and the one flying higher escaped to even higher ceilings, while at the same time following the unwanted flight by its sensors. The pilot was called by the colours of the parachute and by the number visible on it by informed FIS, and messages were displayed on LED screens of the police car following him, telling him to leave as soon as possible and not to change altitude.

2.1 Key enablers

Operational implementation of "First 2 hours" use cases, similarly to previous group, is significantly dependent on implementation of solutions related to air traffic management. It requires previously identified ATM functions ("blue light priority" and BVLOS flights), but **arrangements enabling safe and coordinated drone operations above emergency site** are also necessary.

Responding services need to have organisational and procedural solutions aimed at coordination of drone flights involved in the operation. There is a need for clearly identified position – person responsible for air operations coordination – as well as operational procedures for such coordination. Such procedures need to be compatible between different stakeholders to enable coordination of flights from all involved institutions. Implementation of a dedicated IT system supporting communication among pilots and providing common picture of aerial operations to all stakeholders should be considered. In some cases there will also be a need to coordinate with human-operated aviation – point covered in "Complex operations" chapter.

ATM systems need to enable rapid establishment of air traffic restrictions. Creation of a restricted geographical zone to eliminate third-party drones over emergency site should be possible without any delay. Establishment of a restricted zone (for both unmanned and manned aviation) should also be possible. Furthermore, there is a need for universally recognised method of indicating ongoing rescue or crisis operation to third-party VLOS pilots – informing them that any interfering flights are prohibited.

In general, there is a high value in establishing working relations between rescue services and agencies responsible for air traffic management. Such cooperation should include participation of ATM personnel in crisis management exercises.

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Another important aspect is incident commanders' ability to effectively use drones in activities they lead. There is a need for **dedicated trainings that will enable better understanding of drone capabilities**. Such trainings should prepare them to request information that may be obtained as well as to initiate conduct of other missions. Where appropriate, selected methods of using drones may be introduced and facilitated through definition of standard operational procedures related not only to flight activities, but also to command processes. In general, the need for improving commanders' competences has been identified by professionals as one of the most critical enablers for increasing efficiency of drones in typical rescue operations.

An important factor influencing efficiency of use of drones is **presence of GIS systems that are prepared for drone-derived data**. Appropriate procedures need to be implemented to ensure not only efficient data processing and sharing, but also their inclusion into analytical and command processes. Sharing of drone-derived products (in form of actionable intelligence) between stakeholders involved in crisis management should also be covered by such procedures.

2.2 Technical solutions

"First 2 hours" bases on a variety of technical solutions, of which some have reached maturity while many others are under development. By nature of these use cases the scope of available technical capabilities will be ever-growing.

The key technical solutions that will enlarge scope of drone capabilities supporting typical emergency response activities are:

- Automatic image and video analysis (including fire, water, damage and person/object recognition) including use of machine learning/AI analytics.
- Effective data transmission (drone-to-ground) enabling real-time data analysis on the ground.
- On-board data analysis.
- Automatic mobile (vehicle-based) docking stations enabling semi-automatic flights with minimal effort from pilots.
- Fleet coordination (ensuring drone-to-drone safety), including autonomous flights.[2]
- Ability to monitor of all drone traffic/all aerial traffic by air traffic management systems.

An important feature of technical solutions, specific for crisis operations, will be increasing automatization and growing autonomy, resulting in minimising effort required to control them. This is particularly important in early phase of an operation, when all responders may be overloaded with other activities.

2.3 Use cases

Majority of the information gathering use cases presented below are already in different phases of implementation by rescue services and the coming 5 years will bring a significant progress in efficiency. Other use cases ("flying robots") are in different stages of experimenting with. Of all use cases,

[2] Such systems may be based on data exchange between control systems. An important achievement will be implementation of a standard for data exchange between different brands. Other developments will be focused on use of on-board aerial situational awareness (autonomous collision avoidance).

practitioners consider “search and rescue”, “decision support” and “specialised sensors” as those that may have the highest positive impact on rescue and crisis management activities. “Fire suppression” is judged as the lowest, but still impactful.

Situation/damage assessment, monitoring of response activities: video transmission (optical and IR), geotagged images

Drones can be used for situation and damage assessment as well as for monitoring response activities, utilising various technologies including video transmission and geotagged imaging.

Drones equipped with high-definition cameras are deployed to survey areas affected by emergencies or disasters, such as natural disasters, accidents, or humanitarian crises. The drones capture real-time video footage and images of the affected areas, providing responders with detailed visual data for assessing the extent of damage, identifying hazards, and determining the overall situation on the ground. Optical video provides clear visuals of the surroundings, while thermal imaging allows for the detection of heat signatures, which can be particularly useful for identifying survivors or hotspots in disaster zones. This reduces the need for personnel to be exposed to direct threats.

The drones are able to transmit live video feed to the command centre or emergency response teams in real-time. This live video transmission enables responders to gain immediate situational awareness, make right decisions, and coordinate response efforts effectively. Introduction of combined GSM and satellite internet communication will bring even more efficient solutions.

As drones fly over affected areas, they capture high-resolution images that are geotagged with precise location data. These geotagged images provide valuable documentation of the damage, landmarks, and points of interest within the disaster zone. The geo tagging allows for accurate mapping and analysis of the affected area, aiding in the planning and prioritisation of response activities.

After initial reconnaissance drones continue to fly over affected areas, providing ongoing surveillance and monitoring of response activities. This allows responders to track progress of recovery efforts, identify emerging threats or hazards, and make adjustments to their strategies as needed.

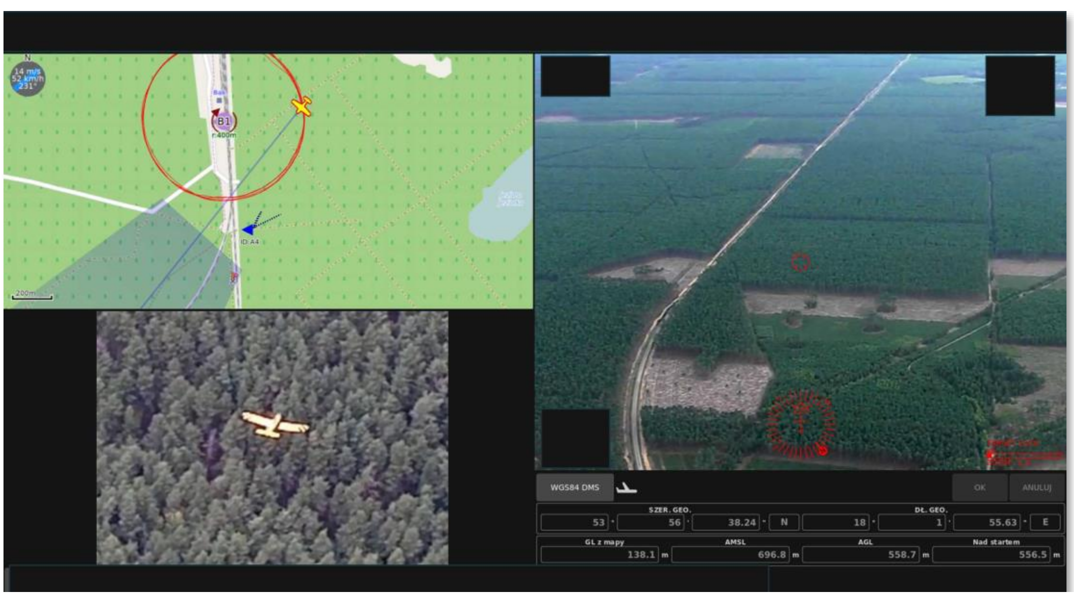

Figure 2.1. Mock-up of a strategic drone display modelled on footage collected by FlyEye drones during Las2021 exercises organised in Borsk, Poland. Mock-up created by the curtesy of WB GroupGrup, who provided fixed-wing UAV for the exercise.

Decision support and evidence gathering: generation of maps and 3D models, automatic emergency delineation

Drones can be used to generate maps of crisis area. Today this requires use of standard photogrammetry approaches resulting in delay between flights and availability of maps. Rapid processing of drone-derived data will become more common and eventually data will be transmitted directly from drones resulting in near-real-time mapping.

Drones equipped with LiDAR or photogrammetry capabilities can provide data to create detailed 3D models of the disaster area, facilitating accurate measurement of damage and help in planning response efforts. Such data can be used for further area calculations and estimations of volumes.

Automatic emergency delineation using drones enables rapid and accurate assessment of emergency situations. These algorithms analyse the collected data to automatically identify and delineate areas affected by emergencies. This may include automatic mapping of wildfire fronts, burnt area, areas covered by water during flooding, destroyed housing and infrastructure or even assessing conditions of roads.

Geotagged images captured by drones, when properly processed, offer a combination of visual and spatial data, enabling import into GIS environments and integration with other information layers – for further analysis, better situational awareness or communication with public and media.

An important value of maps generated in early phase of crisis situation is documentation of situation close to initial conditions. Such data represent a useful evidence for criminal investigation and prosecution, often providing information that are later lost during course of rescue activities.

Figure 2.2. Information materials derived from drones flying automatically over the site. From left: a photo and 3d model of a mountain river bend; a detailed ad-hoc mosaic overlaid on an older aerial photo and with a visible diagram of the road infrastructure. Such products can today be processed on the fly or within minutes via cloud-based processing unit. Collected and processed by CIK in 2018.

Search and Rescue operations

Drones enable rapid surveillance of a large area in search of people, significantly facilitating search and rescue operations. Equipped with visual light and thermal cameras supported by image recognition capabilities, or even by cell phone detectors (IMSI-catcher), drones can aid in the detection and identification of individuals, even in low-light or dense environments.

Drones can also facilitate communication with the missing person or ground crews through loudspeakers; provide illumination during night operations with spotlights; and even guide rescuers or be used to mark points of interest.

UAV swarms can cover large areas simultaneously, improving the efficiency of SAR missions. Swarms can also help to quickly locate survivors in disaster-stricken areas.

Figure 2.3. Exemplary image recognition: recognition of human silhouette. Credit: (Robotto, 2024)

Specialised sensors

Drones equipped with specialised sensors can conduct special reconnaissance and monitoring tasks, including:

- **CBRNE** (Chemical, Biological, Radiological, Nuclear, and Explosive) detection and mapping: drones equipped with specialised sensors can detect hazardous materials or substances in the environment. These sensors can identify chemical or biological agents, radiation levels, and explosive materials. By mapping the presence and concentration of CBRNE threats, responders can assess the situation remotely and plan appropriate countermeasures without exposing themselves to danger. All measurements can easily be geolocated and shared.
- **Avalanche search:** Drones with avalanche search capabilities are equipped with sensors and cameras designed to detect signs of buried individuals in avalanche areas. These sensors can detect signals from avalanche transceivers worn by victims, as well as heat signatures or body movement under the snow. Using this technology, search and rescue teams can quickly locate and rescue individuals buried by avalanches, potentially saving their lives.
- **Cell phone detection:** Drones can be equipped with sensors capable of detecting signals emitted by cell phones or other electronic devices. In search and rescue operations, this capability allows responders to locate missing persons based on the signals emitted by their mobile phones. By identifying the approximate location of cell phone signals, drones can narrow down search areas and improve the efficiency of search efforts, especially in remote or densely wooded areas where traditional methods may be less effective.

Support for operations on site

Drones equipped with other specialised payloads can conduct specialised supplementary missions, such as:

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- **Efficient lighting systems**: despite the triviality of this solution, drones can relatively easily be equipped with wide-field illuminators or search lights. In areas where mobile lighting towers cannot be deployed, or until they arrive, lighting from above can provide vital assistance to rescuers, especially in scenarios involving construction disasters or deluged terrains.
- **High endurance for long-duration operations** (e.g. 5 days of 16 hours continuing operations) by tethering. Tethered drone is a ground-powered aircraft that hover at given place, for long-duration operations. It allows for prolonged hoover (e.g. constant sensing via specialised payload) while being able to lower itself freeing up space for other low-flying craft. Its advantage over anchored aerostats is the absence of a significant expense of consumed lighter-than-air gas.
- **Internet connection and other supplementary mission** While solutions based on a satellite provided internet usually satisfies the needs of the incident command, it is not sufficient for in-field rescuers that utilise personal GIS C2 interfaces. To address that, several-hundred-meter radius Wi-Fi bubble can be stretched using a retransmitter on a drone. Due to foreseen longevity of such service, cable power connection (tether) seems appropriate. This solution can extend Internet access even to areas that are difficult to penetrate by the signal - such as steep mountain valleys or to interfere with or transmit radio communications. Even multi-day deployments may be necessary e.g. in areas where the high air traffic or unstable terrain prevents the rapid deployment of an observation / telecommunications masts. Such tethered sets are being developed as part of the EUSPA Overwatch project3 or other similar endeavours4.

Fire suppression

For fire suppression drones can be deployed to inaccessible or hazardous areas where traditional firefighting methods are impractical or dangerous for human responders. The drones may carry payloads such as water, foam, or fire retardants, which are released onto the fire from a safe distance. Additionally, drones equipped with thermal imaging cameras can identify hotspots and guide firefighting efforts more effectively. By providing a rapid response and aerial perspective, drone-based fire suppression can help prevent the spread of wildfires, protect property, and enhance the safety of both firefighters and the public.[5]

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[3] **Overwatch (2022 – 2025)**[3] **Overwatch (2022 – 2025)** – funded by EUSPA. The OVERWATCH project will develop an integrated holographic system that will support emergency and crisis management for wildfires and floods. Website: https://overwatchproject.eu/en/

[4] ***WiFi – World Food Programme (2021)*** (World Food Programme, 2021) developed by Ericsson Response (member of the UN Emergency Telecommunications Cluster ETC), a donut-shaped orange tube sends out a signal that covers an area of 12 km² with Internet connectivity, 17 times what is currently being provided in emergencies.

The Rapid Response Connectivity Carrier (R2C2), is a drone with a long-range Wi-Fi transmitter. The cable links both power and data connectivity, enabling it to stay up in the air and transmit 24hrs a day.

[5] The results of OVERWATCH consultations (EUSPA-funded R&D project) suggest that, among experts deeply interested in utilisation of drone-related innovations, the fire suppression by UAV means enjoys very moderate support. It seems that the cause may be noticeable deficits in the ability to carry cargo by individual drones and disputable added value (considering implementation costs) to engage multiple swarming drones. More confidence is being placed in providing information generated by drones to support manned aircrafts operations. That subject is covered in sections dedicated to ATM coordination of air operations.

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Figure 2.4. Demonstration at University of Coimbra's Forest Fire Research Laboratory. Credit: (BBC, 2023)

Transport of specialised equipment

The drone can fly faster than ground means and also they may fly unhindered over a disaster-stricken area while some road links will become impassable and areas will be shut down. In smaller-scale scenarios, multirotors are becoming increasingly popular in delivery of tools, resources or means of communication. This is particularly beneficial in difficult-to-access areas such as the mountains, in terrain ruined by a disaster (e.g, urban search and rescue, delivery of heavy equipment at height), or when it may be dangerous for rescuers to reach their destination.

There is growing interest in heavy cargo drone operations among first responders[6]. This may result in improved health and safety for personnel and reduced environmental damage (compared to off-road damage caused by wheeled vehicles) during first responder activities, particularly in the case of wildfires.

[6] For example, one of the fire brigades under Tiepoint, Norway, is using cargo drones as their new airborne utility vehicles (capable of carrying cumbersome equipment such as power generators etc.).

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Figure 2.5. Since 2019, a drone delivery health service is being operated by Zipline drones in Ghana. Credit: (QUARTZ, 2019)

Drone delivery

Zipline, operating in various African countries, employs drone delivery services to efficiently transport critical medical supplies to remote and challenging-to-reach areas. Specialising in healthcare logistics, Zipline's drones provide rapid and on-demand delivery of essential products like vaccines and blood, overcoming geographic obstacles and poor road infrastructure. The system, based on a hub-and-spoke model, integrates with healthcare systems, ensuring regulatory compliance and collaboration with public and private entities. Zipline's use of temperature-controlled drones, data analytics for optimisation, and a focus on public-private partnerships exemplify its commitment to enhancing healthcare accessibility and emergency response capabilities in regions where traditional transportation methods face limitations.

Organ transport for transplant

In March 2023, the first lung for transplant was delivered by drone. The drone carried a human donor lung on a five-minute journey from the roof of Toronto Western Hospital to Toronto General Hospital for a successful transplant. The trip can take 25 minutes by road.

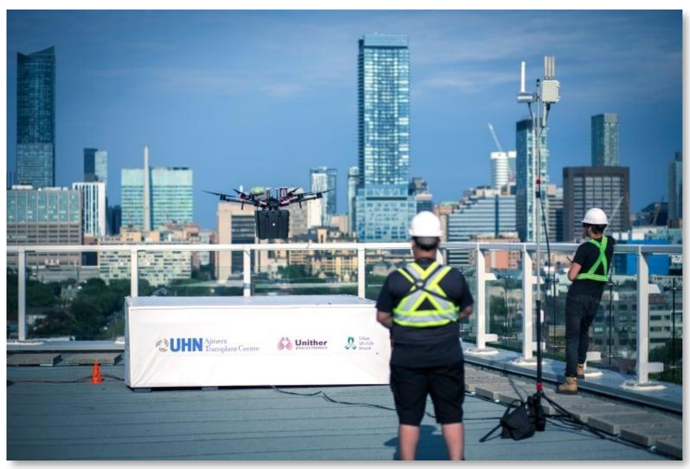

Figure 2.6. Lungs delivered by drone saved an Ontario man's life. Credit: (CBC, 2021)

eVTOL – rapid arrival of first responding personnel / victims' transportation (auxiliary for HEMS)

In close future eVTOLs can be used to transport first team of responding personnel. They can also be used for transportation of victims, serving as auxiliary assets for Helicopter Emergency Medical Services (HEMS). These electric vertical take-off and landing vehicles will be able to access quickly both densely populated urban areas with high traffic as well as remote locations and areas with limited infrastructure. Such service is expected to be significantly more economical than use of helicopters as well as less interfering for population (eVTOLs are less noisy). As a result, it would be more common to transport first responders, such as paramedics, firefighters, or law enforcement personnel, to the scene enabling prompt assessment and intervention. Additionally, eVTOLs could serve as auxiliary platforms for HEMS, providing more affordable rapid transportation of injured or critically ill individuals to medical facilities, especially in situations where traditional ground or air ambulances face challenges accessing the area.

3. Complex operations. Long-term and large-scale activities

Flying eyes – gathering of information	**Flying robots – other activities**
• Monitoring of area of operations: change detection, specific analysis (e.g. monitoring of evacuated area)	• Transport: logistic of rescue activities • Transport: humanitarian aid • *eVTOL – evacuation of population from affected area*

"Complex operations" covers the most advanced uses of drones during large operations. Simultaneous flights of both high number of drones and human-operated aviation are conducted. They are orchestrated in such a manner that capabilities of both types of aviation are fully available to support response effort. Drones are used for surveillance, monitoring and mapping, but they can also assist logistics of rescue operation as well as transport humanitarian aid for affected population. Drone-derived information is available through common information environment enabling efficient analysis and sharing of drone information between all stakeholders involved.

Large scale wildfire

The summer has been extremely hot and without any significant rainfalls for more than one month. The peatbogs of Biebrza National Park – usually humid moors – are dried and dusted. One day the worse happens – a fire breaks out in a neighbouring pine forest and is quickly spreading. Despite all the efforts of the fire service from the adjacent counties it soon becomes clear that the fire will be very difficult to contain and the operations will last for days, if not

weeks, requiring extensive use of all available resources, including drones of various rescue services units involved. Therefore, When the Incident Command Post is being set, the response management staff includes not only the Air Operation Coordinator, but also the Flight Director.
The AOC oversees the overall tasks performed by the drones, and is a member of the staff, carrying out queries from all sections and optimizing task execution. He can be also tasked by Operations Center (JIC, EOC[7] etc. if such are active). He has authority over the drones deployed by various agencies and prioritizes the flights performed by manned aviation as well as drones. AOM is the person with an overview of the overall crisis and executes the orders of the Incident Commander in conducting flight management. He has the tools to do so.
The Flight Director during this time, performs the task of overseeing aircraft, managing them and responding to changes. He makes corrections and recommendations on the trajectory of individual ships, also manages the airspace assignments. His primary job is the management of all drones and all air volumes.

In a major event like a large-scale wildfire, drones operate on par with manned vessels. Their flights are organized as “a sandwich”. "Strategic" aircraft (usually bigger, fixed-wing drones) observe from higher altitudes the general area and support, for example, precise guidance of water drops through direct communication with the pilots of water-bombing planes. At the same time smaller aircraft, flying well below the manned planes, continuously "draw" the area under fire and transmit the data for the use of section commanders. Thanks to that approach the IC is not only able to have a permanent monitoring of the fire situation at both strategic and tactical level, enabling him to dispatch the available resources where they are most useful and needed. Local commanders have up-to-date information about terrain obstacles in their area of operation, they know exactly which roads are blocked and which are passable. Unfortunately, GSM coverage in a national park was already sketchy at best and with some infrastructure destroyed by the fire there are areas with no connectivity. Several tethered drones have to be brought in to serve as flying radio masts providing satellite internet access for rescuers, who otherwise would have been almost completely “deaf and blind”.
After some days the fire service managed to put out the fire in the area that was affected first and moved on to other location. Drones with optical sensors were then used to map the damaged area and help to assess economic and environmental losses. Luckily, the experienced IC also asked for regular monitoring of the burnt-out area by UAVs equipped with thermal scans. One such flight detected a spot with higher temperature, which was checked out by a fire unit – at the very last moment, since it turned out that even though the fire on the surface of the peat was extinguished, it was still burning inside and another fire outbreak was imminent.

3.1 Key enablers

“Complex operations” by its nature require implementation of enablers from both “First on scene” and “First 2 hours” groups. **Air traffic management arrangements must permit simultaneous safe and**

[7] Emergency Operations Centre operates on strategic level, possibly managing many disaster sites; Joint Operation Centre covers multi-agency coordination; Joint Information Centre is a media interface.

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coordinated flights of both human-operated aviation and drones. Minimising limitations for freedom of their operations will enable a concerted effort of manned aviation used mainly for transportation, observation and firefighting if needed and drones realising wide scope of their activities. This ability is considered by civil protection practitioners as the most important gamechanger – factor that may greatly increase effectiveness of drones for crisis management.

The systemic arrangement needs to extend capabilities described in "First 2 hours" and altogether its functionalities should include:

- implementing restrictions for third-party air traffic over the crisis area;
- procedures for coordination of crisis-related air operations, recognised by all stakeholders (in particular different services involved in operations);
- establishment of a dedicated position (Air Operations Coordinator – AOC) responsible for such coordination;
- means of communication and exchange of situational information among all pilots, including pilots of human-operated aircraft;
- technical ability to negotiate and approve, supervise and modify if necessary parameters of clearances issued for BVLOS flights.

For complex operations with participation of several human-operated aircraft there is a high value in involving personnel with air traffic controller's competencies (Flight Director). Such person may act as assistant of AOC, coordinating on his behalf the air operations with use of aviation radio. Flight Directors might be detached for large crisis operations from ATM agencies or military, but it is critically important that they participate in civil protection exercises to develop understanding of crisis management operation realities.

Implementation of dedicated IT solution – system supporting communication among pilots and providing common picture of aerial operations to all stakeholders – should be considered. Such system has already been recommended in "First 2 hours", but it's even more important for improving coordination of complex operations. Such system should be able to exchange information with ATM systems.

Availability of advanced GIS systems is needed to **optimise utilisation of drone-derived data, which should be integrated into an overall geoinformation ecosystem used for crisis management**. This will enable integrated use with other data and lead to enhanced analysis (e.g. automatic change detection on maps) and innovative applications like tracking-on-video (real-time visualisation of rescue services units on drone video). Advanced GIS functionalities need to be implemented through establishment of proper standard operational procedures for both analytical and command processes as well as an appropriate training.

Effective sharing of drone-derived information among different stakeholders may have a major impact on efficiency of cooperation in complex situations. Such ability is considered by civil protection practitioners as one of the most important factors that may increase efficiency of use of drones. It may be implemented by establishment of common GIS systems or by ensuring interoperability between systems of all stakeholders. The end result should be a situation in which **if one sees something, all can see it**.

3.2 Technical solutions

Technical capabilities have already been described for all key functionalities of "Complex operations" use cases.

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Progress in all areas indicated in "First 2 hours" will also increase efficiency of complex operations. Beyond those, increases will result from further developments in data processing, analysis and sharing, in particular resulting from improvement machine learning/AI and increasing availability of computing power. They will include i.a.:

- advanced analysis of images and video (e.g. advanced assessment of scale of damage, road accessibility);
- advanced integrated analysis of data from different sensors (e.g. visual, IR, lidar scanning);
- detection and interpretation of changes between different sets of data acquired during the operation (both video and maps);
- detection and interpretation of changes in comparison to pre-event data from different sources (including satellite images);
- rapid generation of mapping products, in particular real-time growth of map based on data transmitted from overflying drones;
- ability to combine video with other geospatial data (visibility of map or GIS data as overlay on real-time video).
- Ability for data based cooperative and non-cooperative surveillance[8] of the airspace.

Other technical improvements affecting long-term crisis management activities are related to increasing drones flight time and hence their availability to conduct missions. In particular improved capabilities of tethered drones may lead to facilitating long-term continuous monitoring of affected area and rescue activities. They may also offer functionalities of temporary telecommunications masts.

3.3 Use-cases

Monitoring of area of operations: change detection, specific analysis (e.g. monitoring of evacuated area)

This use case represents extension of "Situation/damage assessment, monitoring of response activities" and "Decision support" cases from "First 2 hours". During complex and long-term operations drones can be used for generating an integrated common operational picture of area of operations. The high-flying drones can be used to provide real-time video surveillance of any area of interest. Regular data acquisitions enable regular mapping, analysis and detection of changes. Lower flying drones can provide information support locally over specific sites and conduct non-information gathering activities.

Use of automatic analytical solutions, including those based on machine learning and AI, facilitates analysis of situation and provides continuous updates about critical events (e.g. changing position of fire fronts or newly observed presence of water during flooding). Specific issues may be monitored, e.g. detection of presence of individuals in evacuated area. Video and maps can be enhanced through integration with other types of data e.g. indicating position of rescue units (from tracking systems) or inhabited houses (from public register).

[8] In contrast to the declarative approach, the data-driven approach involves active detection of aircraft using, for example, radar, audio or optical sensors. This will make it possible not only to detect non-cooperative aircraft, but also will allow better control of the position of ships involved in operations that, for whatever reason, do not broadcast their position accurately or frequently enough.

Easy access to such information significantly increases situational awareness and improves command processes. Ability to share information – all stakeholders participating in rescue operation can have access to the system – results in significantly easier coordination of activities leading to increased efficiency of the operation.

Transport: humanitarian aid and logistic of rescue activities

Drones equipped with cargo compartments or payload systems can carry specialised equipment needed during rescue activities. They can also carry items such as medical supplies, food, water, communication devices, and rescue equipment to affected population in disaster-stricken or isolated locations. This capability significantly enhances the speed and effectiveness of rescue operations, especially in situations where traditional transportation methods are impractical or unavailable. By bypassing ground obstacles and traffic congestion, drones can quickly deliver life-saving resources to those in need, contributing to the overall success of rescue missions. Additionally, drone transport reduces the risk to human responders, as it minimizes their exposure to hazardous conditions and allows them to focus on other critical tasks.

eVTOL – evacuation of population from affected area

The eVTOL fleets, despite their controversial nature (discussed further in the General enablers: public acceptance section), should be included also in Civil Protection planning. They can be expected to participate effectively in the evacuation from areas where ground access is not possible (modularity may allow fast adaptation for HEMS missions), deliver experts and supplies and carry out other helicopter tasks.

Transport of people via drone – Paris 2024 use-case

The Paris City Council recently rejected the idea of introducing flying eVTOL taxis during the 2024 Olympic Games, despite initial enthusiasm for this innovation. The project, which would have involved around ten small electric eVTOLs called Volocity, was deemed environmentally unfriendly and absurd by Parisian officials. The Volocity, built by a German start-up, would have been used for an aerial transportation service on predefined routes, connecting airports and the Paris heliport. Despite the interest in developing this mode of transport, particularly for medical emergencies, the planned experimentation during the Olympics has been postponed. Meanwhile, China is leading the way in certifying a recent electric and autonomous flying taxi, paving the way for commercial operation of this technology in major Chinese cities. This marks a turning point in aviation history, with China outpacing Europe in this field.

Several elected officials highlighted the Environmental Authority's decision in September to halt the flying taxi project due to an incomplete impact study, particularly concerning the future "vertiport" of Austerlitz. The study raised concerns about noise pollution, the impact on surrounding activities and biodiversity, and the significant footprint on the Seine river. It also noted that a journey by eVTOL brings30 times more pollution than by subway. Despite this, the Region and its partners are eager to proceed with the experimentation, aiming to be the first among major cities, albeit at the expense of other mobility investments. However, critics argue that this rush is unnecessary, given the substantial environmental impact, the lack of necessity and the high energy consumption of these flying vehicles, nearly 190 kWh per 100 km. The project is seen as environmentally destructive, prioritising the convenience for privileged individuals over climate urgency. It was denounced by the City Council as an ecological aberration promoting social separatism, with the exorbitant cost of 140 euro for a 35 km journey, making flying taxis inaccessible to many.

The City of Paris' main concerns regarding the incomplete environmental impact study:

- *Potentially significant and poorly assessed noise pollution;*
- *Unevaluated impact on activities adjacent to the port;*
- *The landing site on the Seine river occupies space within 25 metres between the quay and the navigation channel. The VNF and DRIEAT rule, of maintaining a distance of 5 metres from the navigation channel, is not respected. In addition, landing and taking off so close to the navigation channel, thereby potentially disrupting water traffic, have not been addressed in detail in the documentation. Currently, this sector is part of the P23 zone prohibited for air navigation, which would require an exemption from this prohibition;*
- *Impacts on biodiversity are undeniable, but not properly assessed;*
- *Insufficient and underestimated CO_2 and energy footprint;*
- *Potentially high impact on safety and risks to people and property.*

Figure 3.1. Volocopter's VoloCity aircraft was supposed to be used during Paris 2024 Olympic Games. Credit: (Volocopter, 2023)

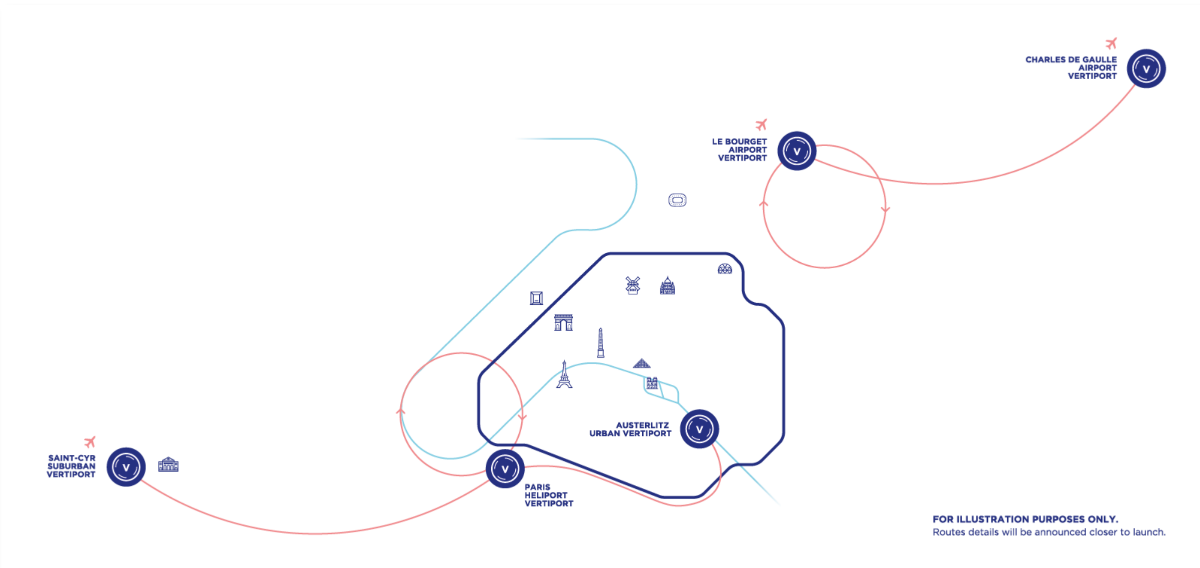

Figure 3.2. Electric air taxi routes planned for Paris 2024 Olympics (not realized). Credit: (Volocopter, 2023)

4. Supplementary use cases

This chapter presents two additional groups of use cases. They represent additional functionalities of drones not covered by previously discussed groups, but in general they are based on the same enablers and technologies.

4.1 Threat monitoring

Flying eyes – gathering of information	Flying robots – other activities
• Monitoring during high-risk periods (flooded dykes, very dry forests) • Regular infrastructure monitoring	

Use of drones for monitoring of threats covers observation activities conducted not during crisis, but as a preventive measure. They are realized by drones equipped with various sensors to observe and assess potentials risks or to early detect emergencies. Flights may be undertaken during high-risk periods or conducted regularly.

Threat monitoring is of a more orderly nature, very closely comparable to, for example, routine technical flights for the maintenance of linear infrastructure, or for the transport of goods by unmanned aviation. However, it is conceivable that such activities could also be implemented on an ad hoc basis, in response to risks such as flooding. Then, of course, it will require the use of tools to change the Airspace Usage Plan by adding new volumes there and changing old ones.

Heavy rainfalls causing the risk of flood

For almost a week heavy rains have been falling in an isolated mountain area, causing the local rivers to overflow and carrying the high water levels further to a rural area with lots of crops about to be collected and several relatively densely inhabited villages located close to the main river.

Anticipating the arrival of floods, experts report to the leading emergency responder with a demand to establish a routine of technical inspections of the embankment that will soon be put to the test: high water. Since adequate resources are held by the military, a request for support is written to the appropriate agency.

When the strain on floodwalls increases, long-range aircraft take to the skies, using thermal and RGB cameras to watch the embankments for indicators of impending failure (by hand as well as automated by post-processing image recognition). In one location, a pool of water is detected outside of a levee, with temperature lower than the surroundings, suggesting a possible seepage from the river. A team is dispatched to the site to verify the situation and strengthen the levee. At the same time, in specific regions drones with LiDAR equipment are flown to perform a comparison of the current relief of the embankments with its previous recording, looking for anomalies, subsidence, etc. Several "risk spots" are thus detected and

> *repaired in advance. In one case a simulation made on the basis of drone data suggests that a break in the embankment would be a threat to a herd of cattle, several farms and fields, so the animals are moved to a safe location, crops gathered immediately and houses safeguarded by the firemen and prepared for evacuation.*

In terms of key enablers and technologies “Threat monitoring” use cases are analogous to “First on scene” as they operate as BVLOS flights. They will also benefit from development of some technologies related to data processing and analysis described in “Complex operations”.

Monitoring during high-risk periods (flooded dykes, very dry forests)

During periods of increased risk drones can be used for risk-specific monitoring. Two specific areas are: monitoring of dykes during floods; and surveillance of forests and green areas during periods of drought/very high fire risks.

Drones can carry different types of sensors, such as cameras, LiDAR, thermal imagers, and environmental sensors, allowing for comprehensive data collection. By flying predefined routes or patterns, drones can repeatedly gather data over time, enabling detection of emergencies as well as monitoring, analysis, and comparison of changes or trends in the area of interest.

During floods and high-water periods repetitive measurements of dykes with photogrammetry and lidar enable detection of small geometry changes which may indicate potential instability. Detection of thermal anomalies inside the dyke or presence of water on the “dry side” may be an early indication of growing risk of hydraulic punctures. During drought periods monitoring of forests focuses on presence of smoke and thermal anomalies – very small fires can be detected early, enabling rapid response and preventing their expansion.

Regular infrastructure monitoring

Drones are used to conduct regular flights to monitor infrastructure and check conditions of its operation (thermal irregularities of solar panels / power lines, signs of illegal earthworks e.g. removal of turf near dykes).[9] Ability to detect abnormal situations related to critical infrastructure, either natural or resulting from human actions, represent an important method of improving their safety and security. Such activities may be economical in comparison with traditional methods and can cover difficult-to-reach areas which are not inspected regularly. They also allow low-cost verification of execution of contracted infrastructure maintenance work. In addition, regular drone monitoring may deter petty thieves who often try to loot remote infrastructure.

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[9] Currently such flights are being carried out, but there are complaints about the high entry threshold for legalizing such flights.

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Shark detection (Australia)

Started in 2017 and supported by NSW Government as part of a 5-year safety strategy, the program has been extended to run for an additional 4 years. Flights are approximately 20–25 minutes, 2 flights per hour. 450 pilots keeping beaches of NSW coasts.

According to Southern Cross University researcher Andrew Colefax, the day is nearing that autonomous drones — which do not require a line-of-sight operator — will be able to offer shark detection at any point along the coastline.

He has spent four years of intense research and development in the field of drones and shark detection, and said artificial intelligence (AI) and machine learning will be a game changer on beaches in the near future.

Figure 4.1. Artificial intelligence-guided shark detection drones are the next step in beach safety. Credit: Southern Cross University (News, ABC, 2020)

4.2 Safety of public events

Flying eyes – gathering of information	Flying robots – other activities
• Situation visual monitoring • CBRNE monitoring	• Safe interception of rogue drones

The final group of use cases covers use of drones in close proximity of public gathering of all kinds. The aerial surveillance helps organisers and security personnel to effectively monitor crowd behaviours, detect any signs of disturbances or emergencies and by doing so, ensure the safety and security of all attendees. Use of drones enhances situational awareness and enables proactive measures to maintain order and safety during public gatherings and to react more swiftly and effectively to emergencies.

Use case scenario storyline: Safety of public events

#1 Poland hosts Europe's largest open-access music festival every year. The multi-day event requires adequate facilities - in addition to multiple stages and food and beverage outlets, there are uncontrolled tent fields that stretch for hectares.

As long as the event has a standard-setting approach to emergency medical services, steward communications, a container-based command and control centre (that hosts liaisons from all services), that events staff manages based only on verbal communication and photos sent over the GSM network. The area can only be viewed from cameras on top of the stage and on the shortwave transmitter tower, but there are countless blind spots. Not to mention the lack of a full picture of the entire event and its crowd dynamics.

Of course, flying over crowds is not recommended for security reasons, but a properly constructed aerostat or drone circling the event area continuously in a distant "orbit" can successfully monitor the area, detecting critical signals (e.g. open fire seen in thermal imaging, dangerous crowd behaviour, potential signals of a terrorist attack etc.) or just providing overwatch for staff on the ground. Small drones in safety cages, meanwhile, could provide a convenient way to find paramedics who are waiting in a packed crowd for the arrival of an ATV with a rescue trailer.

#2 Social unrest, which often occurs spontaneously and in areas where flying is restricted or entirely forbidden, is a phenomenon that will uniquely benefit from the safe use of drones. Drones that will quickly go to the designated launch sites, and in proper coordination with AOM, operate as safely as possible. Assisted flight with selection of least vulnerable areas would allow drones to move around, and for highly sensitive areas, the forces Staging Area can serve as a safety buffer for a stationary lookout.

The presence of a constant stream feeding the Joint Information Centre, allows to transmit a fair message including - automatic and unbiased recalculation of participants, comparison of images at the start of recording / after actions for estimating losses, precise tagging, tracking and collection of evidence of criminal actions. It is also possible to assume the existence of psychological effects, the source of which would be a mutual awareness of the constant

surveillance of the site, both on the part of the participants in the activities, bystanders and responders (provided that there is open access to the recordings recorded).
Methods of anonymization (black bloc) used by criminals can be effectively responded to by using tracking mechanisms that provide real-time information on the interface carried by intervention groups.

Drones in law enforcement in France

After huge and violent protests in opposition to the pension reform in 2023, French police are allowed to use drones equipped with cameras for a wide range of tasks including crowd monitoring and border control.

The drones can also be used for the prevention of terrorist acts, the regulation of transport flows, border surveillance, and rescuing people, the decree said.

14/11/2023 - Police began flying drones over the Jeanne-d'Arc neighbourhood in northwest Toulouse to more effectively identify and pinpoint dealers in action.

Figure 5.1. Police drones are used in France to monitor public gatherings. Credit: AFP via Getty Images

Key enablers and technologies required for "Safety of public events" use cases are analogous to "First 2 hours", with particular focus on coordination of multiple flights. They will also benefit from development of more effective solutions related to data processing and analysis described in "Complex operations".

The specific requirement is ability to fly over people, resulting from implementation of solutions minimizing ground risk. Development of relevant technologies will significantly benefit this group of applications.

Situation visual monitoring

Drones during public events can provide an aerial view of the event area, allowing authorities to assess crowd sizes, identify potential safety hazards, and monitor for any unusual activities or incidents. Drones are not a replacement for on-site monitoring systems, but they enhance such capabilities, offering ability to react more flexible to unexpected situations. They are also a highly valuable capability in case of ad-hoc gatherings where existing monitoring infrastructure is not sufficient.

By providing a bird's-eye view of the situation, drones help enhance security measures and ensure the safety of participants during public gatherings. During emergencies they can also be used to relay voice messages directing evacuation or helping to control crowd behaviour. It may also be possible to use them as visual indicators of danger (red) or safe (green) areas.

Drones can also offer methods to dynamically mark points and people in the crowd that are of interest to officers. They can lead to these points, either transmitting coordinates or physically gliding safely over the heads of the crowd.

CBRNE monitoring

This use case is analogous to “Special sensors” in “First 2 hours”, but is indicated here due to special importance of such monitoring in case of some public events. Drones equipped with specialized sensors can collect real-time data, detect and map potential risks, including: air quality, presence of hazardous substances, radiation levels, and even samples of biological hazards analysis. This capability allows for rapid response and decision-making by authorities.

Safe interception of non-cooperative drones

This report in general does not cover the theme of counter-drone activities. However in the specific context of public events it is necessary to recall importance of this issue.

The safe interception of rogue drones involves using specialized counter-drone technologies to neutralize unauthorized or malicious unmanned aerial vehicles that may pose a threat to safety and security. In case of public events safety of interception is of highest importance. Typical methods employ a range of technologies, including radio frequency jamming and spoofing, drone capture nets, kinetic impact systems, and directed energy weapons, to disable or immobilize rogue drones effectively.

Interception over the public event represents extremely high risk and in majority of situation will be avoided. In specific cases when it may be necessary, use of own drones to “catch” the intruder into safety net or similar system may represent an optimal method minimising risk for the public below.

Alternatively, other means might be used to disrupt non-cooperative drones’ operation - such as dazzling[10]: an effective jet safe countermeasure towards unauthorised information gathering. Method bases on following the drone’s optical sensor with an aimed focused energy source (e.g. laser beam) to effectively blind it (Grundmark, 2021). Such counter-intelligence, surveillance, and reconnaissance (C-ISR) systems already find their experimental usage in military, (e.g. ODIN - Optical Dazzling Interdictor, Navy) (NAVSEA Naval Sea Systems Command, 2020).

[10] Dazzling Interdictor devices, counter-intelligence, surveillance, and reconnaissance (C-ISR) capabilities (e.g. ODIN - Optical Dazzling Interdictor, Navy)

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5. General enablers

The final chapter provides overview of issues that may limit effective and efficient use of drones in civil protection organisation.

Public acceptance

Public acceptance is essential for the successful integration of drones into civil security operations. Engaging communities in discussions about drone usage fosters transparency and ethical considerations, ensuring that safety and security measures align with public values and respect individual rights. When communities understand the benefits of drone technology in enhancing security and public safety, they are less likely to resist[11] or obstruct drone operations.

During COLLARIS project activities authors have encountered many individual examples where the lack of public confidence or lack of public awareness regarding the degree of safety of UAV flights being performed affects the perception from both the public and the emergency actors themselves[12], as well as contributes to an apparent reluctance on the part of other airspace users[13].

Publicising examples of positive drone use should help reverse this trend, stemming in part from behaviour that can be attributed to *the curse of knowledge* bias: the assumption that the benefits of drone use by the blue lights sector (colloquially: emergency response institutions) are obvious, while in a person's statistical perspective, drones may seem like an overpriced toy. Additionally, drones reputational damage, suffered among professionals during initial inflated expectations that resulted (in some countries) by anchoring unreliability and underperformance to drones is already reversing. Even without additional measures, it will osmotically transfer to officers who have not yet managed to convince themselves of the utility of unmanned aircrafts.

Privacy and cyber security issues

While use of drone data have significant value for crisis management activities, obtaining and storing the same data rise issues related to respecting privacy. Institutions collecting and using such data need to ensure that it is properly protected against accidental or intentional interception. While its use for rescue and crisis management needs enjoys high level of public acceptance, it is critical to avoid compromising that attitude and accumulated public trust by any widely publicised mishaps.

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[11] (The City of Paris, 2023) - Notice regarding the request for authorisation to create a vertiport on the Seine in Paris, quai d'Austerlitz (13th arrondissements). The argumentation cited in the document refers to false characteristics of unmanned vessels (in this case eVTOLs) (noise generation, ability to conduct operations, unfair comparisons to diesel helicopters) which may indicate the occurrence of multiple biases against aviation of this type.

[12]As an example, there is a tendency to avoid flying over people also in the context of a rescue area (see: SOP in France, Sweden, Norway - Deliverable D2.1 – Overview of doctrine, best practices and SOPs of UAS use in selected thematic areas: Similarities and differences). However, a risk analysis performed by the Association for the Promotion of German Fire Protection (vfdb, 2021) indicates that German rescuers are equipped with full-body protective equipment which is certified up to 250J (protecting against a 900g drone free-falling from up to 30m). This could suggest the need to revise the general regulations used to date in the context of saving lives.

[13] Based on the list of potential advantages presented next, we suggest that the perception of drones by manned pilots (in the context of both manned flights for rescue operations and the general approach of GA pilots) be influenced so that safety buffers can be reduced and pilots relinquish some of their privileges (eg. HEMS respecting 150m limitations, GA pilots avoiding areas where they spot blue lights etc.)

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Data acquired during different types of crisis management activities often contain sensitive information (e.g. related to critical infrastructure or operational procedures of different services) and may represent a potential security threat. Implementation of proper cyber security measures is a general requirement that must be obligatory in any systemic solutions. Furthermore, definition of specific regulatory framework for GIS systems may also be needed. Lack of such mechanisms may lead to reluctance founded on national security in implementation of innovative solutions based on drone-derived information analysis – solutions offering major benefits for efficiency of crisis operations.

Another issue results from wide use of drones of foreign manufacture. While they offer high capabilities at very affordable price, issue of information security remains unresolved. There is a need to balance national security concerns and ability to afford low unit price drones (and related hardware, including phones and tablet used for controlling them). One of possible intermediate approaches may be recognition of separate information security regimes for different drone systems and limiting use of those at lower level of security for non-sensitive activities.

Resilience to GNSS distortion

Non-military drones are fully dependent on satellite navigation (GNSS). As a result, any substantial GNSS distortion eliminates ability to use such systems and cause safety risks. GNSS distortions can occur due to various factors such as signal jamming[14], interference[15], or spoofing[16], which can disrupt drone navigation and cause safety and security risks.

While currently there are no practical methods to fully eliminate these challenges in low- and medium-price drones, it is necessary to realise existence of these risks. There is also a need to seek mitigation of this dependence with research efforts aimed at more resilient navigation systems that can adapt to GNSS disturbances or rely on alternative navigation methods.

Specialised training

Multicopter drones are already so easy to operate that in authors opinion basic pilot training should not be considered a barrier to their use[17].

Research conducted by the COLLARIS project has shown that there are currently no flight trainers dedicated to emergency response issues (many institutions, such as VALABRE, have a trainer that is not a simulator). However, in response to the need, such systems should be developed, and their design should take into account two aspects: realistic flight physics in an immersive simulator environment (e.g. google VR or AR coupled to a wind sensor for field training; peripherals identical to the proper ones; the pilot's perspective (ground view); properly simulated telemetry (also reflecting malfunctions, interferences and

[14] Sending radio-frequency signals to interfere with radar operation by saturating its receiver with noise or false information.

[15] It is distinguished from intentional jamming in that it can occur due to the operation of other devices, malfunctions or other random circumstances.

[16] Intentionally sent signal, the content of which causes it to be successfully identified as another.

[17] At a conference on aspects of defence against UAV-type means, the following general observations were shared: about 10-15% of personnel are unable to learn how to operate remotely controlled devices such as unmanned turrets, electronically controlled water cannons and UAVs. Detailed statistics were not disclosed, but representatives of the Polish Army declare a decreasing trend in this regard. The following observation was also shared: it seems that those who declare exposure to computer games, especially those controlled with pads, are achieving proficiency in the use of equipment faster (Wolski, 07.02.2024).

signal loss) and realistic representation of crisis scenarios, including physics of phenomena (e.g., winds inducted by wildlife fires), immersive animated rescue operations and allow multi-pilot operations in a single instance (multiplayer).

There is also a general lack of electronic training tools for flight management (air traffic management aspects), but such training can be done conventionally, using table-top methods.[18]

Different countries approach standards for training and verifying skills of drone pilots in different ways. Currently, the prevalent approach is to refer to national regulations in line with EASA standards, which can be compared to a "driver's license" for remote pilot, continued by informal training in units. Some countries provide dedicated training: the U.S. NIST has additionally proposed a standard test methods and performance metrics for pilots allowing quantitative measurement and comparison[19].

Authors anticipate that in the next 3-5 years each member state will create (or at least establish) its own Emergency Response Aviation drone pilot training competency. There is a high value in facilitating dissemination of good practices in training and examination methods (which is already realised by networks such as COLLARIS and IEDO). However, as indicated in this report, commanders training at the tactical and operational levels in use of drone capabilities should not be overlooked either. While the issue itself is not complicated, delivery of appropriate training (including practical training) to all commanders requires a noticeable effort. The success will significantly depend on existence of appropriate training mechanisms in each institution.

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[18] Polish PANSA declares its willingness to develop a suitable trainer functionality to extend their ATM system Search&Help as a possible continuation of this already completed project.

[19] https://www.nist.gov/el/intelligent-systems-division-73500/standard-test-methods-response-robots/aerial-systems

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