# Resilient communications and UAV fleet for future Search & Rescue operations

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## ABSTRACT

In modern search & rescue (SAR) operations, rapid deployment, situational awareness and first responder (FR) safety are the most important prerequisites for a successful outcome. In the EU project CURSOR autonomous robotic assets, geophones and resilient communications are developed and combined to augment the operational capacity of FR teams and to improve the probabilities of recovering as many live victims as possible from the disaster area. In this work, two such platforms are described as part of the CURSOR project (H2020), offering high mobility and multiple capabilities: the Emergency Gateway, a robust portable communications hub for worksite deployment, and the Drone Fleet, a multi-drone, multi-role assembly of aerial drones for area mapping, continuous monitoring and heavyweight transportation of sensing equipment and tools. These technologies are currently under development and already prototyped as part of the SAR Kit of the CURSOR project, which is to begin field testing activities next year.

**Keywords:** Search and Rescue (SAR), resilient networking, worksite communications, Unmanned Aerial Vehicle (UAV), drone, emergency responder, earthquake.

## 1. INTRODUCTION

During the last decade the advancements in various technological fields including electronics miniaturization and ruggedization, resilient wireless communications, battery efficiency and capacity, etc, have enabled the design of communication & networking equipment and Unmanned Aerial Vehicles (UAVs) for SAR operations. UAVs are used today to establish a quick overview of the disaster area with visual and night-vision cameras, assisting in the detection of trapped victims with thermal/infra-red cameras, as well as acting as temporary communication relays in the field. These functionalities rely on establishing resilient data links between the aerial assets and the First Responder (FR) teams inside the disaster area, as well as between the FRs and the Command Center. Novel designs for autonomous UAVs and portable networking hubs, specifically tailored to the highly demanding environment of a disaster area are two of the technologies developed by CURSOR[1] for SAR operations. These new technologies improve the rapid deployment, the situational awareness and the safety of the FR teams, augmenting the Common Operational Picture (COP) for all the assets in the field.

[1] This work is supported by the project CURSOR, which has received funding from the European Union's Horizon 2020 (H2020) programme under grant agreement No:832790.

## 2. WORKSITE COMMUNICATIONS AND AERIAL ASSETS

Two components from the SAR Kit of the CURSOR project are described below. Specifically, the Emergency Gateway (EG) is the proposed solution for portable and resilient worksite communications, coupled with Multiple-source Data Fusion Engine (MDFE), and Drone Fleet (DF) is the multi-drone approach for UAV-based operations.

### 2.1. Portable and resilient worksite communications

In every disaster event, emergency response efforts rely on portable, reliable and efficient communications technologies between the FRs inside the worksites and the Command Center. Moreover, technologies that require stable and high-capacity data links, such as aerial drones, extend these requirements even more. In the SAR Kit of the CURSOR project, the communications between the disaster worksite components and the Command Center (UCC/OSOCC) is performed by the Emergency Gateway (EG). In its core, the EG is a modern computing platform that incorporates various network communication technologies required by the deployed components, packed in a portable computing platform inside a ruggedized case. The functionalities of the EG include:

- Seamless interoperability and ubiquitous connectivity via Wireless Ad-Hoc Networking.
- Security-by-design on all offered communication channels (authenticated and encrypted).
- Resilient operation in the harsh environment and degraded R/F signal in a disaster worksite.
- Central EGs connected to power generators and UPS units; portable battery-operated EG.
- Gateway to the World Wide Web (internet access) and other local services & deployed components.
- Easy deployment and operation: small form factor, switch on and forget.

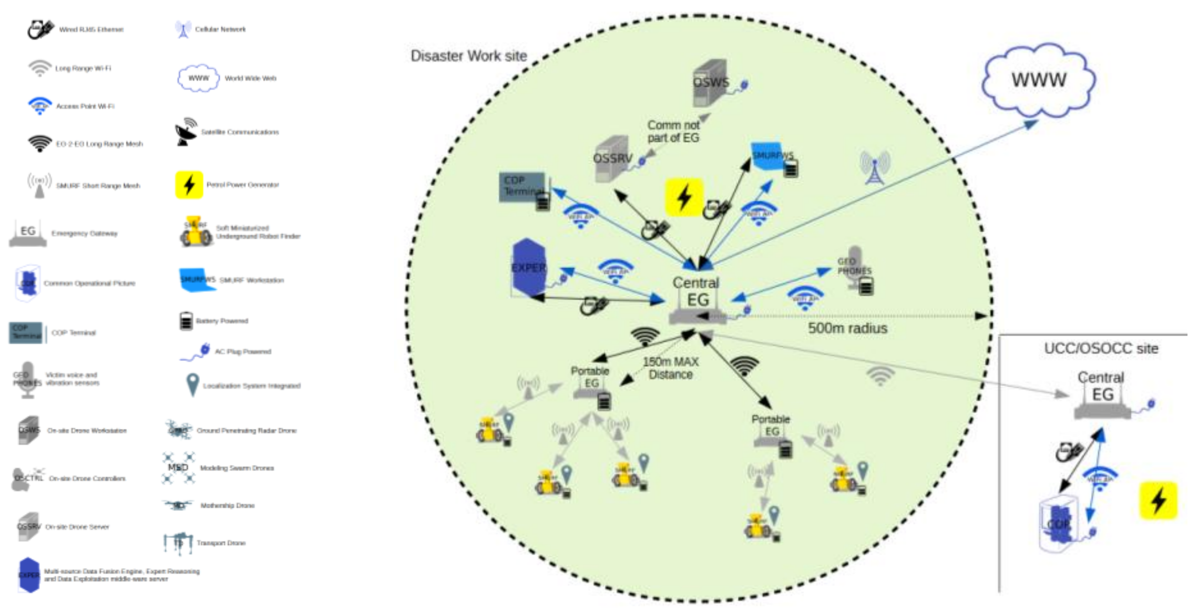


**Figure 1.** Overview of multiple Emergency Gateway deployments with a central EG and multiple portable EGs, providing resilient data links between all the deployed SAR Kit components inside the worksite area.

The EG design is targeted for rapid deployment, ease of use and robustness at all levels. The system is comprised by a computing board, a storage device that contains the operating system and allows limited storage and a series of modular network communication components. The absolute minimum is the inclusion of a wireless network card for the 2.4-5 GHz WiFi Access Point and Mesh networking. This allows direct connectivity of EGs and other deployed components in a common WLAN, including aerial drones, mobile user terminals, geophones, etc. plus routing network traffic to the Internet when necessary/permitted. The Internet connectivity is provided by Cellular Modem network cards (main & backup), set up to work in 4G LTE networks of different providers. Connection of a wired device via RJ45 cable to the gateway is also possible. For extra redundancy of the Internet connection, it is possible to use external Satellite Internet Connection via an antenna dish and a modem. This feature is extremely useful in large-scale disaster areas where the LTE networking is unavailable, at the cost of having a slightly more complex deployment. The whole device can be carried by members of the FR team, in order to be deployed on demand and cover larger areas, thus partitioning the number of components communicating with each deployed EG. Smaller EG configurations can be carried by FR members in a backpack and a central EG can provide the link with Command Center and the Internet (see Figure 1).

## 2.2. Multiple-source Data Fusion Engine (MDFE)

Several data fusion architectures have been proposed in the literature to deal with data fusion challenges for capturing reliable, valuable and accurate information in massive data like the Joint Directors of Laboratories (JDL), the Luo and Kay's and the Dasarathy's architectures. Traditional data fusion techniques include probabilistic fusion, evidential belief reasoning fusion (e.g., Dempster-Shafer & complexity reduction) and fuzzy set theory-based fusion. In CURSOR, a Multiple-source Data Fusion Engine (MDFE) developed to fuse heterogeneous data sources and information generated from CURSOR *in situ* sensors, providing a semi-empirical probabilistic indication of detection (alerts & heatmaps) and the location of the trapped victims. More analytically, a fusion framework is established for collecting, parsing, integrating, and fusing heterogeneous data of different size, type, velocity and veracity; as well as a data publication process to a middleware stack via Message Brokers. Considering a 3-level fusion architecture, machine learning (ML) algorithms are applied to evaluate the high quality of collected data (signal level data fusion), extract features (feature level information fusion) and support a data-driven decision making (decision level fusion). Furthermore, feature-selection approaches, combining machine learning with optimization algorithms are implemented for identifying decision variables, facilitating feature engineering & extraction, and human-in-the-loop approaches for knowledge discovery.

## 2.3. UAV: Drone Fleet (DF)

An important component of the SAR Kit in the CURSOR project is the Drone Fleet (DF) of UAVs, consisting of (see Figure 2) [2]:

1. **Mothership Drone (MD)**: a tethered drone with HD zoom video camera, flood lights, megaphone and WiFi access point, serving as 24/7 "Eye in the Sky" over the disaster area;
2. **Modeling Swarm Drones (MSD)**: five drones in swarm formation, generating a photogrammetric 3D model of the disaster zone, as well as a 2D orthomap; in "FR mode" individual drones can provide local situational awareness;
3. **GPR-equipped drone (GPRD)**: a ground penetrating radar (GPR) unit mounted to a drone, identifying alive buried victims;
4. **Transport Drone (TD)**: a heavy-lifting drone, carrying a container filled with sensor-equipped UGVs (SMURF units) or other equipment and tools to deployed FR teams.

In order to tackle the challenges brought on by a disaster event in a large urban area (e.g. earthquake), it was decided that for the DF a combination of two UAV types will be used:

(a) one common drone airframe (GAIA 160) for heavy-lifting tasks (transporting ground penetrating radar (GPR) for making radargrams; transporting and unloading ground-based miniaturized robots with multiple sensors (Soft Miniaturized Underground Robot Finder – SMURF) to be released on scene, and as tethered drone for 24/7 area monitoring;
(b) one common airframe (DJI Mavic Pro) for a swarm of fast, small drones providing mapping and advanced situational awareness (3D model of disaster area).

The MD system employs a 30x optical HD zoom-camera with encrypted HD video transmission, floodlights, a megaphone system (125 dB) and a WiFi access point. The GPRD system is a GAIA160 drone with the GPR sensor hanging from a cable on a remotely controlled winch. The GPR is able to detect survivors buried under several meter of debris by differentiating between slight movement, strong movement and breathing. The GPRD also employs radiometric Flir 640 and RGB HD cameras and floodlights. In TD mode, the GAIA160 drone is equipped with HD video camera, thermal camera, as well as floodlights and a megaphone. The TD is able to carry a special container for unloading SMURFs at selected sites to identify victims buried under rubble. The MSD system is comprised of altogether five DJI Mavic Pro (MP) drones operating as a swarm, with three intelligent flight modes are incorporated: (a) Obstacle Avoidance, (b) Active Track (objects), (c) TapFly ("point and fly" mode).

**(a)** **(b)** **(c)**

**Figure 2.** Components of the Drone Fleet (DF) in the CURSOR project: (**a**) Mothership Drone (MD); (**b**) GPR Drone (GPRD) and Transport Drone (TD); (**c**) Modeling Swarm Drone (MSD).

The DF system enables crisis managers to identify risks and emergencies due to damaged structures (e.g., zooming into buildings), to detect survivors under rubble (e.g., radargram), and to provide communication services (e.g., alerting via megaphone; WiFi access point). The different types of data provided by the DF are integrated into the COP for the mission area. Using the DF to create a 3D model from aerial photogrammetry, the camera is mounted on a drone of the MSD fleet and can be moved vertically and horizontally. Multiple overlapping photos of the ground or object to be modeled are taken along an autonomously programmed flight path, with a precise scan zone overlap of 80% to 90%.

## 3. CONCLUSIONS

Modern technological advancements in field communications and aerial drones will enable the use of such assets in an autonomous and effective way within the context of real-world SAR operations. The highly demanding environment of such missions requires improved performance and autonomy, as well as complementarity with the standard operational procedures applied by FRs. The CURSOR SAR Kit will provide such technologies, which are already prototyped and at the beginning of field tests.

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