Towards the RESPOND-A initiative: Next-generation equipment tools and mission-critical strategies for First Responders

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***Abstract*—First Responders (FRs) must access reliable and flexible information management systems that provide better Situational Awareness and a better Common Operational Picture as climate change, and industrial accidents become more severe. Using network-enabled tools and novel equipment, the Respond-A platform aims to provide FRs with instant access to technical breakthroughs while also continuously assessing security risks. Pre-disaster planning, on-scene planning, and post-disaster planning may all be achieved in this fashion, allowing FRs to plan for many layers of safety at all stages of the crisis lifecycle.**

***Index Terms*—5G, augmented reality, virtual reality, iot, sensors, communication, uav, first responder, risk**

I. Introduction

The term "First Responder" (FR) became popular after the September 11, 2001 attacks on the World Trade Center and Pentagon. FRs are trained to respond in emergencies. Counselors, psychologists, and doctors work in mental health. The European Environment Agency (EEA) classifies hazards based on their impact on society and the economy: hydrometeorological (storms, forest fires, floods), geophysical (snow avalanches), and technological (i.e. oil spills, industrial accidents,etc.). IFAFRI considers FRs' safety and efficiency essential. Good risk management, cutting-edge technologies, and conceptual frameworks can improve FR safety. Proactive risk management is crucial, especially with FRs. Adopting risk management principles and applying new knowledge helps resolve real-time risks. By embracing risk management and situational awareness, investing in upstream assessment and planning reduces incident uncertainties and time pressures [1] [2]. MFRs can stay in constant voice and data contact using MC 4G/5G networks and software. FRs will have real-time access to video from drones, medical records, bio-data from wearable sensors, and contamination level data to increase their Situational Awareness. AR intelligence and accurate indoor-outdoor localization will enable analytics to uncover essential information and present it in an emergency. A good Common Operational Picture (COP) will help FRs prepare and improve their Situational Awareness without detracting from their main goal.

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II. Technical Analysis

A. Objectives Overview

Identify situational awareness requirements. Situation awareness is crucial for decision-making in aviation, air traffic control, emergency response, and command and control operations. Low situation awareness contributes to human error accidents. [3].

Develop and provide enhanced equipment tools. To improve Situational Awareness and COP for organisational operations, RESPOND-A technologies are arranged and implemented. These technologies include: (i) personal safety sensors, (ii) CBRNE sensors for the incident area, (iii) mission-critical next-generation communication networks and applications, (iv) high-definition 360o and thermal cameras, (v) personnel localisation beacons, (vi) Internet of Things (IoT) devices for patient tracking and triage, and (vii) aerial platforms with various sensors. **Deploy and use on demand connected fleets of unmanned aerial vehicles (UAVs)**. In Search and Rescue (SAR) operations, FRs will locate missing persons and

Regions of Interest (ROIs) much FRs will see through smoke to assist in complex firefighting scenes and look for hot spots to prevent flare-ups.

Extract knowledge and directions for training exercise of FRs. The goal is to conduct training exercises throughout the project to better understand the needs and expectations of various FR organisations.

Deploy on site and in position experimental testing and perform real-world validations. RESPOND-A plans three pilots in Cyprus, Greece, and Spain to test and validate its proposed equipment, tools, and software.

Design and establish novel practices. FRs often walk or operate dismounted in risky situations. So they favor lightweight devices driven by developing Information and Communications Technology (ICT). RESPOND-A will explore each FRs' organisational characteristics that influence technology uptake and usability to establish a common practice for all FRs.

B. RESPOND-A Architecture

RESPOND-A combines modern telecommunications technologies with novel FR practices to save lives and protect itself. Perception, Network, Processing, Comprehension, and User Interface layers can be customized for any EEA-type disaster. Perception identifies and collects multi-disciplinary data from FR safety and biometric sensors, environmental sensors, personnel location sensors, and UAV and tactical robot sensors. This layer streams 360o, infrared, and AR camera videos. Data from the Perception layer will be transferred and processed to enable I FRs and Command Centres connectivity via 5G portable telecommunications system with dynamically adjustable UAVs/drones network coverage umbrella, and (ii) ultra-reliable mission-critical services via real-time sharing of uninterruptible video flows and data-rich multimedia content formed to be projected by any kind of device. The Processing layer collects and processes Network layer data to I remove redundant data to avoid network overload, (ii) quickly aggregate large amounts of information to foster Situational Awareness and COP with Multi-access Edge Computing (MEC), (iii) fuse and compare information with patterns of previous incidents to discern statistical trends for Early Warning, and (iv) formulate path planning schemes. The Comprehension layer integrates all collected/aggregated/processed data into a common ICT system infrastructure to generate precise SAT and COP. This layer includes I the Command and Control Center, (ii) an AR module for overlaying real-time video streams with augmented data, (iii) a medical support system, and (iv) Early Warning. The User Interface layer aims to deliver the Situational Awareness COP via mobile apps, user-friendly web apps, and intuitive AR/haptic devices, all of which are aided by interactive processes like gesture recognition and context recognition.

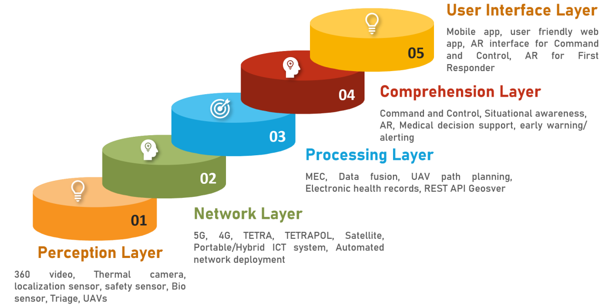

Fig. 1. Layer Architecture

III. Technologies

MC communications: PPDR organizations must communicate to coordinate field FRs with Command Centers. PPDR organizations use PMR legacy technologies like TETRA and TETRAPOL for group communications, but they are limited to voice, short message, and narrowband data. As threats and technology advance, PPDR organizations need new capabilities and services. Non-essential IoT applications include asset tracking, remote monitoring and control, automatic level detection, traffic management, and environmental monitoring. IoT can support FRs in dangerous or hostile situations. Current IoT products and solutions aren't designed for MC/PS. Real-time sensor data must be integrated into the COP for end users, command centers, and field FRs. Mission Critical (MCX) was designed for 4G, but 5G requires changes (e.g. slicing). 5G will have higher density (for large events), higher performance (for high-quality video flows), and guaranteed services due to slicing technology. RESPOND-A will integrate AR-based devices (e.g., glasses) to assist FRs with decision-making and ASA. Respond-A introduces a revolutionary hybrid PPDR architecture, allowing FRs to use 4G/5G for rich multimedia while maintaining a TETRA layer for off-network operation. FRs have trouble processing multi-dimensional, multi-source, time-varying, and geographic digital data. This requires fast, integrated, interactive technologies to access, present, and convey visually vast information spaces. Geovisual Analytics (GVA) is an emerging interdisciplinary field based on visual analytics applied to geographical representations. It uses highly interactive visual interfaces and creative data visualization. Traditional interactive techniques make it difficult to uncover high-dimensional data insights. RESPOND-A uses multimodal interaction, direct manipulation, AVR, and digital fabrication tools. AR/VR tools that help users interact with and see event patterns in time and space or any abstract landscape. RESPOND-A provides immersive tools for FRs that improve their cognition by enabling physical-virtual collaborative environments for analytic exploration and communication. **AR Experience Optimisation for FR applications:** RESPOND-A improves the AR experience by generating consistent illumination between the actual and virtual environments. RESPOND-A enables users (e.g. Command and Control officers) to interact with an augmented world in real-time. Surrounded by a layered situation awareness map, the augmented world will allow users to manipulate and interact multi-modally with sensors and FRs. The user can manipulate real/virtual items using augmented gesture control with natural haptic feedback.

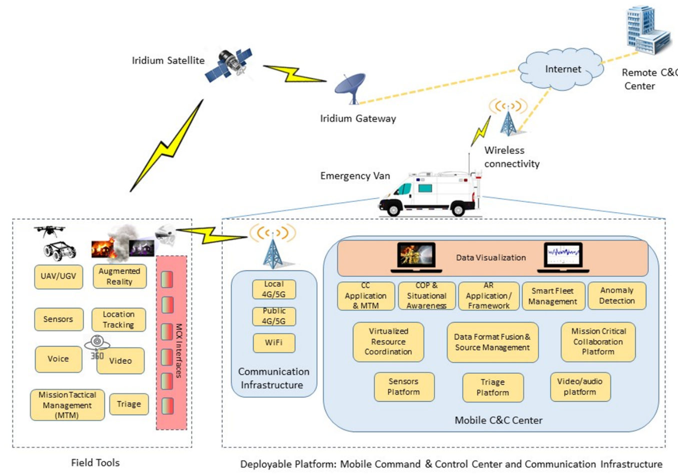

Fig. 2. RESPOND-A Technologies

This immersive AR area allows security professionals to spend less time analyzing network activities and more time mitigating potential risks. **Interactive and low-latency multi-view 360o VR video streaming.** Research and development of RESPOND-A leads to an end-to-end 360o VR video streaming system that overcomes the highlighted issues, as well as fully harnessing the potential of 5G technologies (e.g., in terms of latency, bandwidth availability, scalability, virtualisation, etc.). **Reliable localisation for FRs in indoor environments:** Because the Global Navigation Satellite System (GNSS) is not available indoors, providing reliable indoor localisation is critical to improving FR efficiency and safety. With the advent of affordable IEEE 802.154a Ultra-Wide Band (UWB) radios, RESPOND-A investigates how to advance the State-of-the-Art in FR indoor localisation. Sensor fusion techniques utilized to compute FR positions in real-time using data gathered by Inertial Measurement Units (IMUs) and UWB range measurements. **Wearable sensors for health monitoring:** Selection of suitable substrates for inconspicuous movement, manufacturing procedures, simultaneous monitoring of diverse signals, and secure and uninterrupted signal readout devices for continuous health monitoring are issues. RESPOND-A integrates health, environmental, and emergency sensors and uses advanced data analytics to detect and categorize injuries. High-tech fabrics with embedded sensors provide more accurate real-time readings, improving CC Situational Awareness. Thin film technology, a conductive system, position sensors, and data analytics detect and identify injuries. All of these are on the ”Future FR’s” uniform. On-demand emergency sensor activation extends battery life, vest autonomy, and monitoring times. Smart fusion and processing of sensor data give a new perspective on the data acquired; I injury and personalized health metrics based on a decision support model, (ii) strict oversight to prevent potentially harmful consequences from device/sensor misuse, and (iii) inaccurate data or misinterpretation of sensor data.

Tracking for FRs: Respond-A uses active and passive tracking technology and affordable tags. This allows for accurate mapping of reactions. The COP creates a single technological platform for FRs and commanders. FRs’ smart glasses can display a casualty’s medical history and status. Wearables allow FRs to quickly report casualties and update their status while providing clear, instantaneous tactile feedback. External sensor data may be linked automatically by the tracking device. Vital signs and environmental data will be linked to digital patient records by health sensors. **Usage of UAVs/Drones for FRs’ operations:** RESPOND-A develops public safety drone technology. The project’s capabilities let pilots use drones. Lab experiments, controlled field trials, and in situ demonstrations can help. Improved drone payloads include infrared, 360o, and sensors. They’re connected to the Command Center via Iridium satellite backhaul and a portable 5G system, triggering an information-sharing decision-making process. Portable 5G communication systems and drones support operations like tracking FR teams. RESPOND-A drones have additional communication payload for network coverage extension and pop-up connectivity. RESPOND-A combines 4G/5G modems with tiny cells. End-to-end communications security (telemetry, control, video feeds) is also evaluated. As drones combine their views, they become more autonomous and can operate beyond VLOS (BVLOS). **Usage of robots for FRs’ operations:** Autonomous mobile robots can explore with near real-time sensors that can detect environmental risks and remotely examine difficult-to-access regions to help find and aid survivors. The new RESPOND-A technology allows FRs to quickly analyze the surroundings using sensors carried by the UGV, including gas danger detection and wide video broadband communication using dedicated wireless connections and 5G modules. This semi-autonomous solution will revolutionize many operations. As a ”mule,” the robot will transport vital equipment and act as a communication relay for RESPOND-A infrastructure and FRs or victims on the field. The robot can act as a FR by finding threats and victims and delivering first aid kits and instructions when personnel can’t reach them.

IV. Use Cases approach

A. General Architecture method

RESPOND-A adopts the proven Risk- and Cost-Driven Architecture (RCDA). RCDA assists in comprehending stakeholder needs, creating and delivering the optimal solution in a lean, mean, and agile manner. Throughout the process, architectural issues and decisions are balanced against stakeholder needs. The application of RCDA brings various advantages to RESPOND-A: (i) Facilitates communication between solution architects and stakeholders, (ii) In lieu of hypes or personal preferences, it provides a defined and agreed-upon set of architectural requirements for design decisions, (iii) reduces delivery delays and budget overruns, (iv)improves solution quality, and (v) supports transparency in costing structures.

B. Training methodologies for FRs

The RESPOND-A initiative intends to maximize the influence of new technologies on emergency management by training FRs. Training methodologies used to achieve this goal include (i) training end users on proper use of technological products, (ii) engaging stakeholders in RD initiatives, (iii) improving knowledge of technological aspects through experience, (iv) collecting new end-user feedback to create the best possible innovative solutions, and (v) improving skills and capabilities of FRs. The trainings are tailored to the RESPOND-A outcomes. The instructional model (synchronous or asynchronous) is assessed first. Exploratory research methodologies are used with a pre-selected sample of targeted questionnaires and/or semi-structured interviews. Then a pilot study is performed to test the tools. During this process, FRs obtain a greater knowledge of the technology being created while providing input to technical Partners. Using RESPOND-A technology, FRs gain a variety of skills [4]. RESPOND-A aims to provide training for FRs based on serious games technology, tabletop exercises, and simulations. A serious game is defined as "any piece of software that merges a non-entertaining purpose (serious) with a video game structure (game)". Serious games have a positive and encouraging impact on the player, increase and develop the skills and the knowledge across domains, assist brain function, offer multiple cognitive benefits, and improve social skills [5]. A tabletop exercise focuses on the verbal description of an incident. These exercises usually begin in a hypothetical incident narrative, after tasks in the emergency response system with the form of problems are allocated to participants. Often participants, who are usually located at a single location, respond directly to event demands by explaining the activities they will initiate since they are usually communicating with other responders or Authorities [6]. Moreover, the progress in the ICT domain the last 20 years provides us the possibility to use novel simulation tools for the needs of FRs. Using computer simulation, it is possible to simulate individual scenarios, assess and improve them, while the results can be afterwards applied in a real-life incident. Moreover, simulation can support preparation, education and decision-making skills in real-world contexts. Examples of using simulations/serious games/TableTop Exercises in training context are the following: firefighting, rescue operations, fire brigade management and coordination between FRs. In the context of RESPOND-A project, the table exercises educate FRs with the use of novel technology in the decision-making process and strategies evaluation, while training them in the communication practises in real-life situations. Serious games, simulation activities, virtual/augmented environments are not meant to amuse the FRs but to cover the need for training through storytelling or gaming. In addition, serious games are designed with educational and pedagogical principles on gaming and entertainment technologies in contrast to entertainment games that do not follow the same principles. Real-life scenarios are represented by means of simulations providing a lively experience in a controlled environment to understand human nature, develop teamwork, offer trust and insight into the nature of trainees [7].

During the project, five trainings are planned. Each training will focus on one or two key elements of the emergency response, covering various aspects (coordination between FRs and command and control centers, coordination among FRs) and levels of complexity (i.e. simple and complex operations). The RESPOND-A partners benefit from the trainings as they develop the technologies, skills, and abilities required to best present the project outcomes. Each training is evaluated using assessment forms.

C. Pilots and Final Demonstration

Besides from training, RESPOND-A actively involves FRs and stakeholders to define a set of concrete and appealing pilots for the RESPOND-A platform. Following is an initial list of pilots demonstrating Responders' interests throughout the project preparation process:

1) Pilot 1: Weather-related EEA classified hazard (Cyprus): This trial will focus on ongoing communications, SAR, and FR health and safety (WUI). The goal is to familiarize practitioners with 5G professional radio devices, UAVs, and protective clothing for complex emergencies. As a result of this experiment, FRs plan to reduce the time needed to provide COP and mobilize resources, request more support, and/or start the Union Civil Protection Mechanism (UCPM). This pilot aims to I increase the percentage of forces devoted to emergencies, (ii) decrease the time required to mobilize FRs with appropriate skills and specialties, (iii) improve the health and safety of FRs and speed up their recovery time, (iv) increase FR protection during complicated emergencies (fire, smoke, chemicals, etc.), improve or create new SOPs for complex emergencies, joint teams, unmanned vehicles, and equip FRs.

2) Pilot 2: Geophysical EEA classified hazard (Greece): Cellular (and fixed) services can't always meet emergency network demands. Emergency cellular and fixed telecommunication congestion causes lack of service. FRs use emergency-ready networks. During and after a crisis, one communication path is affected. So, impacted areas and needy communities' information doesn't reach FRs Call Centres. FRs lack crowdsourced information on the crisis' impact. Responders should use helicopters because people are on the streets. FRs from different fields must collaborate (e.g. para-medics, Fire Fighters, police officers, etc.) A strong earthquake in Attica causes panic in Athens. Minor power outages and communication problems occur in the capital. Everyone in Athens calls family and friends on their phones. An Athens suburb warehouse collapses after the earthquake. The burning building is damaged. Multiple authorities must respond to this disaster (building collapse and fire). Available FR manpower must be wisely distributed in the affected region for SAR, fire control, and differentiation. Through this pilot, FRs plan to I track 5G portable telecommunications rollout, (ii) validate that the infrastructure can be implemented easily and autonomously in any place and environment, (iii) ensure high-quality voice and video communications for mission-critical services for a set period of time, and (iv) verify the broadband network's support for multiple data-rich services (VR, AR, etc.).

3) Pilot 3: Technological EEA classified hazard (Spain): Ports exacerbate the marine industry's security issues. Human error, often fatigue, causes most maritime accidents. 70% of maritime injuries and events happen in ports or coastal areas. Valencia is the Mediterranean's busiest import, export, and transhipment port. Due to the presence of oil and chemical vessels, Valencia's coast and beaches are prone to spills. Some Valencia port terminals store oils, kerosene, acids, etc. Most of these commodities are explosive, so port fires and explosions must be considered. Valencia's Port Authority has SPPs for each port (Valencia, Sagunto, and Ganda). This SPP aims to protect lives and minimize damage to the port's infrastructure, environment, and surroundings. It plans emergencies. All government and private agencies that respond to incidents or accidents involving ships, corporations, and facilities in the port, as well as any natural or legal person in the port's service area, coordinate properly. The Port Authority of Valencia has an Internal Emergency Plan and a Contingency Plan to address pollution from hydrocarbon leaks. The coordination between port, sea, and land FRs could be improved. Through this pilot, FRs plan to I establish a Safety Assessment and Early Warning structure, (ii) establish a robust 5G private mobile network in the incident area, (iii) evaluate 5G's capacity and latency for drone video transmission and FR smart glasses, and (iv) improve stakeholder coordination in an emergency by sharing real-time health, position, and situation data across officers of the same (or separate) FR organizations.

V. Expected Impacts

FRs use equipment to support mission objectives and protect themselves during natural and man-made disasters. Command and Control Centers in temporary camps near the disaster scene and Responders' mobile devices, such as smartphones, are used to achieve the COP and organize mission objectives. As disasters get worse, better COP and FR techniques are developed. RESPOND-A aims to maximize COP, Situational Awareness, and FR safety. We identified 3 similar H2020 projects, SIXTHSENSE [8], FASTER [9], and INGENIOUS [10], that have attempted a unified technology and conceptual framework to help FRs save lives more efficiently and effectively, but RESPOND-A also considers FR protection. RESPOND-A is expected to have a significant impact on FRs and their emergency organizations (Police, Firefighters, Medics, Rescuers), the European economy and productivity, business, investment and market opportunities, academic and industrial research and innovation, national Health systems, and the wider society by increasing FRs' confidence. RESPOND-A aims to strengthen European competitiveness by assessing and highlighting cutting-edge technologies and applications across the crisis lifecycle. The agile, autonomous, and easy-to-use RESPOND-A equipment tools will create opportunities for new players (SMEs/start-ups and academia) to develop highly innovative and modern solutions such as software modules, new platforms, communications, and AR/VR enabled applications. The research outputs should be commercial products that expand their presence in the growing 5G and IoT industries, where they may gain a competitive edge. This project will allow European and international researchers to pursue new research avenues. Researchers in 5G IoT and autonomous vehicle coordination will benefit immediately from new insights. RESPOND-A can reduce deaths and injuries before, during, and after disasters, improving public health and saving money. By convincing EU residents that major disasters, which occur more frequently due to industrial operations and/or climate change, are not as unsafe and insecure as before, it will help solve key societal problems.

VI. Conclusion

With the RESPOND-A project, the EU is attempting to establish itself as a world leader in the field of next-generation mission-critical networks with the highest possible COP and Situational Awareness, which will be accomplished through multidisciplinary investigation between communication engineering, mathematics, and operational field studies. Developing mission-critical systems that can withstand both man-made and natural disaster events is vital to Europe's economic and social well-being because of the rapid evolution and scalability of both disasters.

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