Monitoring with drones during a major emergency

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Abstract. The monitoring of the consequences of a major incident spreading in the territory is one of the most important actions. It also has to ensure the safety of the people who may be involved so that the Civil Protection and other Bodies involved in handling the emergency can intervene immediately. In order to determine the immediate (and critical) actions to circumscribe and counteract the consequences of a major incident, monitoring of the ongoing emergency includes the observation, analysis and assessment of the spread of fires (causes also of possible domino effects between neighbouring industrial structures), of contamination and pollution of the soil, water and atmosphere by hazardous substances. The use of Unmanned Aerial Systems (UAS), commonly known as Drones, is excellent for many of the essential monitoring functions, both from a visual and from an analytical point of view. They provide spectral analysis detection systems and lasers to avoid exposing personnel working in the emergency to possible risks. The technological evolution reached enables monitoring missions to be set directly from a laptop and to receive information directly via an extremely reliable, safe connection. The observer Drone (or drones) can also be aimed manually at points of particular interest. This report illustrates a complete system (hardware and software) dedicated to the visual and instrumental monitoring of the consequences of a major incident in the territory, supported by pre-set criteria to assess the spread of the effects.
Key Words: UAV, drone, emergencies, fire, contaminants, toxic substances.

Introduction

Major emergencies. Plants that exceed a specific threshold of quantities of hazardous substances, present within the system, are defined as being at risk of a major fire according to the Italian Legislative Decree 105/2015 (Seveso III). Same legislative decree defines a major incident as: "an event such as a large emission, fire or explosion, due to uncontrolled developments, which occur during the activity of a plant subject to this decree, and which gives rise to a serious, immediate or delayed hazard for human health or for the environment, inside or outside the plant, as a result of one or more hazardous substances". From the above description, the harmful events which can trigger the release of these substances into the environment are emissions, fires or explosions, resulting in a state of emergency for the area surrounding the point of release. In addition to these harmful events, there are also natural catastrophic incidents, that is to say events not ascribable to human action, such as landslides, earthquakes and hydrogeological activities. As the latter do not involve toxic or harmful substances, they do not lead to deferred damages on the population in the neighbouring area, but only on the immediate circumstances that have a long-term effect as a result of the extensive damages caused.

Applicability. The possibility of viewing a major event from above with multiple spectrum analyses demonstrates the potential of these aerial systems. The instruments on board the aircraft also allow the point viewed to be georeferenced with decimal precision to show the major incident moment by moment on a map.

The continual view, for example, of a fire with a thermal camera enables its movement over time to be analysed. Thus, the possible future development of the fire can be predicted and contained. A similar control can be developed during incidents involving plants, to predict the possible domino effects that may occur inter- and intra-plant. The identification of the hottest areas in the equipment, which may involved in a fire, enable preventive manoeuvres to be used, such as cooling mechanisms of the area involved, where present.

The range of sensors that can be installed on board the craft also includes gas detectors. This enables the concentration of that specific gas to be identified in a point in space which, thanks to the GPS on board, is georeferenced. A series of samples of the concentration data enables the space and/or cloud to be destroyed over time. The data obtained in the event of a continual release can be used to obtain a map of the cloud and to identify the area of release, by using possible specific algorithms. In the event of an instantaneous release, on the other hand, it enables us to identify the direction of the trend of the maximum peak and its spread over time.

The regular viewing of areas of seismic and hydrogeological risk allows a continual control to be maintained on the morphology and, therefore, enables areas subject to landslides or incidents to be identified. The opportunity to provide a three-dimensional reconstruction of the area under analysis via the application of software, with the photogrammetric reconstruction of the images acquired during flight, enables an archive to be created on the variation over time and the identification of the landslide volumes. This application, therefore, enables the seismic status of specific areas to be analysed and possible future earthquakes to be predicted (www.tirreno.it 2014) (www.unige.it 2014).

Material and Method

Monitoring with UAS. The proposal uses UAS (Unmanned Aerial Systems), equipped with opportune sensors, to fly over the area surrounding the plants and to give the possibility of managing major incidents and identifying the areas of release. The continual communication of the data collected and its reprocessing at the control station on the ground enables specific, targeted actions to be taken to reduce or even to cancel undesired secondary effects.

The use of these means allows the risk ascribable to the use of human operators to be eliminated both during sampling to highlight anomalies and to manage emergency events in progress. Even though the operators hold portable alarms, their lack of knowledge of the substance could drastically increase the possibility of causing injuries to the workers.

The main feature is the possibility of regularly monitoring the areas of interest, which are at greatest risk of coming into contact with the substances being analysed. This use enables events (releases) to be identified, which may not be identified by the normal monitoring systems, and above all it enables rapid interventions before the spread of the substances causes greater, unpredictable damage. The capacity of the craft to fly over wide areas enables the extent of the release to be analysed in detail. This is of specific importance if the substance is released into a river or sea, where no watertight means is available, into which the substance must spread and where there is turbulent movement which encourages it to spread.

Historic analysis. A historic analysis of accidental events that have occurred in recent years gave the idea of having to use a suitable means to control vast areas. This shows how a delay in identifying the event can cause the toxic agent to spread and increase the area of damage.

The detailed study of the incidents focuses on the more catastrophic events or those that had a great impact on the population, and on the flora and fauna present. The main causes of these events were mainly due to structural or operational failings of the system. The events considered were: Oppau, Germany – 1921; Feyzin, France – 1966; Flixborough, UK – 1974; Seveso, Italy – 1976; Youngstown, Florida – 1978; Bhopal, India – 1984; San Juan – Mexico City – 1984; Priolo – Italy – 1985; Piper Alpha, UK – 1988; Pasadena Texas, USA – 1989; Bangkok, Thailand – 1999; Enschede, Holland – 2000; Tolosa, France – 2001; Buncefield, UK – 2005; and Danvers, USA – 2006.

The list includes all the scenarios which could occur in the production or storage areas or in transport logistics. A concentration can be seen of explosions and fires, and also of toxic dispersions (Bhopal, India – 1984) and events with a domino effect (e.g.: Feyzin, France – 1966, San Juan – Mexico City – 1984 and Pasadena Texas, USA – 1989). The study is not concerned merely with the events that caused deaths, but also damage to the population or the surrounding environment, the most famous of which was the event in Seveso, Italy - 1976, where dioxins were released and caused the phenomenon of chloracne in the population. This event was the spearhead for the creation of the European directive, which took the name of the place of the event, Seveso (ICARO Srl, Historic analysis 2011).

As regards major events of release into water, the most famous is the one involving the River Danube in 2000. To be precise, the event took place on 30 June 2000, following a breach in the decantation basin of the storage company AURUL, located in Baia Mare. The decantation waste containing cyanides was released into the river near Baia Mare. The latter is a tributary of the River Somes, Tibisco and then flows into the Danube. This easily spread the contaminated water, which devastated all the surrounding flora and fauna (UNEP 2000). The most recent event took place in April 2016, when there was a spillage of crude oil from the pipeline in Fegino of the company Iplom of Busallo.

The historic analysis used the major databases and enabled the incidence of natural events to be identified as a cause of incidents for industrial systems. Over a time span of 100 years, approximately 16,000 incidents have occurred and only 1.42% of these are ascribable to natural events. In turn, only 10% of that value concerns earthquakes, whereas floods account for 22%. Although these values are not high, the numbers of accidental events is increasing if placed side by side with the incidents that cause damage in civil environments.

The analysis allowed us to identify five main activities arising from the development of major incidents, which are:

- explosions or fires;
- release of toxic/flammable substances into the air;
- release of contaminants or toxic substances into water;
- release of toxic substances into the soil;
- search for survivors.

These gave rise to five UAS configurations, each designed for a specific solution. Each of the drones have the necessary standardised features and we will proceed to describe the basic device and the specific customisations according to the action required. A specific paragraph will be dedicated to each craft, showing the main characteristics of both hardware and software.

Results and Discussion

Explosions or fires*.* The basic conformation in the first four accidental events is a fixed wing system. This is a craft in which lift is created by an opportune wingspan and by its relative speed. The structure requires a minimum consumption of energy to keep it in the air and therefore allows it to travel medium/long distances. The main prerogative, which allows it to travel continually over the areas required over time, is the need to remain at a height for times requested by control, and therefore it must possess a high level of autonomy of flight. The solution was to provide the craft with a large "tank", that is with a quantity of batteries that prove to be the optimum compromise between the additional mass and the additional consumption of energy. The craft was designed to be able to fly 24 hours a day, day and night. The UAS is equipped with regulatory position lights according to the rules of aviation, as it is also considered as an aircraft. Flight at night does not enable it to be seen. The vehicle is continually tracked by the addition of a transponder to identify the position of the UAS in space. The possibility of obstacles near the craft makes optic and sonar distance sensors necessary. These communicate with the internal flight system to enable deviations from the planned route during flight. All the instruments and, therefore, the vehicle itself, communicate continually with a ground station where, via dedicated software, the telemetric and position data and data from the preinstalled sensor is processed. The presence of a station on the ground is fundamental for man to be able to intervene at any time. The GCS (Ground Control Station) is equipped with joystick, lever and digital pedals, as in any aircraft. In the event of an anomaly, the pilot takes control of the UAV just using the joystick and brings the craft back safely. For the sake of safety, the UAS needs to be equipped with a flight terminator (in compliance with the legislation in force). This component is preassembled on the drone and, in the event of an emergency, blocks the energy supply and the system drops to the ground. In our specific cases, as the environment beneath the drone is extremely dangerous, a simple flight terminator would not be the best solution. It requires a system that guides the drone to a free area, where it can glide and land autonomously. The UAS internal hardware has extra parallel sensors to be able to reduce the fault rate of the machine and guarantee a greater operational capacity (Austin 2010). From this description one can sense that one of the critical problems whilst flying over these areas is to guarantee a high level of safety to keep the craft in flight in the preset areas. A picture of the vehicle described is given in Figure 1, and Table 1 gives the main features of the craft.

Figure 1. Fixed wing UAS.

Table 1

Main characteristics of the fixed wing UAS

Specifications	*Value*
N° rotors	1
Propeller diameter	279.4 mm
Maximum payload	~1.6 Kg
Wingspan	1730 mm
N° batteries	2
Autonomy (limited for aeronautical safety)	80 minutes
Maximum distance covered	~110 Km
Maximum speed	~120 Km h^{-1}
Operational speed at maximum efficiency	~80 Km h^{-1}
Wind resistance with speed	~40 Km h^{-1}

The equipment described and designed is "customised" to function specifically for that particular activity. In the case of explosions and fires, critical weather conditions must be taken into account, which could possibly give rise to ascending currents and the dispersion in the atmosphere of unburnt material. These problems required a specific study into the safety of the material of the structure and into the protection of the sensors assembled on board, which must not be damaged or blacked out.

The UAS payload consists of a thermal camera side by side with a visible camera, to give a view of the temperatures in the areas adjacent to the fire (essential for the identification of possible domino effects) and give a visual shot side by side of the same area. The data measured is recorded and sent to the operator, who analyses in real time the data monitored by the system. The software to be coupled with this hardware enables a slightly rough identification of the development as the event unfolds, to enable a future targeted intervention. The operations to acquire and manage the data change, depending on whether the area of monitoring is inside or outside the plant system. In the event of a fire outside the system, the flight is carried out to follow the interface between the flames and the surrounding vegetation. This is made possible by opportune programming of the internal flight software. The position of the drone, and as a result, of the interfaces of the flames, is continually transmitted to the management platform on the ground. This information enables the development of the fire and the possible interface over time to be reconstructed in a virtual and georeferenced system. The use of a camera enables the type of vegetation present to be analysed and opportune parameters to be adjusted in order to obtain a more accurate temporal reconstruction. In the second case, flight is centred on the area of the system in order to photograph the area involved in the fire as close as possible. The visible image immediately enables the equipment involved by the event to be monitored, together with the equipment which may be involved in a domino effect. Thanks to the view from the thermal camera, a study of the surface temperature of the equipment involved in the fire and the knowledge of the construction material enables the time that will elapse to be calculated before the structural collapse of the equipment. The management software in this case identifies the georeferenced conformation of the flames which, when superimposed on a map of the system, enables the adjacent equipment at risk to be identified. Vision with a thermal camera allows the temperature of the equipment hotspots to be identified and, thanks to structural algorithms inside the software, to determine the time it will take to collapse.

Release of toxic/flammable substances into the air. Clouds of gas are strongly influenced not only by weather conditions, such as wind and the Pasquill stability class, but also by the structural conformations in the adjacent area, which may deviate or modify cloud dispersion. In the majority of cases, the concentration of the cloud is such that it does not allow the gas to be seen (unless the gas is coloured), making visual identification difficult. The UAS associated with the operation does not require substantial modifications compared to the basic version. There are numerous sensors on board: vision camera, thermal camera and gas detector or electronic nose, which enable the substances and concentration present in that space to be identified. During flight, the data recorded by the thermal camera and vision camera is transmitted to the GCS screen to allow a rapid identification by the operator.

The management software works side by side with systems simulating the dispersion (e.g.: ALOHA) with preset parameters inside to provide the rough structure of the cloud, together with some basic information for assessment. The same software has to enable a simpler management of the identified threat. This must allow: the cloud and the substance monitored, the possible spread in the space and the type of release to be identified. The cloud can be identified from a distance thanks to the thermal camera. This is because the substances commonly sought interact with the spectral area of the infrared detected by the sensor of the thermal camera (Gerhart et al 2013). Figure 2 shows a thermal image of a cloud.

Figure 2. Example of a thermal image of a cloud of hydrocarbons (www.cnn.com).

In this case, flight cannot be programmed. Instead it has to be continually changed, depending on the images provided by the thermal camera to allow an opportune collection of georeferenced data. The ability of the craft to "follow" the cloud enables the type of release to be identified: continual or instantaneous. An instantaneous release produces an isolated puff cloud, whereas a continual release produces a plume cloud, from which it is possible to identify the continuity with the release point. The software allows the release point of the cloud to be roughly identified, together with its possible development over time, thanks to the analysis of the consultations present, of the models of release provided by the auxiliary software, of its movement over a short time and the shape of the cloud. The system output is the accurate positioning of the isopleths, constant concentration curves, provided by the software of the models (at possibly different intervals), which are automatically uploaded to georeferenced platforms (GIS – Geographic Information System).

The use of this method enables the spatial and temporal development of the cloud to be promptly identified, as well as the point of release in the section of the system. Thus, targeted interventions can be promptly organised to limit the damage, such as the elimination of the leakage and the preparation of plans to protect the population and surrounding environment. Furthermore, the knowledge of the area which may be involved in the cloud facilitates the identification of the area to be cleared, thus reducing the polluted land with a reduced economic impact on the company responsible.

Release of contaminants or toxic substances into water. Water sources are a fundamental asset for man for drinking water and for crop cultivation and for breeding animals. The quality of the water is one of the principal environmental factors that determine human health. The vast water surfaces, e.g. the length of a river from its source to the mouth or into the sea make this an excellent vector to transport polluted substances, whether dissolved or collected on the top. The identification of these substances enables the spread of the pollutant to be avoided and plans to be drawn up to limit the possible harmful development for land or water organisms and for vegetation.

The use of the UAS with its specific sensors enables superficial collections and possible dissolved pollutants to be monitored via the monitoring of interactions between the toxic substance and the vegetation.

The operative principle is based on the analysis of individual spectra, solar radiation, and surface reflections. The reflected bands that can be analysed are given below:

- blue (B): electromagnetic band within the visible spectrum, with maximum peak around one wavelength equal to 470 nm. It is used for atmospheric shots and for deep sea shots;

- green (G): electromagnetic band in the visible spectrum, with maximum peak around one wavelength equal to 560 nm. It is used for shots of vegetation and aquatic environments at a medium depth;

- red (R): band of electromagnetic radiation within the visible spectrum, with maximum peak at a wavelength of 600 nm. It is used to photograph man-made objects, shallow water and some types of vegetation;

- red-edge (RE): band of electromagnetic radiation placed spanning across the visible and infrared spectrum. The maximum peak is placed at 700 nm with a 50% reduction in intensity at the extremes of the interval between 680 and 730 nm;

- near InfraRed (NR): there are two electromagnetic bands that enable the internal area of the NIR to be covered:

  - the nearest to the visible spectrum has a wavelength that falls within the interval between 700 and 830 nm,
  - the furthest band has a wavelength with the interval extremes between 830 and 1000 nm,
  - the latter are dedicated to the remote monitoring of natural environments.

A multispectral sensor is required that can go from a minimum of three bands (NIR-G-B) to an optimum of six bands (NIR2-NIR1-RE-R-G-B); the one most commonly used has four bands (NIR-R-G-B). The algebraic combination of the intensity of these bands enables specific indices of identification to be created for anomalous substances compared to the water and the stress level of the vegetation to be identified (e.g. NDVI – Normalized Difference Vegetation Index) around the aquatic source. An additional video camera is sometimes associated with this sensor, depending on the number of bands analysed (www.tetracam.com).

The drone needed for the operation has not been drastically changed compared to the basic version. The only additional device was to protect the structure from sea salt, which can be sprayed when the craft flies at excessively low levels. The flight of the UAS varies according to the type of water under examination:

- in the case of a river: the craft leaves the mouth and flies back upstream to the source, so as to identify the furthest point from the release;

- in the case of a lake: flight is circular to give a global view of the stretch of water;

- in the case of an analysis of the coastline: the flight runs parallel in both directions to identify the areas of land nearest to a possible contact with the substance;

- in the case of open sea: flight is circular compared to the departure point and can be calibrated according to what is identified during the actual flight.

This enables the complexity of the software to manage the activity to be understood to provide a considerably flexible use. The sensors on board continually provide data that is collected to allow the operator to make an initial, visual, screen check. The software to reprocess the data allows the anomalous substances to be easily identified, thanks to the graphic, brightly coloured reworking of the data.

It is used to identify even extensive anomalies and to prepare a prompt intervention by the competent authorities to limit the dispersion of the toxic substances and limit the relative damage. Preventive flights also reduce or, in the best cases, eliminate the risk associated with poison attacks on the population by third parties on the water basin in the area. This is possible thanks to the control of the water surfaces and via a visual check of the areas adjacent to the basins.

Release of toxic substances into the soil. It is difficult to inspect underground pipelines, as any loss is not directly visible. The leak of hydrocarbons or even toxic/harmful substances can lead to plausible damage of the surrounding targets, such as people and the environment. The loss of the substance also has an economic damage not only due to the loss of the product and for future reclamation for redevelopment, but also for the company’s own reputation. Thanks to opportune sensors, drones enable the identification not only of surface pools and saturated ground, but also of infiltrations into the subsoil.

Analysis requires the knowledge of multiple data in the visible and in the infrared spectrum. The study of reflected radiation in specific bands, similar to those mentioned in the previous chapter, enables us to determine the variations in the superficial continuity of the soil, thus allowing the identification of pools and saturated ground. The reflectance of hydrocarbons differs in particular in the NIR band (Near InfraRed), which allows them to be detected. The identification of anomalies in the subsoil is possible thanks to the measurement of the ground surface temperature. The data extracted from the analysis of the bands also enables the health of the plants to be established, as this is a possible first alarm of underground losses, since the substance harms the plant. The necessary instruments on board, therefore, consist of three sensors:

- camera;
- multispectral camera;
- thermal camera.

The latter identifies the surface temperature of the objects under analysis by interacting with the radiation in the IR region (10÷12 μm) emitted by the object. The release of hot substances or a temperature that is higher than that of the ground are thus easily identified. By exploiting the thermal properties of the different substances and the thermal inertias that may be in play, it is possible to also identify underground releases of cold fluids.

The characteristics of the craft are exactly the same as those of the basic conformation, as the main characteristic to be complied with was flight duration to allow flight over considerable distances. Flight is prepared so as to follow along the entire length of the pipeline from above. The data obtained by the visible cameras are transmitted continually on to two separate screens at the operator’s ground control station (GCS) to allow an easy, rough check. In the presence of any anomaly, post-production software reprocesses the data from the multispectral and thermal cameras, in order to provide georeferenced information of the position of the loss and the images regarding the area. The outputs are designed to easily identify the possible loss and for a specialised operator to check the real danger of the event.

This method enables losses to be identified rapidly even for areas extending for hundreds of kilometres. The need to identify rapidly is linked to the need to limit pollution of the surrounding soil which, if located near a water table below, could lead to a greater diffusion of the polluted water and to a greater number of potential targets.

Search for survivors. The conformation of the UAS for the fifth point differs from the one presented for the preceding four solutions. In this case, the best choice is a multicopter (aircraft where lift is created by the rotation of propellers) as it is possible to get close to targets, such as ruins or dangerous structures. The main prerogative of interest was the need to balance the craft’s autonomy, which has to be as high as possible, and its stability in flight. Autonomy can be compensated by inserting a double battery (an alternative could be a battery with greater amperage) at the expense, however, of the mass that can be transported. Stability in flight, on the other hand, increases as the number of rotors increases and, at the same time, the sizes and mass transported increase. This is at the expense of the craft’s autonomy, but hexacopters and octocopters (with 6 and 8 rotors respectively) in case of failure of one rotor can independently return to home and land safely without falling. These considerations led to the best solution which was a conformation with 6 rotors (i.e. a hexacopter) to balance consumption, the load to be transported and stability in flight. The need to avoid collisions with the surrounding structures both laterally and vertically required the presence of reliable, surplus, proximity sensors, thus avoiding additional damages in the surrounding area. The propellers with optimum profile and size must avoid contact with protruding objects, which would otherwise cause malfunction and create sparks. This was avoided by adding propeller shields, i.e. semicircular, light resistant material to cover the surface of the disk created by the propeller (Stretti 2015). Flight over areas at risk must be possible in any weather condition, whether with strong winds or with rain. For this reason, this UAS can resist strong gusts of wind and is also waterproof. As previously mentioned, the aircraft that flies over areas struck by an earthquake must not constitute an additional hazard. Possible flammable gas leaks are very common in these areas and, therefore, the drone must not ignite the leaks as it flies overhead. The solution is to use the UAS and standardised ATEX (area 1) instruments that are ignition-proof. A picture of the vehicle described is given in Figure 3, and Table 2 gives the main features of the craft.

Figure 3. Rotating wing UAS.

Table 2

Main characteristics of the rotating wing UAS

Specifications	*Value*
N° rotors	6
Propeller diameter	406.4 mm
N° batteries	1
Autonomy	~40 min
Payload	~1.0 Kg
Operational speed (limited for safety)	~35 Km h^{-1}
Maximum speed	~45 Km h^{-1}
Wind resistance with speed	~36 Km h^{-1}
Propeller shield material	Titanium
Propeller shield diameter	457.2 mm
Waterproof	Yes

The sensors required to identify people and animals in the debris are the visible and thermal cameras. The analysis of the visible spectrum helps identify the possible presence of suspect movement by living creatures with direct vision and subsequent reprocessing of the data. The ability to photographically reconstruct can be used to show the damaged area in three dimensions and to proceed to estimate the recovery process. The use of the thermal camera, on the other hand, enables possible thermal anomalies to be identified that are people trapped under the rubble. The method designed envisages the flight of the drone with a recording in both the visible and thermal spectrum, plus the video transmission of the images taken in order to conduct an initial, rapid, on-the-spot inspection. The acquisition of frames in the visible spectrum requires the craft to remain in one point with a step rotation compared to the yaw axis, at preset intervals. The video is uploaded in the software, which compares the frames regarding the period of stationary shooting. This can be seen in the variations in the pixels in an area of the images. It produces GPS coordinates as output to allow a localised investigation of the area. Georeferencing is possible thanks to the knowledge of the geographical coordinates of the drone and to the use of algorithms that work on the pixels of the images. Furthermore, the software reprocesses the radiometric video from the thermal camera, to highlight and georeference the sections with thermal variations.

This system avoids using human life as far as possible in the search, since this cannot be replaced in the event of an accident, unlike the UAS. By applying the software and hardware, the area can be safely probed and analysed to identify the possible location of any missing persons. This method reduces the risk for the operators to a minimum.

Conclusions. The solutions proposed enable a large number of emergency situations to be covered, in which there is considerable risk for human health and for the surrounding environment. The preceding points have demonstrated the strong points of each individual application, designed for that specific use. The hardware and software has been presented for each one to provide an integrated package of emergency management. The development of packages has a considerable advantage for the use of the UAS to monitor vast areas, as it is easy and automatic to use and operators do not require specific information. Above all, the graphic interface enables data to be interpreted immediately.

Immediate intervention on the scene of an incident requires basic effective methods. It needs specific structures containing all the instruments near the places where these events may occur and a 24/7 presence of operators in charge of working the UAS. At the same time as using this system in an industrial system, there is also a need for the control structure of the UAS inside the perimeter of the plant to provide not only a rapid response in the event of an alarm, but also regular control flights. A greater cover so that adjacent areas can be covered can be given by keeping a mobile ground station or a van containing the GCS and the instruments to reprocess the data, so that it can follow the UAS to easily and continually transfer the data. This approach is more complicated to apply in the event of a civil emergency, as the territories to be managed are vast and varied. A possible solution is to provide both types of craft (fixed wing UAS and rotating wing UAS) with interchangeable sensor slots to the forces scattered across the territory:

- civil protection;
- police;
- Carabinieri police;
- forest rangers.

Extensive distribution would cover the entire area and, in the event of a major incident, information about the event could be gathered in real time. A multitude of means over a wide area enables the problem of time to be solved to allow services to arrive as soon as possible at the scene of the incident.

These systems allow us to control vast areas without the need for direct human intervention and to reduce as far as possible the area of damage in an accidental event. This is the result of a craft with the ability to fly over high areas for a long period and, at the same time, to provide a very detailed view in certain precise bands of spectral analysis of the situation facing the UAS.

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Received: 17 January 2017. Accepted: 07 March 2017. Published online: 16 March 2017.
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How to cite this article:
Giovani M., Ramalli G., Manning N. C., Manneschi M., 2017 Monitoring with drones during a major emergency. AES Bioflux 9(1):45-55.