Search and Rescue operations in urban environment: Lessons from disaster events in Attica

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ABSTRACT

Emergency response operations in large-scale urban/suburban disaster events is often addressed by the standard protocols and international guidelines for collapsed buildings, heavy debris, etc (INSARAG). However, a wide range of First Responder (FR) operations need to address various other contexts, work environments and hazards. In this paper, two real disaster events are explored as use cases for such urban/suburban FR operations, namely a flash flood and a wildfire, both in Attica, Greece (2017-2018). Based on our team's experience from these mobilizations and active participation in both these events as FR actor in the field, we present the challenges, the complexity of such multi-aspect disaster events, the limitations of emergency response, the technology gaps of the FR teams, as well as the lessons learned during these deployments. Finally, we make some notes on future prospects and possible advancements in tools and technologies that would greatly enhance the operational safety and readiness of the FR teams in such events.

Keywords

First Responders, Search and Rescue, Flash Flood, Urban Wildfire, Urban Operations.

INTRODUCTION

Today's emergency response operations need to address a very wide range of missions, from localized accidents with very few victims to large-scale disaster events with hundreds of known and unknown victims. The context of such operations also ranges wildly in terms of working environment (open/closed spaces), hazards, weather conditions, time constraints, medical emergencies, evacuation routes, etc. It is imperative that the First Responder (FR) teams and the Communication & Coordination Center (C3) have the necessary resources to operate with safety,

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reliable information, concise operational view for the FRs and detailed Common Operational Picture (COP) for the team commanders.

In urban and suburban environments[1] there are several considerations and challenges that increase the complexity of large-scale disaster events, as well as the emergency response plan and the mobilisation of the FR teams. In case of large earthquakes or floods in a dense urban environment, debris from collapsed buildings or mud slides may cause partial or complete blockage in one or more choke points along the main access routes. Similarly, wildfires in suburban environment may result in a very high rate of injuries and fatalities in a short time frame due to the high speed of the moving fire front, dense smoke covering entire neighbourhoods and the quick negation of access to the natural evacuation routes. On top of all these complications, urban and suburban areas are more easily affected by overload in the landline and cellular phone network due to saturation as the disaster event is evolving. Previous experience has shown that, while dense urban areas are usually affected by the large number of affected users, the suburban areas are usually affected by the sparsity of the access hubs (antennas) to the network backbone. In both cases, communication to and from the affected area becomes extremely problematic or impossible.

This paper provides an overview of such issues regarding the challenges, the complexity of disaster events, the limitations of emergency response, the technology gaps of the FR teams, as well as the lessons learned from two recent large-scale events in Attica, Greece. Specifically, a case of flash flood in the western region (2017) [**6**] and a case of wildfire in the eastern region (2018) [**7**] are the baseline for describing these aspects of emergency response and FR teams, with special focus on technological resources used or in-need for such operations. Our team was mobilized and operationally involved in both these cases, as part of the Civil Protection, the agency in charge (Fire Department) and the regional authorities that were activated. Since then, our team is participating in four R&D projects (EU Horizon H2020) that specifically investigate ways and means to overcome these challenges, optimize response protocols and develop new technologies and solutions for the field operations.

The rest of this paper is structured as follows: Background presents the general context of Search and Rescue (SAR) operations and more specifically in the Urban (USAR) context, including a brief outline of the two real disaster events that are used as use cases; Challenges describe the operational assessment in these two cases, the technology gaps identified, the limitations and the lessons learned; finally, Future Prospects and Conclusions provide insights on how to improve existing technologies, both in the general/C3 level and at the FR team level, propose possible advancements in tools and technologies that would greatly enhance the operational safety and readiness of the FR teams, which is crucial in preparation for the 'next time'.

BACKGROUND

Emergency is defined as a serious, unexpected, and often dangerous situation requiring immediate action in order to protect lives and property. It may affect population or damage public infrastructure and private property. It can be either natural or man-made. Emergency response is the process of gathering resources and acting upon the problems immediately after the incident happens. While the scope of emergencies can be very broad, we identify two (2) major threats defined as the basis for managing emergency response, namely: (a) Man-made: biological, nuclear/radiological, incendiary, chemical, explosives, etc; or (b) Natural: wildfires, earthquakes, floods, tsunamis, severe storms / cyclones, etc.

FR teams are often called to anticipate, confront and overcome these hazards operating in hostile environments, putting themselves in identified or unknown threats. Using tools that are not technologically adequate means that they may not be fully aware of their real tactical situation and, thus, may not be able to make fast and safe decisions. In case of a major urban or suburban disaster event, FR organizations operate almost always under the national or regional Civil Protection agency or the Fire Department which is usually the local coordinator. The overall response process evolves into several phases of readiness level, activated subsequently within the first few hours of the main disaster event (escalation) and gradually exiting the emergency mode (de-escalation):

1. First response, activated by local fire fighters and policemen immediately after the incident;
2. Local/regional response, including assessing, planning and mobilizing additional resources;
3. Emergency response escalation, in which the severity and scope of the emergency is increased beyond the capabilities of local or regional agencies, i.e., national and even international resources may be involved;

[1]While there is no strict definition of these terms and it depends on the country, topological properties, etc, the general notion is that: *urban* means inside the main city grid; *suburban* means outside the city grid but inside a structured neighbourhood; and *rural* means outside a structured neighbourhood.

4. Gradual de-escalation of the operations, moving from emergency response to mid-/long-term disaster relief operations for the affected population;

5. Ending of the operations, closing down worksites, disengagement of resources, debriefings, post-analysis.

The previous outline is a general description of an emergency response process cycle in regional, national and international level. In relation to the exact context and type of emergency, these stages may be distinct or somewhat merged, informal or standardized internationally (e.g. INSARAG [**1**; **2**; **3**], UNDAC/GDACS [**4**; **5**]), and the resources and actors involved may or may not be officially certified to get involved at all stages and command levels. Thus, operationally capable local NGOs may be involved as FR teams under the command of Civil Protection or the local Fire Department.

From FRs point of view, is obvious that even in a relatively simple emergency response environment, the agencies involved in this response effort must interconnect their own activities and collaborate very efficiently. Ineffective interconnections and misunderstandings at any contact point may affect the overall progress of the response cycle. The successful response to a disaster, either natural or man-made, is built upon employing well-established procedures, proper dissemination of them across all the actors involved, proper training and skill sets for the actual FR teams and highly capable technologies and operational tools in the field.

In the following sections the two disaster events in Attica, i.e., flash flood in Mandra (2017) and wildfire in Mati (2018), are briefly described as use cases. The general context in both events is Urban Search and Rescue (USAR), since it is focused on urban/suburban environment and the emergency response of FR teams from time zero (main USAR) up to a few days after the event (mostly search for missing/fatalities). However, USAR operations that are not closely linked to collapsed buildings and heavy debris are not typically addressed via standard international procedural guidelines, e.g. INSARAG. Therefore, it is imperative that the FR teams with USAR operational experience in such contexts disseminate their knowledge, best practices, lessons learned and solutions to the FR community.

Mandra: Flash flood

On November 15th 2017, a low-pressure front over the north-western region of Attica produced extreme rainfall for several hours. Measurements showed that the overall precipitation was of a return period higher than 150-200 years for that region. As a result, a flash flood was created and swept through the main roads of the urban grid, devastating neighbourhoods in Mandra and claiming 23 fatalities in the process.

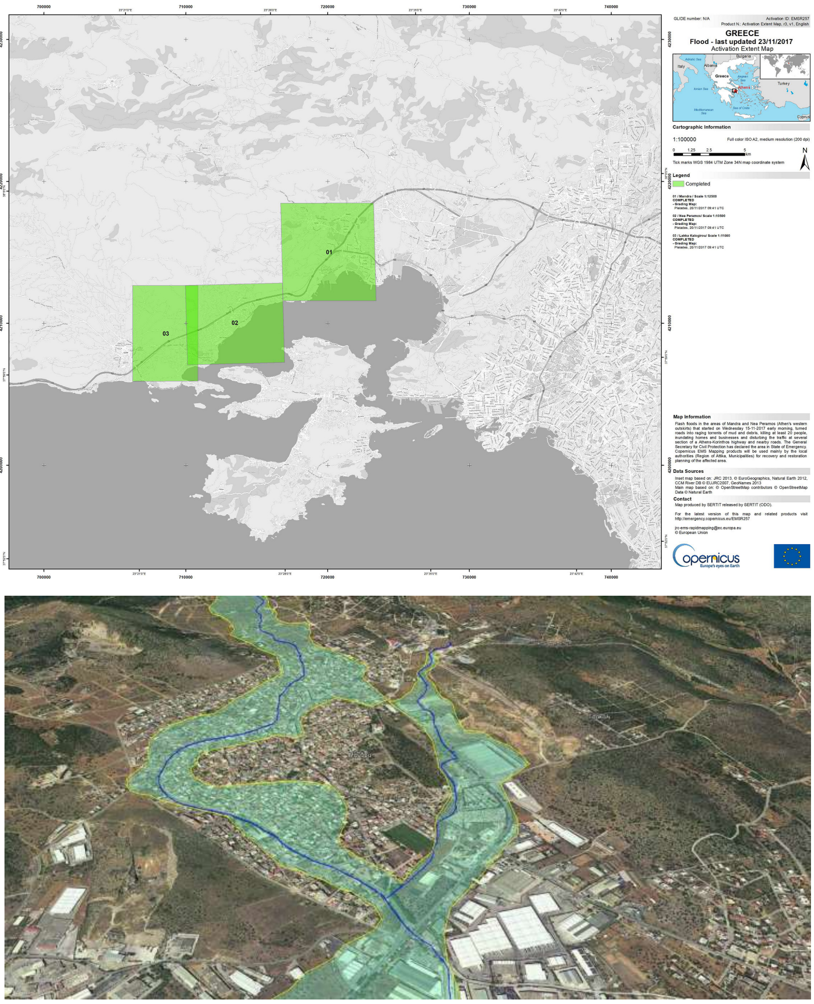
For several days after the main event, many areas inside and around Mandra were covered with thick layers of mudslide, which was partially enforced by the fact that in July, only a few months earlier that summer, large wildfires have swept the eastern side of mount Pateras, directly above the affected area, causing the heavy rainfall to create unobstructed floods and mudslide downhill. In addition, the lack or inadequacy of storm protection infrastructure, as well as the severely obstructed cross-sectional areas of the two main streams of Mandra due to various private and public constructions, essentially blocked the normal flow of the large volume of water and light mud towards the sea. Nevertheless, some of the victims, cars and other debris were carried up to a distance of several km away from the area of the main event.

In the aftermath, several SAR teams and other Civil Protection resources were called on-site for missing persons/victims and for restoration of the essential provisions for the affected population.

Mati: Urban wildfire

On July 23rd 2018, at approximately 13:00’ local (EET), a wildfire started at the western Attica region near Kineta, attracting the attention and fire-fighting resources there. A few hours later, probably around 17:30’, another wildfire front broke out at mount Penteli at the eastern region of Attica. Due to the very high wind speed and gusts, measured up to 124 km/h or 12 Beaufort, the fire front moved rapidly downhill on the eastern side, burning open fields and rural areas, while at the same time the front at Kineta was endangering houses and urban grid. Hence, most of the fire-fighting forces, including airplanes and helicopters, continued their work on the western front until late in the afternoon.

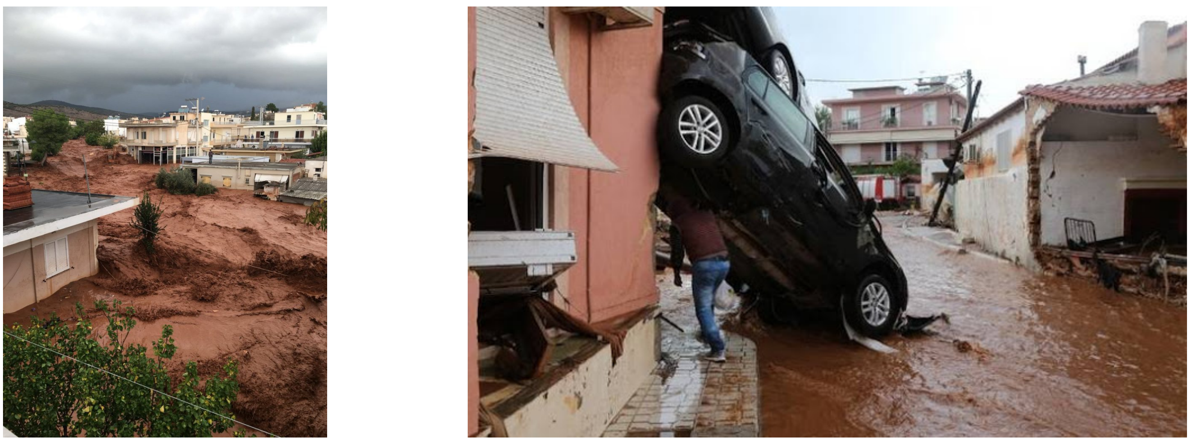
As the eastern front reached the first houses at Neos Voutzas, it was too late to divert forces there. Fortunately, an entire summer camp of 620 children was preemptively and safely evacuated from that area. The fire swept rapidly through the open field and reached Marathonos avenue within about 1.5-2 hours from its start, a few km uphill. In previous events with similar wildfires in this area, the avenue which is about 20m wide provided a natural barrier for



(a)

(b)

Figure 1. Mandra areas affected by the flood (source: Copernicus)



(a) (b)

Figure 2. Mandra center (a) during and (b) after the flood (source: local media)

(a)

(b)

Figure 3. (a) Mati areas affected by the fire (source: Copernicus); (b) people reaching the sea waiting to be evacuated (source: Greek media).

the fire. However in this event, in contrast to the previous experience of the local authorities and residents, the fire front jumped from one side of the avenue to the other without any delay, probably due to the very high flames and temperature reached by that time. From there on, within 20-25 minutes the fire front entered the main urban grid in Mati and Kokkino Limanaki (just north of Rafina port), swept through the entire area of roughly 2x2 km2 and stopped at the sea front, which is mostly rough rocky and cliff coastline with only few passages down to the sea.

Post-event analysis revealed that the local weather conditions, specifically the very high winds, low humidity (19%) and high temperature (30C) due to summer, created a very unique localized ‘micro-climate’ that enabled the fire to grow and move rapidly across the plain. Inside the urban areas of Mati and Kokkino Limanaki the flames were so intense that people got trapped inside their houses within seconds. The area was covered mostly by dense pine trees, so exploding pines and burning animals trying to escape the front contributed to the spreading of the fire towards the sea front within few minutes. The intensity and speed of the fire was very evident in the aftermath, where on several spots the houses were charred at the first floor and above with glass items melted inside from the extreme temperature, while some ground floors were only smoked and relatively undamaged from flames.

Many people trying to escape by car were trapped in congestion near the shore inside the very few escape routes. As a result, many of them were intoxicated by smoke and burned inside their cars, hundred of which were found charred in one particular street stuck in a deadly traffic jam 150-200m long. First-witness reports and telecommunications logs revealed that, even as the flames were inside those urban areas and cars were being jammed in the path of the fire front, lack of communication between the authorities continued to direct some of the traffic from Marathonos avenue away from the immediate front in the north but into harm’s way inside the sweeping fire in Mati and Kokkino Limanaki.

Figure 4. (a) Mati example of the fire front; (b) Mati main traffic jam near the city center (source: Greek media).

The result of the wildfire at the eastern front resulted in 102 fatalities and hundreds of severe injuries, including smoke intoxications, direct burns from flames and secondary complications from extensive skin injuries. It was the deadliest wildfire event in Greece since many decades and the second most severe one since 2001, after the 2009 Black Saturday bushfires in Australia with 180 fatalities. Only five other similar events world-wide have claimed more lives since 1918.

CHALLENGES FOR FIRST RESPONDERS

Operational assessment

Our team operates mostly for Search & Rescue (SAR) in three main fields: Wilderness (mountains, forests, non-urban areas), Water (open sea, underwater/scuba, coastline, rivers, swift water, lakes) and Urban (earthquakes, floods, tsunamis). For each field of operations there is a corresponding element of highly trained individuals, ranging from level-1 support members to level-4 fully operational members, all acting as a team and tailored to each specific operation at hand. All our members/rescuers attend mandatory certifications for a wide range of trainings, ranging from Basic Life Support (BLS) to Emergency Medical Technicians (EMT) and from mountain rescue to rescue divers. Our team is registered with the General Secretariat of Civil Protection (GSCP) of Greece, collaborates closely with the Fire Department and other local/regional services and is actively involved in the JRCC (Greek maritime Search and Rescue) action plan.

In both these events of the flash flood in Mandra (2017) and the wildfire in Mati (2018) our team was mobilized and tasked according to the national plan of the Civil Protection, under the direct guidance of the Fire Department HQ which is the agency in charge of such large-scale disaster response operations. We assisted with several Urban Search & Rescue (USAR) elements in the field for several days in both events, mostly operating alongside or under the direct guidance of the Special Disaster Response Unit ('EMAK') of the Fire Department.

One of the most important factors identified during the operations in these events was the availability of prompt, reliable and continuously updated information. The main mobilization plan of our team often includes the rapid deployment of a first 'scout' team inside the affected area to gather information and up-to-date status reports on access routes, number of victims, expected emergencies, identification of liaison contacts, etc, while our main resources are prepared for deployment. As a result, during the first few hours of the wildfires in Mati our team was able to assess the severity of the situation, provide organizational assistance in the local authorities and identify areas where the USAR resources should be immediately deployed. Our rapid deployment element was inside the hotzone were people were gathering for protection and assisted in their evacuation by boats, including our own inflatable boat stationed near the Rafina port. Similarly in the flash floods in Mandra, our team was able to quickly determine the extent of the damage, the impassable access routes into the affected area, as well as the provisional resources that would be necessary in the next few hours and days for the needs of the affected population.

Another important aspect in both events was the inefficiency in organization, resource management and communication between local/regional/national authorities in charge of the emergency response, mostly due to the unclear boundaries of responsibility between adjacent local authorities and municipalities. During the first few 24hrs of USAR operations in Mati our team was coordinated by the Coast Guard authority in the Rafina port (local), due to the fact that the main evacuation route for about 736 people that night was via the sea to the Rafina port, with the search for missing persons and victims focusing mostly on coastal and surface sea searches. Then, the operations were taken over by the Fire Department (regional) and USAR operations were focused mostly inside the most severely devastated spots of the urban grid, searching for unidentified/missing victims. Indeed, the scene in the wildfires in Mati was unique, in the sense that within a relatively small affected area the USAR operations had to incorporate multiple elements: urban/suburban, coastal, sea surface and sea underwater (later on). Nevertheless, lack of organization and coordination by some central authority, especially during the first few hours of the event, was a crucial factor for the severity of the outcome.

On the other hand, self-organization of small groups of volunteers, either locals or regional NGOs, played an important role in addressing organizational and logistics gaps, especially in the days that followed and in the aftermath of the main events. In the wildfires in Mati, groups of people worked in parallel with the main USAR resources for locating and rescuing domestic animals, while others were using their own means of transportation to distribute provisions to the affected population and even to the USAR elements in the field. Additionally, simple means of information exchange was extremely valuable in the field, as for example the numerous hand-written notes posted at the door of burned houses stating that the particular family is already evacuated and they are all safe - thus limiting the amount of time allocated by the USAR teams searching for possible victims in buildings where it was not necessary.

Another issue worth mentioning is media handling and the interaction of USAR teams with journalists and reporters, especially in the field. In many cases, our team had to hide its true intentions or distract reporters with cameras during the search for missing persons, as any hint of a new finding triggered the setup of multiple cameras and people with microphones trying to come closer or even get a statement from members of the USAR element while they were working. This is a very sensitive issue, especially when dealing with missing persons/victims and with family members watching live feeds from the field operations. Normally in localized events the area is isolated by the authorities, but in such large-scale disaster areas this is almost impossible to ensure. Similar considerations apply to the C3 of teams, although in this case the information flow management and dissemination control are much easier to establish.

In summary, the main operational issues can be viewed under the standard four-phase operational plan:

1. **Preparedness:** High level of readiness in both equipment and personnel; prior arrangements and contacts with local/regional/national authorities w.r.t. emergency response; well-tested organizational and communication procedures.

2. **Deployment:** Proper training and field experience of the team elements selected to go into the hotzone, especially for the 'scout' rapid deployment; prompt, reliable and up-to-date information about the situation, access routes, severity of the event, expected emergencies; alternative and overlapping means of deployment, e.g. cars and boats, in order to ensure quick and safe access into the hotzone.

3. **Mission:** Continuous updates to the C3 of the team; integration of multiple sources for better COP; reliable communications and contacts with the authorities; strict operational protocols for safety and effectiveness in stressful and hazardous environments.

4. **Disengagement:** Proper debriefing of all the personnel involved; provision of Psychological First Aid if required; extensive follow-up work with the logs, documentation, recorded material for post-mission analysis and data protection.

Technology gaps

In most cases, our team had provisioned all the necessary equipment and tools for the field operations. These included a wide range of things, from hand-held electronic devices like smartphones to simple paper-and-pencil notes as backups. For the most part, everyday technologies and open-access services were the elements most heavily used and exploited by our team during the USAR operations.

Regarding communications, cellular phones were marginally available near and inside the affected areas as the main events were evolving. When available, voice calls and data transfers (images, videos) to and from the deployed teams were extremely important for up-to-date information sharing in both directions. Specifically in the case of wildfires in Mati, lightweight data exchange via Internet access (e.g. messaging applications, social media posts, but not regular SMS/MMS) were proven as relatively reliable and resilient tool during the hours of network saturation. These means of communication were occasionally used by the USAR teams in the field, in areas where R/F communication was problematic due to the topology or channel saturation; however, their use also requires specific protocols and discipline as with every other aspect of operational communications. These problems with R/F were much more severe when operating in closed spaces (inside buildings), between hills, under high-voltage electric lines, etc.

Another important aspect of the operations in both cases was geolocation and online mapping services, available on-site and open-access, with small handheld devices and typical smartphones (e.g. Google Maps). As long as the team had prepared such devices beforehand, downloading all the necessary maps for offline use, geolocation via standard GPS sensors and geo-mapping in the field of operations was readily available to all USAR elements, independently from any other coordination and guidance from the on-site C3 of the team. Inside the disaster area in both the flash floods in Mandra and the wildfire in Mati, recognition of the exact location and use of reference buildings/constructions was often impossible to do visually, due to the extent of the damage. In such cases, the exact location of the USAR element down to specific street numbers, the planning of search patterns in open fields, as well as the tracking of area coverage during the search operations, were crucial to the reliability of the findings or the lack of those (clear of any victims). One additional aspect of geolocation capabilities in the field is when marking possible findings for further investigation, e.g. bone fragments, to be conducted by a follow-up team of experts later on.

Limitations in operations

As described above, during the deployment in these two disaster events our team had the chance to identify and evaluate several operational aspects that are inadequately addressed or missed altogether by today's standards and guidelines for emergency response.

In brief, these can be summarized as follows:

- **Safety:** FR teams were often required to assess possible hazards, entry points and search plans on a per-house basis. When no other information was provided and no visual clues were available, the team had to plan, enter and search the houses one by one for possible missing persons/victims, in most cases resulting in no finding, thus putting the team in unnecessary risk and waste of time. Also, there was very limited or no on-site marking w.r.t. assessment of hazards by any agency or other authority, when the FR elements needed to enter a building or damaged structure. As this assessment is usually performed in next days or weeks, FRs themselves have to address this lack of information on-site, quickly and safely.
- **Communications:** Bad propagation conditions and channel saturation were often a problem in R/F communications. Cellular phones and mobile Internet access provides some complementary functionality, but mostly in post-event conditions. Additionally, in dense urban areas with no street/number information or other reference point (due to extensive damage), precise location identification and reporting is a challenge for the FR teams in the field.
- **Situational Awareness & Logistics:** The evolution of the disaster event as it is happening, as well as the changes in the situation, severity, emergencies and most-prominent search locations are issues that severely affect the level of situational awareness of both the FR teams and the on-site C3 of the team. Lack of communication and coordination between the authorities and the FR resources is a crucial factor.

- **Missing persons/victims:** In many cases the FR teams were required to assess the validity of findings at a level outside their normal scope and expertise, e.g. if some bone fragments are from a human or an animal. This is a very difficult task to formulate into a well-defined procedure, since on one hand some findings are inherently difficult to classify (e.g. end parts of collar bone, ulna, radius, isolated finger bones, etc) and on the other any false negative characterization translates into a real victim not being detected and identified.

Additionally for the aspect of Logistics, provisions available and needs of the affected population is an extremely important factor. There is a very clear and identified 'last mile' information gap inside the affected area between the victims and the available services/goods nearby, which has not been properly addressed by any current protocol, service or guideline. Self-organization of communities and residents addresses some of the immediate problems in the first 48 hours after the disaster event, e.g. packs of water bottles placed in various spots in neighbourhoods for the locals, but this is usually proves to be very inefficient and slow. Our team had the chance to discuss this specific issue recently with experts from EU/ECHO and UN/OCHA, who indeed confirmed that the current focus of emerging technologies is almost entirely towards enabling the FR teams and procedures, rather than endpoint services for requesting help, volunteering or reporting everyday needs from individuals, e.g. food, drinking water, shelter, clothing, medical services, power supply, waste management, psychological support, etc.

FUTURE PROSPECTS

Based on the operational aspects of these two disaster events and the experience of our team's deployment in both cases, each with its unique set of requirements and challenges, several issues have been identified for possible improvements with the introduction of new technologies, tools and practices.

In Safety, 'smart' wearables, handheld and portable devices should enable the FR teams to operate autonomously, safely and with increased situational awareness. This includes possible on-the-spot searching for victims remotely, mapping of access routes and possible hazards (e.g. gas leaks), extensive documentation of scenes and assistance from the C3 (e.g. medical emergencies), etc.

In Communications, there is a clear need for resilient, high-capacity and energy-efficient mobile technologies for the FR teams, especially for use inside closed spaces or under debris. The devices should be designed for personal safety, inter- and intra-team (C3) information exchange via voice or data (e.g. images, streaming video), as well as easy integration into information fusion platforms for enhancing COP.

The Situational Awareness factor also includes the easy and extensive use of geolocation and on-site mapping services, which should be open-access and available also for offline use (no Internet connection). The geolocation tools should be enhanced with tracking area coverage, waypoint/route planning, search patterns planning, automatic reporting to the on-site C3, tagging of digital material captured in the field (images, videos, voice notes), as well as being adequately ruggedized and robust to survive real-world operations.

Missing person/victim identification and registration should be enabled as an on-field technology, especially for forensic findings (e.g. bone identification) after a large-scale disaster event where the number, possible location and identity of victims is unknown for several days or even weeks. This is an issue that directly affects the planning of the SAR operations, as well as the support to the families and the affected population.

Finally, special attention should be placed upon creating specific procedures and enabling technologies for the 'last mile' information gap in disaster areas, i.e., a very easily available, rapidly deployable and operationally resilient way to establish a link between those who provide the services & goods and those in need for them.

CONCLUSIONS

In this paper, two recent large-scale disaster events in the Attica region, Greece, are presented as case studies for the exploration of current USAR practices, technologies used, gaps and limitations. Several aspects of organizational, operational and technological needs are identified, in relation to problems and drawbacks faced during the deployment of our team in these two cases.

Personal safety, resilient indoor communications, enhanced situational awareness at the FR team level, highly adaptive logistics support, as well as on-the-fly forensic analytics for missing persons/victims are discussed as crucial factors for efficient and reliable SAR operations. These issues are also the main focus points for game-changing emerging technologies in the area of SAR, providing a new generation of technologies and tools to the FR organizations.

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