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D2.2 System Specifications and Architecture

Next-generation equipment tools and mission-critical strategies for First Responders

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Consortium Partners

The RESPOND-A Consortium consists of the following partners:

Participant No	Participant organisation name	Short Name	Country
1	EUROPEAN UNIVERSITY CYPRUS	EUC	CY
2	AIRBUS DS SLC	ADS	FR
3	SAFRAN PASSENGER INNOVATIONS	SPI	DE
4	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	NCSRD	GR
5	FUNDACION CENTRO DE TECNOLOGIAS DE INTERACCION VISUAL Y COMUNICACIONES VICOMTECH	VICOM	ES
6	FUNDACIO PRIVADA I2CAT, INTERNET I INNOVACIO DIGITAL A CATALUNYA	I2CAT	ES
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13	HELLENIC INSTRUMENTS IKE	HI	GR
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Definitions, Acronyms and Abbreviations

Acronyms/ Abbreviations	Description
API	Application Programming Interface
AR	Augmented Reality
BVLOS	Beyond Visual Line of Sight
C&C	Command & Control
CFR	Charter of Fundamental Rights
CII	Critical Information Infrastructure
COP	Common Operational Picture
DFF	Data Format Fusion
EMT	Emergency Medical Technician
ERCIT	Emergency Response Communications and Information Technology
FR	First Responder
GDPR	General Data Protection Regulation
FMEA	Failure Mode and Effect Analysis
FTA	Fault Tree Analysis
FR	First Responder
HARA	Hazard Analysis and Risk Assessment
IFRC	International Federation of Red Cross
INSARAG	International Search and Rescue Advisory Group
JSON	JavaScript Object Notation
LEO	Low Earth Orbit
MAVLink	Micro Air Vehicle Link
ML	Machine Learning
NFC	Near-Field Communication
OECD	Organisation for Economic Co-operation and Development
OR	Operational Requirement
PCS	Portable Communication System
PMR	Private Mobile Radio
PPDR	Public Protection and Disaster Relief
PTT	Push-To-Talk
QOS	Quality of Service
REST	Representational state transfer
RFID	Radio-Frequency Identification
SAR	Search and Rescue
SATCOM	Satellite Communications
SELP	Social, Ethical, Legal and Privacy
SME	Small and Medium Enterprise

SPP	Self-Protection Plan
TCP/IP	Transmission Control Protocol / Internet Protocol
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UHF	Ultra-High Frequency
UWB	Ultra-Wideband
UxV	Unmanned Vehicle
VHF	Very-High Frequency
VR	Virtual Reality

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Executive Summary

The RESPOND-A project aims at leveraging the First Responders safety and efficiency by maximizing the Situation Awareness and enhancing their operational capabilities. Bringing together a variety of novel technologies, it boosts Early and Safety Assessment, Risk Mitigation, while ensuring clear Common Operational Picture and optimal operations management, even between different emergency units. The system architecture and tools' specifications are the key elements of the RESPOND-A system, towards a unified and flexible framework for supporting the aforementioned functions. The purpose of this deliverable (D2.2) is to present and explain the RESPOND-A system architecture and tools' specifications. It is the output of Task 2.2 of WP2, where the First Responders' requirements (D2.1), as well as the use cases (D2.3) and Description of Action (DoA) requirements and constraints were taken into consideration for developing a system architecture capable of offering tools interoperability and cooperation, towards a unified and concrete solution for answering the above requirements and supporting the First Responders. This deliverable will be shared between the development team of the project as a base for realizing the RESPOND-A platform.

1. Introduction

1.1 Purpose of the Document

This document is the deliverable 2.2 (D2.2) of the RESPOND-A project. The purpose of this report is to provide a full description of the RESPOND-A system architecture and tools specifications and requirements, which are the main outcome of Task 2.2 (T2.2) [1].

1.2 Scope and Intended Audience

The scope of this document is to present and describe the basic components of the RESPOND-A system architecture and to provide its tools specifications and requirements, which will be shared between the development team of the project. The document is public, meaning that not only the partners of the project will have access to it, but anyone who may be interested in these technologies.

1.3 Structure of the Document

The structure of the document is as follows:

- Chapter 2 provides a brief overview of the objectives of T2.2, the methodology that was followed, the milestones achieved, as well as a brief overview of the task main inputs (i.e. the use cases and First Responders (FRs) requirements).
- Chapter 3 presents the RESPOND-A system architecture and analyses its main components and their requirements and specifications.
- Chapter 4 presents the tools of the RESPOND-A ecosystem and their requirements and specifications.
- Chapter 5 concludes the report providing an overview of T2.2 activities outcomes and discusses them in relation to the rest of the project activity.

1.4 Referenced Documents

The main inputs of T2.2 and D2.2 were based on D1.1, considering the procedures and guidelines and on D2.1 for the FRs requirements [2]. D2.2 also received input from the draft versions of D2.3 (as D2.2 and D2.3 have the same delivery date) [3], regarding the use cases requirements and it acts as an input to the deliverables of WPs 3, 4 and 5, regarding the development of the RESPOND-A system tools.

2. Methodology, Requirements and Constraints

2.1 Task 2.2 Overview and Objectives

The objective of T2.2 is to define the RESPOND-A architecture fed by the FRs requirements. Specifically, the identified requirements from the T2.1 were analyzed in order to determine a set of system specifications covering all the technological states of the RESPOND-A project. The system architecture acts as a communication framework to help all stakeholders understand the system. The primary goal is to address the complexity of the FRs applications providing distributed Situational Awareness through immersive technologies, which take into consideration the communication and security requirements, the data presentation and analysis, the process time, and conditions that differ among the various FRs groups. In conclusion, the final outcome of this task is the system and tools specifications and the architecture of the RESPOND-A project that is understood and shared between the development team of the project.

2.2 Methodology and Milestones

T2.2 followed the process of interpreting stakeholders' requirements, and subsequently designing and delivering the best fitting solution in a lean, mean and agile manner. Architectural concerns and decisions were weighed throughout the process, and FRs requirements were constantly taken into account. The methodology that was followed and the milestones that were achieved in task 2.2 for the development of the RESPOND-A system architecture consisted of:

1. Analyzing the FRs requirements to understand the FRs operational needs.
2. Taking into consideration the use case requirements.
3. Taking into account the RESPOND-A goals.
4. Collecting and understanding the offered technologies and expertise of the technology partners of the consortium.
5. Bringing together a variety of novel technologies and partners from different WPs towards a unified ecosystem
6. Deriving the RESPOND-A System Architecture

2.3 Use Cases Requirements

In RESPOND-A, use cases are a fundamental element to ensure that the system and components to be developed and used in the project serve the needs of FRs in real situations of emergency. The project includes three use cases, each one taking place in a different country.

The first use case, taking place in Cyprus, describes the hypothetical though realistic scenario of a severe forest fire as often occurring in most southern European countries. In this use case, RESPOND-A tools are intended to be used in 4 crucial moments during this emergency: a) in the detection, recognition and monitoring of the affected area, b) in the search and rescue of firefighters affected by the fire, c) the evacuation, search and rescue of civilians in danger, and d) the support of the necessary operations when the fire reaches a highly explosive area.

The second use case takes place in Greece, in the industrial area of “Elaionas” in the city of Egaleo. This use case simulates a severe earthquake scenario that evolves in multiple fires in the damaged buildings. In this case, the RESPOND-A solution is used to cope with two specific emergencies. The first situation is the search and rescue of a civilian trapped in the rubble of a building affected by the earthquake. The second emergency simulates the rescue of a first responder and a civilian affected by the fire caused by the earthquake in a building.

Finally, the third use case occurs in Spain, where two different scenarios take place in the port of Valencia and the surrounding neighborhoods. In the first scenario, a vessel crashes the north breakwater of the port causing a big oil spill which affects the port and the nearest beach of the city. In this scenario, the RESPOND-A tools are used to monitor the affected area and rapidly evacuate and rescue the bathers in danger. The second scenario simulates the crash of two trucks in the port area close to the city producing a fire in the affected area. This accident also provokes the emanation of toxic gases that force the evacuation of the inhabitants of the surrounding neighborhoods. The rescue of injured civilians and FRs will be boosted thanks to the usage of the RESPOND-A system and its tools.

To realize these use cases, the RESPOND-A system and tools to be used need to address a series of technical requirements. These requirements are identified from the detailed description of these use cases in collaboration with the FRs involved. Each simulated scenario is composed of a set of steps that helped to identify potential technologies that could be used. In the Deliverable D2.3 [3], all these use cases and their requirements are described in detail. A total of 70 requirements have been identified. These requirements were taken into account for the design of the architecture described in this document.

2.4 First Responders Requirements

The overall system specification process, as overviewed in Figure 1, included a number of activities distributed among the different tasks under the umbrella of WP2 of the RESPOND-A work plan. The process began with the collection of inputs from all RESPOND-A end users participating in the project's use cases in close coordination with the use case leaders. The input collection from those end users was initially performed via interviews and was later supplemented with an Operational and Safety Requirements questionnaire (see D2.1 [2]). Moreover, safety and data privacy legal frameworks, regulations and guidelines that shall be adhered to by the RESPOND-A solution were identified and analyzed. As a result of the work described in D2.1, over 130 FRs requirements have been elicited, analyzed and prioritized with 74 requirements capturing high-priority (i.e., must have), 42 capturing medium-priority (i.e., should have) and 16 capturing low-priority (i.e., could have) user needs.

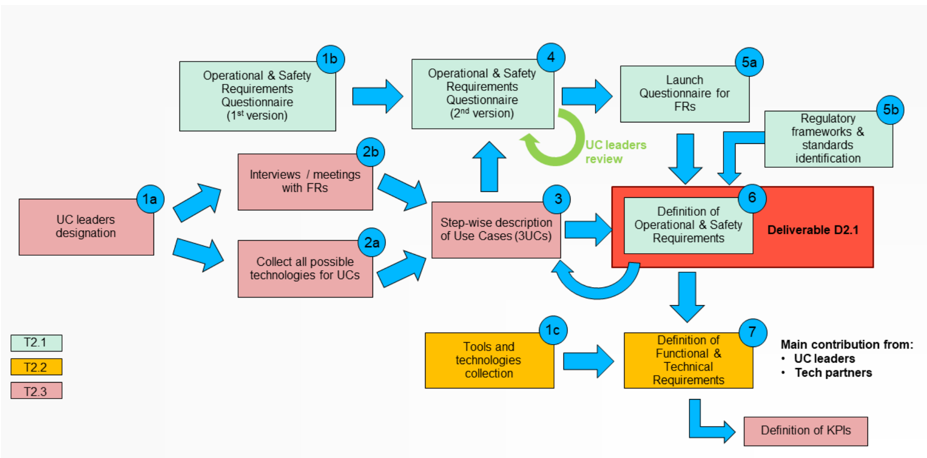

Figure 1: RESPOND-A System Specification Activities Workflow

Using this information, the FRs needs were identified and the required specifications were extracted and defined. The derived Functional (F) and Non-Functional (NF) specifications in relation to the FRs operating requirements are shown in table 1:

Req. ID	FRs Requirements Description	Technical Specifications Functional (F) / Non-Functional (F)
OR01	A command-and-control centre shall be used for ensuring the successful outcome of a First Responder's operation	● The command and Control centre exchanges/manages data to support the FRs operations **(F)** ● The command and control centre runs multiple applications for mission adaptation **(F)** ● The command and control supports different groups of users for a multitask mission **(F)**
OR02	The coordination of activities between different groups of First Responders during operations shall be supported by a Command-and-Control centre.	● The command and control centre coordinates the activities between Departments and Groups created according the mission and /or echelon of FR organization **(F)** ● The command and control centre can support unlimited number of users **(NF)**
OR03	**A command-and-control centre shall provide functionalities relating to:**	
OR03 .1	Visualization of data relating to the operation (e.g., type of incident, map of incident location, first responder groups on scene)	● The command and control centre provides geolocation of FRs on Map **(F)** ● The command and control centre visualization can be divided on different screens for smoother data processing from operational administrators **(F)**
OR03 .2	Establishment of a Common Operational Picture between First Responders and Command-and-Control centre (e.g., information sharing regarding the operation parameters)	● Common Operational Picture (COP) establishment **(F)** ● Information sharing between the FRs and the officers in the Command and control centre **(F)**
OR03 .3	Mission Management (e.g., tracking and monitoring of equipment, coordination of resources between different groups of First Responders)	● Central mission management **(F)** ● Coordination of FRs, equipment and resources of the mission **(F)** ● List all available assets in the network **(F)** ● Information about security incidents in case of anomaly detection **(F)** ● Alarms for new security incidents **(F)** ● Network anomalies detection in less than 30 sec **(NF)**
OR03 .4	Data Source Management capabilities for contextual data processing and fusion	● Support input of data from various data sources and sensor types **(F)** ● Storage database in a common format preserving context based information **(F)**
OR03 .5	Victim localization and tracking	● Casualty tracking at incident scene **(F)** ● Casualty care path tracking and planning for command **(F)**
OR03 .6	First Responder localization and tracking	● Locate and track the FRs **(F)** ● Location accuracy equal or better than conventional GPS **(NF)**
OR03 .7	First Responder health status (including biometrics)	● Display First Responder health status in the command and control center **(F)** ● Handle and display the required amount of health data of the First Responders per mission **(F)**

OR03 .10	Live traffic information	● Not supported by Respond-A
OR03 .11	An estimative quantification of the magnitude of the accident (e.g., m2 or ha for an oil spill or a fire)	● Record and analyze location status (NF)
OR04	**A mission management system shall be able to support functionalities relating to:**	
OR04 .1	Risk assessment, risk dynamics and incident quantification	● Special module for Risk and statistical representation (NF)
OR04 .2	Cataloguing and location of necessary equipment	● Provide support to store and show asset location **(F)** ● Equipment location and tracking **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)**
OR04 .3	Coordination of operations and resources between different groups of First Responders and their action plans	● Coordination of FRs, equipment and resources of the mission **(F)** ● List all available assets in the network **(F)** ● Provide information about security incidents in case of anomaly detection **(F)** ● Inform the network operator for new security incidents **(F)** ● Detect network anomalies in less than 30 sec **(NF)**
OR04 .4	Tracking of victims and property damage	● Casualty tracking at incident scene **(F)**
OR05	**A mission management system shall be able support the exchange of information relating to:**	
OR05 .1	· Location, type and severity of incident	● Supports any data from different sources including location, type and severity incident **(F)**
OR05 .2	· Location and action plans of different groups of First Responders	● Supports any data from different sources and groups of FRs **(F)**
OR05 .3	· Location and status of equipment	● Supports data from any equipment is connected including location and status **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)**
OR05 .4	· Location and medical status of victims	● Supports data from any user is connected including location and medical status **(F)**
OR05 .5	· Location and extend of damage of property	● Supports data from any user is connected including locational and damage of property **(F)**
OR06	**A Common Operational Picture shall be established for operation planning, by providing to First Responders information relating to:**	
OR06 .1	· Early warnings and alert about potential incidents	●Operational administrator can send alerts and information's about incidents by any user **(F)**
OR06 .2	· Location and type of incident	●Operational administrator can send alerts and information about incidents any user **(F)**
OR06 .3	· Existence of injuries, casualties	● Special module for AI on injuries (NF)
OR06 .4	· Damage to property, public infrastructure	● Special module for AI on damages (NF)
OR07	**A victim localization and tracking system shall be able to support functionalities relating to:**	

OR07 .1	· Collection of victim profile (e.g., age, sex, status, medical history)	● Casualty demographic data collection at incident scene (F)
OR07 .2	· Location of victim (e.g., GPS coordinates, street address, distance to nearest hospital)	● Casualty tracking at incident scene **(F)**
OR07 .3	· Data exchanges with relevant agencies (e.g., hospitals, civil protection agencies, law enforcement, firefighters)	● Casualty data sharing at incident scene **(F)**
OR08	**Secure and reliable communication channels shall be established during operations between:**	
OR08 .1	· Command-and-control centre(s) and First Responders on the scene	● Can be operated by in a mobile and Command and Control Centre exchanging information from/to any FR on the scene **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)** ● Provide information about security incidents in case of anomaly detection **(F)** ● Inform the network operator for new security incidents **(F)** ● Detect network anomalies in less than 30 sec **(NF)**
OR08 .2	· Different groups of First Responders on the scene (e.g., police and firefighters)	● Can coordinate and manage different Groups and Departments **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)** ● Provide information about security incidents in case of anomaly detection **(F)** ● Inform the network operator for new security incidents **(F)** ● Detect network anomalies in less than 30 sec **(NF)**
OR08 .3	· Command-and-control centre(s) and UxVs (e.g., drones, robots)	● Connection between the Command-and-control center and the UAVs are supported via radio link, 4G or Iridium satellite communications **(F)** ● Communication protocol between UAVs and the control center shall be based on MAVLink messages **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)** ● Provide information about security incidents in case of anomaly detection **(F)** ● Inform the network operator for new security incidents **(F)** ● Detect network anomalies in less than 30 sec **(NF)**
OR08 .4	· First Responders on the scene and UxVs (e.g., drones, robots)	● First Responders can monitor the UAVs and the transmitted data from sensors and instruments on-board **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)** ● Provide information about security incidents in case of anomaly detection **(F)** ● Inform the network operator for new security incidents **(F)** ● Detect network anomalies in less than 30 sec **(NF)**

OR08 .5	· Command-and-control centre(s) and wearable sensors (e.g., vital monitoring vest)	● Communication module compatible with 4G/5G/Wi-Fi networks (F) ● All wearable sensors data are transmitted through a wearable central sensors unit (F) ● List all available assets in the network (F) ● Update the asset list every 2 minutes (NF) ● Provide information about security incidents in case of anomaly detection (F) ● Inform the network operator for new security incidents (F) ● Detect network anomalies in less than 30 sec (NF)
OR08 .6	· First Responders on the scene and wearable sensors (e.g., vital monitoring vest)	● Wearable sensors and central sensors unit **(F)** ● Auto-check of connected sensors operational integrity on central sensors unit start-up **(F)** ● Minimum data transmission rate from a sensor to the central sensors unit: 5 seconds **(NF)** ● Maximum data transmission rate from a sensor to the central sensors unit: 90 seconds **(NF)** ● UART connection between sensors and central sensors unit **(F)** ● List all available assets in the network **(F)** ● Update the asset list every 2 minutes **(NF)** ● Provide information about security incidents in case of anomaly detection **(F)** ● Inform the network operator for new security incidents **(F)** ● Detect network anomalies in less than 30 sec **(NF)**
OR09	**The communication infrastructure used during operations shall be able to support the exchange of the data relating to:**	
OR09 .1	· Text	● Communications infrastructure to support text messaging **(F)** ● Support of text messaging between different groups of FRs **(F)**
OR09 .2	· Voice	● Communications infrastructure to support voice **(F)** ● Support of voice communication between different groups of FRs **(F)**
OR09 .3	· Image	● Communications infrastructure to support image transfer **(F)** ● Support of image transfer between different groups of FRs **(F)**
OR09 .4	· Video	● Communications infrastructure to support video transfer **(F)** ● Support of video transfer between different groups of FRs **(F)**
OR09 .5	· Satellite data for location-based services (e.g., GPS signal)	● Communications infrastructure to support location based services **(F)** ● Support of location based services for different groups of FRs **(F)**
OR09 .6	· Virtual reality (VR) applications	● Communications infrastructure to support Virtual Reality (VR) applications **(F)** ● Support of text Virtual Reality (VR) for different groups of FRs **(F)**
OR09 .7	· Augmented reality (AR) applications	● Communications infrastructure to support Augmented Reality (AR) applications (F) ● Support of Augmented Reality (AG) for different groups of FRs (F) ● Superimposed shared information on top of real-time video transmission (F)
OR09 .8	· Alert signals	● Alert signals generation upon exceeding set sensors data thresholds **(F)** ● Transmission of Alert signals to the Alert Mechanism and the C&C Centre **(F)**

OR09.9	· Device metadata (e.g., metadata from sensors)	● Use of OGC Sensor Things API, supporting models including information of metadata from central sensors unit and sensors **(F)**
OR10	The area in which a First Responder operation takes place shall have adequate cellular network coverage.	● Cellular Network Coverage in the mission area **(F)** ● Radius of the Coverage Area at least 300m **(NF)** ● Guaranteed QoS at the cell edge **(F)** ● At least 1 supported cell **(NF)** ● To support up to 1000 users per cell **(NF)**
OR11	The communication infrastructure used during operations shall allow high-speed data exchanges.	● 5G network coverage where is possible **(F)** ● Total Data rates for 5G of 600Mbps in Uplink and 150Mbps in Downlink **(NF)** ● Support of MIMO 4X4 in downlink **(NF)** ● Bandwidth up to 50MHz **(NF)**
OR12	**Communication between First Responders during operations in areas with limited or no cellular network coverage shall be supported by:**	
OR12.1	· Push-to-talk radios (e.g., VHF, UHF, HF, SIMPLEX)	● Devices subscribing on extended coverage (F) ● Devices running Push-To-Talk voice application (F)
OR12.2	· Repeaters, aerial relays	● Aerial relays to extend the coverage of the communications beyond the cell edge (F) ● Aerial relays to enhance the capacity of the communications at the cell edge (F) ● Aerial relays to cover communications coverage holes in the cell (F)
OR12.3	· Mobile cellular transmitters, towers	● Mobile/Deployable Communications Infrastructure **(F)** ● Core and RAN All in one **(F)** ● Deploy time no more than 15 minutes **(NF)** ● Total weight no more than 15 Kg **(NF)** ● Compact size-dimensions no more than 40X30X40 cm **(NF)**
OR13	**Incident (call-to-action) notifications to First Responders shall be able to be communicated by:**	
OR13.1	· Phone call from civilians to emergency number	● Not supported by Respond-A
OR13.2	· Phone call or radio notification from Emergency number operators or other First Responder organisation(s)	● Not supported by Respond-A
OR13.3	· Email from civilians	● Not supported by Respond-A
OR13.4	· Specialised means of communication (e.g., VTS for marine vessels and port authorities)	● Not supported by Respond-A
OR14	**The minimum necessary communication infrastructure for the deployment of mobile Command-and-Control centers shall be able to support:**	

OR14.1	· 4G broadband cellular network coverage	● 4G Network Coverage in the mission area **(F)** ● Radius of the Coverage Area at least 300m **(NF)** ● Bandwidth up to 20MHz **(NF)** ● MIMO 4X4 support in Downlink **(NF)** ● Data Rates of at least 100 Mbps for Downlink and 50 Mbps for Uplink **(NF)**
OR14.2	· 5G broadband cellular network coverage	● 5G Network Coverage in the mission area **(F)** ● Radius of the Coverage Area at least 300m **(NF)** ● Bandwidth up to 50MHz **(NF)** ● MIMO 4X4 support in Downlink **(NF)** ● Data Rates of at least 600 Mbps for Downlink and 150 Mbps for Uplink **(NF)**
OR15	· During operations, the deployment of unmanned aerial platforms (e.g., drones) shall be supported	● Drones will be provided to support the FRs operations (F) ● Flight autonomy of the drones of at least 30 min (NF) ● Minimum horizontal range of the UAVs of 600m (NF) ● Maximum vertical range of the UAVs of 120m (NF) ● Semi-autonomous mission, upon computing offline the waypoints (F) ● Update of mission plan based on on-board AI to recognize obstacles and points of interest (F)
OR16	· During operations, the deployment of robots shall be supported	● Will provide extra support to FR (F) ● Capability to add other sensors or accessories (F) ● Provide customized information about temperatures (F)
OR17	**The minimum necessary additional resources for the deployment of UxVs during operations shall consist of:**	
OR17.1	· Dedicated personnel to handle UxV	● UxV specialized pilot to operate the UxV **(F)** ● At least one pilot per UAV operation **(NF)**
OR17.2	· 4G broadband cellular network coverage	● UAVs support communications via 4G broadband cellular **(F)** ● Latency in the e2e communications up to 200-300ms **(NF)**
OR17.3	· Satellite link for communications	● UAVs support communications via Iridium satellite link (F) ● Latency in the e2e communications up to 1500ms (NF)
OR18	**UxVs deployed during First Responder operations shall be able to support the following functionalities:**	
OR18.1	· Image capture from incident area	● Captured images from on-board cameras transmitted to ground **(F)**
OR18.2	· Video feed from the incident area	● Video feed from 360 camera transmitted to ground only via 4G/5G link **(F)**
OR18.3	· Localisation (e.g., GPS coordinates) of victim(s) or infrastructure	● Drone position transmitted to ground or reachable through API (F) ● Robot GPS position available through API and HMI (F)
OR18.4	· Data feed from specialised sensors (e.g., thermal imaging)	● Specialised thermal sensors are used to capture and transmit thermal imaging data **(F)**
OR18.5	· Telemetry data transmission	● UAVs send telemetry data from the sensors on-board to the ground control station **(F)** ● Bandwidth constraints according to the type of link under use (4G or Iridium) **(F)**

OR19	**The definition of the flight plan of an unmanned aerial platform during First Responder operations, shall be able to account for:**	
OR19 .1	· The altitude, above ground level (AGL) of the intended flight path	● The ground station UAV software should provide and adjust the flight altitude (F) ● Altitude sensitivity of less than 1 meter (NF) ● Altitude check at least two times per second (NF)
OR19 .2	· The duration of the flight plan	● The ground station UAV software should provide info about the duration of the flight plan (F) ● The ground station UAV software should able to adjust the duration of the flight plan (F)
OR19 .3	· The features of the operational environment (e.g., urban environment, air traffic)	● The UAV management system should support UTM/ADS-B (F)
OR19 .4	· The conditions of the operational environment (e.g., wind speed, temperature)	● The UAV system should support weather station information (NF) ● The weather station should provide data more than 1 time per minute (NF)
OR20	· On-body sensors for tracking the position of First Responders shall be available and functional during operations.	● Locate FR in indoor environments **(F)** ● Data processing is performed on-board **(F)** ● Durability of the battery larger than the operation (several hours) **(NF)** ● Weight no more than 500g **(NF)**
OR21	· On-body sensors for tracking the vital signs of First Responders shall be available and functional during operations.	● Body Sensors detect ECG and Breath signals plus HR and BR (F) ● Data processing is performed on-board (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight is inferior to 300 g (device plus vest) (NF)
OR22	· Helmets with augmented reality data (AR) displays shall be available and functional during First Responder operations.	● AR displays in the form of smartphones or glasses (F) ● AR displays able to receive Infrared Video Stream (F) ● At least one AR system must be supported for use in the field by FR (NF)
OR23	· Augmented reality headsets with augmented reality data (AR) displays shall be available and functional during First Responder training.	● Detect Personal Protective Equipment (PPE) **(FN)** ● Data processing is performed on-board **(FN)** ● lifespan: up to 6 months **(NF)** ● weight no more than 600g **(NF)**
OR24	· Virtual reality (VR) goggles shall be available and functional during First Responder operations.	● Video feed from 360 cameras made available for real-time consumption on off-the-self VR goggles (via their web browser) **(F)** ● FR can freely inspect around the captured 360º environment by using the VR goggles **(F)**
OR25	· Virtual reality (VR) goggles shall be available and functional during First Responder training.	● Allow FRs to train on real tools, devices and scenarios and see their score **(F)** ● Allow customisation of various aspect of training in later date **(F)** ● lifespan up to 6 months **(NF)** ● weight no more than 550g **(NF)**
OR26	**During First Responder operations, on-body sensors shall be able to track parameters related to:**	

OR26 .1	· Electrocardiography (ECG)	● Body Sensors detect and send the ECG signal one lead (F) ● Data processing is performed on-board (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight no more than 300 g (device plus vest) (NF)
OR26 .2	· Heart rate	● Body Sensors detect and send the user's heart rate (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight no more than 300g (device plus vest) (NF)
OR26 .3	· Breathing	● Body Sensors detect breathing signal (F) ● Data processing is performed on-board (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight no more than 300g (device plus vest) (NF)
OR26 .4	· Breath rate	● Body Sensors detect and send the breath rate (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight no more than 300g (device plus vest) (NF)
OR26 .5	· Body posture (e.g., laying, standing)	● Body Sensors detect and send the body posture (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight no more than 300g (device plus vest) (NF)
OR26 .6	· Activity classification (e.g., standing still, walking, running)	● Body Sensors detect and send the activity classification (F) ● The wearable system is not a hindrance for the user (F) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight no more than 300g (device plus vest) (NF)
OR26 .7	· Body temperature	●Wearable sensor (F) ●Update the assets every risk level change (NF) ●Provide info action to the alarm mechanism (F) ●Send info to the Data logger (F)
OR26 .8	· Blood oxygenation	●Wearable sensor (F) ●Update the assets every risk level change (NF) ●Provide info action to the alarm mechanism (F) ●Send info to the Data logger (F)
OR26 .9	· Radiological dose of the environment	● Body Sensors detect the Gama radiation of the environment (F) ● Sensor is calibrated (F) ● Radiation detection up to 200 µSv/h (NF) ● Sensor life span (without maintenance) up to 2 years (NF) ● weight less than 50 g (NF)

OR26 .10	· Chemical contamination of the environment	● Body Sensors detect the following toxic gases: NO2, SO2, H2S, CH4 and O2 **(F)** ● Sensors are calibrated **(F)** ● Weight less than 200 g **(NF)** ● Sensor life span (without maintenance) up to 2 years **(NF)**
OR27	**During First Responder operations, a triage system shall be able to track data related to:**	
OR27 .1	· Timestamp of first contact with the victim	● Timestamp recorded on assigning of casualty with a tag **(F)**
OR27 .2	· Location of the victim	● Geographic coordinates recorded on FR interaction with the tag assigned to a casualty **(F)**
OR27 .3	· Triage classification of the victim (code or colour)	● Store multiple colours of tags to match triage status **(F)** ● Make colours obvious for FRs to identify the triage status **(F)**
OR27 .4	· Vital signs of the victim	● Allow the FR to record the vital signs of the casualty **(F)**
OR27 .5	· Treatment(s), medication(s) administered	● Allow the FR to record the administered treatments of the casualty **(F)**
OR27 .6	· Injuries sustained	● Allow the FR to record the injuries sustained by the casualty **(F)**
OR27 .7	· Name, age, gender of the victim	● Allow the FR to record the name, age and gender of the casualty **(F)**
OR27 .8	· Medical history of the victim	● Allow the FR to record the medical history of the casualty **(F)**
OR27 .9	· Known allergies of the victim	● Allow the FR to record the allergies of the casualty **(F)**
OR27 .10	· Contamination (chemical or otherwise)	● Allow the FR to record the contamination status of the casualty **(F)**
OR27 .11	· Aggregate numbers, statistics about the number of victims on the scene	● Maintain casualty statistics of the whole incident area **(F)**
OR27 .12	· Breakdown of victim numbers per triage classification	● Maintain casualty status statistics of the whole incident area **(F)** ● Display the classified casualties by triage status **(F)**
OR27 .13	· Breakdown of victim numbers per age group	● Maintain casualty demographic statistics of the whole incident area **(F)** ● Display the classified casualties by age group **(F)**
OR27 .14	· Breakdown of victim numbers per gender	● Maintain casualty demographic statistics of the whole incident area **(F)** ● Display the classified casulties by gender **(F)**
OR28	**The minimum necessary additional resources for the deployment of a triage system during operations shall consist of:**	
OR28 .1	· Broadband internet access	● Not supported by Respond-A
OR28 .2	· Integration with third party systems (e.g., VTMIS) for provision of services (e.g., location tracking)	● Not supported by Respond-A
OR28 .3	· Compliance with existing, established triage protocols of First Responder organisations	● Not supported by Respond-A
OR29	**During First Responder operations, a triage system shall be operated by:**	

OR29 .1	· Medical personnel	● Casualty data can be entered and edited at incident scene **(F)** ● Casualty data is synchronised **(F)**
OR29 .2	· Fire fighters	● Basic casualty status data is entered at incident scene **(F)** ● The ruggedized tagger will maintain functionality within registered operational temperature range and under IP65 water conditions **(NF)**
OR29 .3	· Other search and rescue personnel (e.g., SAR, MRCC)	● Basic casualty status data is entered at incident scene **(F)**
OR30	· Relevant smartphone applications shall be able to be used by First Responders during operations, without impeding their activities.	● First responders must be able to access relevant data using smartphone applications during an operation **(F)** ● Smartphone applications intrusiveness is kept to a minimum **(NF)**
OR31	· Helmets shall be able to be used by First Responders during operations, without impeding their activities.	● First responders must be able to access relevant data using applications developed for helmets in the field during an operation **(F)** ● Helmet applications intrusiveness is kept to a minimum **(NF)**
OR32	· Virtual reality (VR) goggles shall be able to be used by First Responders during operations, without impeding their activities.	● Video feeds from 360 cameras made available for real-time consumption on off-the-self VR goggles (via their web browser) by FR at the C&C centre **(F)**
OR33	· Helmets with augmented reality (AR) data displays shall be able to be used by First Responders during operations, without impeding their activities.	● First responders must be able to access to relevant data displayed as AR during an operation **(F)** ● Helmet AR applications intrusiveness is kept to a minimum **(NF)**
OR34	· Real-time 360º video shall be accessible during First Responder operations	● Video feeds from 360 cameras made available for real-time consumption on off-the-self VR goggles (via their web browser) by FR at the C&C centre **(F)** ● Video feeds from 360 cameras made available for real-time consumption on mobile devices and PCs (via their web browser) **(F)**
OR35	**A real-time 360º video platform shall be able to provide:**	
OR35 .1	· High-quality video feed	● Support for Resolution of at least 4K in real-time **(NF)** ● Support for quality level adaptation based on available bandwidth **(F)**
OR35 .2	· Ability to zoom on video	● Support for zooming feature **(F)** ● Support for at least 2 zoom levels **(NF)**
OR35 .3	· Dynamic switching between different camera angles	● Support for dynamic switching between the available camera feeds **(F)** ● Support for at least 2 camera feeds **(NF)**
OR35 .4	· Ability to freely explore the omnidirectional operational environment	● FRs can freely and seamlessly explore the 360º space for the selected camera feed **(F)**
OR35 .5	· Ability to collaboratively inspect the same video feed with other remotely located First Responders	● Support for collaborative watching between different remote FRs **(F)** ● Support for sessions with at least 4 remote FR **(NF)**
OR35 .6	· Ability to communicate via audio with other collaborators when inspecting the available video feeds	● FRs in the same co-viewing session can interact via an audio chat channel **(F)** ● FRs in the same co-viewing session can interact via a video chat channel **(F)**

OR35 .7	· Ability to access the video feed on traditional desktop-based displays	● The available camera feeds can be played out in real-time on desktop-based displays **(F)**
OR35 .8	· Ability to access the video feed on VR displays (e.g., VR goggles)	● The available camera feeds can be played out in real-time on VR displays (e.g. VR goggles) **(F)**

Table 1: FRs requirements to functional and non-functional specifications mapping

In the context of this deliverable, those requirements will provide the framework upon which the specification of the RESPOND-A architecture will be constructed. A mapping of the operational requirements (OR) to specific tasks of the technical work packages of the RESPOND-A work plan has been performed and can be accessed in Annex I. This mapping will facilitate the integration of user needs, captured by such requirements, to the technical specification activities undertaken during the rest of the project, ensuring that the development of the RESPOND-A solution is guided by the needs of its end users. It is noted that the offered tools and system architecture accommodate even more specifications (that are not directly extracted from the FRs needs) in order to ensure smooth and complete technology integration and mission effectiveness.

3. RESPOND-A Architecture

3.1 Overview

The aim of the RESPOND-A system architecture is to leverage FRs efficiency and safety, by introducing a joint technological and conceptual framework for maximal Situational Awareness in terms of boosting Early Assessment, Safety Assessment and Risk Mitigation capabilities, together with the clear COP and the optimal management of operations. It associates modern telecommunication technology, network enabled tools and advanced equipment with novel practices for FRs saving lives, while safeguarding themselves more effectively. The introduced architecture is designed based on the FRs and use cases requirements (D2.1 and D2.3) so it can be flexibly elaborated to support multiple levels and types of customizations, for the intended technologies and practices be able to adapt to any EEA-type disaster scenario.
Figure 2 depicts the generic concept diagram of the RESPOND-A implementation:

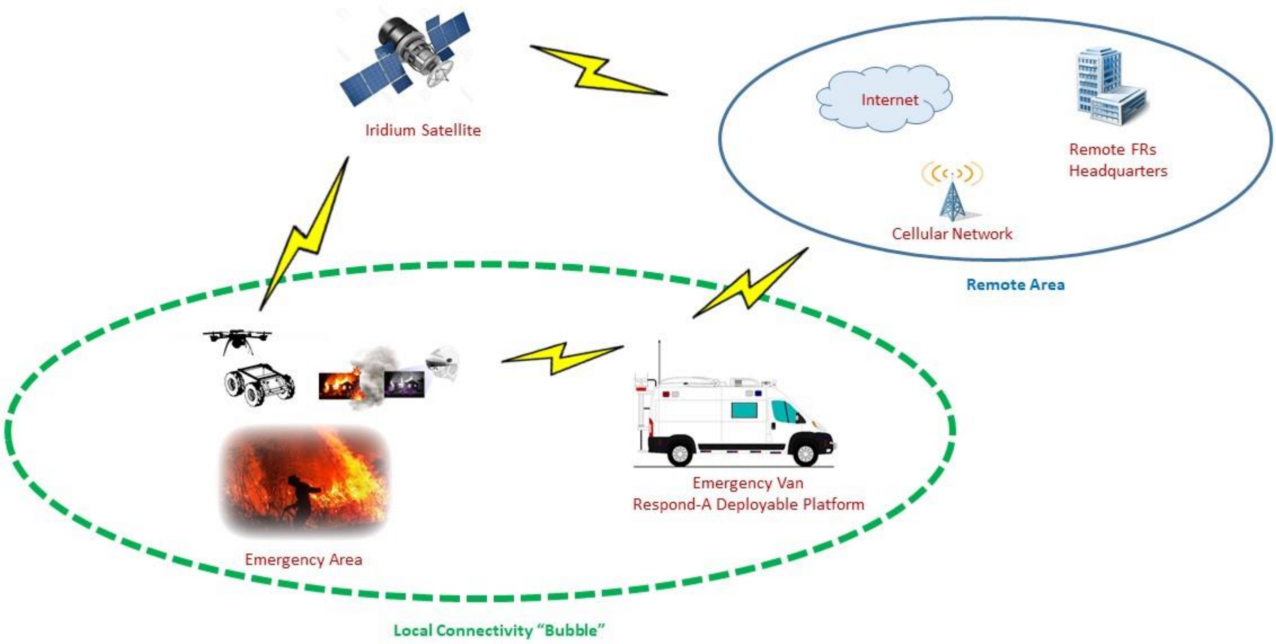

Figure 2: RESPOND-A Concept

The different units of FRs (e.g. Firefighters, paramedics, police, etc.) will operate in the incident area, not only using new technologies and wearable equipment for enhancing their capabilities, but also fully supported by a deployable platform, installed in a van for approaching fast and easy the incident scene. This platform will act as an autonomous mobile Command & Control (C&C) center and a communication system, organizing FRs mission, offering guaranteed communication (even if the public network is out of service/reach) and sending them critical information for completing their mission secure and effectively. The mobile unit will also act as a gateway to the remote FRs headquarters and the internet.

3.2 System Architecture

RESPOND-A develops new and innovative technologies, coming from different scientific fields, for supporting a variety of FRs and use cases needs, towards the safety and efficiency of FRs missions. Thus, the main challenges of system architecture design are to embed all the different technologies, provide integration and interoperability and produce a unified system, capable of supporting rescue operations in different environments and situations. Figure 3 shows all necessary components of the architecture of RESPOND-A system for achieving an optimized and effective coordination and function of all the required technologies.

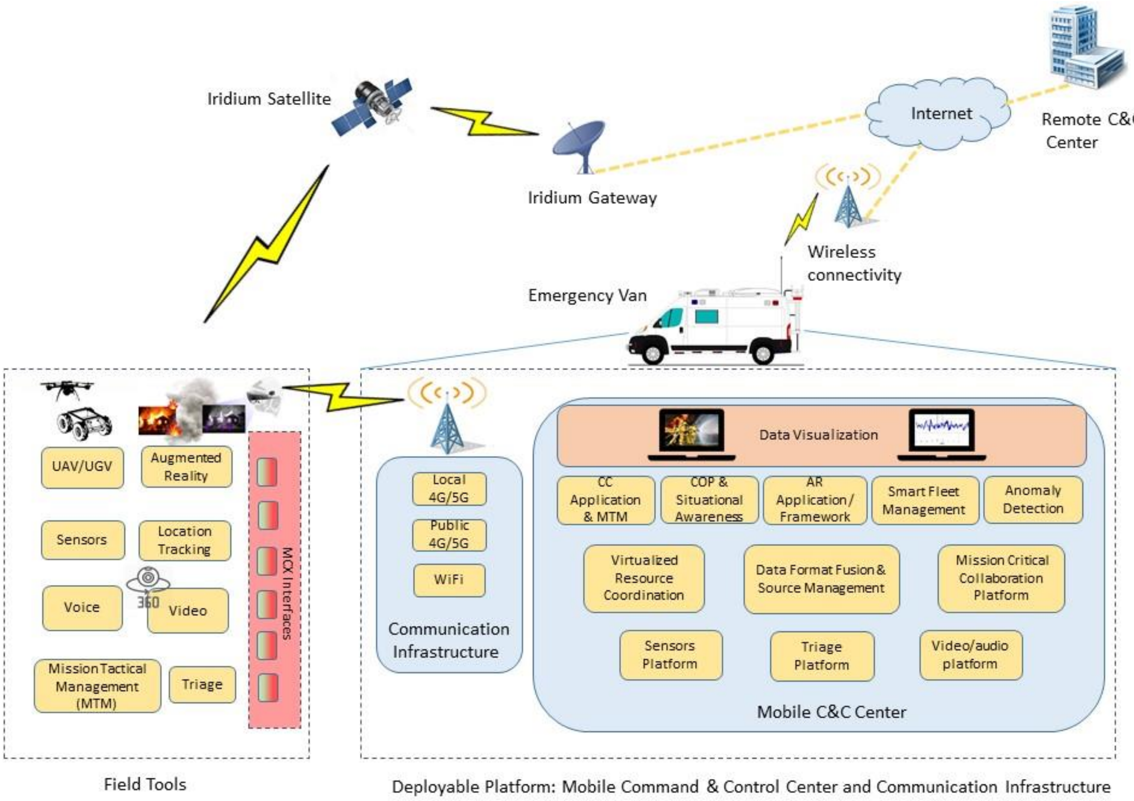

Figure 3: RESPOND-A System Architecture

The Deployable Platform is the RESPOND-A component that offers communications and C&C services to the operating FRs. The dashed box underneath the Emergency Van includes all the architecture elements of this platform, which is further distinguished into two main functions: A) Communications Infrastructure; and B) Mobile Command & Control center. The first one offers local connectivity to the wider incident area, so for the different FRs units to be able to communicate not only between them, but with the C&C center as well. Furthermore, it achieves connectivity to the remote FRs headquarters and the internet. The second one processes all the incoming data and support, coordinates and organizes the operations of all the different FRs units.

The left dashed box includes all the field technologies that support the FRs during their operations. It includes technologies that are embedded on FRs equipment (e.g. jackets, helmets, smartphones, etc.), as well as technologies that are onboard of the Autonomous Unmanned Vehicles (i.e UAVs, UGVs). The FRs will be able to communicate and send/receive data through terrestrial communications, the local network created by the van or the public network if it exists, while the autonomous vehicles will also have the option of satellite communications (Iridium), reaching the internet and the remote headquarters.

The data produced by the applied technologies in the incident area, where the FRs operate, are transmitted to the mobile C&C center, where are stored, analyzed, processed and are made available to the appropriate applications, either further in the van or back to the FRs, for extracting Situational Awareness, enhancing the effectiveness of FRs and managing the overall rescue mission. Fusion, source management as well as resource coordination are required for effectively managing and processing all the available data. All the above functions are realized on the edge of the network (in the mobile van), meaning as close to the FRs as possible rather than on distant C&C centers, offering flexibility, robustness and efficiency. The architecture components are further analyzed in the following chapters.

3.3 RESPOND-A Deployable Platform

The core of RESPOND-A ecosystem is the Deployable Platform, a light-weight physical platform built on a ruggedized field-proven transportable rack to be vigorously shipped to the disaster area for deploying the necessary infrastructure for organizing and enhancing the FRs mission and establishing broadband and reliable telecommunication ecosystem between UAVs, robots and FRs. The Mobile Control and Command Centre and the Communication Infrastructure realizes the aforementioned functions respectively.

3.3.1 Mobile Control and Command Centre

The Mobile Control and Command Centre processes, analyzes and stores all the received mission data towards Situational Awareness and FRs safety and mission enhancement. The necessary components of its architecture are:

Control and Command Application and Mission Tactical Management (MTM): This is the architecture component that provides the mechanisms for the FRs missions coordination and management. It includes all required applications for the officers to communicate with the different emergency units in the field, and send the appropriate commands and feedback to the FRs, either to individual units/rescuers or to groups of them (e.g. firefighters only, paramedics only etc.). It consists of tools like ***FlexControl*** and ***GeoVislayer*** from VICOM, ***Maestro*** from IANUS, ***Xbello*** from 8BELLS, ***MMM*** from ADS, and ***MCC*** from PROBO *(all tools are further presented and analyzed in Chapter 4 of this document)*. The input of this element is the data produced by the corresponding clients of these tools, running on FRs smartphones/tablets in the field, after being processed by the Data Format Fusion (DFF), for achieving data homogenization. The data are then analyzed/evaluated and information is sent back to the FRs for helping and managing their operations.

COP & Situational Awareness: COP and Situational Awareness are two of the most important and critical aspects of RESPOND-A project. When different emergency units operate simultaneously in the field, while life-threatening phenomena and incidents are in progress, the personnel management and situation assessment gets incredibly challenging. The officers require perception of the elements in the greater incident environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future after some variable has changed. While a lot of the technologies (e.g. AR devices, wearable sensors, infrared cameras etc.) implemented in the project are towards direction of providing situational awareness, this element of architecture includes all the functions that will optimize the provision of situational awareness, bringing enhanced intelligence to the extraction procedure. False alerts and misuse of resources must be minimized. Tools like ***Maestro*** from IANUS, ***FlexControl*** and ***GeoVislayer*** from VICOM and ***MMM*** from ADS will provide the officers with all the centralized necessary information for the mission, properly retrieved and layered in order to facilitate its efficient presentation, while ***Cyclops*** from PROBO will use Artificial Intelligence (AI) technology to effectively off-load the officers from multi-data processing, offering them the optimized COP fast and thoroughly. This element gets its input from the DFF, collecting data from the field, and the outcome is either visualized on screens or is used as an input to the C&C center system element.

AR Application/Framework: Another core objective of RESPOND-A is to leverage cutting-edge technologies in order to provide human augmentation by enhancing experiences of real-world situations and offering advanced Situational Awareness and Early Warnings to FRs and officers. This architecture element includes all the mechanisms to ensure modularity, interoperability and seamless integration of different AR related modules towards a unified AR experience. The officers will obtain access and interact with an augmented world in real time and manipulate and interact multi-modally with sensors and First Responders. AR application framework includes tools like ***LBRS Server*** from VICOM and ***MCX Augmented Expert*** from ADS. It receives data from the corresponding clients software that run on FRs smartphones/tablets, through the DFF (for data homogenization) and sends output the C&C application, COP and Situational Awareness architecture elements, offering mission enhancement to both the officers and FRs.

Smart Fleet Management: Unmanned autonomous aircrafts or ground robots (mostly known as drones) is a rapid developing technology with tremendous potentials. RESPOND-A utilizes not only individual drones but a fleet of them to maximize the efficiency and flexibility of their missions. Controlling and managing a fleet of drones is a quite challenging task. This architecture element applies the required mechanisms to successfully fulfill autonomous drone fleet operations, either in Visual-Line-of-Sight (VLoS) or Beyond-Visual-Line-of-Sight (BVLoS). ***AiRFLOW Platform*** & ***MCC*** from PROBO, ***HMI*** from ROB and ***applied algorithms*** from SPI will offer vehicles authentication, control and communication protocols, implementing Machine learning/AI-based techniques for semi-autonomous UAV/UGV missions, including path planning, fleet navigation coordination, fleet crash avoidance, obstacle mapping and avoidance. ***Nightwatch*** from CLS will offer an extra level of mission security, detecting any mission deviation and producing alerts for the ground users. This architecture element takes input directly from the unmanned vehicles in the field, without any data processing in the DFF, in order to keep the latency and the error probability as low as possible. The output is the autopilot of the unmanned vehicles for direct and real time navigation, while the telemetry data (e.g. drones position, altitude, speed etc.) are also sent to the DFF in order to be available to other elements of the system, like the COP, the C&C center or the AR platform.

Visualization: Not only COP, but other functions require data visualization, like smart fleet management, AR technologies or the video platform. This architecture component includes all the screens for either combined and generic or specified visualization of the received information from the field and the output of the mobile C&C center tools functions. The visualization element takes input from C&C applications, COP and situational awareness mechanisms, AR application framework, Smart fleet management and the video platform.

Anomaly Detection: Detection of security attacks is critical in a complex and multi-level system like RESPOND-A. This architecture entity implements the mechanisms for security monitoring and analysis of the network coming in form of security events and visualization widgets. It includes the ***SiVi*** tool from SID, a human-interactive visual-based anomaly detection system that is capable of monitoring and promptly detecting several devastating forms of security attacks. The tool's novelty lies on the development of intuitive visualization graphs capable to offer a quick and reliable overview on the network. SiVi also implements a range of data visualization techniques aimed at providing the administrator with a full anomaly detection ecosystem, including both traditional visualization techniques (graph lines, tables, etc.) and advanced visualization graphs (activity gauge, dependency wheels, heatmaps etc.).

Virtualized Resource Coordination: RESPOND-A ecosystem utilizes a variety of applications and functions, either locally in the portable computers or in the cloud, running on individual servers or in virtual machines (VMs). Management and orchestration (MANO) is a key element for cloud based resource coordination and virtual network functions (VNFs) deployment. This system element will apply the appropriate mechanisms for rapid and reliable NFV based resource coordination and service deployment. It includes the ***Talent*** tool from I2CAT. It receives input from Mission Control Collaboration Platform and sends output to Cloud/Edge (virtualized) infrastructure.

Mission Critical Collaboration Platform: Communication capabilities are the cornerstone of Public Protection and Disaster Relief (PPDR) organizations procedures for FRs coordination in the field. Different operation units need different commands and information, with optimized data prioritization and information sharing and guaranteed Quality of Service (QoS). This architecture element applies the mechanisms for creating groups of users, ensuring the flexible and efficient communication between not only the FRs and the officers, but between FRs themselves. It includes ***MCX*** and ***Maestro*** tools from ADS and IANUS respectively, implementing MCX services (MCPTT, MCData, MCVideo) and group communications management, like sharing real-time video flows within a group of users or with the Command Centre, and location-based Situational Awareness services, but also enabling a wide range of capabilities leveraging rich multimedia content and smart devices of all kinds through open APIs. The Critical Collaboration Platform offers communication capabilities between client applications available on FRs' devices on the field and with the application in the Mobile C&C Center: the right data are immediately available and shared to the right FRs at the right time. The platform may be interfaced with DFF or other servers in order to allow the exchange of data with other systems. The outputs of the platform are video, text or picture as a data for analysis and the inputs of the platform are the result of those analysis to be sent to the group of users.
The Mission Critical Collaboration Platform is running on top of 5G Network infrastructure and offers full 3GPP MCS compliant Multimedia communications.

Data Format Fusion (DFF) & Source Management: RESPOND-A ecosystem integrates a variety of sensors and devices that produce a great amount of data, continuously and in different format and structure. Multiple system elements use this data for analysis and creation of the final information required for the officers and the operating FRs. This system entity applies the necessary mechanisms for handling all the data coming from the field devices or the platforms of the mobile C&C center and effectively fusing them to the required system elements. Techniques like data homogenization, redundancy removal and source management will enable effective, real time and two-way data communication between users and devices. This system element includes ***DFF*** tool from 8BELLS. It receives inputs from the FRs Sensors Platform, the triage platform, the anomaly detection platform and the smart fleet management (telemetry data only) and makes them available to the C&C application element, the COP & situational awareness element and the AR framework. The COP & situational awareness modules could also provide their input acting as a data producer. The video, the voice and the unmanned vehicles control data don't use the DFF platform.

<u>Sensors Platform:</u> RESPOND-A ecosystem embeds a variety of sensors for monitoring the environment and the human state and health. FRs will utilize wearable sensors for continuously collecting data and sending them in real time to the mobile C&C center for further processing and evaluation. The sensors platform is the architecture element where these data from the field will end up, stored and further sent to the required system applications. This platform is also responsible for receiving the ***Forensics*** and ***Health records*** data coming from the operational area, including the corresponding tools from PRO. It gets inputs from the ***Data Logger*** (by HI) which is embedded on the FRs suit, transmitting sensors and tracking data and from triage and forensics devices (by PRO) which both operate in the field. It outputs the sensors and forensics data to the DFF platform for making them available to other system elements, while it propagates the triage data to the corresponding platform.

<u>Triage Platform:</u> Emergencies, especially when multiple casualties are involved, are chaotic. It is usually difficult to determine how many people have exactly been affected, where they are and what their last-known condition is. RESPOND-A system enables tracking technology helping FRs to track and monitor people and objects with whom they interact during operations, such as casualties involved in an incident. ***Triage platform***, implemented by PRO, receives and processes all the triage data from the field corresponding devices using ***Tag & Trace*** (by PRO) and forwards them to the DFF in order to be available to other system elements of the mobile C&C center (e.g. COP and CC application) or to remote headquarters and other entities (e.g. hospitals, ambulances etc.). The inputs of this architecture element are the triage field equipment and the FRs Sensors Platform, while the output is the DFF.

<u>Video platform:</u> In emergency and mission critical scenarios, the video stream from the field is one of the most important assets for early warning and situational awareness. RESPOND-A utilizes specified equipment for capturing the image from the field and offering incident visualization to the officers and FRs. The video devices, like ***360 view cameras*** *or* ***thermal***, are located on unmanned vehicles (UAVs/UGVs) or are carried by the FRs (e.g. on their helmets), respectively. Video platform is the architecture element that receives the video streams from the cameras in the field, processes and stores them. The video streams, either raw or processed, are then fed to the appropriate architecture elements for exploitation. More specifically, the AR framework uses this video for enhancing the FRs visibility (e.g. see through smoke using the thermal image) or sharing visual information to specified FRs groups and COP & situational awareness tools enable global view of the incident and estimate the emergency magnitude.

Figure 4 provides an overview of the aforementioned implemented system tools in relation to the RESPOND-A architecture:

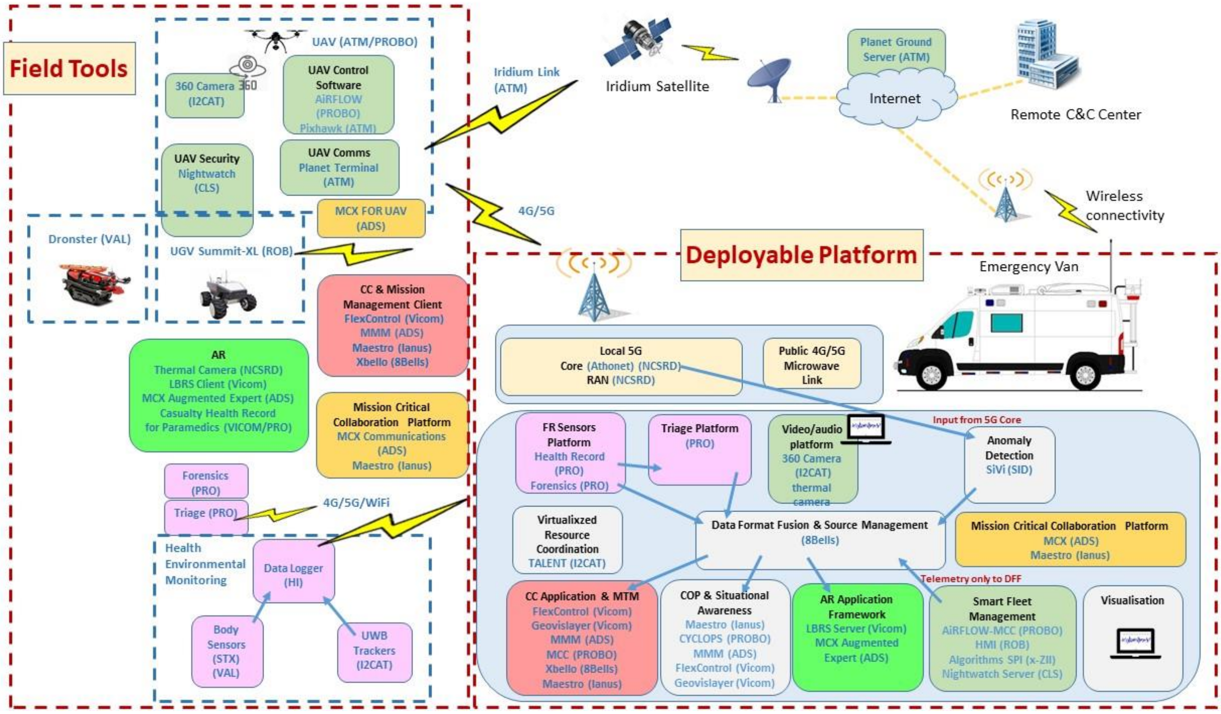

Figure 4: RESPOND-A tools in relation to the system architecture

3.3.2 Communication Infrastructure

Fast and reliable communications are essential requirements for the RESPOND-A ecosystem, not only as a mean of emergency personnel communications, but also for devices interconnection and data exchange. The RESPOND-A deployable platform utilizes such an infrastructure for establishing communication links between the field and the officers. The mobile van uses cellular technology (4G/5G) for creating a connectivity "bubble" in the wider incident area, offering local broadband network coverage. While alternative connectivity solutions are also offered (e.g. WiFi, dedicated microwave links etc.), the main implemented technology is the 5G network, for enabling all the complex and demanding, in terms of bandwidth, reliability and latency, operations of the RESPOND-A ecosystem. The communication infrastructure of the mobile C&C center consists of a complete autonomous ***5G system***, ***core*** (provided by ATH) and ***RAN***, along with supplementary equipment like ***RF amplifiers*** and ***panel antennas***, provided by NCSRD. Besides establishing a local 5G network, this architecture element offers connectivity to the public network, acting as a gateway to the internet and the FRs remote headquarters, when it is possible.

3.4 Field Technologies

While the core of the RESPOND-A system is the deployable platform, which offers the connectivity and the mechanisms for effective mission enhancement, management and unit coordination, the technologies that are implemented in the field are responsible for the generation of the data which would enable the safety and situational awareness of the operating FRs. The technologies deployed in the field are:

Wearable Sensors: A variety of ***sensors*** (e.g. health, environmental, etc.) will be embedded on FRs normal equipment, like jackets and helmets, collecting data and sending them to the mobile C&C center through the ***Data Logger*** (by HI), a device that manages and transmits data from the field to the van.

Tracking system: FRs and victims location will be tracked using ***GPS*** and ***Ultra WideBand (UWB)*** devices. The latter, utilizing UAVs as anchors (or fixed points when UAV flight is not feasible), will be able to extract the human position even indoors, where the GPS signal is not available. The localization data will be transmitted to the mobile C&C center through the Data Logger.

Triage field system: Collects victim's ***health data*** from the field and sends them wirelessly (utilizing cellular or LAN connectivity) further to the RESPOND-A ecosystem.

Forensics: Forensic evidence gathered in the field will be tracked using the forensics platform. The forensics platform uses its Tag & Trace mobile application and tamper proof NFC tags to maintain secure chain-of-custody of the forensic samples.

Augmented Reality (AR): FRs will use the AR application for enhancing their capabilities in the field, during operations. ***AR goggles, thermal cameras*** and smartphones/tablets running the AR client applications of ***LBRS*** (VICOM), ***MCX Augmented Expert*** (ADS) and ***Casualty Health Record for Paramedics*** (VICOM/PRO) will be utilized, communicating with the mobile C&C center platform in the van.

Mission Critical Collaboration platform: This is the client platform of ***MCX*** (ADS) and ***Maestro*** (IANUS), running on the FRs smartphones/tablets. It exchanges data with the corresponding mobile C&C center platform using the available wireless network.

CC and Mission Management Applications: This is the client platform of ***Maestro*** (IANUS), ***Xbello*** (8Bells), ***FlexControl*** and ***MMM*** (ADS) running on the FRs smartphones/tablets. It exchanges data with the corresponding mobile C&C center platform using the available wireless network.

Autonomous Unmanned Vehicles: ***UAVs*** and ***UGVs*** will operate in the field, embedding specialized equipment and software for being integrated into RESPOND-A ecosystem. Unmanned Vehicles will carry the ***thermal camera*** (NCSRD) for offering enhanced visualization to the officers and FRs, as well as ***Nightwatch*** tool (CLS) for ensuring mission security. The ***Pixhawk autopilot*** will run ***AiRFLOW*** (PROBO) control software, while all the data communications (Control and Telemetry) will be realized through the 4G/5G cellular network (local or commercial), or Iridium satellite if the cellular coverage does not exist. The onboard ***Planet modem*** (ATM) will offer the connectivity for the vehicles and their equipment, while ***MCX for Unmanned Vehicles*** will ensure the communications QoS and prioritization.

3.5 Respond-A Components and Multiple FRs Teams Integration

3.5.1 Architecture Components and Operational Requirements Mapping

Respond-A architecture components realize the mechanisms for ensuring smooth and ubiquitous coordination of different groups of FRs in the field and effective support of their mission. Table 2 summarizes the scope of each system component and the accommodated FRs operational requirements.

Deployable Platform			
#	**Architecture Component**	**Scope**	**Operational Requirements**
1	Control and Command Application and Mission Tactical Management (MTM)	To provide the mechanisms for the FRs missions coordination and management	OR1, OR3.1, OR3.3, OR3.5, OR3.6, OR3.7, OR4.2, OR4.3, OR4.4, OR8.1, OR8.2
2	COP & Situational Awareness	To optimize the provision of situational awareness and bring enhanced intelligence to the data extraction procedure	OR3.1, OR3.2, OR3.3, OR3.5, OR3.6, OR3.11, OR4.1, OR4.4, OR6.1, OR6.2, OR6.3, OR6.4
3	AR Application/Framework	To provide human augmentation by enhancing experiences of real-world situations and offering advanced Situational Awareness and Early Warnings to FRs and officers	OR3.5, OR3.6, OR3.7, OR9.7
4	Smart Fleet Management	To provide the mechanisms for managing the autonomous drones fleet	OR17.1, OR18.4, OR19.1, OR19.2, OR19.3, OR19.4
5	Visualization	Screens for combined/generic/specified visualization of the received information from the field and the output of the mobile C&C center tools functions	OR3.1, OR3.2
6	Anomaly Detection	To monitor and promptly detect devastating forms of network security attacks	OR3.3, OR4.2, OR4.3, OR5.3, OR8.1, OR8.2, OR8.3, OR8.4, OR8.5, OR8.6
7	Virtualized Resource Coordination	To apply the mechanisms for rapid and reliable NFV based resource coordination and service deployment	OR08.1, OR09, OR11, OR37.4
8	Mission Critical Collaboration Platform	To provide the mechanisms for creating groups of users, ensuring the flexible and efficient communication during the mission	OR4.3, OR7.2, OR7.3, OR8.1, OR8.2, OR9.1, OR9.2, OR9.3, OR9.4, OR12.1
9	Data Format Fusion (DFF) & Source Management	To provide the mechanisms for handling all the data coming from the field devices or the platforms of the mobile C&C center and effectively fusing them to the required system elements	OR3.4, OR5.1, OR5.2, OR5.3, OR5.4, OR5.5

10	Sensors Platform	To receive/store the sensors data and further sent it to the required system applications. Also to receive the Forensics and Health records data coming from the operational area	OR8.5
11	Triage Platform	To receive/processes/forward all the triage data of the mission	OR03.5, OR03.7, OR04.4, OR07.1, OR07.2, OR07.3, OR27.1, OR27.2, OR27.3, OR27.4, OR27.5, OR27.6, OR27.7, OR27.8, OR27.9, OR27.10, OR27.11, OR27.12, OR27.13, OR27.14, OR29.1, OR29.2, OR29.3
12	Video platform	To receive/store/process the video streams from the cameras in the field	OR18.2, OR24, OR32, OR34, OR35.1, OR35.2, OR35.3, OR35.4, OR35.5, OR35.6, OR35.7, OR35.8
13	Communication Infrastructure	To establish a 4G/5G connectivity "bubble" in the wider incident area, offering local broadband network coverage to the FRs and the officers	OR10, OR11, OR12.2, OR12.3, OR14.1, OR14.2, OR17.2, OR17.3,
Field Technologies			
#	**Architecture Component**	**Scope**	**Operational Requirements**
1	Wearable Sensors	To collect environmental and health data and send them to the mobile C&C center	OR26.1, OR26.2, OR26.3, OR26.4, OR26.5, OR26.6, OR26.7, OR26.8, OR26.9, OR26.10
2	Tracking system	To locate and track the FRs and victims in the field	OR3.5, OR3.6, OR7.2, OR20
3	Triage field system	To collect victim's health data from the field and send them wirelessly (utilizing cellular or LAN connectivity) further to the RESPOND-A ecosystem	OR7.1, OR7.2, OR7.3, OR29.1, OR29.2, OR29.3
4	Forensics	To track the collected forensic evidence/samples from the field	OR4.4
5	Augmented Reality (AR)	To enhance the FRs capabilities in the field	OR9.7, OR22, OR30, OR31, OR33

6	Mission Critical Collaboration platform	To exchange data with the corresponding module at mobile C&C center. (Client platform of Mission Critical Collaboration Platform)	OR8.1, OR8.2, OR9.1, OR9.2, OR9.3, OR9.4, OR12.1
7	CC and Mission Management Applications	To exchange data with the corresponding module at mobile C&C center. (Client platform of Control and Command Application and Mission Tactical Management Platform)	OR1, OR3.1, OR3.3, OR3.5, OR3.6, OR3.7, OR4.2, OR4.3, OR4.4, OR8.1, OR8.2
8	Autonomous Unmanned Vehicles	UxVs systems and payload in the field	OR8.3, OR8.4, OR15, OR16, OR17.2, OR17.3, OR18.1, OR18.2, OR18.3, OR18.4, OR18.5

Table 2: Architecture components to operational requirements mapping

3.5.2 Integration of Multiple Teams of First Responders

In real life operations different FR entities are detached in the Incident Area under Operational Control (OPCON) under the Scene Commander. Every FR entity retains the internal Command and Control structure and SOPs. Communication is set up between the Scene Commander and the Heads of other FR entities that in many cases have different communication infrastructure and devices. This situation is even more difficult when it involves FRs from foreign countries operating as reinforcements in another country. To this end, RESPOND-A has the tools and the ability to set up communications between the various commanders and staff officers as soon as they are assigned to RESPOND-A platform as users by simply using mobile applications and getting access to RESPOND-A platform. The core technologies supporting the aforementioned function are MCX, XBELLO and MAESTRO, which can organize and handle different groups of users.

Specifically, the MCX allows the creation of 'groups of groups' through an administration tool or through a provisioning API with an administrator account or a field commander account. When creating a group of groups, the administrator / field commander can add single users and one or more existing groups into this group. The MCX solution will be provisioned with pre-configured groups for the FRs organizations. Groups of groups (also called super groups) will be also pre-configured or created on-demand in order to merge the groups from different organizations together and enable MCPTT (voice), MCVideo (video) and MCData (messaging and location) group communications between all the users in the different FRs organizations. This is done without any need for field user interaction and the users will automatically see the centrally configured groups of groups becoming available on their devices.
XBELLO offers two modules to FRs, the web application (Desktop) and mobile application (smart phone). Both applications are connected to the core of XBELLO (Server) from which can be retrieved all the information according to individual credentials. The communication channels can be any mobile network or Wifi.
MAESTRO platform is an integrated Information Management System (IMS) that allows FR from different entities (Law Enforcement, Fire Service, Emergency Medical Service and other) to communicate and exchange information from the field (area of operations) to Command-and-Control Center. MAESTRO provides a complete Common Operational Picture (COP) to all FRs in the field provided they are assigned as users to the platform and use the MAESTRO mobile App.

Details on the specific tools can be found in the next chapters, while the final integration procedure will be further investigated and developed in the next project technical deliverables and throughout the implementation phase of the project.

4. System Tools Description and Specifications

This chapter presents the tools of the RESPOND-A system, their specifications and requirements in the context of RESPOND-A architecture and the FRs operational requirements (OR) that these tools answer. While some of the tools will be developed for the project needs from the scratch, some others are already commercial products that will be further developed/modified in order to be integrated in the Respond-A platform. Table 3 shows the initial status and the readiness level of the system tools. The tools are further presented in the chapters that follow and are described in more detail in the technical deliverables of the project.

#	Tools	Technology Development (Off the Shelf/Developed for the project)	Technology Readiness Level (TRL)
1	GeoVislayer	Developed for the project	Starting TRL Level: 3 Target TRL Level: 5-6
2	Data Logger	Developed for the project	Starting TRL Level:1 Target TRL Level (by the end of the project): 7
3	Sensors: Toxic gases detection	Off the Shelf	Product acquired at TRL Level 9 and integrated with the RESPOND-A project (Data Logger)
4	Sensors: Radiation detection	Off the Shelf	Product acquired at TRL Level 9 and integrated with the RESPOND-A project (Data Logger)
5	T&T Ruggedized tagger	Developed in previous project	TRL Level: 6
6	Tag & Trace application	Developed for this project	Starting TRL Level:5 Target TRL Level (by the end of the project): 7
7	Vest for physiological signal monitoring	Customised for the project	Starting TRL Level:6 Target TRL Level (by the end of the project): 7
8	Data Format Fusion	Developed for this project	Starting TRL Level:3 Target TRL Level (by the end of the project): 7
9	XBELLO	Developed for this project	Starting TRL Level:3 Target TRL Level (by the end of the project): 7
10	PLANET	Customised for the project	Starting TRL Level: 3 Target TRL Level (by the end of the project): 5

11	UAVs (provided by ATM)	Developed for this project	Target TRL Level: 6-7
12	XR2T (Mixed Reality Training Tool)	Developed for the project	Starting TRL Level: 3 Target TRL Level: 4
13	NightWatch	Developed for the project	Starting TRL Level: 3 Target TRL Level: 6
14	5G Communication Infrastructure (Core and RAN ALL in One)	Off the Shelf	TRL Level: 8
15	5G Mobile Core	Off the Shelf	TRL Level:7-8
16	MAESTRO	Developed for this project	Starting TRL Level:4 Target TRL Level (by the end of the project): 7-8
17	Edge Computing and Communications Platform	Developed for the project based on off-the-shelf cloud technology: kubernetes	Starting TRL: 3 Target TRL: 5-6
18	Offline/Online Mission Planning Tools	Developed for the project	Starting TRL: 2 Target TRL: 3-4
19	Tracking system (indoors)	Developed for the project	Starting TRL Level:2 Target TRL Level (by the end of the project): 6-7
20	SiVi Tool	Customised for the project	Starting TRL Level:4 Target TRL Level (by the end of the project): 6
21	FlexControl	Customised for the project	Starting TRL Level:6 Target TRL Level (by the end of the project): 7
22	Thermal Camera	Off the Shelf	TRL Level:8
23	LBRS	Developed for the project	Starting TRL Level: 2 Target TRL Level: 4-5
24	Mission Control Center (MCC)	Customised for the project	Starting TRL Level: 6 Target TRL Level: 8
25	Cyclops (Integrated AI)	Customised for the project	Starting TRL Level: 6 Target TRL Level: 8
26	AiRFLOW (Drone Operations Platform / Cloud & Offline Systems)	Customised & extended for the project	Starting TRL Level: 7 Target TRL Level: 9
27	Summit-XL HL	Customised & extended for the project	Starting TRL Level: 7 Target TRL Level: 9
28	Heat stroke sensor	Developed for the project	Starting TRL Level:1 Target TRL Level (by the end of the project): 7
29	Co blood poisoning + Alarm mechanism	Developed for the project	Starting TRL Level:2 Target TRL Level (by the end of the project): 8

Table 3: System tools initial status and readiness level (TRL)

4.1 Wearable Sensors and Equipment

FRs will be equipped with several types of sensors embedded on their bodies and suits. These sensors will monitor the FRs' vital signs (e.g. Heart Rate, Breath Rate, SpO2, etc.), their environment status (level of toxic gases and radiation) and their location. The wearable sensors are designed to be small sized and light-weighted, in order not to diminish the dexterity of their users. The generated data from these sensors are received locally by a Data Logger, which transmits them via 4G/5G or Wi-Fi networks to the Sensors Platform, for further use by the Triage Platform and the C&C Centre.

4.1.1 Body Health Sensors

The wearable body health sensors constitute a platform for measurement of physiological signals (Figure 5).

Sensorized Vest

Rusa device

Figure 5: Sensorised Vest and Rusa Device

The vest made by STX (Figure 5) is textile sensors based and is used to monitor the vital signs of the FRs directly from their body, in the most comfortable way. The main specifications/requirements of the developed sensorized Vest are the following:

#	Specifications/Requirements	Description / Values
1	Electrodes	Textile stainless steel
2	Breath sensor	Textile piezoresistive
3	Cabling	Textile stainless steel cables
4	Connector	Jack (4 pins)
5	Fabric of the vest	Oeko-Tex certified
6	Washable	50 cycles at 30°C

Table 4: Specifications/Requirements of the Sensorized Vest

The system is equipped by an electronic device to elaborate the acquired signals (RUSA, Figure 5). The RUSA is able to acquire and record, into the internal memory, the following signals: ECG, Gyro (X,Y,Z), Acc (X,Y,Z), Mag (X,Y,Z), Breath Piezo, Breathing rate, ECG HR, ECGRR, and Activity Classification (the device is able to process the signals and provide a classification of the type of movement that the subject performs in real time. E.g., standing still, walking, running). The device is connected to the Data Logger by a wired UART communication port.
The main specifications/requirements of the developed RUSA electronic device are the following:

#	Specifications/Requirements	Description / Values
1	Battery	Lithium-polymer 660mAh
2	Battery charging	Through USB
3	Memory	Internal (micro-SD 16GB)
4	Autonomy in recording and streaming (BT)	Up to 8 hours
5	Autonomy in streaming	More than 12 hours
6	Stand-by time	More than 30 days
7	Memory capacity	More than 400 hours
8	File format	.wwsx (proprietary format)
9	Communication protocol	Bluetooth or UART (wired)
10	Communication with Data Logger	UART (wired communication)
11	Operating temperature	0°C – 50°C
12	Dimensions and weight	58x52x15 mm, 50gr

Table 5: Specifications/Requirements of the RUSA Device

The wearable system is developed in the Task 3.1 "Wearable sensors and gear for First Responders" of WP3, and it addresses the following RESPOND-A Operational Requirements:

- OR21 "On-body sensors for tracking the vital signs of First Responders shall be available and functional during operations"
- OR26.1 "Electrocardiography (ECG)"
- OR26.2 "Heart rate (HR)"
- OR26.3 "Breathing"
- OR26.4 "Breath rate"
- OR26.5 "Body posture (e.g., laying, standing)"
- OR26.6 "Activity classification (e.g., standing still, walking, running)"

The system inputs to RUSA electronic device are:

- Two analog inputs: one for ECG signal and one for Breath signal.
- 9 DoF IMU (Inertial Measurement Unit) sensors.

The device elaborates the input signals and send, via UART (wired) streaming to the Data Logger, the following outputs: ECG Hear Rate (HR), Breathing rate, Activity Classification.

Heatstroke sensor

The Heatstroke Sensor measures the heart rate, and the body temperature and the skin humidity, the sweat, to establish an indicator of the risk of suffering a heat stroke.
VAL uses a plethysmography sensor and a temperature and humidity sensor integrated into a smart watch (Figure 6) to perform such measurements. The smartwatch will be worn on the wrist of the FR and will send the data via wireless Bluetooth communication to the Data Concentrator. The Concentrator will analyse the

sensor's data and calculate the risk of heat stroke, and will also send the risk index to the Data Logger via wired communication and under request (polling system).

Figure 6: Smartwatch device (not the final product)

Specifications:

#	Specifications	Values
1	Dimensions (H x W x D)	~100x90x50 mm
2	Weight	~50gr
3	Emissivity Settings	Coloured LED display, Green LED-based plethysmographic sensor, Bluetooth communications
4	Accuracy	3-level risk index : low, medium and high
5	Battery Life	Approximately 48 hours
6	File Formats	N/A

Table 6: Heat stroke sensor device

The Heat Stroke Risk Index will be used by FRs to advise them in case they are having the symptoms of a potential heat stroke: the body temperature increasing, for example when the FR is exposed to a fire situation, heart rate accelerates and sweet increases to try to reduce the skin temperature, but skin temperature reduction does not succeed, the sweat disappears, the heart rate continues increasing till the stroke come in.

The Data Concentrator will include an alert mechanism to advise the FR via a buzzer, a vibrator and an LED colour code related to the level of risk of heat stroke:

- Green = Safe
- Orange/yellow = Risk
- Red= Danger

The level of risk information shown to the FR through the alert mechanism will also be sent to the Data-Logger and shared with other parties of the RESPOND-A consortium for their interest.

This tool is involved in serving the OR26 "Smart Equipment, Wearables, Sensors, AR/VR".

As VAL perform different body measurements to calculate the index of risk of heat stroke, this information can be additionally provided to the RESPOND-A system if other mechanisms wish to make use of it.

In RESPOND-A architecture, the inputs of the Heatstroke Sensor are the body temperature, heart rate, and sweat measurements. The output is an Alert Mechanism showing a 3-colour code LED, namely Green-Orange/Yellow-Red, representing the FRs' risk exposure as well as a buzzer and a vibrator to alert the FR of a change in the risk level; this alert mechanism is shared with VAL's CO Poisoning Sensor system. At the same time, the risk data goes to the Data Logger to be managed from the C&C Centre.

CO poisoning sensor

The CO Poisoning Sensor (Figure 7) measures the CO concentration (in parts per million, ppm) and the time the FR is exposed to it, in order to estimate the Carboxyhaemoglobin (COHb), i.e. the amount of CO absorbed by the blood cells, resulting into the disease known as CO poisoning or carboxyhemoglobinemia.
The carbon monoxide (CO) poisoning is a quite invisible disease, as it affects a FR without showing any symptoms and the consequences of the poisoning can arise some hours, or maybe days later. For this reason, measuring it while at scene is crucial, even if the reading is just an estimation.
VAL brings the CO Poisoning Sensor integrated into the VAL box, together with the Alert Mechanism (used to provide alerts on both the Heatstroke and the CO Poisoning sensors) and the Data Concentrator, which connects via wire communication with the Data Logger.
The CO Poisoning is calculated from the CO concentration using an electro-chemical CO sensor that will be located near the mouth, in the neck area of the jacket of the FR. Therefore, the whole pack containing the Alert Mechanism, the CO Poisoning Sensor and the Data Concentrator will be located in the same zone.

Figure 7: CO Poisoning Sensor

Specifications:

#	Specifications	Values
1	Dimensions (H x W x D)	35x45x70 mm
2	Weight	~100 gr
3	Emissivity Settings	Red/Yellow/Green LEDs, buzzer, vibration and Bluetooth communications

4	Granularity of indicators	3-level risk index: low, medium and high
5	Battery Life	Mín. 48 hours
6	File Formats	N/A

Table 7: CO sensor device specifications

The CO Poisoning Index will be used by FRs to advise them in case their exposure to the CO has been during a prolonged period and/or the concentration of CO in the environment has been very high.

CO Poisoning Sensor embeds an Alert Mechanism that will advise the FR via a buzzer, a vibrator and a LED colour code related to the level of risk of poisoning, in the same way it will indicate for the Heatstroke sensor:

- Green = Safe
- Orange/yellow = Risk
- Red= Danger

Apart from the Alert Mechanism, the Poisoning Risk Index will be sent to the Data Logger through a wire connection and will be shared with other parties for their interest.

This tool is involved in serving the OR26 Smart Equipment, Wearables, Sensors, AR/VR.

The measurements involved in this tool, namely the concentration of CO in the air of the surroundings of the FR, can be provided in raw to the Respond A system for others partners to use it.

In the RESPOND-A architecture, the CO Poisoning Index is calculated measuring the CO concentration on the air around the FR mouth and the time of exposition. The output index is connected to the Alert Mechanism and indicate to the FR the current risk of poisoning and the changes on the risk level. At the same time, the risk data is sent to the Data-Logger to be managed from the C&C Centre.

Alert Mechanism

At the same VAL box where is located the device of the CO poisoning sensor it will be embedded the Alert Mechanism. This mechanism will work as an output device. Once the data of the Heatstroke device and CO poisoning is analysed in the Concentrator (located in the same VAL box), the Alert Mechanism will transform the risk data in one of three colour LED to advice the risk level of the FR.

- Green = Safe
- Orange/yellow = Risk
- Red= Danger

Figure 8: LED alert system

Also, this mechanism will integrate a buzzer which will vibrate to advice the FR, with physical inputs.

Figure 9: Buzzer alert device

Specifications:

#	Specifications	Values
1	Dimensions (H x W x D)	35x45x70 mm
2	Weight	~100 gr
3	Emissivity Settings	Red/Yellow/Green LEDs, buzzer, vibration and Bluetooth communications
4	Accuracy	3-level risk index : low, medium and high
5	Battery Life	Min. 48 hours
6	File Formats	N/A

Table 8: Alert Mechanism specifications

The Alert mechanism will be used by FRs to advise them in case they are having the symptoms of a potential Heatstroke and CO poisoning, as previously explained for HeartStroke and CO poisoning sensors.

This tool is involved in serving the OR26 Smart Equipment, Wearables, Sensors, AR/VR.
As VAL perform different body measurements to calculate the index of risk of heat stroke, we can additionally provide this information to the RESPOND-A system if others mechanisms want to use it.

In RESPOND-A architecture, the input of the Alert Mechanism is the data of the Heartstroke sensor and the CO poisoning data provided by Concentrator. The output is a 3-colour led and a buzzer advice. This alert mechanism is shared with VAL's CO Poisoning Sensor system. At the same time, the risk data goes to the Data Logger to be managed from the C&C centre.

4.1.2 Triage Equipment and Platform

The Triage equipment uses NFC technology to easily store and communicate health data of the subject. This system uses a mobile device connected to a network (4G/5G or Wi-Fi) or a ruggedized arm tagger with radio connectivity and its mobile base station that converts the radio data to be transported via WLAN or LAN. Both the mobile device and the ruggedized arm band interact (Figure 10) with the NFC tags using RFID technology.

The Triage Platform is hosted on a server and takes the input from the two types of sources and processes and stores the data. This data is able to be shared to the mobile devices connected with the system and to the DFF to be used in the C&C system.

Figure 10: Triage Platform field devices (app, ruggedised tagger and base station)

The main specifications/requirements of the developed Triage Platform base station are the following:

#	Specifications/Requirements	Description / Values
1	Size	Medium size container 35 X 25 X 15 (cm) Antenna 100 X 1 X 1 (cm)
2	Weight	10 kg
3	Power supply	Rechargeable battery (Power autonomy for at least 6 hours in operation mode) Direct connection to a 220v power source
4	Operating temperature	−20 °C to +50 °C
6	Water resistant	Comply to IP65
7	Data model compatibility	OGC SensorThings API
8	Communication module	LAN, WLAN

Table 9: Specifications/Requirements of the developed Base Station

The main specifications/requirements of the developed Triage Platform ruggedized tagger are the following:

#	Specifications/Requirements	Description / Values
1	Size	25 X 15 X 5 (cm)
2	Weight	300 grams
3	Power supply	Rechargeable battery (Power autonomy for at least 24 hours in operation mode)
4	Operating temperature	−20 °C to +50 °C
6	Water resistant	Comply to IP65
7	Data model compatibility	Proprietary
8	Communication module	Radio frequency

Table 10: Specifications/Requirements of the developed Ruggedized Tagger

Besides the ruggedized tagger, used by firefighters at the incident scene, paramedics will be equipped with a smartphone running the Tag & Trace triage app developed by PRO. This app allows paramedics to scan and read the triage wristband worn by a casualty and do data entry when needed.

The Triage Platform is addressing the following RESPOND-A Operational Requirements:

- OR03.5: Victim localization and tracking
- OR03.7: First Responder health status (including biometrics)
- OR04.4: Tracking of victims
- OR07.1: Collection of victim profile (e.g., age, sex, status, medical history)
- OR07.2: Location of victim (e.g., GPS coordinates, street address, distance to nearest hospital)
- OR07.3: Data exchanges with relevant agencies (e.g., hospitals, civil protection agencies, law enforcement, firefighters)
- OR27.1: Timestamp of first contact with the victim
- OR27.2: Location of the victim
- OR27.3: Triage classification of the victim (code or colour)
- OR27.4: Vital signs of the victim
- OR27.5: Treatment(s), medication(s) administered
- OR27.6: Injuries sustained
- OR27.7: Name, age, gender of the victim
- OR27.8: Medical history of the victim
- OR27.9: Known allergies of the victim
- OR27.10: Contamination (chemical or otherwise)
- OR27.11: Aggregate numbers, statistics about the number of victims on the scene
- OR27.12: Breakdown of victim numbers per triage classification
- OR27.13: Breakdown of victim numbers per age group
- OR27.14: Breakdown of victim numbers per gender
- OR29.1: Medical personnel
- OR29.2: Fire fighters

- OR29.3: Other search and rescue personnel (e.g., SAR, MRCC)

The inputs to the Triage Platform are data from field equipment (mobile device and ruggedized arm tagger) and the Sensors Platform. The outputs of the Triage Platform are these data, sent to the DFF and used by the C&C Centre. In addition the C&C Centre outputs these data to the AR casualty health records for paramedics.

4.1.3 Data Logger and Sensors Platforms

Data Logger is an electronic device that receives and records data from different type of sources, like sensors or any instrument measuring values (e.g. meteorological data). Data Loggers are generally small, battery powered, portable, and equipped with microprocessors, internal memory for data storage, and sensors. HI is developing a small sized, wearable Data Logger, which receives data from all sensors embedded to the FR's suit and transmit it to the Sensors Platform via 4G/5G or Wi-Fi. Also, the Data Logger will be processing the received data from the wearable sensors and generate 'alarm' command to the 'Alert Mechanism', if any certain data exceeds the set critical threshold, informing immediately the FR.

Data from the Data Logger developed by HI will be shared with the Sensors Platform created and hosted by PRO. Its primary responsibility is to process sensor data and merge it into a distinct electronic health record for each first responder. Secondly, the Sensors Platform will also track the gathering of physical forensic samples by first responders. Using a mobile device, a user can collect the location and other such metadata of a physical sample and apply it to a tamper proof NFC sticker. This sticker will ensure the chain of custody of the evidence as it moves from one first responder to another is recorded. Lastly, the Sensors Platform will be responsible for sharing sensor data with the DFF.

The main specifications/requirements of the developed Data Logger are the following:

#	Specifications/Requirements	Description/Values
1	Size	Small-sized wearable device >20 X 15 X 6 (cm)
2	Weight	Lightweight >500 gm
3	Power supply	Rechargeable battery (Power autonomy for at least 6 hours in operation mode and 12 hours in standby mode)
4	Operating temperature	−10 °C to +60 °C
5	Solid particle protection	Comply to IP5X (IEC60529)
6	Water resistant	Comply to IPX4 (IEC60529)
7	Data model compatibility	OGC Sensor Things API
8	Communication module coverage	4G / 5G / Wi-Fi
9	Communication with wearable sensors	UART (wired communication)

Table 11: Data Logger specifications/requirements

The Data Logger is addressing the following RESPOND-A Operational Requirements:

- OR08.5: Secure and reliable communication between Command-and-control centre(s) and wearable sensors
- OR08.6: Secure and reliable communication between First Responders on the scene and wearable sensors
- OR09.8: Communication infrastructure able to support the exchange of the data relating to Alert signals
- OR09.9: Communication infrastructure able to support the exchange of the data relating to Device metadata (e.g., metadata from sensors)

Each FR will be equipped by a Data Logger that receives data from all wearable sensors attached to the FR's suit and transmit it to the C&C Centre. The data Logger will be connected using UART with the wearable sensors, including the 'Alert Mechanism' and its communication module will support 4G/5G and Wi-Fi networks for the transmission of the sensors data to the Command & Control Centre.

The inputs to the Data Logger are data from wearable sensors (sensors measuring vital signs, environmental factors and localization). The outputs of the Data Logger are these data, sent to the Sensors Platform for further analysis by the C&C Centre. Also, other outputs are the generated 'alarm' commands to the 'Alert Mechanism'.

4.1.4 Tracking System

The i2CAT tracking system is a solution for providing indoor real-time positioning for the FR. This system is made of two components; the UWB units (worn by the FR) and the UWB anchors, which will be installed outside the building. The position of the FRs will be computed based on the communication between the UWB devices. Moreover, this tracking system will be connected with the Data Logger to send all the positioning data to the Sensors Platform.

The operational requirements covered by the tracking system are: OR03.6 "First Responder localization and tracking" and OR20 "On-body sensors for tracking the position of First Responders shall be available and functional during operation"

As for the inputs and outputs of our system, these are divided in the two components described above; the UWB units and the UWB anchors.

UWB anchors

Inputs:

- Information about the exact position of other anchors in the field. This information is necessary for the positioning solution in order to synchronize the system. This information could be known/configured in advance (before the fire-fighters enter the field). In order to make the system more flexible, we will consider improvements to transmit this information through a wireless interface in a dynamic manner (provided that the location information of the drones could be retrieved through an API).

Outputs:

- At the moment the UWB anchors are used for localization purposes; but the information is provided by the localization units. Thus, no data information is transmitted from the UWB anchors to the architecture.

UWB units

Inputs:

- Information about the exact position of other anchors in the field. This information is necessary for the positioning solution in order to synchronize the system. This information could be known/configured in advance (before the fire-fighters enter the field). In order to make the system more flexible, we will consider improvements to transmit this information through a wireless interface in a dynamic manner (provided that the location information of the drones could be retrieved through an API).

Outputs:

- The UWB localization units will transmit computed data to the Data Logger. The Data Logger will poll data from us each 5 seconds, timestamp it and send it to the control center. We assume that the control center will be in charge of creating a dashboard to visualize this data and have a database to store it.

4.1.5 Radiation and Toxic gases detection Sensors

Toxic gases sensors are small sized devices, able to detect the concentration of certain toxic gases in the surrounding environment, while radiation sensors are able to detect the dose or radionuclide contamination of α, β and γ radiation within the sensor's proximity area.

HI plans to integrate Toxic gases and Radiation detection sensors with the RESPOND-A system of sensors. These sensors will be selected to match the needs of the project and will comply with certain set standards, based on FRs' requirements.

Both type of sensors (toxic gases and radiation detection) should be very small sized, light weighted, calibrated and compatible with the communication protocols of the developed sensors system.
The Sensors measurements are:

#	Sensor type	Description of measurements
1	Toxic gases detection	NO_2 (Nitric Dioxide) SO_2 (Sulphur Dioxide) H_2S (Hydrogen Sulfide) O_2 (Oxygen) CH_4 (Methane)

2	Air quality	temperature, humidity and pressure
3	Radiation detection	β and γ

Table 12: Sensors Measurements

The toxic gases and radiation sensors are addressing the following FRS' Operational Requirements:

- OR26.9: During First Responder operations, on-body sensors shall be able to track parameters related to Chemical contamination of the environment.
- OR26.10: During First Responder operations, on-body sensors shall be able to track parameters related to Radiological dose of the environment.

The inputs of Toxic gases and radiation sensors are the relevant measurements received from the surrounding environment of the FR. The outputs of these sensors are data of these measurements, sent to the Data Logger.

4.2 Unmanned Vehicles Systems and Onboard Equipment

Unmanned Vehicles (UxVs) offer low-cost and sophisticated remote sensing and communications solutions in search-and-rescue missions, while being easy to deploy and operate. Various studies have been carried out in the last years, demonstrating that, when a team equipped with a drone finds the victim, they need on average 3.18 minutes less than the no-drone team [4], [5].

The goal of RESPOND-A unmanned vehicles is to align and, ideally, improve these experimental results by making the fleet more autonomous and providing more stable communications. Unamanned vehicles will be part of a heterogeneous communication systems relying on 4G/5G technology and complemented with Iridium satellite backhaul whenever the cellular coverage is insufficient. Via these links, UAVs will be connected to the command-and-control center and the portable 5G communication system, which trigger an information sharing based decision-making process. Moreover, UAVs will support this process by tracking the First Responder teams and sending critical data from the 360°camera and sensors on-board.

Additionally, UAVs will be infused with AI capabilities offering services like human tracking, recognition of blood and injuries, recognition of obstacles, recognition of damages in buildings, detection of fire and smoke and enhanced smart control for autonomous flights.

Ultimately, UAVs in RESPOND-A scenarios will be equipped with 4G/5G modems and a Wi-Fi Access Point to deliver network coverage extension and network connectivity to the FRs. In particular, the provision of Iridium link will be key. Specially in the use case of Cyprus, where the availability of either commercial 4G/5G network cannot be granted; or of Spain, where one of the scenarios takes place in the sea, having the possibility to communicate with the FRs, even with limited bandwidth, can impact the success of the rescue operation.

Furthermore, in places where no backhaul link is available, UAVs could still be controlled and monitored BVLOS and low-definition images from the on-board camera could be sent to the remote command-and-control center. With this information, the severity of the accident could be estimated, allowing to define a safe and optimal strategy.

4.2.1 Unmanned Aerial Vehicles

PROBOTEK AI (PROBO) will voluntarily provide one big and one small drone (personal costs/corporate ownership) to assist in the Proof of Concept (PoC) in Greece and help all partners to integrate their technologies. Meanwhile, it will proceed with the integration of MCC APIs.
The specifications for each drone are as follow:

- PHOBOS
  - Fully custom drone (Developed by our parent company PROBOTEK in Greece)
  - Details:
    - Type: Hexa-copter
    - Base: Carbon Fiber
    - Length: 1000mm
    - Diagonal: 1000mm
    - Width: 1000mm
    - Height: 600mm
    - Weight: 4kgr
    - Motors: 400KV
    - Battery: 2 x 6S LiPo 16000mAh
    - Speed: 50 to 60 Km/h (max)
    - Flight Duration: 24min to 45min (max)
    - Operating temperature: -20 to 45 °C
    - Max wind: 12 m/s
    - Water Resistant: Yes
    - Telemetry: Digital (encrypted) via 4G & 5G / RSA 4096 bit
    - Effective radio range: Unlimited
    - AI subsystem: PERCEPTRON
    - Ground control station: Portable (MCC on MCS)
    - Payload: 2 to 3 Kg
    - Sensors:
      - Accelerometer
      - Magnetometer
      - 4/6 ultra-sound sensors
      - Cameras (Ultra HD, Stereoscopic)
- Gray Mantis
  - Small Form Factor drone
  - Customized from ANAFI USA (by Parrot)
  - See all the technical details at [6]
  - The Gray Mantis comes with a proprietary mobile control system. Detailed info can be found at [7]

The RESPOND-A Description of Action (DoA) states that Atmosphere (ATM) would provide the drones to support the pilots of the RESPOND-A project. The first option was to acquire them from the German supplier Quantum Systems, as expressed in the DoA. However, the change of direction of this company towards small drones, makes them unsuitable for satellite communications and the requirements of the RESPOND-A payload systems. The final decision has been for ATM to build their own drones within the scope of the project. The design and manufacturing process will be carried out in their German office in Weßling.

There are several advantages that encourages ATM to build the drones, mainly related to the flexibility that it would imply in terms of installing the hardware and the antenna, as well as performing the tests during the first phases of the project. Owning and having the mechanical know-how also eases acting in a more reactive way in the event of modifications or repairs.

The fleet provided by ATM will comprise two octocopters. It is still under discussion whether a third octocopter or/and a fixed-wing drone would potentially be available for the Spanish and Cypriot pilots. More detailed information and specifications of the UAVs are available for consultation in D4.1 *Design choices and initial integration activities for UAV and UGV enabled use cases*. With these drones and the provision of (at least) a licensed pilot, ATM will contribute to cover OR12.2 "Communication between First Responders during operations in areas with limited or no cellular network coverage shall be supported by aerial relays", OR15 "During operations, the deployment of unmanned aerial platforms (e.g., drones) shall be supported", OR17.1 "Dedicated personnel to handle UxV" and will support all the functionalities in OR18" UxVs deployed during First Responder operations shall be able to support the following functionalities".

4.2.2 Unmanned Ground Vehicles

SUMMIT-XL

The Summit-XL robot is a modular mobile robot that can navigate autonomously or being tele-operated through different communication protocols. Due to its versatility, the Summit-XL is used in different kind of applications such as R&D, Surveillance, Military or Inspection.

Figure 11: Summit-XL

The Summit-XL specifications are:

#	Specifications	Values
1	Dimensions (H x W x D)	720 x 614 x 416mm
2	Engine	4 x 500W servomotors
3	Payload	65kg

4	CPU	Linux PC i7
5	Slope	80%
6	Autonomy	10h
7	Connectivity	Internal: USB, RS232 y GPIO; External: USB, RJ45, 12 VDC and battery
8	Speed	3 m/s
9	Weight	65kg

Table 13: Summit-XL specifications

DRONSTER

Dronster (Figure 12) is an already developed tool that will provide support in the RESPOND-A system. It will allow other partners' tools to be incorporated in the scenario from the Dronster UGV, making the operations safer. Dronster is a high-performance professional machine designed to work in the emergency sector to enhance operational safety and efficiency when working in risk situations. A remote-control device that's capable of working steadily at a constant speed for triple the squad performance.

Figure 12: Dronster

VAL brings the VAL Dronster vehicle that can be transported to the actuation area via helicopter or loaded in a truck. Dronster Specifications are shown in Table 14 below:

#	Specifications	Values
1	Dimensions (H x W x D)	1023x887x1710mm
2	Engine	Kubota 3-cylinder 4-stroke | 32.8 HP (24.5 kW)
3	Hydraulic unit	Bosch Rexroth piston pumps
4	Diesel fuel | oil tank	18.5 L | 40 L
5	Tread	Axial piston engines | Rubber chains
6	CPU	Bodas RC Series 30 controller | 4 CAN ports
7	Protection for electronic components	IP 65 protection
8	Remote control	Rechargeable batteries
9	Control panel	Hour timer | Levels | Temperature

10	Front winch	Can drag up to 1,000 kg
11	Speed	0-5 km/h
12	Weight	Machine weight without implements 850 kg; with a forestry weeder 1050 kg

Table 14: Dronster specifications

The wide front attack angle to overcome obstacles, off-ground chassis and built-in swing in the traction system absorb irregularities in the ground like stones, trunks and small stairs without destabilizing. Flexible mobility at a speed of 5 km/ h.

Capable of working efficiently on slopes of more than 30º. The small size means it can pass through 1 m bushes. Suitable for cleaning work, fire prevention and controlled burns.

Dronster can simultaneously equip a front and rear implement as well as accessories over the top with capability that is difficult to beat.

This tool is involved in serving the OR16 Unmanned and Autonomous Vehicles.

In RESPOND-A architecture, the Dronster takes input from the Smart Fleet Management and using accessories like Wildland brush chopper, Trencher, Rear Blade, Forestry weeder, Skid unit, Monitor, Snowplough and Fan, proceeds with its mission.

4.2.3 UAV Control Systems

PROBOTEK AI (PROBO) is utilizing the proprietary Mission Control Center (MCC) to fly its drones and 3rd party integrated drones. MCC is based on a virtual or physical Mission Control Server (MCS) and has a connection with the AiRFLOW cloud of PROBOTEK (GR).
It allows virtual communication with any 3rd system via Web API (REST) / microservices of any subsystem. More details on the infrastructure can be found in the AiRFLOW Infrastructure Diagram of Figure 13.

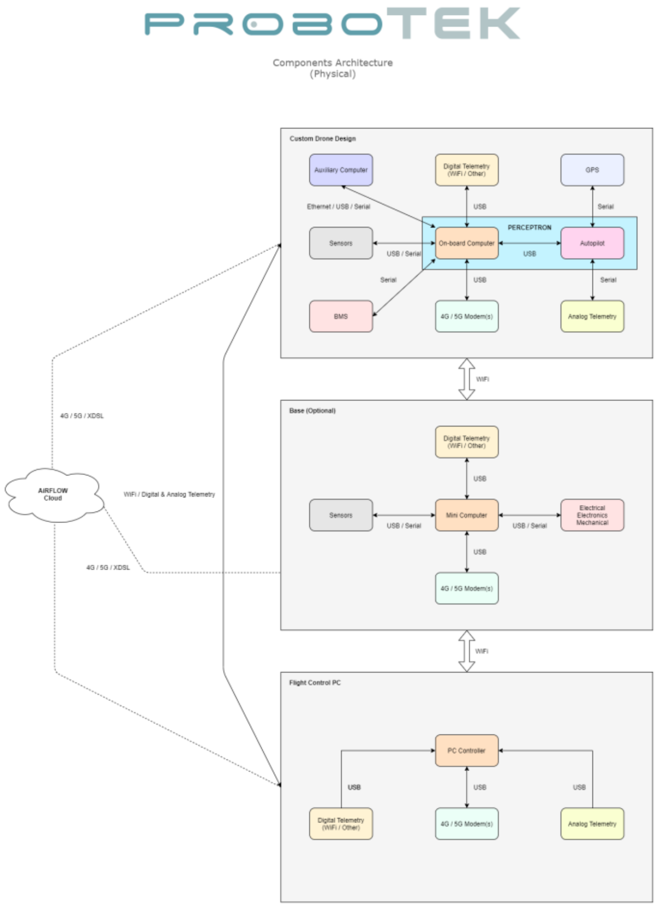

Figure 13: AiRFLOW Infrastructure Diagram

The infrastructure is provided by the parent company (PROBOTEK in Greece). PROBOTEK AI (PROBO) is only involved in the process of writing code, utilizing services and integrating components in the software domain.

In order to command and control the ATM drones, the MCC should provide messages that are compatible to the flight controllers installed on board. ATM drones rely on Pixhawk4 autopilot, compatible with the MAVLink (Micro Air Vehicle Link) communication protocol. MAVLink communication protocol [8] specifies a comprehensive set of messages exchanged between unmanned systems and ground stations. This protocol is used in major autopilot systems and provides powerful features, not only for monitoring and controlling unmanned systems missions but also for their integration into the Internet.

It is still under discussion with PROBO whether a suitable solution could be found, that would allow to control ATM drones with their MCC. In the meantime, ATM relies on the open-source mission control station QGroundControl to start performing autonomous flights tests. QGroundControl station [9] provides full flight control and vehicle setup for Pixhawk4 powered vehicles, delivering high end feature support for experienced users.

4.2.4 UAV Communication Systems

In order to support communications between the ground and the drones, ATM plans to integrate its connectivity solution, called PLANET. PLANET incorporates a network service based on Iridium satellite modems and cellular communications. The use of Iridium satellite communications network provides aerial work operators with global connectivity and low-latency data services, crucial for real-time mission information exchanges. Moreover, with the emergence of new SatCom solutions, such as Iridium Next and its range of new products, PLANET is expected to be enriched with new features that require higher bandwidth.

PLANET system encompasses both the ground and the on-board segments, as displayed in Figure 14.

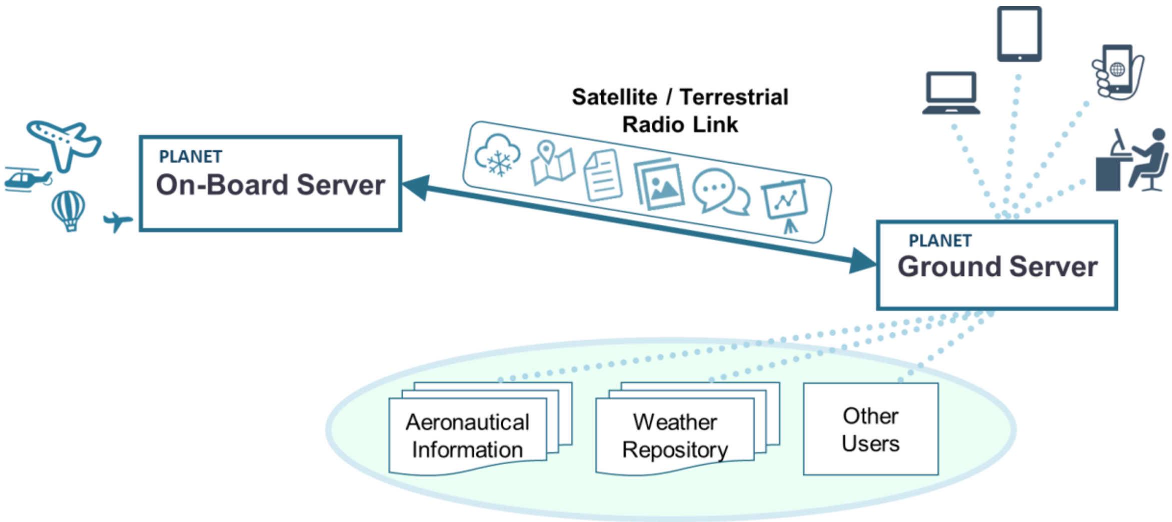

Figure 14: High-level architecture of PLANET system

The on-board segment is based on the PLANET terminal (Figure 15), which is a light equipment enabling mobile communications via satellite link (Iridium) or cellular networks (4G/5G). It will be carried on board of the drones, interacting with the different payload systems such as the VR360 camera or the sensors. Telemetry is forwarded to the ground, the choice of the communications depending on the bandwidth constraints. The terminal acts as a universal mobile router equipment for autonomous vehicles connectivity, or for real-time critical mission data exchange. Moreover, it supports remote platform control protocols over serial ports (e.g., MAVLink) and provides optimal Quality of Service (QoS) management. The specifications of the PLANET terminal are compiled in Table 15.

#	Specifications	Values
1	Weight	700g
2	Size	205.4 x 120.4 x 50 mm
3	Average consumption	700 mA@12VDC
4	Peak consumption	2A@12VDC
5	Operating temperature	-25°C to +70°C
6	Iridium modem	Legacy 9523, targeting Certus 9770 for RESPOND-A
7	Cellular 4G modem	4G LTE Telit LE910V2
8	Cellular 5G modem	To be decided
9	GPS receiver and other sensors	To be decided

#	Specifications	Values
10	Internal battery	3 x Lithium-Ion battery pack: 7.2V-2.6Ah

Table 15: Planet on-board terminal specifications

Occupying a satellite link is not for free, so a preliminary cost estimation is necessary for the realization of the mission. The use of Iridium RUDICS link is billed as 1€ per minute. Taking into consideration one of the longest use cases described in D2.3, the *User Story Scenario 4* in Cyprus (highly explosive area) of 5 hours of duration, the cost of the UAV operation under Iridium connectivity would be of 300€ (per drone). This scenario assumes that the drone would only connect via satellite. However, this will most likely not be the case, and there will be alternation with the commercial 4G or 4G/5G network provided by the local infrastructure, where the cost for the data depends on the chosen provider and the agreed data packet.

The PLANET terminal receives as inputs the command-and-control messages and other traffic sent from the ground. The terminal routes them to the autopilot or the desired equipment on-board of the drone. Regarding the air to ground direction, the terminal receives the telemetry and payload data (sensor measurements, video and images) and send them to the ground. For the payload traffic, the data could be directly sent to the user processing station without passing through the PLANET ground server, in the cases where this is required.

On the other hand, PLANET ground server is the endpoint of the communications with the terminal carried by the UAVs. It supports coordination and collaboration functionalities during complex missions with multiple users and aircraft or UAVs. Moreover, it offers the possibility to interact with weather and aeronautical information services. The server is hosted in a high reliability data center and available 24/7.

In the context of RESPOND-A system architecture, the PLANET ground server would receive the command-and-control messages from the MCC in the appropriate protocol. These messages are then forwarded to the drones either via satellite link or via 4G/5G, allowing to command the UAVs from longer distances than with traditional radio link and supporting Beyond Visual Line of Sight (BVLoS) flights. The opposite path is followed in the case of the telemetry: the PLANET ground server receives the messages from the drones and forward them to the MCC or to the i2CAT processing station, the Data Format Fusion or the Edge Computing and Communication Platform (for instance, payload data such as sensor measurements, video and images). From the local and remote scenarios, i.e., the emergency van and the remote-control center, the users can access the PLANET ground server via the website or its API (Figure 15). To this aim, guaranteeing access to the public internet is a must.

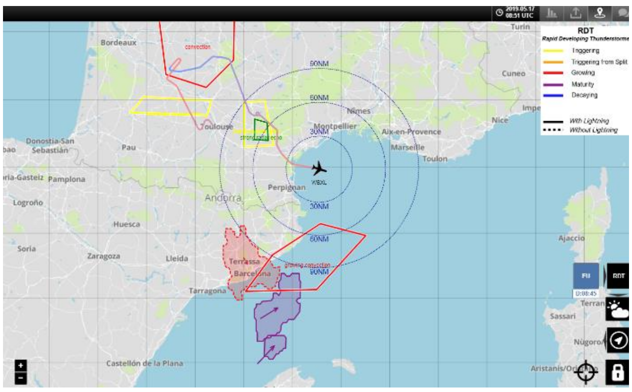

Figure 15: PLANET on-board terminal (left) and PLANET ground server, accessed via website (right)

The overall PLANET solution will give answer to all the sub-functionalities enumerated in OR18 "UxVs deployed during First Responder operations shall be able to support the following functionalities" and provide the deployment of the drones with "4G broadband cellular network coverage" (OR17.2) and "satellite links for communications" (OR17.3). Finally, PLANET will also contribute to cover OR08.3 and OR08.4 "Secure and reliable communication channels shall be established during operations between Command-and-control centers and UxVs" and "First Responders on the scene and UxVs".

4.2.5 UAV Security

CyberLens B.V. (CLS) will provide NightWatch as an integrated solution for monitoring the cyber-physical security of UxVs (drones and robots) in the context of the Smart Fleet Management module of the RESPOND-A architecture. NightWatch incorporates statistical-based intelligence and reasoning that will run on computationally constrained robotic systems and will allow for quick self-detection of cyber-physical threats, in real-time, in order to ensure their seamless operations. More specifically, in the context of the RESPOND-A project needs, NightWatch will monitor and detect sensor anomalies and mission plan deviations for UxVs and provide relevant alerts.

The deployment of the NightWatch solution can be either fully on-board a UxV or in an offloaded manner where the processing of the necessary data occurs in a dockerised application executed in a server, preferably located within the ground infrastructure provided by the MCC. In both deployment scenarios, a dedicated hardware module will be developed and integrated on board of UxVs which will include a number of sensors responsible for the collection of the necessary data for the monitoring of the functionality of the UxV. In case of the fully on-board deployment scenario, the processing unit is also integrated as part of the NightWatch hardware module so there is no need for the deployment of the dockerised application. In case of limitations to an UxV's payload capacities, the processing can take place in a ground server where the telemetry data from the NightWatch hardware module and the UxV mission plan data are communicated as input and the potential alerts are produced after the necessary processing is performed. The technical specifications of the NightWatch solution are listed in the table below.

#	Specifications	Values
Hardware Module		
1	Dimensions (L x W x H)	10 x 7 x 7 (cm)
2	Weight (approx.)	300 g
3	Sensors	Multiple IMUs with 9 DoF, barometer, thermometer

4	Processing unit	Raspberry Pi, GNSS receiver, RGB camera, 4G dongle, battery
Ground Server Application		
5	Docker image size (approx.)	2.5 GB

Table 16: NightWatch Technical Specifications

In the context of RESPOND-A, NightWatch will serve as a supplementary module to ensure the detection of cyber-physical attacks towards the UxV infrastructure. As such, it will not require direct interaction with the project's end users and is only directly associated with OR 18.4. Nonetheless, by ensuring the uninterrupted functionality of UxVs, it indirectly contributes towards the satisfaction of all other ORs related to them.

Finally, in terms of data dependencies, NightWatch requires the consumption of certain types of data which is generated either by the UxVs themselves or their supporting infrastructure (e.g., ground stations, mission planning software). More specifically, the module uses as input various telemetry data points from UxVs along with some basic descriptions of the expected UxV mission plan such as the expected waypoints of the UxV's route, its current status, etc. In terms of outputs, NightWatch produces alert messages when a cyber-physical anomaly is detected, containing relevant information addressed towards the Command-and-Control interface.

4.2.6 VR360 Camera

A VR360 camera (Figure 16), also referred in bibliography as 360º and omnidirectional camera, is an instrument composed of multiple lens or of a camera rig to simultaneously capture views in every direction of the 360º space, typically with overlapping angles to be able to stitch together all camera views into a single, high resolution and seamless panoramic video. Although providing an accurate, seamless and real-time 360º video stitching has been a relevant challenge in the last years, current off-the-shelf cameras already provide integrated and good quality stitching solutions. Likewise, current of-the-shelf cameras already provide IP-based streaming solutions, and high video resolutions, e.g. up to 12K.

Figure 16: Kandao QooCam 8K VR360 camera

I2CAT, and also ATM, will bring 2-3 Kandao QooCam 8K VR360 cameras [10] (Figure 16) in the context of VR services for FRs. Table 17 summarizes the main camera specifications:

#	Specifications	Values
1	Lens	2 x 200° FOV
2	Image sensor size	1/1.7 inch BSI-COMS 20MP
3	Video (360)	7680*3840@30fps, 8/10bit 3840*1920@120fps, 8/10bit
4	Photo (360)	7680*3840, 12bit DNG(RAW),DNG8(16bit output)
5	Video format	MP4
6	Audio format	PCM
7	Photo format	JPG、DNG
8	Video bit rate	Up to 200Mbps
9	Video codec	H.264, H.265
10	IMU	6-axis IMU
11	Screen	2.4 inch colorful touch screen
12	Photo mode	Still image, Timed photos, DNG8, Time lapse photo
13	Video mode	Video, Slow motion, Sports mode
14	Live streaming	8K/4K 360° Live, RTMP and RTSP protocols
15	EV	-2EV ~ +2EV
16	Exposure	EV (auto): -2EV ~ +2EV Manual Mode: Photo: 1/6400s-1s DNG8: 1/6400s-1s Video: 30fps:1/6400s-1/30s 120fps:1/6400s-1/120s ISO: 100-6400 Sports Mode: There are two choices to control the maximum shutter time: Mode 1, Mode 2. For 50Hz, Mode 1 is 1/50s, Mode 2 is 1/100s For 60Hz, Mode 1 is 1/60s, Mode 2 is 1/120s Sports EV: {-2.0EV to +2.0 EV}
17	White Balance	AWB, Fluorescent, Incandescent, Cloudy, Daylight
18	Weight	Approx. 275g

19	External Dimensions	179mm*57mm*33mm
20	WiFI	2.4G/5G
21	External interface	USB Type-C, LAN, HDMI
22	Storage	Internal 64GB EMMC
23	SD card	Support external TF Card (up to 256GB), U3 card is recommended
24	Mic	Build-in Mic; Line-in 3.5mm
25	Battery	Built-In Lithium-Ion Battery, 3000 mAh Approx. 90 minutes for 8K@30fps or 4K@120fps video recording. 360° Live: 90 minutes. USB-PD Fast Charge with 3A or above is commended
26	Operating Temperature	32 to 95°F / 0 to 35°C Humidity: 5 to 95%

Table 17: VR360 Camera Specifications

The VR360 cameras, in the context of RESPOND-A, will be used to capture high-quality, realistic and immersive scenes from the areas of interest regarding the emergency situation. The camera is a quite lightweight and compact device, so it can be attached to the drones, dronsters and robots (UxVs) to be able to capture the scenes of interest. It provides a live high-quality 8K VR360 stream using RTMP or RTSP protocols, which can be directly provided to VR360 players, or to an intermediate processing station to provide an optimized stream to each involved FR (see Section 4.3.7).

This tool is involved in serving the OR18 "UxVs deployed during First Responder operations shall be able to support the following functionalities: (OR18.2) Video feed from the incident area", OR34: "Real-time 360º video shall be accessible during First Responder operations" and OR35: "A real-time 360º video platform shall be able to provide: (OR35.1) "High-quality video feed"; (OR35.4) "Ability to freely explore the omnidirectional operational environment".

In the context of RESPOND-A system architecture, the input of the VR360 camera is the omnidirectional images captured from the cameras mounted on the drones, dronsters and robots (UxVs) and the output will be an optimized VR360 video stream concentrating the video resolution in the users' Field of View (FoV). The video stream can be provided to the video platform of the Mobile C&C Center, directly to the screen/goggles of the FR, and/or to remote FR.

4.2.7 Offline and Online Mission Planning Tool for Semi-Autonomous UAV Mission

UAV aided operations through UAV missions are receiving enormous attention in recent years. Typical applications include environment monitoring, goods delivery, smart maintenance, special events and many others. This market segment has also attracted attention as a new potential market to fuel over 5G mobile technology roll-out. As such, H2020 projects like 5G Drones [11] aim to provide real life demonstrations of drone mission enabled by 5G. Generally, UAV operations are subject to severe regulations depending also the specific environment in which UAV should operate. Typically, a professional pilot lays in Line Of Sight (LOS) of the drone to pilot and taking it back to the base any time. Anyway, it is nowadays paramount to enable UAV missions beyond LOS (BLOS), even when the UAV is left unattended by the pilot as the UAV flies over hard to reach areas. Moreover, mission coordination of UAV swarms in BLOS condition is also key for the development of the UAV market.

Several challenging scenarios are those tackled by FRs as in the case of RESPOND-A. FRs required to enter a dangerous and/or inaccessible area can greatly benefit from the presence of UAVs. The benefit that FRs can receive by the presence of UAVs is multi fold. For example, UAVs can be sent to perform autonomous BLOS missions collecting crucial information before sending FRs in the incident area (natural and man-made disasters, public safety, etc.). UAVs thus send video and images to the command center for planning subsequent phases of the mission involving human intervention. Similarly, UAVs can be used in the aftermath of a crisis. In another scenario, UAVs can cooperate with the FRs during a mission providing also radio communications means to coordinate teams on the field, as well as with the command center. Since the scientific literature around UAV problems is very rich, a comprehensive search would turn unmanageable. Thus, only some relevant survey papers are used for the sake of this report, emphasizing the fact that they have an extensive list of references to use.

In addition to the concepts stated above, the combination of UAV with cellular communications has also received significant attention in past years, both in terms of a new type of user equipment that can be controlled over the mobile network technology and to mount flying base stations to improve coverage, spectral efficiency and user experience’s quality. The survey available in [12] presents relatively recent advancements in this field, including standardization and regulatory aspects, technical challenges and possible solutions, the new opportunities arising from UAV combined with cellular technology and an overview of prototypes and test bed activities. It is hence key to position correctly the current surge of interest around UAV connected as client to the mobile network and/or mounting a base station.
Along the line of enabling efficient UAV missions, offline and online computation of the UAV path is a topic that has been intensively investigated since UAVs in overall are a hot topic. As such a rich research literature exists that delves around both offline and online UAV path plan computation. Different methods and algorithms were proposed as well summarized in [13]. Traditionally, the UAV path planning problem was solved by using dynamic programming or geometric algorithms like A-star search (i.e. a variant of the shortest-path algorithm). As stated in [13], throughout time several new approaches were studied by researchers based on the concept of Computational Intelligence (CI). CI has become popular to relieve limitations of the above mentioned traditional approaches, especially when solving the problem with multiple constraints. CI is a set of nature-inspired approaches to solve real-world problems on the basis of incomplete knowledge, which can result in control actions modified in adaptive way. A concise review of the most relevant CI methods that were used to solve the UAV path planning problem is shown herein below based on [13].

1 **Genetic Algorithms (GA):** in this type of approach, the optimal path is found starting with a population of candidate solutions to an optimization problem that is made evolving toward a better UAV path planning solution. The evolution begins with a set of randomly generated paths or solutions, and in each

generation of evolution the fitness of every solution is evaluated whereby an objective function. Based on the genetic model, each path solution has a set of properties (i.e. chromosomes) to be muted in each evolution phase.

2 **Particle Swarm Optimization (PSO):** in this approach a swarm of candidate solutions or particles is moved around a search space to find a satisfactory solution to the UAV path problem. Since particles are allowed to memorize information shared globally lower complexity and better feasibility than genetic algorithms can be achieved. A key challenge while solving the UAV path planning problem is to modify the basic PSO algorithm to prevent the solution to remain stuck in local optima. The PSO has also been combined with GA algorithms to relieve the problem of local optima, improve convergence time in computing the UAV path under various obstacles and threats constraints.

3 **Ant Colony Optimization (ACO):** it stands for a set bio-inspired algorithms to obtain the best path chosen by a colony of ants. Similarly, for the UAV path plan all possible paths of the ants constitute the whole solution space. With iterations some paths increase in probability to be selected until converging on one optimal path. Although the original ACO suffers from local optima limitations and convergence speed shows to be slow, several improvements were introduced. The way of practically modelling the ACO is to create a grid model of a flying scenario and compute the path between a grid point and the destination.

4 **Artificial Neural Network (ANN):** this set of methods is based on constructing a neural network and use parallel computing, which enables fast convergence to obtain an optimal path. The UAV path computation is solved through non-linear programming, whose complexity can be reduced approximating the system dynamics and objective function. An example of ANN used to solve the UAV online path planning problem can be found in [14].

5 **Fuzzy Logic (FL):** while in general Fuzzy logic is a form of multi-valued logic with incomplete knowledge of the problem in which true values of variables range between zero and one, this approach has been used in the UAV path planning problem that deals with ambiguous optimization objectives. Often FL is used in combination with other CI methods like genetic algorithms to generate inputs for other methods based on the fuzzy logic. FL has found also application in methods to compute on-line UAV path with real-time constraint.

6 **Learning-based Methods:** it comprises different learning techniques, including Q-Learning, cooperative and geometric learning, that were proposed for UAV path planning computation. Generally, learning methods are divided between supervised like imitation learning and unsupervised like machine learning with the latter one registering higher popularity to tackle UAV problems.

UAV planning tool description

The UAV path planning tool stands as a research tool that targets to solve both offline and online UAV path planning problems taking into account the due differentiations. The overall goal of the mission planning tool is to output a set of waypoints expressed in terms of GPS coordinates (i.e. the mission plan) that allow the UAV(s) to carry out the mission even in BLOS loading the mission plan in the UAV(s) autopilot. A more formal definition of offline and online path computation that is relevant in this context is provided below.

Definition 1: offline mission plan is defined as the ensemble of GPS coordinates that are computed before a mission begins, both in case of defining start and points of the mission and in case of a full area search.

Definition 2: online mission plan is defined as the GPS coordinates that are computed on-board the UAV for obstacle detection or mission target detection.

At the beginning of a mission, a trained pilot can start the UAVs and enable the autonomous flying mode loading the mission plan obtained from the offline planning tool. Specifically, the offline path planning can take place in the Edge Computing and Communications Platform explained in Section 4.5.2, and it can tolerate an execution time in the order of several minutes. It is worth recalling that the edge computing platform shall be located in correspondence of the local mission control center (MCC), either in the van or in a suitable IT room in proximity. The mission goals can be different, for example reach a destination point or explore a search area. The offline tool should take into account also the presence of obstacles, different area size and number of UAVs participating the mission. The tool should also account for constraints such as energy increase of a battery operated drone or residual fuel. The basic assumption should be that when a user defined level of residual battery is reached, the drone should return to the starting point. In the same way, after accomplishing the mission a UAV should return to the base. A possible example calculation of the output returned by the offline path planning tool for a 2-dimensional grid map is shown in Figure 17, whereas logical illustration of the path planning building blocks is presented in Figure 18. It is worth emphasizing that a pilot should be anyway present to reclaim control of the UAVs in case of detected malfunctions, damages and other dangerous situations. On the other hand, Figure 19 shows the UML sequence diagram of the offline mission planning.

On the other hand, the online mission planning tool is meant to be executed on-board the drone and thus to re-plan autonomously the mission by adding new waypoints in case for example an unknown obstacle is detected. In case of a sudden obstacle indeed the detection and reaction should occur in the least feasible amount of time. Therefore, such online path plan is imperative to take place on-board the UAV and add a minimal number of waypoints so that to enable fast convergence. At the same time the algorithm should require minimal number of iterations to converge. Indeed, if a candidate algorithm for offline path plan can be based on PSO, the online could be based on A-star search or fuzzy logic. A different situation is anyway provided by the case in which the camera installed on-board the UAV (e.g. high-resolution 360º camera) provide a video feed that is processed by the video processing tool. Such video processing could take place on-board or just run as a service on a platform made available in the local MCC. In case a target of interest is detected (e.g. a victim), this can be the trigger to compute new waypoints to modify the original mission plan. The most suitable choice can be to run through an online path computation on-board the UAV to produce a minimum number of waypoints in order to survey more thoroughly a specific spot area of interest. Generally, a new full path computation may take place also in the edge computing platform in the form of an offline path computation. Anyway, such an approach has the drawback to possibly introduce a considerable amount of time to create a new complete mission plan that has to be loaded in the UAV(s) autopilot.

To summarize, the following high-level objectives were devised for the tool as shown below.

1. Support the UAV pilot to deliver BLOS mission of multiple UAVs.
2. Compute offline a set of waypoints (i.e., GPS coordinates) to be loaded in a UAV autopilot to define the mission plan taking into consideration known obstacles.
3. Modify the mission plan by online re-computation of waypoints anytime an obstacle is detected, or a target of interest is detected (e.g., victim).
4. Enable running the offline mission planning tool in the Edge Computing and Communications Platform (Section 4.5.2).
5. Run the online mission planning tool on-board the UAV.

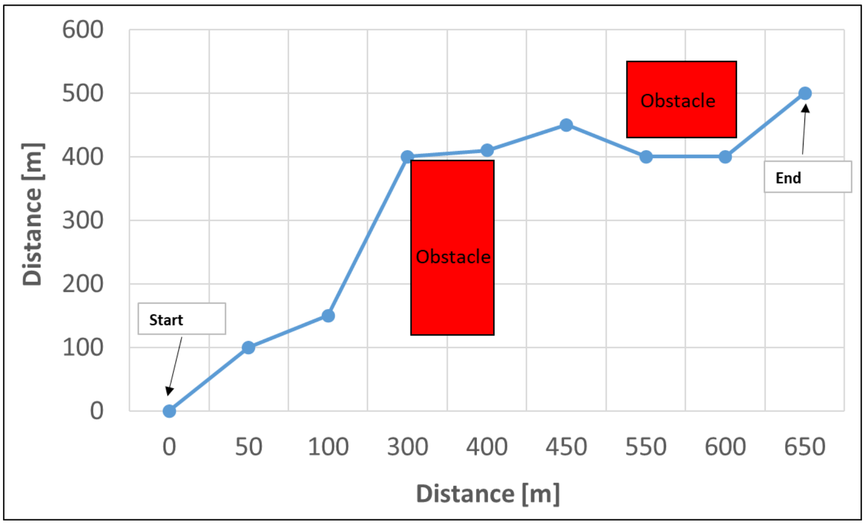

Figure 17: Offline path computation example on a 2-D grid map with one UAV

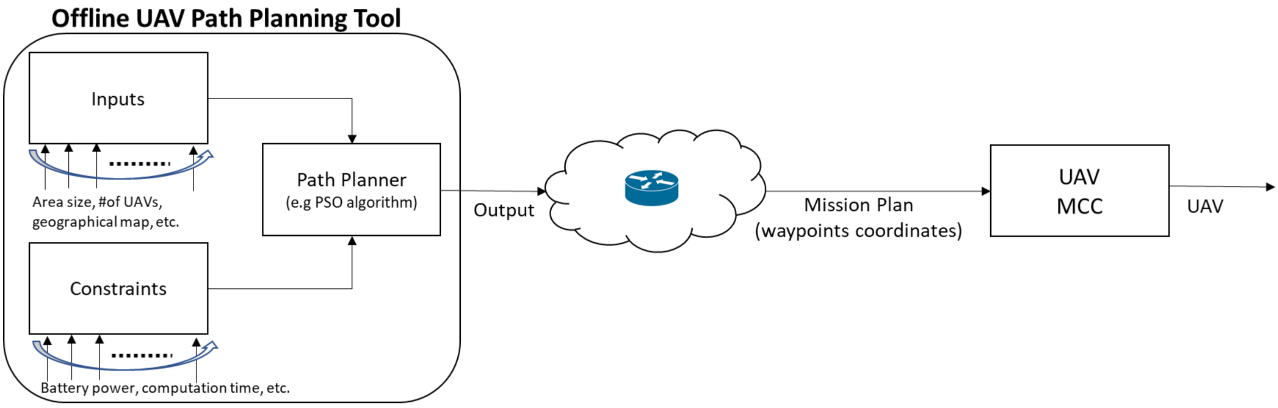

Figure 18: Logical system architecture of the mission planning tool

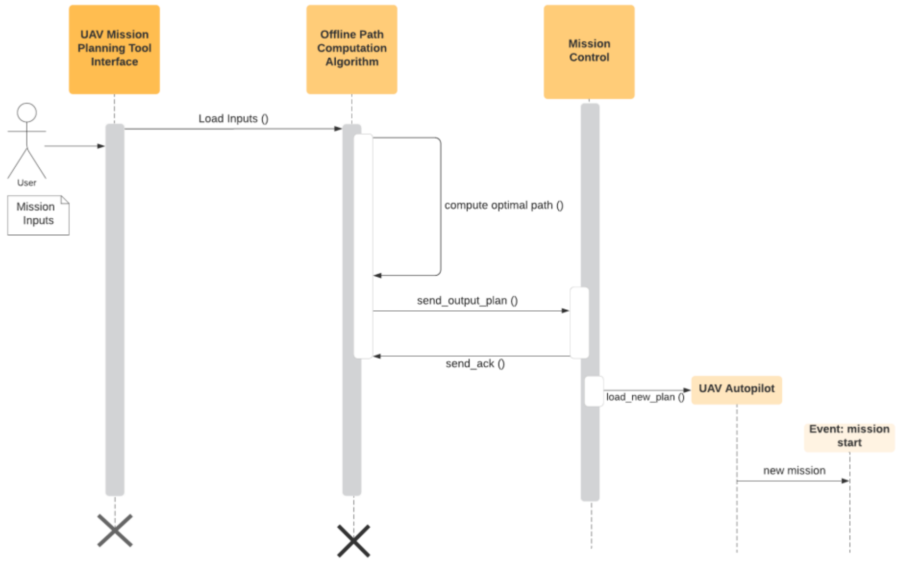

Figure 19: UML sequence diagram of the offline mission planning tool

The operational requirements that the tool answers are the following:

- OR15 "Suitable software and hardware artefacts shall be made available to an advanced communication infrastructure for unmanned vehicle operations" - The offline and online mission planning tool is meant deliver a path planning for UAV prior to and during the mission, though targeting a technology readiness level not higher than TRL 5
- OR19.2 "A UAV mission planning tool shall take into account the flight time" - The offline and online planning for UAV shall automatically take into account the battery lifetime leaving a safety margin to reach the base
- OR19.4 "A UAV mission planning tool shall into account the environment flight conditions" - The offline and online mission planning tool for UAV shall take into account, to the extent possible, the external conditions of a mission by leaving an extra safety margin to avoid the risk of depleting the battery; for example wind speed can be considered as an extra payload that may contribute to drain the battery

4.3 Augmented Reality (AR) and Virtual Reality (VR) Systems

The following tools are envisioned to be provided by the RESPOND-A Consortium under the category of Augmented and Virtual Reality (AR / VR) Systems.

For each tool, a short description and a list of specifications and requirements is given. In addition, the FR requirements identified regarding AR and VR are associated to each tool. Finally, the main input, output and interactions with other tools are given.

4.3.1 Augmented Reality (AR) Goggles

Augmented Reality (AR) Goggles are specific hardware devices that offer capabilities to augment information over the surrounding scene visualization through a set of see-through glasses. This section does not describe a specific RESPOND-A solution, but commercial devices that during the first stage of the project have been identified as interesting for deploying the AR solutions that the consortium is currently developing.

AR solutions can be deployed in a wide range of hardware devices, such as smartphones, tablets, and head up displays or this type of goggles. Different hardware is linked to a different set of development frameworks and APIs, as well as different ways of physically using them. AR goggles, specifically, are wearable and offer hands-free visualization of the augmented information. However, their use in some real-world emergency operations may be limited, due to environmental (extreme temperatures, humidity...) and FR (e.g. if they are already wearing a helmet) constraints.

In WP5, a deeper analysis of existing hardware devices has been done, which is described more in detail in D5.1 [15]. As a summary, the AR goggles selected are the following, which will be used to deploy different types of functionalities:

- Microsoft Hololens 2 [16]
- Vuzix M4000 [17]

4.3.2 Localization Services

The main function of this tool is providing and displaying geolocation-based information around each FR using it (heading and distance to other nearest FRs, location of risks...). This tool will include a **server-side** and a **client-side** solution. The server-side solution is expected to be used by other client applications tools if needed, if they require any type of location-based data.

At the moment, the first version of AR client the consortium is working on, is an ARCore-based Android application. This application is oriented to FRs working in the field, instead of the Command and Control Centre. Throughout the project, some developments over Vuzix AR goggles will also be tested. The AR server will provide secured REST-API/asynchronous messaging functionalities.

#	Specifications	Values
1	Smartphone OS	Android 9.0
2	Smartphone connectivity to CC center backend	WiFi / 4G / 5G (optional)
3	HeadUp display hardware	Vuzix M4000 (optional)
4	Server-side Data storage	PostgreSQL 12
5	Server-side OS required	Windows / Linux / Docker
6	Security	HTTPS
7	Server-side Web framework	Java Spring, React
8	Server-side Web services	REST (OpenAPI 3) + Swagger

Table 18: Localization Services' main specifications

The operational requirements met by this tool are the following ones:

- OR03.5: "A command-and-control center shall provide functionalities relating to: Victim localization and tracking". If the Triage platform provides this information to the DFF, it will be displayed.
- OR03.4: "A command-and-control center shall provide functionalities relating to: First Responder localization and tracking". Information about First Responders localization will be displayed.
- OR03.7: "First Responder health status (including biometrics)". The health status provided by the Sensors' Platform, if sent to DFF, it will be displayed in this solution (both Smartphone and AR glasses version).
- OR30: "Relevant smartphone applications shall be able to be used by First Responders during operations, without impeding their activities". The main solution is based on an Android Smartphone application. It will provide different ways to interact with the application.

This tool receives inputs from the Data Format Fusion & Source Management. In addition, it will also send information to the Data Format Fusion & Source Management.

4.3.3 Thermal Camera

Thermal camera (Figure 20), also referred in bibliography as infrared camera, thermal imager or thermal imaging camera, is an instrument that captures the black body radiation of the objects (i.e the radiation that every object emits as a function of its temperature). The higher the temperature of the object, the more the radiation that emits. Although the radiation is emitted in a continue spectrum (included the visible one), most of it is radiated in the infrared section (700nm to 1mm - not visible), for not extreme high temperatures. Thermal cameras detect these invisible waves and convert them to visible images for the human.

Figure 20: FLIR One thermal camera

NCSRD brings FLIR One Gen2 [18] thermal camera (Fig. 20) in the context of AR services for FRs. It is a lightweight (34.5gr) and compact (34 x 67 x 14mm) camera that it is designed to be attached on a mobile phone, compatible with Android operating system. Its dynamic range is –20 °C to 120 °C, making it suitable for most of the FRs activities, while it is quite durable, as it has an approval of mechanical shock from 1.5m height drop. Table 19 summarizes the main camera specifications:

#	Specifications	Values
1	Dimensions (H x W x D)	34 x 67 x 14mm
2	Weight	34.5g
3	Non-Operating Temperature	-20 °C – 60 °C
4	Scene Dynamic Range	-20 °C – 120 °C
5	Emissivity Settings	Matte: 95%, Semi-Matte: 80%, Semi-Glossy: 60%, Glossy: 30% Reflected background temperature is 22°C
6	Operating Temperature	0 °C – 35 °C
7	Mechanical shock	Drop from 1.5m
8	Focus	Fixed 15cm – Infinity
9	Palette	Gray (white hot), Hottest, Coldest, Iron, Rainbow, Contrast, Arctic, Lava and Wheel.
10	Visual Resolution	1440 x 1080
11	Accuracy	±3°C or ±5%, typical Percent of the difference between ambient and scene temperature. Applicable 60s after start-up when the unit is within 15 °C – 35 °C and the scene is within 5 °C – 120 °C
12	Spot Meter	Off / °C / °F. Resolution 0.1°C / 0.1°F
13	Thermal Sensitivity [MRDT]	150mK
14	Battery Life	Approximately 1h
15	File Formats	Still images – radiometric jpeg Video – MP4

Table 19: Thermal Camera main Specifications

The thermal camera, in the context of RESPOND-A, could be used either by a FR or an Unmanned Vehicle in order to detect and sense objects or victims when the visibility is limited (e.g. smoke, low light etc.). In the first case (FR carries the camera), the camera is attached on FR's mobile phone or anywhere else on his body equipment (e.g. helmet). The image of the thermal camera will be visible to the FR (e.g. on his mobile screen) and it can also be transmitted to the required system destination, according to the needs. In the second case, a UAV or a UGV will carry the camera and the video will be transmitted to Mobile C&C Centre. In both cases, an established transmission link is required (e.g. 4G/5G, WiFi etc.), capable of handling the video stream.

This tool is involved in serving the:

- OR22 "Helmets with augmented reality data (AR) displays shall be available and functional during First Responder operations"
- OR30 "Relevant smartphone applications shall be able to be used by First Responders during operations, without impeding their activities"

- OR33 "Helmets with augmented reality (AR) data displays shall be able to be used by First Responders during operations, without impeding their activities"

as the video stream from the thermal camera can be fed to the FRs AR goggles/displays, offering them enhanced vision capabilities, without requiring any complex operation from the FRs side that could impede their activities. Beyond the AR services to the FRs, the image from the thermal camera could be further used and processed by other elements or tools of RESPOND-A system, like (COP, Mission Management etc.) as a complementary source of information from the field, contributing to the success of the mission.

In the context of RESPOND-A system architecture, the input of the thermal camera is the infrared spectrum emitted by the objects of the environment and the output is a video stream that will end up to the video platform of the Mobile C&C Centre and/or directly to the screen/goggles of the FR.

4.3.4 MCX Augmented Expert

This tool allows connection between FRs on the field and remote experts. Based on the features provided by the tool, remote experts are able to share advices to FRs in order they could perform the best action on the field and support the decision making process. The tool applies on MCX Critical Collaboration platform.
The tool applies on Android devices, which are connected to the MCX Critical Collaboration platform (Figure 21) through local wireless connectivity or Internet (depending on experts' localization). FRs are able to share their local video in Real-Time or the Mobile C&C Centre which are sharing a drone video to a specific group communication in which experts are connected.
The picture below shows the architecture view from the tool perspective:

Figure 21: MCX Augmented Expert Architecture View

Based on the video shared on real-time, experts are able to point out or draw specific information which are useful for the local management for taking decision and sharing with FRs on the field.
Experts can continue to follow the Real-Time video and exchange with local management depending on the evolution of the situation. This tool shares internal data or are able to receive data from over video sources (e.g. drone).

The operational requirements this tool answers are:

- OR02 "The coordination of activities between different groups of First Responders during operations shall be supported by a C&C centre." - The tool is inserted in the coordination of activities value chain for FRs. The decision will be taken based on a common understanding picture and shared by all stakeholders

- OR04.3 "Augmented reality (AR) applications" - The tool applies Augmented Reality features in order to enhance required information overlayed on the video displayed on smart devices
- OR09 The communication infrastructure used during operations shall be able to support the exchange of the data relating to:
- OR09.7 Augmented reality (AR) applications
- OR30 Relevant smartphone applications shall be able to be used by First Responders during operations, without impeding their activities.

The MCX Augmented Expert tool runs on following devices:

- Working on MCX Connectivity on top of 4G or 5G networks;
- Devices running Android 9 operating system and above.

#	Specifications	Values
1	Smarphone hardware	RAM 2Go ROM Memory 1Go
2	Smartphone OS	Android 9.0
3	Smartphone connectivity	WiFi / 4G / 5G (optional)

Table 20: Casualty health records main specifications

4.3.5 Casualty health records for Paramedics

This service uses the Localization Services Client smartphone application to interact with the Triage Platform client app running on a smartphone carried by the FR to display the contents on the AR glasses.

This tool allows for heads up display for paramedics and medical first responders to display the medical history of the casualty they are treating. This history will be tracked within the Triage Platform (using Tag & Trace technology) and using this data the paramedic will see relevant data on the casualty, such as vital signs and provided treatments. The paramedic accesses the casualty's health record by scanning the tag the casualty is wearing. The Vuzix AR goggles will be used as an information overlay.

#	Specifications	Values
1	HeadUp display hardware	Vuzix M4000
2	Smartphone OS	Android 9.0
3	Smartphone connectivity to CC center backend	WiFi / 4G / 5G(optional)
4	Localization Services Client version running on smartphone	Required
5	Triage Client version running on smartphone	Required

Table 21: Casualty health records main specifications

The operational requirements covered by this tool are:

- OR22: “Helmets with augmented reality data (AR) displays shall be available and functional during First Responders operations". The solution provided will rely on AR glasses to display information to First Responders (in special to Paramedics and Medical First Responders)
- OR31: “Helmets shall be able to be used by First Responders during operations, without impeding their activities". The solution provided is oriented to paramedics, who usually don’t wear helmets.
- OR33: “Helmets with augmented reality (AR) data displays shall be able to be used by First Responders during operations, without impeding their activities". The glasses (not full helmets) are not expected to be disturbing for their operational use.

This tool will receive inputs from the Tag & Trace Triage Platform. It will not generate any output to be sent to other tools, the output will be the visualization overlay.

4.3.6 Mixed Reality (AR/VR) systems for training

In the scope of the RESPOND-A project, we aim to facilitate first responder’s situational awareness. Using AR solutions, first responders will be able to understand better what is currently happening in their surroundings. Scene analysis helps to improve tremendously the reaction time of first responders and allow them with the decision-making process. To perform scene analysis, we plan to implement deep learning and computer vision techniques. The deep learning models would allow to detect and recognize events or objects in a scene displaying useful information to the first responders. The aim is to first train the deep neural network on offline data and evaluate its performance. Then to export the deep learning model to the devices to provide an integrated scene understanding solution that is also portable and therefore easy to use by the first responders and paramedics.

Augmented reality is widely spread over our smartphones with social media and gaming applications. But using a mobile device on the field would not be efficient for first responders and paramedics. In fact, having to hold a phone and look at the screen can be distracting and dangerous in emergency situations [19]. Another hardware solution that allows to use augmented reality are glasses and headsets. The most well-known devices nowadays are the Magic Leap and the HoloLens. The difference between them is that HoloLens 2 offers an improved hand tracking technology and better visualization quality. In fact, Magic Leap comes with a remote when HoloLens is entirely based on hand tracking. This makes a huge difference of usability and therefore it is easier to use HoloLens for applications related to first responders and paramedics. Table 22 below shows the specs in a comparative analysis between the two AR devices.

	MAGIC LEAP ONE	HOLOLENS 2
CPU	SOC Nvidia Parker 2 64 bits cores 4 64bits ARM cortex A57	Qualcomm Snapdragon 850
GPU	Nvidia Pascal 256 cores CUDA	HPU (Holographic processing unit) from Microsoft
DISPLAY	1280X960	2048 x 1080 (per eye)
FOV	30	52

Table 22: Specifications for Magic Leap and HoloLens 2

Furthermore, the HoloLens 2 relies on Microsoft technologies supporting all the related AI services [20]. It offers a highly immersive experience thanks to the following functionalities:

- The user can see more holograms at once through the increased field of view.
- It is also a way more comfortable device than its previous version, it is possible to keep the glasses for an extended period without feeling any discomfort.
- It allows to keep personal glasses if needed.
- It allows to flip the headset over the head to proceed to real life tasks that do not require the use of HoloLens making it a highly ergonomic device.
- The interactivity of the headset relies on the user's gestures, in fact, touching, grasping, or moving holograms can be performed intuitively.
- The headset is untethered (no wires or external packs are required) which gives a lot of freedom of movement to the user.
- The HoloLens 2 headset is a self-contained computer with Wi-Fi connectivity.

In Figure 22, the two main components of the deep learning solution for scene analysis are shown. The green elements represent the training and the evaluation of the Deep Neural Network (DNN) performed offline with publicly available labelled datasets. Once the model training is completed, it is then possible to deploy the DNN model to the supported device shown in Figure 22 with blue color. After being deployed, the DNN will be able to analyze the observed scene and return useful information to the device for visualization. The input data will be the images or videos of the observed scene and the output of the scene analysis is expected to semantic information to the end users.

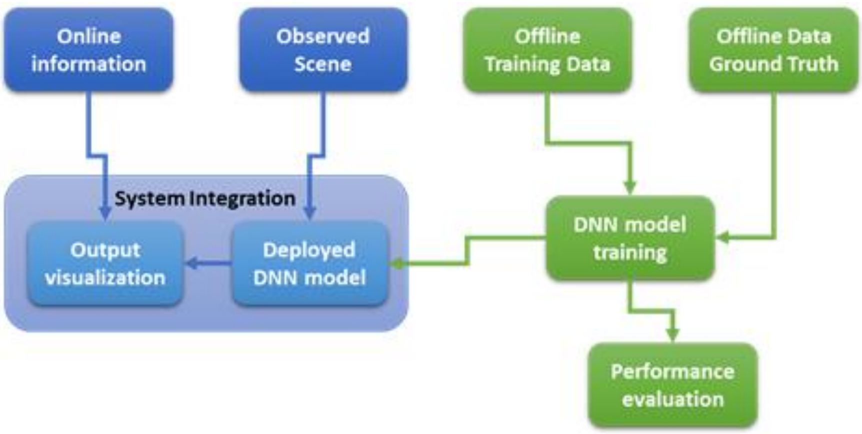

Figure 22: The proposed system for scene analysis using Deep Learning solutions

In the scope of the FRs requirements, this tool answers the following FRs requirements:

- OR 23 "Augmented reality device with AR data displays shall be available and functional during FRs training" - The scene analysis tool will be usable during training sessions. Allowing first responders to practice situational awareness but also to know how to operate the AR tool
- OR 25 "Virtual reality goggles shall be available and functional during FRs training" - In addition to the AR tool, it is expected to provide a VR tool allowing first responders to do training sessions in a safe environment

Compared to other professions, FRs such as firefighters or Emergency Medical Services (EMS) can face significant challenges that can be quite unique. When facing these situations, FRs can use AR technologies in order to have access to off-site resources such as allowing them to be in direct communication with a doctor in order to provide the best care to on-site casualties. Regarding firefighters and other FRs when equipped with AR technology, they may be able to access and share helpful information of the surrounding areas such as location of other personnel or areas, events and items of interest. As a result, by providing a scene analysis and visualization tool, it will be able to improve the situational awareness of first responders and paramedics.

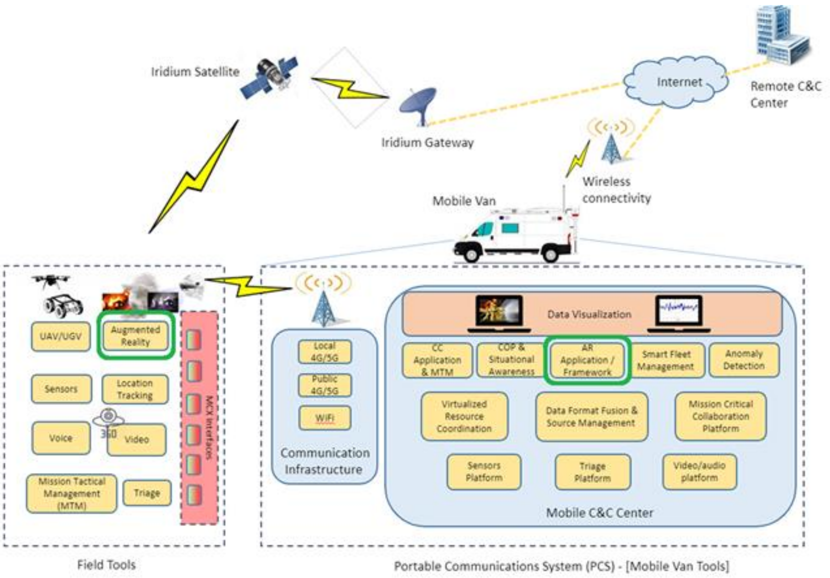

Figure 23: Corresponding Elements in RESPOND-A Architecture

In relation to the system architecture the proposed tool will be related to the AR components as we can see in Figure 23. The AR scene analysis and visualization tool receives video and image data as input and provides semantic information to the end user. The tool's input will be video or image data from the FRs surroundings. It will analyze the scene using the deep neural networks already trained offline. The system will output additional semantic information to the end users, improving their situational awareness.

4.3.7 Interactive VR360 System

With the goal of enhancing the situational awareness, RESPOND-A will develop an interactive end-to-end VR360 system taking the videos captures by the cameras on the UxVs as inputs. The system will provide an optimized VR360 video stream to each involved FR, based on the available resources (network, devices, etc.) and dynamically concentrating the video quality on the current Field-of-View (FoV). The system will allow switching between the available camera streams (if more than one camera is involved), and will enable multiple remote users to simultaneously watch the captured 360º scenes with the desired (or even planned) exploration patterns, focusing on independent regions of interest and with independent zooming features. These users will be able to interact via bi-directional low-latency audio/visual communication channels.

Table 23 summarizes the main specifications of the interactive VR360 system:

#	Specifications	Values
1	Format of Video Input	H264, H265 (MP4)
2	Format of Video Output	H264, H265 (MP4) [But extensible on demand]
3	Resolution of Video Input	7680*3840@30fps, 8/10bit 3840*1920@120fps, 8/10bit

4	Resolution of Video Output	As the video input, but configurable, and being able to keep the original video resolution in the FoV
5	Input Video bit rate	Up to 200Mbps [Configurable]
6	Output Video bit rate	Up to 200Mbps [Configurable multi-quality video]
7	Format of Audio Input	PCM
8	Format of Audio Output	PCM / AAC [But extensible on demand]
9	Format of Video Chat Channel	H264 [But extensible on demand]
10	Format of Audio Chat Channel	PCM / AAC [But extensible on demand]
11	Supported types of consumption devices	Desktops, laptops, smartphones, tables, VR goggles.

Table 23: Interactive VR360 system main specifications

Figure 24 provides a high-level overview of the end-to-end VR360 video system architecture to which the VR360 videos are injected. Basically, the system is divided into three main modules:

- *Capturing Module*: cameras mounted on drones, robots and/or dronsters (i.e. UxVs). It transmits the high-quality videos to the Processing & Interaction Module.
- *Processing & Interaction Module*: processing station deployed at the local C&C Centre. It performs transcoding and protocol conversion processes in order to provide optimized streams to the 360º video players, concentrating dynamically the video resolution on the Field-of-View (FoV) of each particular FR watching the video. This module also includes the communication and signaling server to enable group-based audiovisual interaction between the active FRs watching the VR360 videos.
- *Presentation Module*: It includes the VR360 video players that receive the optimized streams from the Processing & Interaction Module. To be able to receive an optimized stream, each player will periodically send the FoV coordinates to the Processing and Interaction Module. The player will also provide interactive features such as multi-stream switching (in case multiple camera views are available), video zooming features, and guiding methods to inform the viewing area of the other FRs.

The *Capturing Module* and the *Processing & Interaction Module* will communicate via the 4G connection provided the PLANET on-board terminal (ATM), which is represented by *Path 1* in Figure 24. The *Processing & Interaction Module* and the *Presentation Module* will communicate via the available or deployed IP network on ground (e.g. 5G cell, or local WiFi) for the local FRs' players, which is represented by *Path 2* in Figure 24, and via a public Internet connection (e.g. via a 4G-based communication module if a commercial connection is not available) to make the VR360 video streams available to remote FRs, e.g. located at the Remote C&C center, which is represented by *Path 3* in Figure 24.

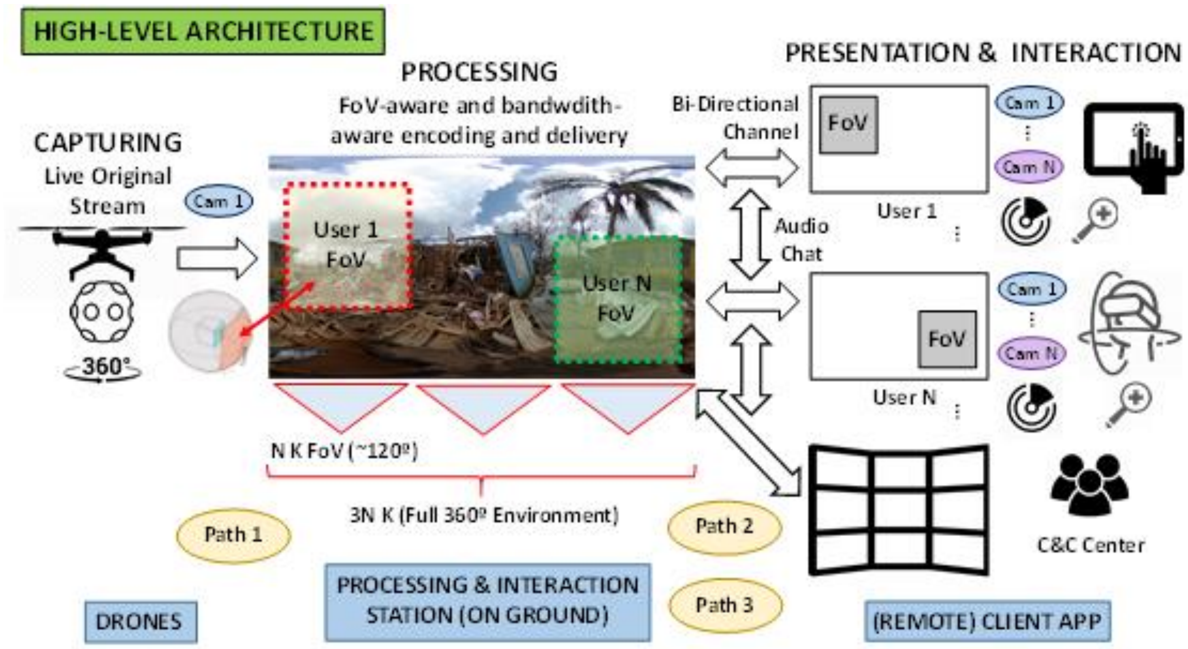

Figure 24: High level Overview of the end-to-end VR360 video system

This tool is involved in serving the OR18 "UxVs deployed during First Responder operations shall be able to support the following functionalities: (OR18.2) Video feed from the incident area", OR24: "Virtual reality (VR) goggles shall be available and functional during First Responder operations", O32: "Virtual reality (VR) goggles shall be able to be used by First Responders during operations, without impeding their activities", OR34: "Real-time 360º video shall be accessible during First Responder operations" and OR35: "A real-time 360º video platform shall be able to provide: (OR35.1) "High-quality video feed"; (OR35.2) "Ability to zoom on video"; (OR35.3) "Dynamic switching between different camera angles"; (OR35.4) "Ability to freely explore the omnidirectional operational environment"; (OR35.5) "Ability to collaboratively inspect the same video feed with other remotely located First Responders"; (OR35.6) "Ability to communicate via audio with other collaborators when inspecting the available video feeds"; (OR35.7) "Ability to access the video feed on traditional desktop-based displays"; and (OR35.8) "Ability to access the video feed on VR displays (e.g., VR goggles)".

In the context of RESPOND-A system architecture, the **inputs of the VR360 system** are the high-resolution video feeds from the VR360 cameras mounted on UxVs (Section 4.2.6) together with the FoV coordinates and the audiovisual streams for the group-based communications provided by each FR's player, and the **outputs of the VR360 system** are the optimized VR360 video streams concentrating the video resolution in the users' FoV together with the audiovisual streams from all involved FR. The video stream can be provided to the video platform of the Mobile C&C Center, directly to the screen/goggles of the FR, and/or to remote FR. Likewise, multiple remote FR will be able to interact via an audiovisual chat channel for a collaborative and more efficient video inspection. It will be possible to dynamically switch between the available camera views, and the video stream can be played out on VR goggles, mobile devices and/or traditional screens.

4.4 Mission Management and COP

The following tools are envisioned to be provided by the RESPOND-A Consortium to provide high-level Mission Management functions and offer a COP.

For each tool, a short description and a list of specifications and requirements will be provided. In addition, the FR requirements identified regarding Mission Management and COP will be associated to each tool. Finally, the main input, output and interactions with other tools are given.

4.4.1 Flex Control

The FlexControl tool is a control system for visualization and interaction with various video and data sources in a crisis room. It is based on Web technologies which does not require installation and can be accessed from different devices.

It allows access from web browsers to all types of content such as video cameras, audio signals, and access to the cameras of the mobile devices of the agents, TV channels, multimedia content, and cartographic information among others.

The solution offers an administrator role that allows to control what is seen on each device, adapting it to the context.

Moreover, the tool ensures the synchronization of all sources of information and makes a temporary record of all actions. Advanced streaming technologies are combined with interaction technologies, thus making the solution intelligent and by itself capable of: creating intelligent interfaces that adapt to each context and automatically learning the preferences shown.

#	Specifications	Values
1	OS Required	Linux / Docker
2	Web Framework	Node.js / HTML5
3	Database	MongoDB
4	Media (WebRTC) Server	Janus

Table 24: FlexControl main specifications

FlexControl satisfies the following operational requirement:

- OR01: “A command-and-control center shall be used for ensuring the successful outcome of a First Responder’s operation". The tool will provide inputs to represent video contents on the CC screens.

The main interaction of FlexControl with other RESPOND-A tools will be with the 360º video. That 360º video will be the input for FlexControl and there isn’t any specific output expected apart from the visualization on screens. This will allow capabilities to present the 360º video coming from the VR360 camera on the Command and Control Centre screens or any other video playing device that is carried by the FRs in the field.

4.4.2 Geovislayer

It is a web interface for layered visualization of 2D and 3D geospatial information, enabling filtering layers according to FR types/groups. It provides representation of location of FRs, areas of interest, statistics of covered/uncovered areas, sensor locations and data.

#	Specifications	Values
1	Data Storage	PostgreSQL 12
2	GIS server	GeoServer
3	OS required	Windows / Linux / Docker
4	Security	HTTPS
5	Web framework	Java Spring, React
6	3D library	Cesium

Table 25: GeoVisLayer's main specifications

This tool is meeting the following requirements:

1. OR01: "A command-and-control center shall be used for ensuring the successful outcome of a First Responder's operation". This solution is a command-and-control center application.
2. OR03.5: "Victim localization and tracking". If the triage platform is available and providing data to the DFF, this data will be shown.
3. OR03.6: "First Responder localization and tracking". If the triage platform is available and providing data to the DFF, this data will be shown.
4. OR03.7: "First Responder health status (including biometrics)". If the sensor platform is available and providing data to the DFF, this data will be shown.
5. OR04.2: "A mission management system shall be able to support functionalities relating to: Cataloguing and location of necessary equipment". This tool will provide authoring options to represent location of sensors of fixed equipment elements.
6. OR04.4: "A mission management system shall be able to support functionalities relating to: Tracking of victims and property damage". It will support this requirement partially (tracking of victims).

The interactions of this tool will mainly be done through the Data Format Fusion mechanism. Expected inputs from the Data Format Fusion are info from FR Sensors and Triage Platforms (which will also include UWB locations). It will also receive inputs from the LBRS solution for spatial AR data and configurations. In addition, direct user input through the user interface will be received (for preference configuration and authoring capabilities). The output expected is visualization on a web browser screen.

4.4.3 Maestro

Despite technological advances and a plethora of technological means there are still inadequacies of current communication between incident commanders and FR in the field. IFAFRI [28] has identified 10 areas where new or improved technologies could greatly enhance the safety, effectiveness, and efficiency of the world's first responders. Real-time tracking of responders, real-time detection, monitoring and analysis of threats and hazards via sensor technology, Integration of information, Interoperable communication, responder health, and actionable intelligence are those among these ten areas. In the same direction, there have been also current efforts in the U.S.A to develop and implement new tools for effective and efficient coordination and communication for FRs [21], [22].

IANUS brings a new solution that covers most of the identified current and future gaps within RESPOND-A with in-house built solutions. MAESTRO is a prototype, which is adaptable to the nature of the using entity (Police, Security Company, Firefighter, Emergency Medical Teams and First Responders) and improves their response time and efficiency with a variety of tools and technologies that can be expanded to meet their specific operational requirements. Figure 25 depicts the MAESTRO architecture with the main software components and associated technologies/ frameworks.

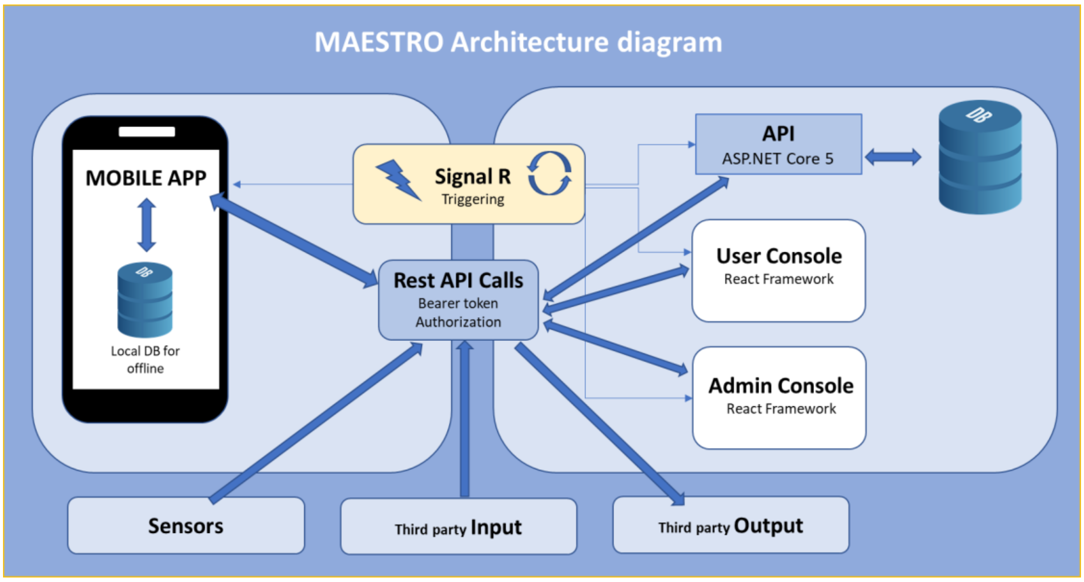

Figure 25: Maestro Architecture

The mobile App (Figure 26) with the Integrated Instant Messaging (IM) allows the exchange of information between First Responders and the Command-and-Control Center or Supervisor Office beyond overloaded radio systems. The users can send directly to the Command-and-Control Center alarms, reports, messages, mission notifications, multimedia files, etc. MAESTRO supports information exchange in all steps of a mission, from the point of planning and dispatch to deployment and after-action assessment.

The User Console module (Figure 27) comprises a complete information system to dispatch, deploy and control First Responders in the field. Mapping with GIS data on real time is used to provide a common view of the operational area to all entities involved at any command level meeting all the operational requirements for the implementation of a COP.

MAESTRO Administrator dashboard module (Admin console – Figure 28) allows organizations to acquire, allocate and manage their resources, at any echelon level (local, regional, national) such as First Responders, materials, machinery, equipment, fleet, and any other resources required for the mission. Organizations can ensure that internal and external resources are used effectively to accomplish their missions.

Finally, MAESTRO API allows an easy information flow from sensors deployed in the field and other data (e.g., meteorological data from third-party providers) based on REST API calls. For MAESTRO's main specifications, see Table 26.

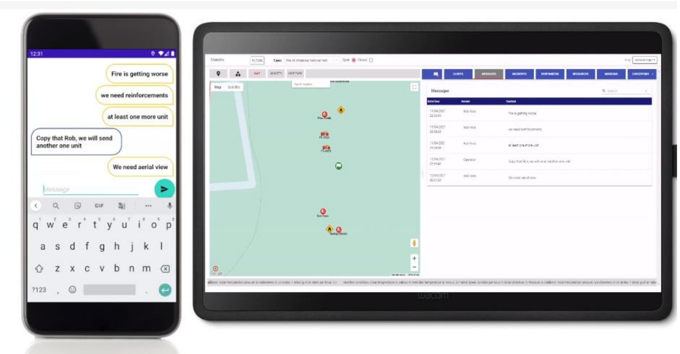

Figure 26: Maestro App and IM Features

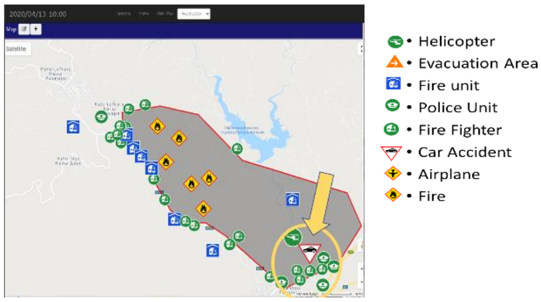

Figure 27: Maestro User Console (CC Center)

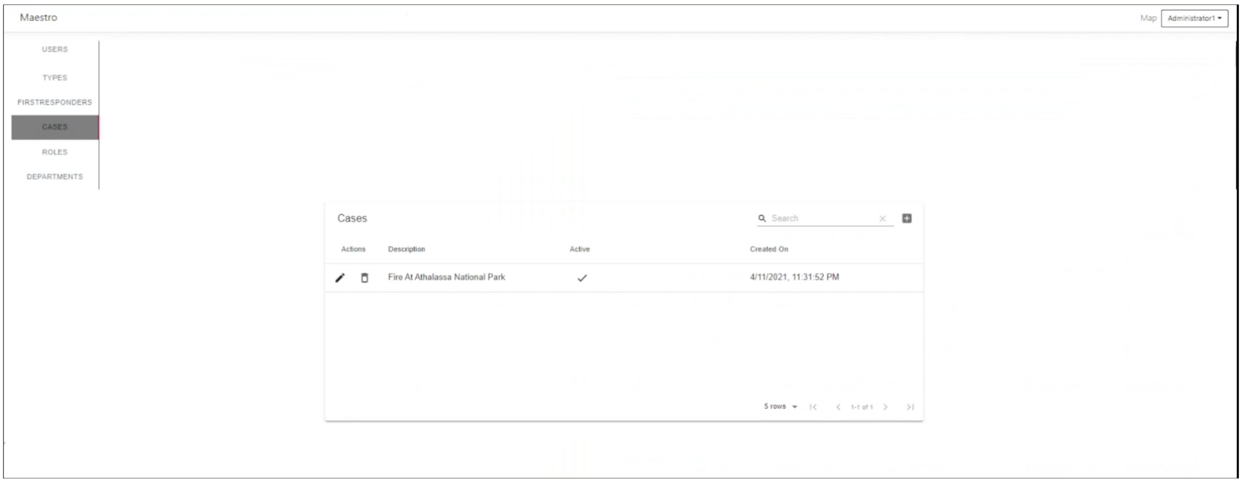

Figure 28: Maestro Administrator Dashboard

MAESTRO main Specifications
Management-tracking-monitoring of users checkpoints / dynamic tags
Tracking per user
Monitoring of events / alarms
Information exchange with users
Real-time reporting with predefined messages
Define affected area (define areas, edit, delete)
Define checkpoints (define, edit, delete)
Set missions (new, change, delete)
Illustration of geographical area (resources, checkpoints, tags),
User definition, user category (e.g., rescuer, ambulance, etc.), roles (Admin, Operator, Responder)
Rights for Admins and Operators (e.g., Resource Management, Disaster Management, etc.).
Keeping Log files
Ability to received 3rd party data via REST API calls.
Deployment on premise or as Software as a Service (SaaS)

Table 26: Maestro main specifications

MAESTRO is meeting the following operational requirements:

- OR01 “A command-and-control center shall be used for ensuring the successful outcome of a First Responder’s operation”.
- OR2 “Mission Control”.
- OR03.1 “Visualization of data relating to the operation (e.g., type of incident, map of incident location, first responder groups on scene)”.
- OR03.3 “Mission Management (e.g., tracking and monitoring of equipment, coordination of resources between different groups of First Responders)”.
- OR03.6 “First Responder localization and tracking”.
- OR04.3 “Coordination of operations and resources between different groups of First Responders and their action plans”.
- OR07.2 “Coordination of operations and resources between different groups of First Responders and their action plans”.
- OR07.3 “Coordination of operations and resources between different groups of First Responders and their action plans”.

In the context of RESPOND-A system architecture, the input and output of data is based on REST API calls. This provides full interoperability with any web service that follows the guidelines of the Representational state transfer (REST) software architecture.

4.4.4 Mobile Mission Management (MMM)

The Mobile Mission Management tool offers real-time crisis management for PPDR users. Its main features are:

- Mission follow-up and users operational status;
- Automated or declared positioning;
- Positioning of object or POI;
- Fast mapping integration (2D map, 3D map, picture or satellite view);
- For better interpretation of the situation, the tool takes into account the elevation;
- Integrated real-time chat.

The Mobile Mission Management tool shares the same contextual situation to all First Responders engaged into the same mission. It supports the decision making and the follow-up of the different action engaged on the field to respond to the crisis. The tool allows the sharing of resources or POI for their mission (e.g. hydrants for Firefighters, identification of hazards, hospital...).

This tool answers the following FRs requirements:

- OR01 “A command-and-control center shall be used for ensuring the successful outcome of a First Responder’s operation” - This solution is a mission management tool for command-and-control center application.
- OR03.5 “Victim localization and tracking” - The application allows the tracking of different type of people.
- OR03.6 “First Responder localization and tracking” - The application allows the tracking of different type of people.

- OR04.2 "A mission management system shall be able to support functionalities relating to: Cataloguing and location of necessary equipment" - This tool share locations of the different assets (drones, camera, vehicles...) and provide a list of engaged assets and their statuses.
- OR04.3 "Coordination of operations and resources between different groups of First Responders and their action plans" - The application supports the coordination of operations and resources. It takes into account the type of FRs engaged and action plans.
- OR05.1 "A mission management system shall be able support the exchange of information relating to Location, type and severity of incident" - The application allows the exchange of information related to incident location, type definition and severity.
- OR05.2 "A mission management system shall be able support the exchange of information relating to Location and action plans of different groups of First Responders" - The application allows the exchange of information related to FRs location and action plans.
- OR05.3 "A mission management system shall be able support the exchange of information relating to Location and status of equipment" - The application allows the exchange of information related to equipment's location (e.g., hydrant) and status (e.g., available, disabled, etc.).
- OR06.1 "A Common Operational Picture shall be established for operation planning, by providing to First Responders information relating to Early warnings and alert about potential incidents" - The application allows the transmission of new information and alert regarding the risk associated to the information.
- OR06.2 "A Common Operational Picture shall be established for operation planning, by providing to First Responders information relating to Location and type of incident" - The application allows the transmission of new information and alert regarding the risk associated to the information

Figure 29 below shows the Mobile Mission Management architecture view:

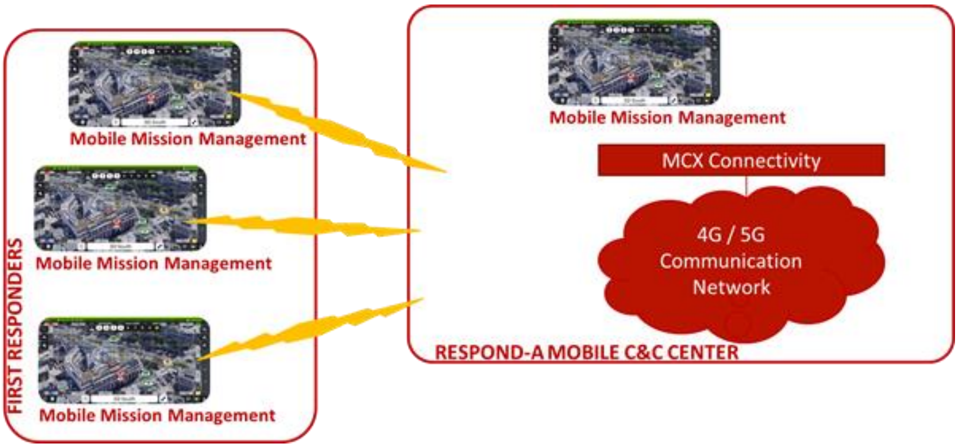

Figure 29: Mobile Mission Management Architecture View

A specific application server runs into the Mobile C&C Center in order to synchronize all the users' application on the field and manage the real-time data sharing.

The tool runs on following system:

- Devices running Android 9 and above.
- WiFi, 4G or 5G connectivity.

4.4.5 Mission Control Center (MCC)

Mission Control Center (MCC) will be the tool that maps the mission plan, instructs the drones and UAVs or Robots to follow predefined paths and will integrate the Cyclops AI subsystem to enable intelligence during operations.
The MCC (Figure 30), provides:

- A complete flight interface (cockpit) for remote flying operations with:
    - Flight information (Speed, altitude, battery capacity, satellite count etc.).
    - Drone movement controls (pitch, roll, yaw).
    - Programmable speed, altitude, geofencing, etc.
    - Selection of flight modes (Auto, semi-auto, manual, etc.).
    - Alarms, indicators, signals, alerting and notifications.
    - Loading, executing and alterations of mission plans.
    - Map with layering and real-time information of GPS.
    - Information for weather conditions (optional).
    - Complete log.
    - Extra features:
        - Flight by joypad, joystick, etc.
        - Automatic battery and motors health condition checkups.
        - Robotic return (RTH).
- An integrated camera viewer & gimbal control with real-time AI subsystem that provides:
    - Real-time stream viewer.
    - Zoom support (camera specific).
    - Camera mode (EO, IR, Thermal, etc.).
    - Real-time object detection, tracking etc.
    - Gimbal control (if exists).
    - AI algorithm detection sensitivity controls.
    - Other generalize or specific indications.

The MCC (Figure 30) get inputs directly from other 3rd party components, interfaces, tools and sensors or indirectly via the API that 8BELLS Data Fusion Platform provides.
The MCC sends outputs to the drones, UAVs and robot directly or through 3rd party systems and shares also telemetry and other information back to 8BELLS Data Fusion Platform or to other components in a direct manner via API calls or any other interface (e.g. serial)

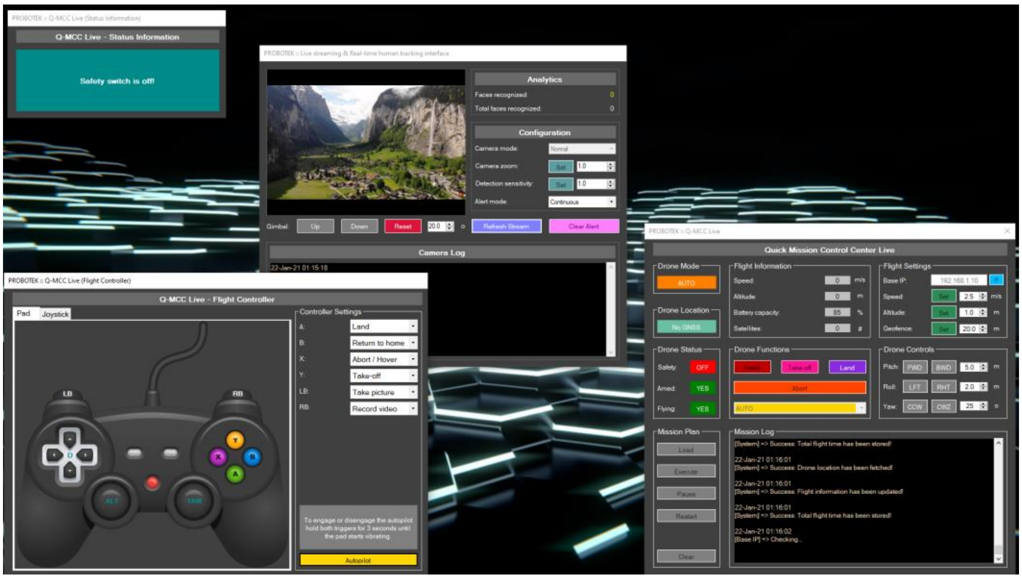

Figure 30: MCC tool

4.4.6 X/BELLO

8BELLS brings an operational closed communications tool/application which will assist in FRs activities during a disaster/emergency operation. There are different groups of FRs active in the field and X/BELLO provides an efficient way for the Head of Operation to manage and communicate with each FR as well as to organize them into a closed group with roles/missions. Each FR has specific credentials (username, password) and user rights which are exclusively assigned by the Administrator/Head of Operation. Enhancing situation awareness, X/BELLO provides functionalities (Figure 31) that enable better viewing and management of the operation by monitoring FR's activities. X/BELLO follows a Restful architecture and is responsible for encrypting the users' communication and protecting their data.

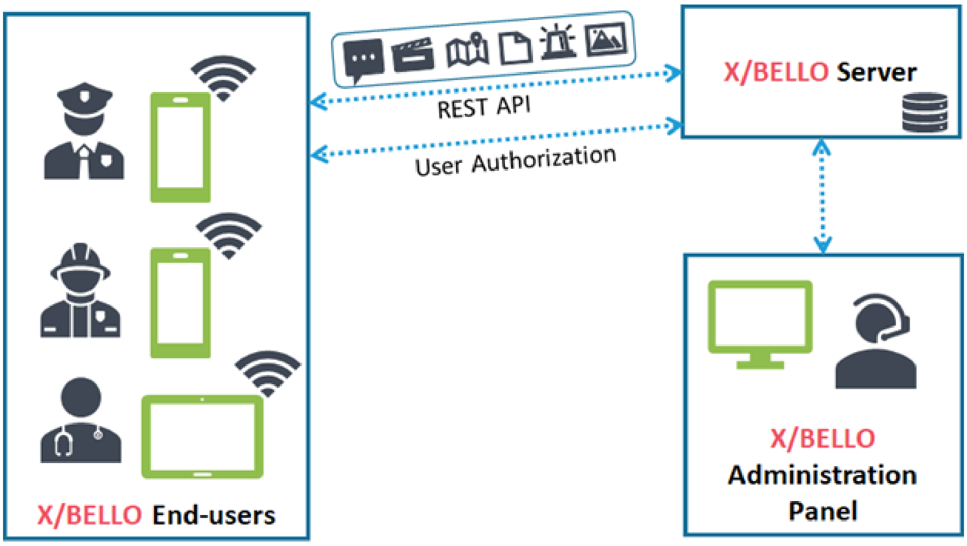

Figure 31: X/Bello Architecture

<u>Mobile Interface (Figure 32):</u> During the operation FRs can exchange information with the RESPOND-A Deployable Platform in the form of instant messages, reports, multimedia files, emergency alerts and notifications under a secure connection. End users can also report back essential information regarding the area of incident such as the location of a FR or victim and the status of equipment directly to the administration panel.

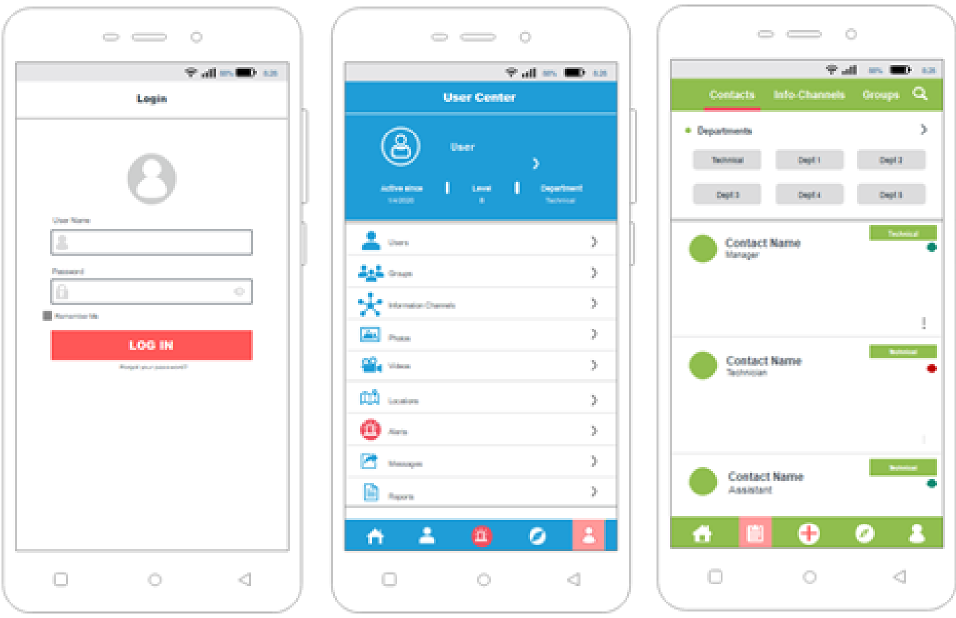

Figure 32: X/Bello Interface

<u>Administration Interface (Figure 33):</u> It is a dashboard module where all FRs on the field are displayed along with their location and status. A map of the incident is displayed providing information about FR on the scene allowing the administrators to monitor their activities during the operation and coordinate the different groups.

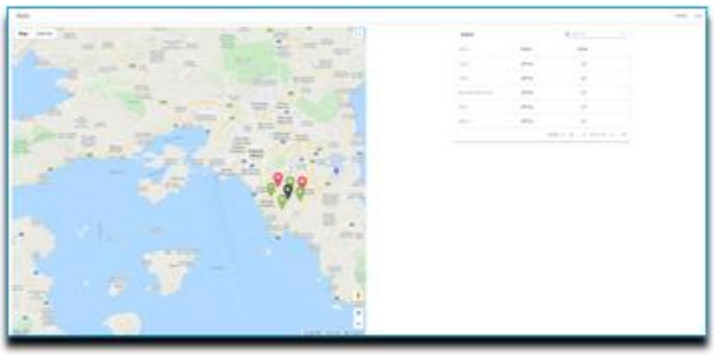

Figure 33: X/Bello Administration Interface

#	X/BELLO main specifications
1	User & Group Management (create/delete/edit users and assign them to closed groups) (e.g User: Firefighter, Group Firefighters Team A)
2	Role Management (create/delete/edit roles and their privileges) (e.g Role : Responder, Rescuer)
3	Multimedia (send or view audio/video/image files in a closed group)
4	Connection to 3G/4G/5G networks or even LEO Satellites (by adding a SATCOM sleeve on smartphone).
5	Geolocation (identification of the geographic location of a user)
6	Visualization of end-users activity on an illustrated map of the disaster area
7	End-to-End encryption
8	Data encryption in transit
9	User authentication (verification of user's identity and their access)
10	Alert notifications
11	Geofencing (Assign predefined set of geographical boundaries)
12	Report back selecting predefined Messages
13	Keeping log files
14	REST API calls
15	Emergency Panic Button

Table 27: X/Bello main Specifications

As already stated, X/BELLO is involved in serving the following operational requirements:

- OR01 "A command-and-control centre shall be used for ensuring the successful outcome of a First Responder's operation".
- OR02 "The coordination of activities between different groups of First Responders during operations shall be supported by a Command-and-Control centre".
- OR03.1 "Visualization of data relating to the operation (e.g., type of incident, map of incident location, first responder groups on scene)".
- OR03.2 "Establishment of a Common Operational Picture between First Responders and Command-and-Control centre (e.g., information sharing regarding the operation parameters)".
- OR03.3 "Mission Management (e.g., tracking and monitoring of equipment, coordination of resources between different groups of First Responders)".
- OR03.5 "Victim localization and tracking".
- OR03.6 "First Responder localization and tracking".
- OR04.2 "Cataloguing and location of necessary equipment".
- OR04.3 "Coordination of operations and resources between different groups of First Responders and their action plans".
- OR06.1 "Early warnings and alert about potential incidents".
- OR06.2 "Location and type of incident".
- OR08.1 "Command-and-control center(s) and First Responders on the scene".
- OR08.2 "Different groups of First Responders on the scene (e.g., police and firefighters)".
- OR09.1 "Text".
- OR09.2 "Voice".
- OR09.3 "Image".
- OR09.4 "Video".
- OR09.8 "Alert signals".

In the context of RESPOND-A system architecture, the input from end-users such as multimedia files and their geographical coordinates are reported back to the Administration Interface Panel, which is managed by the Head Operator of the RESPOND-A Deployable Platform. Connections between interfaces follow a REST architecture and data are encrypted in transit.

4.5 Communications, Security and Data Management

Communication is a critical element in emergency operations, not only for the FRs to talk to each other, but also to exchange mission data and incident information with the officers in the C&C Centre. RESPOND-A offers novel solutions to FRs communications by utilizing new network technologies, like 5G and ensuring security and optimized data management.

4.5.1 5G Communications Systems

5G is the Fifth Generation of mobile cellular networks. Its design promises revolutionary solutions for virtually connecting everything, machines, objects and devices. Characteristics like higher data rates, ultra low latency and massive network capacity are what make it ideal for RESPOND-A operational concept. NCSRD brings a 5G system based on Amarisoft solution AMARI Callbox [23]. It is an all-in-one portable PC based 5G communication, consisting of both the core and radio access equipment. The system also includes extra RF modules (RF amplifier, MIMO and planar antennas for extra coverage radius) and 5G enabled mobile handsets for the end users (Figure 34).

Figure 34: Portable PC based 5G system

Both the Core and the RAN of the system are software defined, acting as acting as a 3GPP compliant eNodeB, gNodeB, EPC and 5GC. It utilizes up to 3 PCIe SDR cards for the front end, providing the option for up to three LTE 2x2 cells or two cells of which the first uses LTE and the second 5G technology simultaneously. The following table summarizes the system specifications and characteristics:

#	Characteristics and Specifications
1	All-in-one system (Core-RAN)
2	Both the Core and RAN functions are software defined (acting as a 3GPP compliant eNodeB, gNodeB, EPC and 5GC)
3	Can be hosted on Linux-based systems (can also be hosted separately, enabling the capability of an EPC/5GC cloud deployment)
4	Portable, PC based (Linux, Intel Core i7), weight 11 Kg, requires power supply AC, 220V
5	Utilize up to 3 PCIe SDR cards for the front end, providing the option for up to three LTE 2x2 cells or two cells of which the first uses LTE and the second 5G technology simultaneously
6	Release 15 compliant NR
7	Up to 3 components carriers (CC), MIMO 4X4, up to 600/150Mbps
8	Core/RAN Remote Access for monitoring/management/configuring
9	Stand-Alone (SA-Option 2) and Non-Stand-Alone (NSA-option3) Modes
10	Sector Coverage Range of 300m

Table 28: 5G System Characteristics and Specifications

The 5G system that NCSRD brings is capable of offering high-bandwidth 4G/5G network coverage and services to a selected area around the mobile Van and where the FRs operate, answering the following FRs requirements for Mission Critical Communications:

- OR10 "The area in which a First Responder operation takes place shall have adequate cellular network coverage".
- OR11 "The communication infrastructure used during operations shall allow high-speed data exchanges".
- OR12.3 "Mobile cellular transmitters, towers"
- OR14.1 "4G broadband cellular network coverage"
- OR14.2 "5G broadband cellular network coverage".

It also exploits the advanced characteristics of 5G communications (like enhanced QoS, ultra low latency etc.) to achieve efficient and real time data exchange, enabling the effective operation of the RESPOND-A platform.

In addition, Athonet provides a fully in-house developed 100% software-based 4G and 5G mobile core network in a box for voice and data networks that runs in public & private clouds, virtualized or enterprise data center environments using standard commercial off-the-shelf hardware. In the figures below we show the core network installed in a COTS HW server and a ruggedized server to fit with public safety needs.

Figure 35: Athonet Core

Such a core in the box can be connected to any 4-5G radio equipment that exposes standard 3GPP interfaces to the core (S1 in 4G, N2-N3 in 5G) and includes the EPC and/or 5G CN functions to support data and voice communications for private 4-5G networks. In the same box, as the SW is virtualized, it is also possible to host applications, such as Push-to-Talk (PTT) or Mission Critical PTT (MCPTT) for local use. In practice, when connected to a radio access equipment in 4-5G technology, this allows users with the SIMs provisioned in such system to communicate each other locally. This is a clear advantage for critical missions in areas without commercial cellular coverage or to back-up the infrastructure when it becomes unavailable, due to backhauling issues or damages to the infrastructure itself (earthquakes, floods, terrorist attacks, etc.).

Over the years, Athonet has also provided a fully integrated solution including small cell, antennas, vEPC, vIMS for VoLTE for mission-critical use cases. These include support for Push-to-talk and standards based MCPTT functionality. These can be provided in ruggedized (see figure 35 on the right) or backpack form (IP65 and extended temperature, figure 36) to suit the specific requirements of public safety, military and other players that work in the mission critical arena. Investigations on the possibility to practically deploy and showcase such a solution on the field (COVID restrictions for travels/shipments and frequency bands to be authorized) during the project lifetime are ongoing.

Figure 36: Athonet Backpack

4.5.2 Edge Computing and Communications Platform

The Edge Computing and Communications Platform (ECCP) is exemplified by a compact yet powerful server that is meant to be used for edge computing scenarios. In the specific case of RESPOND-A, the ECCP server will be accommodated in situ the Pilot 1 (based in Cyprus) and in situ the Pilot 3 (based in the port of Valencia), either inside the mobile van or in a suitable IT room where the local command and control center is located. The size and form factor of the hardware used for the ECCP is shown in Figure 37 below, while the most relevant technical specifications are presented in table 29. A suitable backhaul connection shall be necessary in each pilot and installation location (i.e. mobile van or IT room) to provide remote monitoring and overall ECCP platform control.

From the standpoint of the system functionality, the EECP platform is conceived to run a single-host Kubernetes (K8s) cluster for orchestration of containers. This has to be considered a minimal K8s installation as usually Kubernetes includes several host machines [24]. Container is a well-known cloud technology that provides several advantages over virtual machines in a cloud environment, and this stands out even more in a resource constrained edge cloud platform. In short, the difference can be seen in Figure 38, which illustrates those containers enable removing the presence of a guest OS that allows to be more efficient from the cloud resource standpoint. As it is well known, containers share system files, as well as networking, and that reduces the isolation feature in comparison to virtual machines.

Figure 39 shows a simplified view of the ECCP platform leveraging on K8s for deploying containerized applications. The Master node of Kubernetes provides control plan functionality for deploying different isolated PODs, with the POD representing the minimal ensemble of containers in a Kubernetes cluster. Typical examples of RESPOND-A services may include connectivity components for the UAV mission, the backend service for a video processing tool used on-board the UAV, a UAV mission planning tool and so forth. The main advantage of deploying such RESPOND-A services as containerized applications through a well-established orchestration like K8s consists in a platform independent system that shall require minimal manual configuration. The ECCP server platform can be easily brought in situ in a suitable manner for Edge Computing use cases. Further, Kubernetes allows deploying different services in a homogeneous environment that inherently abstracts host resources. Once the ECCP is activated, the mission can be customized depending on the first responders' requirements, thus activating only the required services in a given context. Description of specific solutions were already provided in previous and shall be used as basis for integrating RESPOND-A solutions over a same platform.

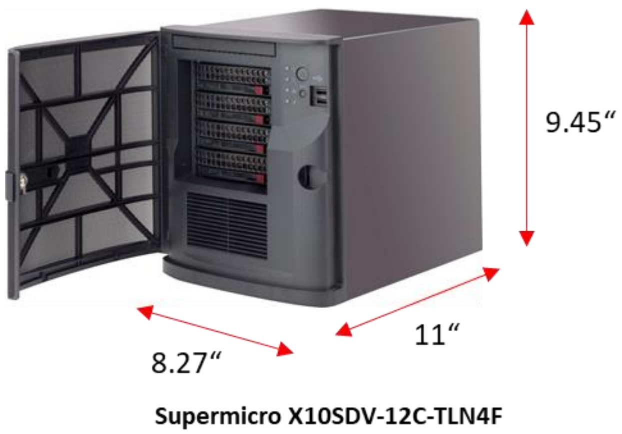

Figure 37: Supermicro X10SDV-12C-TLN4F hardware used for the ECCP

Edge Computing and Communications Platform server specifications	Description
Processor	Intel Xeon D-1557@2133 MHz single socket; 12 cores, 24 threads, 45 W
RAM	128 GB
Networking	2 x 10 GBE, 2 GBE LAN, 1 IPMI LAN
Interfaces	1 x PCI-E, 6 x SATA
Internal Storage	SSD – 2 TB
Operating System (customizable)	Ubuntu server 20.04

Table 29: Main specifications of the hardware platform for the ECCP

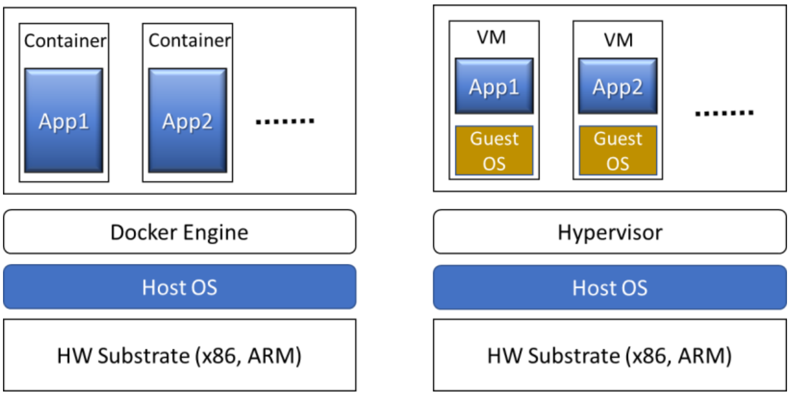

Figure 38: Comparison between containers (left) and virtual machines (right)

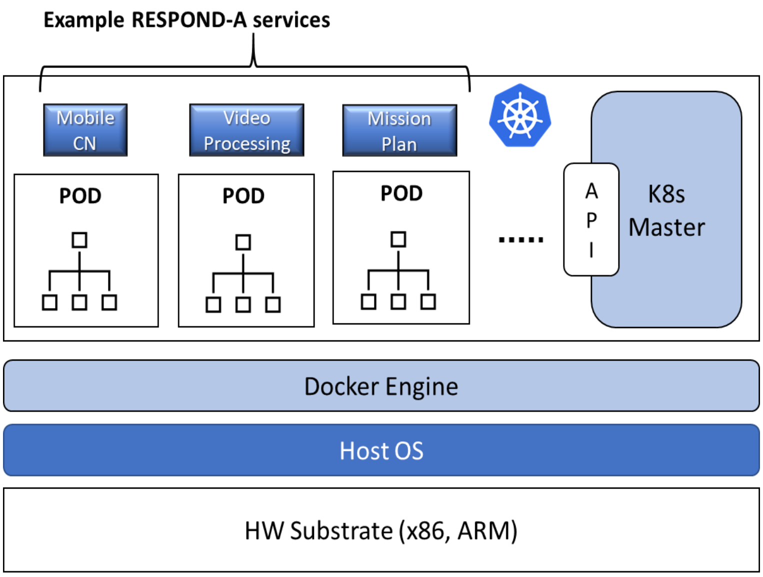

Figure 39: ECCP deployment example of containerized applications through Kubernetes

The Edge Computing and Communications Platform is meant to provide a service-agnostic environment in which different virtualized services can be deployed at the edge. It answers the FRs OR15 "Suitable software and hardware artefacts shall be made available to an advanced communication infrastructure for unmanned vehicle operations".

4.5.3 Data Format Fusion

Efficient data exchange is one of the crucial factors when data should be exchanged amongst different stakeholders. Indeed, once the high volumes of generated data are combined with high data flows from a variety of sources, a standardized way of handling these data can increase the effectiveness of the pipeline that starts with acquiring these data and make them available to other modules. Since many different modalities will be used in the context of RESPOND-A, it is of ultimate importance to introduce a mechanism that will be able to efficiently handle data generated in the field of operations of First Responders from various sensors that need to be distributed inside the RESPOND-A Deployable Platform modules.

The Data Format fusion mechanism, in the context of RESPOND-A, acts as a mediator between the applications, which are hosted inside the Command & Control Centre, and provides functionalities to store or consume data in an appropriate format, through TCP/IP connections.
In detail, within the Data Format Fusion (DFF) concept we define two types of actors, namely the producers and the consumers of data. With the term producer we denote a data source that is capable of transmitting data through a network in a predefined format and under the term consumer, an application or other module that can utilize an API to retrieve data from data storage. In the context of Respond–A, an actor may acquire the role of a data producer, a data consumer or both as long as it can utilize the provided DFF APIs.

DFF will perform the required actions to store the data received over TCP/IP, organize them and make them available to any consumer that will request it via a suitable REST API call. DFF can manage different types of data (input/output) encapsulated in JSON objects.

The utilization of REST APIs provides a standard and easy way of interaction for both producers and consumers.

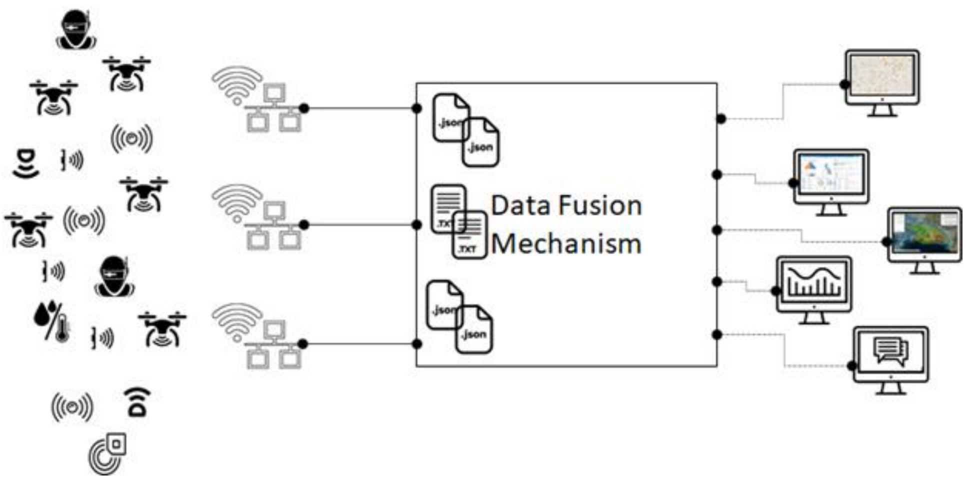

Figure 40: Data Format Fusion

The DFF mechanism brings a bundle of software services with functionalities for user authentication, data storage and access/retrieval as well as data exchange of groups of data. If needed, the DFF allows access only to registered users. For the purposes of the RESPOND-A project different data representation modules developed by partners can be utilized to retrieve the respective data from the middleware using appropriate API requests.
Its Data Access API can be utilized in a RESTful manner, making it easily interactive with data producers and consumers through TCP/IP connections. After establishing a connection, DFF consumes files in a dedicated format (JSON) and stores them inside its databases or makes the data available to consumer modules using structured web requests.
Table 30 summarizes the basic specifications set for the Data Format Fusion mechanism:

#	Specification	Value
1	Communication	REST API Calls
2	Data Storage	Relational (ex. CrateDB) and non Relational (ex. MongoDB) databases
3	Data Exchange Format	JSON
4	Deployment	Docker container
5	Authentication	User Level

Table 30: Data Format Fusion main specifications

As this is an ongoing task and will undergo further development and integration operations with a number of modules the above specifications might be updated in a way to better fit the project needs and requirements on the basis of current technological constraints.

DFF is hosted in the Mobile Command & Control Center serving the OR03.4 "Data Source Management capabilities for contextual data processing and fusion". More specifically devices will be organized in context groups giving the ability to consumers to retrieve data by reference to the context group. Access to specific devices within groups will also be retained.

As already stated, the tool's main functionalities enable exchange of vital information made available during the field operation to the required systems. Thus, DFF is serving the OR05 "A mission management system shall be able support the exchange of information relating to:" category with the following operational requirements: OR05.1 "Location, type and severity of incident ", OR05.2 "Location and action plans of different groups of First Responders ", OR05.3 "Location and status of equipment ", OR05.4 "Location and medical status of victims ", OR05.1 "Location and extend of damage of property ".

In the context of RESPOND-A system architecture, the input of the Data format fusion derives from the software modules residing in the RESPOND-A Deployable Platform (Table 31).

#	Systems
1	FR Sensors
2	Triage Platform
3	Anomaly Detection
4	Smart Fleet Management

Table 31: Systems - Data producers

The output is directed to the software modules which will consume the data for their internal use, inside the RESPOND-A Deployable Platform (Table 32).

#	Systems
1	CC applications & MTM
2	COP
3	AR Application and Framework

Table 32: Systems - Data consumers

4.5.4 Mission Critical Collaboration Platform

MCX tool is based on MCX services from Critical Collaboration Platform. Each user of the Critical Collaboration platform needs to subscribe to it. Depending on its profile, after authentication, the user will get the authorization to enter in allowed group communication with allowed features.

The Mission Critical Collaboration platform will be deployed in the RESPOND-A vehicle to offer MCX Connectivity on location without accessible communication after a disaster.

With the platform, the MCX tools will be deployed to deliver resilient and efficient Multimedia communication for all forces engaged during the response management.

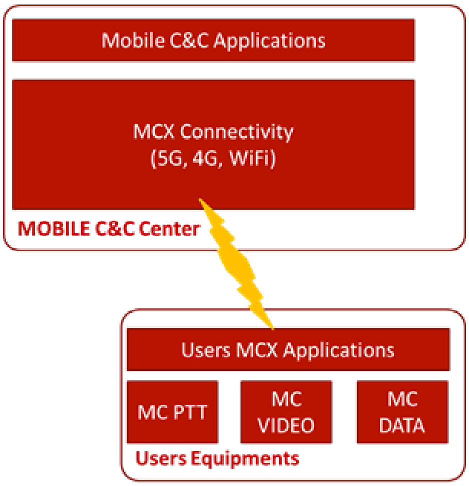

Figure 41: Mission Critical Collaboration platform architecture overview

Based on the user's profile and authorization, the user will be able to use one or more of following MCX tools:

- MC-PTT: this tool offers voice group communication capability based on PTT over IP features fully compliant with 3GPP MCS standards (from release 3GPPP and above).
- MC-VIDEO: this tool offer video group communication in order to have a more efficient discussion and analysis during the response phase of the crisis.
- MC-DATA: this tool offers multiple features in order users are able to chat, send text message, share pictures or videos, make data request (e.g. picture analysis, LAPI...).

The FRs operational requirements this tool answers are:

- OR08.1 “Secure and reliable communication channels shall be established during operations between Command-and-control centre(s) and First Responders on the scene” - The Mission Critical Collaboration platform is compliant with 3GPP MCS standards. The platform enables secure and reliable communications solution during operation between C&C center and FRs on the field.
- OR08.2 “Secure and reliable communication channels shall be established during operations between Different groups of First Responders on the scene (e.g., police and firefighters)” - The Mission Critical Collaboration platform is compliant with 3GPP MCS standards. The platform enables secure and reliable group communications solution during operation between different group of FRs on the field.
- OR09.1 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to text” - The Mission Critical Collaboration platform supports text communications (e.g., chat).
- OR09.2 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to voice” - The Mission Critical Collaboration platform supports voice group communications and direct voice call.
- OR09.3 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to image” - The Mission Critical Collaboration platform supports exchange of data such images or text for database request.
- OR09.4 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to video” - The Mission Critical Collaboration platform supports video group communication or direct video call. And the sharing of video as shared data.
- OR09.5 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to Satellite data for location-based services (e.g., GPS signal)” - The Mission Critical Collaboration platform supports the exchange of data related to location services.
- OR09.7 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to augmented reality (AR) applications” - The Mission Critical Collaboration platform supports the use of data related to Augmented Reality applications (e.g., MCX Augmented Expert).
- OR09.8 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to Alert signals” - The Mission Critical Collaboration platform supports the reception of manual or automated alerts through operational or technical statuses features.
- OR09.9 “The communication infrastructure used during operations shall be able to support the exchange of the data relating to Device metadata (e.g., metadata from sensors)” - The Mission Critical Collaboration platform supports the exchange of the data related to device’s metadata.

Figure 42 shows the place of the tools in the MCX architecture context:

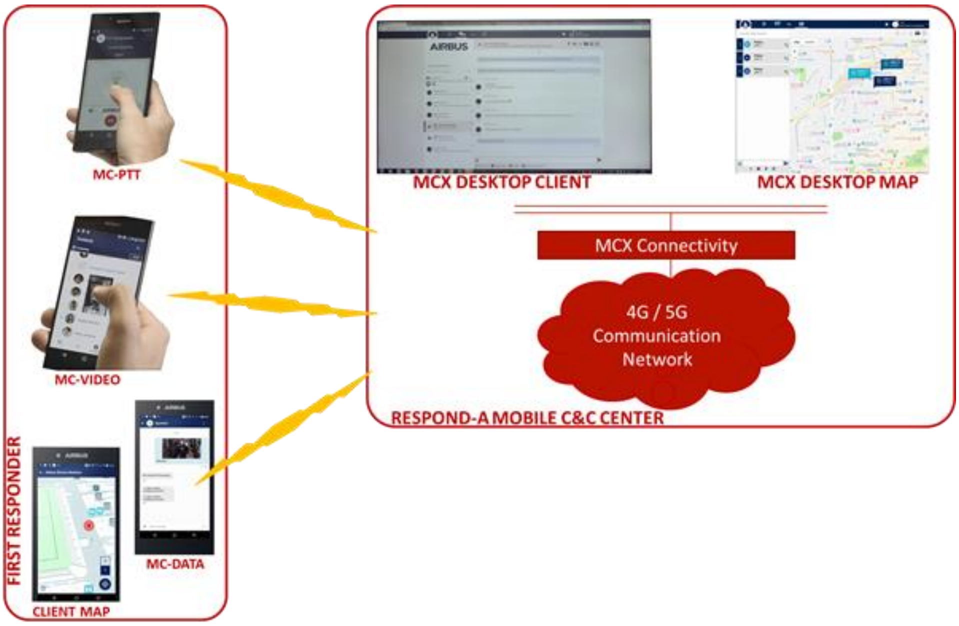

Figure 42: MCX tools in the context of Mission Critical Collaboration platform

Depending on the user's profile and usage, the tools are able to run on following system:

- Mobile devices: Android 10 mobile operating system and above.
- Desktop devices: Windows 10 operating system with Chrome web explorer.

4.5.5 Virtualized Resource Coordination

TALENT is a coordination solution supporting end-to-end services composed of satellite, radio access and cloud/edge computing resources. TALENT provides a user-friendly single point of interaction for all stakeholders in the ecosystem, i.e. terrestrial and satellite operators as well as 5G vertical providers, where they can deploy and manage services over a cloud/edge. TALENT is in-line with 3GPP and ETSI specifications, extending them towards satellite systems. The over-the-top holistic management approach enables TALENT to make satellite systems a near "plug and play" resource for different terrestrial applications for coverage extension.
The original idea of TALENT is based on the definition of hierarchical and distributed orchestration, where an orchestrator is able to manage and coordinate several independent domains (satellite and cloud). We assume, at each domain, there exist a domain manager (DM) able to work with resources of the domain. The internal components of TALENT are detailed as follows:

- **Northbound REST API:** It provides an abstraction layer, which exposes an extensible set of functions serving different needs of operators and verticals (e.g. service instantiation, provisioning, configuration, check service status, etc.).
- **MANO selector plugin**: This module is a reference point where all the required information such as IP address, data model format, vendor and interaction procedures of the supported NFVOs (OSM, ONAP, etc.) and VIMs (OpenStack, OpenVIM, etc.) are kept.
- **Multi MANO LCM:** This module talks to MANO selector Plugin to handle underlying orchestrator and VIM. Currently it supports OSM and Openstack (Queen).

- **Domain Component plugin:** It is a reference point to keep all the required information such as IP address, data model format and configuration settings of the supported satellite components. "Domain Component Plugin" is responsible to register all supported satellite components at the bootstrapping phase. TALENT will be loaded required dependencies and libraries to establish communication with underlying satellite solutions.
- **Domain Configuration:** This module talks to Domain component plugin to manage and coordinate satellite solution. Currently it supports totalNMS of Gilat.

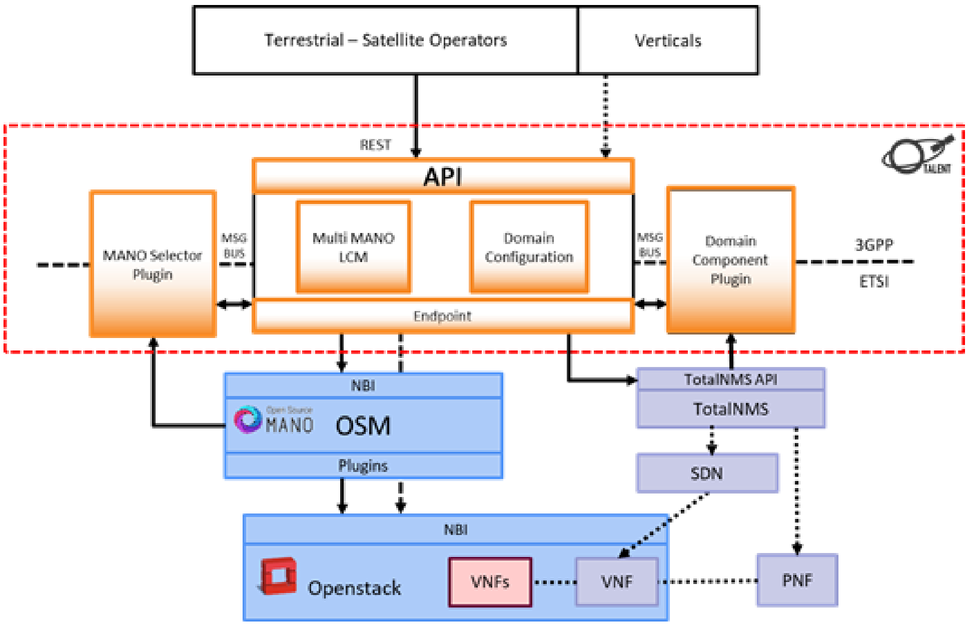

Figure 43: Talent Functional Architecture

<u>TALENT Operational Steps:</u>

TALENT has two main operational steps: bootstrapping and run-time. Bootstrapping consists of setting up the TALENT system to be ready for the proper operation over an infrastructure. It is a one-time process (every time the system starts from the fresh). The system must be loaded with proper inputs for the supported MANO (cloud resource orchestrator) and satellite systems. These inputs later on will be used at the run-time phase. Run-time phase is responsible for execution of operational commands coming from different stakeholders. In principle, TALENT supports two categories of operational commands:

- Network Service-related commands: these are commands for life-cycle management of end to end connectivity and computational resources. TALENT eases the provisioning/termination of end to end services over satellite and terrestrial resources.
- 5G application-related commands: over the provision network services, TALENT is able to run and manage different 5G application.

As illustrated in Figure 44, user triggers the operation by browsing to the bootstrapping page to define new project for provisioning network service on satellite and cloud/edge domains. To do so, user must provide information such as terrestrial and satellite vendors (e.g. OSM, Gilat) and API information (e.g. IP address and port number) of MANO Cloud Manager and Satellite Domain Manager to the system. Once the project is created, the bootstrapping phase is over.

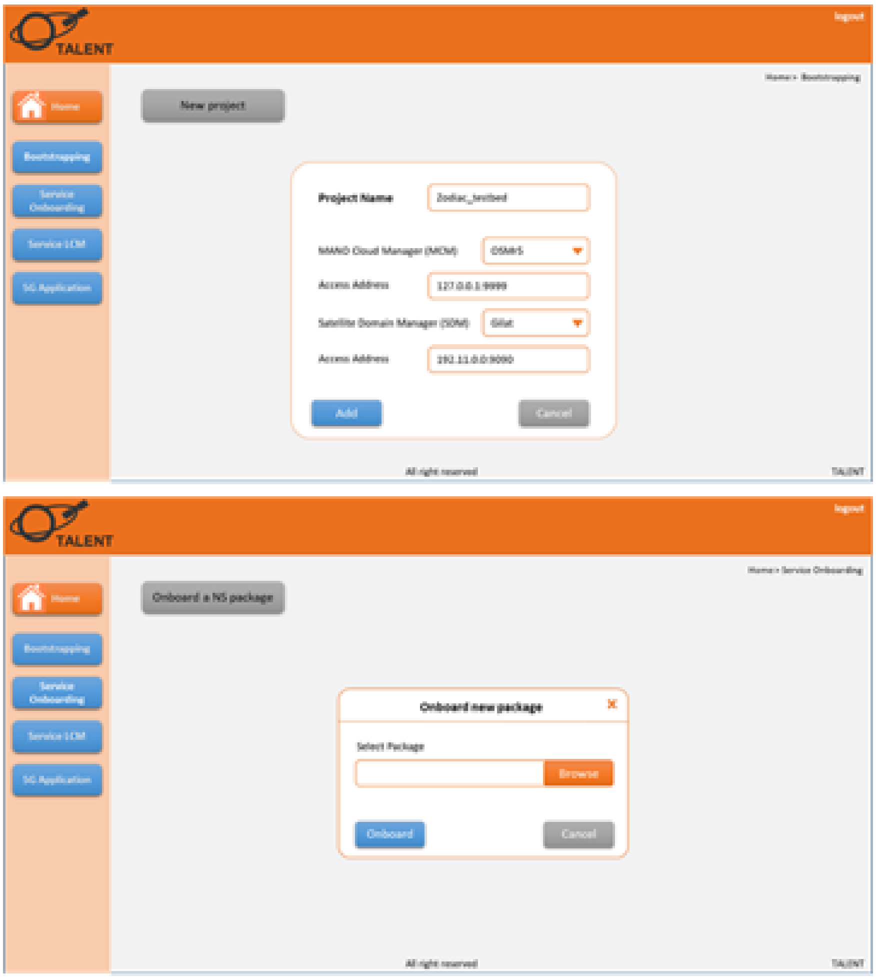

Figure 44: TALENT GUI - Bootstrapping & Run-time

On the run-time phase, user needs to upload a configuration zip file to set up and configure terrestrial and satellite elements. TALENT performs a set of actions on the uploaded zip file based on the zip file definition. A request corresponded to the MANO is forward to the cloud infrastructure and another request correspond to the satellite domain forward to the satellite ground segment devices.

4.5.6 Anomaly Detection

SiVi constantly monitors the network, capturing and analysing the transmitted packets while seeking for inconsistencies and anomalies at the tactical and the operational layer of the Critical Information Infrastructure (CII) environment. More specifically, SiVi combines two different functionalities that are described below:

Security monitoring and analysis mechanism

The first functionality is the "Security monitoring and analysis mechanism" component, an Intrusion Detection System that combines different sensors in different layers. In the **network layer**, SiVi uses the Suricata [25] as a sensor, and several custom Machine Learning (ML) sensors to monitor and analyse the different communication protocols, while in the **host layer** it leverages the functionalities of the OSSEC [26]

Server. Thus, it collects security logs from all these sensors and transforms them into security events (by mapping them in a unified format). Figure 45 presents a high-level architecture describing this process.

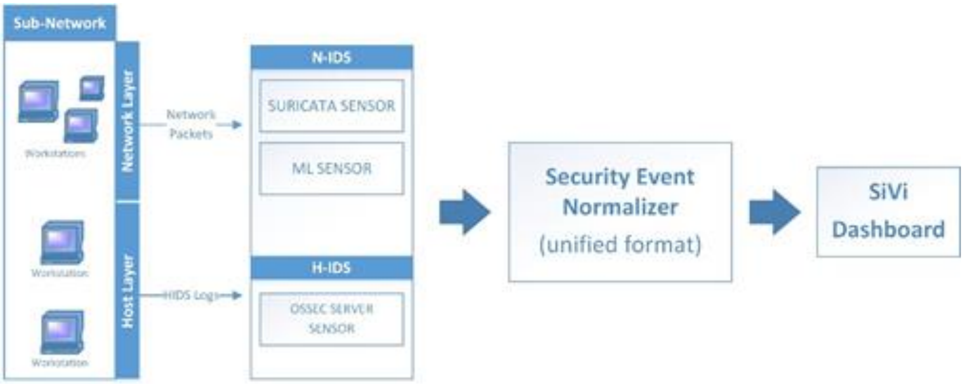

Figure 45: SiVi Security monitoring and analysis mechanism

In the network level the sensors (Suricata and ML sensors) receive network packets that are converted into network flows as an input. These flows are analysed and eventually each sensor results a security log to inform the tool operator for potential security breaches. In the case of host layer sensors, the given input refers to logs coming from the hosts (e.g., syslog, eventlog, snort) while the output of the sensors refers to security logs (alerts in OSSEC terminology). All these security logs coming from different sensors will be translated into a unified security event to be easily interpretable from a correlation engine (not included in SiVi). Eventually, the information is illustrated to the SiVi dashboard providing both quantitative and qualitative metrics enabling a better overview of the network to the security administrators.

Table 33 presents the sensors that are available in SiVi tool. The first column has the name of the sensors, the second the incident identification mechanism, and the third column refers to the layer on which every sensor is deployed.

Sensor name	Incident identification mechanism	Layer
Suricata Sensor	Signature-based	Network layer
OSSEC Sensor	Signature-based	Host layer
Machine Learning Sensor	Machine learning	Network layer

Table 33: SiVi sensors for Security monitoring and analysis mechanism

It is clear that Suricata and OSSEC sensors despite the fact that operates in different layers, network and host layers respectively, they use the same mechanisms to identify incidents, meaning that each sensor applied static rules that will eventually trigger a security event. On the other hand, sensors that are based in machine learning will adapt their "rules" in the network data characteristics being more precise about their predictions. The difference is enormous if we consider the peculiarities of the CII networks, since a "normal situation" in one hospital environment might considered abnormal in energy operator network.

SiVi ML sensor is mainly consisted of a three steps architecture, Pre-processing, Training and Detection. In the first step (Pre-processing) the input data are transformed into a pre-defined format in accordance with the targeted ML model. In the next step (Training) a machine learning model it trained utilizing the normal (or abnormal) pre-processed data or features. Finally, in the third step (Detection) and since the model training is completed, unobserved data will be fed as an input while the sensor will evaluate them whether they constitute normal or abnormal traffic. In the second case, a security event will be triggered.

To train itself on the collected data, the SiVi ML sensor includes several Machine Learning and Deep Learning (DL) methods while it also uses a MINMAX scaling to [0, 1] as a pre-processing step. Table 34 presents the available methods used by SiVi ML sensor as well as the three different approaches applied for anomaly detection.

ML/DL Methods / ML/DL Approach	Supervised Learning[1]	Semi-supervised Learning[2]	Unsupervised learning[3]
Logistic Regression	√		
Linear Discriminant Analysis (LDA)	√	√	√
Decision Tree	√		
Naive Bayes	√		
Support Vector Machine (SVM)	√	√	√ (one class SVM)
Random Forest (RF)	√	√	√ (isolation RF)
Multi-Layer Perceptron (MLP)	√	√	√
Adaboost / GradientBoosting	√		
Quadratic Discriminant Analysis	√	√	√
Dense Deep Neural Network (DNN) Relu [27]	√	√	√
Dense Deep Neural Network (DNN) Tanh [27]	√	√	√

Table 34: SiVi ML Sensor available training methods

After the training stage, a comparative analysis will take place and the SiVi ML sensor will adopt one or two models that outperform the training set. To perform the comparative analysis, the following metrics will be used to evaluate the trained models:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$$

$$True\ Positive\ Rate\ (TPR) = \frac{TP}{TP+FN}$$

$$True\ Negative\ Rate\ (TNR) = \frac{TN}{TN+FP}$$

$$False\ Positive\ Rate\ (FPR) = \frac{FP}{FP+TN}$$

$$F1 = \frac{2TP}{2TP+FP+FN}$$

where implies the number of the correct classifications that classified the cyberattacks as a malicious/anomalous behaviour, signifies the number of the correct classifications that classified the normal behaviours as normal, denotes the number of the mistaken classifications that recognised normal behaviours

[1] Classification approach on labelled data, available as "normal" and "abnormal" or in the case of multiple classes as “normal”, “abnormal 1”, “abnormal 2”, etc.

[2] Build a model representing normal data samples (e.g. network traffic) from a given normal training data, and then evaluate the deviation of a test sample from the learnt model

[3] Clustering approach on unlabeled data assuming that the majority of the instances are normal

as malicious/anomalous and defines the number of the wrong classifications that classified the malicious/anomalous behaviours as normal.

Visualization Engine:

The second functionality that SiVi implements refers to the "Visualization Engine" component. Visualization tools are used to interpret large amounts of data and provide helpful insights from complex logs thus enhancing the decision making. SiVi provides a dynamic dashboard where the network operator can create custom visualization widgets by selecting different data types and multiple features. The SiVi users can create dynamic and personalized dashboard with several historical and real-time visualization widgets. The available widget types are Line charts, Bar charts, Area charts, Scatter 2D charts, Pie and Donut charts. Finally, the "Visualization Engine" can be easily configured to support several kinds of information and not only network flows thus be used as a general-purpose visualization engine. Finally, the "Visualization Engine" can be easily configured to support several kinds of information and not only network flows thus be used as a general-purpose visualization tool.

In conclusion, SiVi implements a series of ML algorithms, realizing both supervised and unsupervised techniques to create security events and timely inform the CII operator for security attacks with divesting results. The ML algorithms are periodically updated with new attack taxonomies offering a constantly growing layer of protection.

In the context of RESPOND-A system architecture, the input of the SiVi **"Security monitoring and analysis mechanism"** component consists of network packets transmitted over the "5G Core Network" component. The input packets will be translated into network flows as they will be evaluated to timely notify the network operator in the case an anomaly is detected. The output of the aforementioned procedure comes in a form of security events in a predefined schema able to support a variety of data formats (e.g. JSON, XML, etc.). The SiVi **"Visualization Engine"** component will use the same input as the "Security monitoring and analysis" component to provide the operators with useful visualization dashboards and widgets. In the PCS, the outputs will be depicted in SiVi's dashboard as a MCX service while also the results will be shared to the rest of the components/tools through the Data Format Fusion and Source Management component.

4.6 System Tools in Mission

RESPOND-A aims to leverage collaboration and coordination of FRs during the Decision Making process. It delivers multiple tools and technologies to support FRs which offer a specific feature used at a specific time for a dedicated purpose (e.g. Infrared Camera before entering a place). RESPOND-A goal is to allow a full collaboration and coordination between all FRs engaged who have defined mission to follow.

An important step to this direction is the MCX connectivity above the 5G network (which is part of scope of work of WP5) offering efficient collaboration and coordination between different groups of tools and the DFF utilization for data fusion from different sources. RESPOND-A platform embeds MCX solutions used by native 3GPP MCS tools to deliver resilient and efficient tools for coordination (MC-PTT (audio), MC-VIDEO (video) or MC-DATA). In order to foster the collaboration, the MCX solutions delivers interfaces to make non-native 3GPP-MCS tools ready to use MCX services, by offering "Best-Offer" Quality of Services for different type of communication (e.g. data collection, video transmission etc.) or implementation of MCS based communication technology (e.g. integration of MC-PTT for tools using voice or MC-DATA for mapping and positioning etc.).

More specifically, the MCX platform offers several APIs and interfaces in order to integrate different tools and technologies which can then be used together during a given mission and take part in the same MCPTT (voice), MCVideo (video) and MCData (messaging and location) communications:

- For MCS native application (3GPPcompliant applications), this will be achieved thanks to the 3GPP MCX Client – Server interface (SIP-1 reference point) as defined in the 3GPP TS 23.280 standard. This interface offers the following services: chat group calls, prearranged group calls, emergency group calls, and private calls with and without floor control.
- For third party applications, this will be achieved using MCS APIs. These APIs are based on REST principles and architecture and each endpoint of the APIs returns a JSON response. They provide user authentication and authorization based on the OpenID Connect open standard. After being authenticated and authorized, these MCS APIs provides both provisioning and communication services to 3rd party applications such as voice, video, messaging but also location services.

The core of the system capability for multiple tools integration is the DFF platform, which brings efficient data collection and data sharing. DFF supports inputs of various data sources and sensor types and can store in its database common format of messages and data, preserving context based information. Multiple system elements use this data for analysis and creation of the final information required for the officers and the operating FRs. Techniques like data homogenization/harmonization, and source management will enable effective, real time and two-way data communication between users and devices. The integrated components of DFF, fuse the information, and keep it available to any other tool of the Respond-A system through a RESTfull API.

While Respond-A offers a group of new technologies and solutions, not all of them are meant to be used by every FR. Each FR staff, will use some of the tools, depending on his specialty, rank and mission. The firefighter for example has different technology needs and limitations from the paramedic. Table 35 shows the total tools of Respond-A that will be carried and the applications that will be used by all the different groups of FRs.

#	Equipment carried and Applications used by the FRs	Hardware/ Application	FR group (Firefighters, paramedics, police etc.)	Weight (g)	Necessity (Optional/ Mandatory)
1	Data Logger	Hardware	All FRs	300 g	Mandatory
2	Sensor: Toxic gases detection	Hardware	All FRs	150 g	Optional
3	Sensor: Radiation detection	Hardware	All FRs	50 g	Optional
4	T&T Ruggedized tagger	Hardware	Firefighters / heavy PPE units	300g	Mandatory
5	Android 5G mobile device	Hardware	All FRs	~250g	Mandatory
6	Tag & Trace (T&T)	Application	Paramedics and 'forensic collector'	0g	Mandatory
7	T&T tags	Hardware	Firefighters and paramedics	15g each	Mandatory

8	Vest for physiological signal monitoring	Hardware	All FRs	250 g	Mandatory
9	XBELLO	Application	All FRs	0g	Mandatory
10	VR360 Video Platform	Web App / PC / mobile device	(Potentially) All FRs	~200g	Optional
11	Tactical Backpack (4-5G)	Hardware	(Potentially) All FRs	10-15 Kg	Optional
12	Tracking system (indoors)	Hardware/ Application	All FRs	<500g	Optional
13	AR Glasses	Hardware	All FRs	~150 g	Optional
14	LBRS	Application	All FRs	0 g	Optional
15	Thermal Camera	Hardware	Firefighters	34.5	Optional
16	Sensors: heat stroke	Hardware	All FRs	50gr	Mandatory
17	MCX client	Application	All FRs	0 g	Mandatory
18	Sensors: CO blood poisoning + Alarm mechanism	Hardware	All FRs	120gr	Mandatory

Table 35: Tools carried and applications used by FRs in the field

Even in the same group of FRs, not everyone will use the same technology. One person from the group may have the thermal camera, while another one will have the T&T Ruggedized tagger, according to the role of each group member. This way, the FRs will have to carry a reasonable amount of equipment that will weight just some grams and will not make their mission too complicated. Furthermore, tools trainings will have proceeded the rescue operations, using specialized training tools in order the FRs to be fully familiar with the offered technology and be ready to use it effectively.

As a preliminary example, in a possible earthquake incident (Greek use case – 1st scenario [3]) the Respond-A platform and the firefighters group may realize the following functions and steps:

1. The mobile Respond-A platform, implemented in a van, approaches the incident area and creates a 5G connectivity "bubble" to cover the wider area of operation.
2. A UAV connected to the 5G network and managed by the smart fleet management module flies around, sends video stream to the video platform in the van. The officers watch the video on the big screen and detect the Regions of Interest (ROI) (e.g. a building on fire).
3. All the members of the firefighters group, beyond their standard equipment, get equipped with the Respond-A tools, like vests with body sensors and data logger and smartphones for running the group communications/positioning applications (e.g. MCX client, XBELLO, LBRS). Some of them will use some extra tools, for special functions, having a specific role in the team. So one team member may also carry the thermal camera for vision through smoke, a second one the AR glasses for receiving specialized information and a third one may use the 360 camera system. That way, each FR is not expected to carry more than 1-2 Kg of equipment or to use multiple and complex applications.
4. Ground autonomous robot (managed again from the smart fleet management module and communicating through the 5G network) enters and scans the damaged building, offering mapping of the interior area. The data reaches the C&C center in the van and the officers evaluate the data (COP module).

5. The officers, using the MCX group communications and the CC applications, command the firefighters to enter the building. The mapping info, enhanced with other data as well (e.g. number of floors, estimated trapped people etc.) are sent back to the operating FRs in the field, using the group communication applications (e.g. MAESTRO, MCX etc.), through the 5G network that has been created. This applications allows the officers to send also specialized directions to certain FRs.
6. The FR who carries the thermal camera enters first and sends through 5G the video stream to the video platform of the van. The video processed by AR application framework gets enhanced with more data is sent back to all the FRs operating in the field.
7. The FRs group can now navigate through smoke (using the received thermal video stream on their mobiles or the AR glasses) and detect the trapped victim.
8. The victim gets tagged for transmitting crucial health and positioning data (using the Triage platform) and is transferred out of the burning building.
9. Throughout the whole operation, the Respond-A platform ensures the data security, using modules like the Anomaly detection for possible network attacks and the smooth services management, using modules like DFF for data fusion and Virtualized Resource Coordination for optimum resource management.

A pre-trail demo was held in Athens in June 2021, where a scenario, like the one previously described, was realized and many of the aforementioned technologies were tested. Important adjustments/modifications, better fine-tuning, more defined and clear integration level will be achieved during the implementation and evaluation phase of the project, where tests will take place and feedback from the lab and field trials will be collected.

5. Conclusion

Deliverable 2.2 (D2.2) presents the RESPOND-A System Architecture and the tools specifications and requirements. It is the output of Task 2.2 of WP2, where taking as an input the FRs Requirements (D2.1), as well as the Use Cases (D2.3) and DoA requirements and constraints, produced all the necessary architecture components for realizing the RESPOND-A platform.

In Chapter 2 the methodology, the input requirements and constraints were explained and presented, while in Chapter 3 the system architecture was analyzed, offering a first overview as well as a deeper insight of the system. The RESPOND-A deployable platform, that includes the Mobile C&C Centre and the Communication Infrastructure, was presented and explained, as well as the field technologies that will be used by the FRs in action. Chapter 4 presented and analyzed the system tools specifications and requirements. Specifically, section 4.1 presented the Wearable Sensors and Equipment, section 4.2 the Unmanned Vehicles Systems and Equipment, section 4.3 the AR/VR systems, section 4.4 the Mission Management and COP tools, and section 4.5 the Communications, Security and Data Management tools.

In an emergency scenario, several units of FRs (e.g. paramedics, fire-fighters, police etc.) get in action, each one having different needs and requirements, while the incident itself requires appropriate operation management, which is not common in every case (e.g. earthquake, forest fire etc.). The main challenge of the work of T2.2 was to bring together all the technologies and expertise of each partner, creating a unified system, providing tools integration and interoperability, towards the support of the FRs missions and lives.

This deliverable will act as a basis for the development team of RESPOND-A project to successfully develop and combine all necessary tools and mechanisms towards a unified and flexible platform for supporting and optimized FRs safety and mission accomplishment. As this task has run in the first year of the project, the work has been done was mainly based in a theoretical level, resulting to possible future changes or deviations from the initial plan, as the work continues, and this is the main risk of this task. However, the potential deviation is beneficial as it will act as a fine tuning for the system, offering effective tools integration and optimized system performance.

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ANNEX I – TOOLS-TO-FIRST RESPONDERS REQUIREMENTS MAPPING

Req. ID	Description	Priority	WP3			WP4				WP5					Responsible partner(s)				
			T3.1	T3.2	T3.3	T4.1	T4.2	T4.3	T4.4	T5.1	T5.2	T5.3	T5.4	T5.5	Partner	Main Tool	Other	Other	Other
OR01	A command-and-control centre shall be used for ensuring the successful outcome of a First Responder's operation	*Must Have*											x		VICOM	GEOVISLAYER/ FLEXCONTROL	MAESTRO	XBELLO	
OR02	The coordination of activities between different groups of First Responders during operations shall be supported by a Command-and-Control centre.	*Must Have*											x		IANUS	MAESTRO	MMM	XBELLO	MCX MOBILE MISSION MANAGEMENT
OR03	A command-and-control centre shall provide functionalities relating to:																		

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OR03 .1	Visualization of data relating to the operation (e.g., type of incident, map of incident location, first responder groups on scene)	*Must Have*					x		x				x		IANUS	MAESTRO	XBELLO	GEOVISL AYER	SiVi
OR03 .2	Establishment of a Common Operational Picture between First Responders and Command-and-Control centre (e.g., information sharing regarding the operation parameters)	*Must Have*					x		x					x	PROBO	AiRFLOW - MCC	Cyclops	XBELLO	siVi
OR03 .3	Mission Management (e.g., tracking and monitoring of equipment, coordination of resources between different groups of First Responders)	*Must Have*					x		x				x		IANUS	MAESTRO	XBELLO		SiVi (passive monitoring)

OR03 .4	Data Source Management capabilities for contextual data processing and fusion	*Must Have*									x			8BELLS	DATA FORMAT FUSION			
OR03 .5	Victim localization and tracking	*Must Have*										x		PRO (VICOM)	GEOVISLAYER	Localizatio n Services	Triage Platform	XBELLO
OR03 .6	First Responder localization and tracking	*Must Have*						x				x		VICOM, I2CAT	GEOVISLAYER	Localizatio n Services	MAESTR O	XBELLO
OR03 .7	First Responder health status (including biometrics)	*Shoul d Have*										x		PRO (VICOM)	GEOVISLAYER	Localizatio n Services	Triage Platform	
OR03 .10	Live traffic information	*Shoul d Have*																
OR03 .11	An estimative quantification of the magnitude of the accident (e.g., m2 or ha for an oil spill or a fire)	*Coul d Have*				x		x					x	PROBO	MCC with CYCLOPS AI			
OR04	A mission management system shall be able to support functionalities relating to:																	

OR04.1	Risk assessment, risk dynamics and incident quantification	*Should Have*							x					x	PROBO	CYCLOPS AI			
OR04.2	Cataloguing and location of necessary equipment	*Must Have*					x		x				x		VICOM	GEOVISLAYER	XBELLO	sivi (not tested in cellular)	
OR04.3	Coordination of operations and resources between different groups of First Responders and their action plans	*Must Have*					x						x		IANUS	MAESTRO	XBELLO	MMM	sivi (passive monitoring)
OR04.4	Tracking of victims and property damage	*Should Have*											x		PRO (VICOM)	GEOVISLAYER	Triage Platform		
OR05	A mission management system shall be able support the exchange of information relating to:																		
OR05.1	· Location, type and severity of incident	*Must Have*										x			8BELLS	DATA FORMAT FUSION			
OR05.2	· Location and action plans of different groups of First Responders	*Must Have*										x			8BELLS	DATA FORMAT FUSION			

OR05 .3	· Location and status of equipment	*Must Have*					x		x			x			8BELLS	DATA FORMAT FUSION	sivi (location not tested in cellular)		
OR05 .4	· Location and medical status of victims	*Should Have*										x			8BELLS	DATA FORMAT FUSION			
OR05 .5	· Location and extend of damage of property	*Should Have*										x			8BELLS	DATA FORMAT FUSION			
OR06	A Common Operational Picture shall be established for operation planning, by providing to First Responders information relating to:																		
OR06 .1	· Early warnings and alert about potential incidents	*Should Have*						x						x	PROBO	CYCLOPS AI	XBELLO		
OR06 .2	· Location and type of incident	*Must Have*					x	x						x	PROBO	MCC with CYCLOPS AI	XBELLO		
OR06 .3	· Existence of injuries, casualties	*Must Have*						x						x	PROBO	CYCLOPS AI			
OR06 .4	· Damage to property, public infrastructure	*Should Have*					x	x						x	PROBO	CYCLOPS AI			

OR07	A victim localization and tracking system shall be able to support functionalities relating to:																		
OR07 .1	· Collection of victim profile (e.g., age, sex, status, medical history)	*Must Have*		x											PRO	Triage Platform			
OR07 .2	· Location of victim (e.g., GPS coordinates, street address, distance to nearest hospital)	*Must Have*										X			IANUS, PRO	MAESTRO	Triage Platform		
OR07 .3	· Data exchanges with relevant agencies (e.g., hospitals, civil protection agencies, law enforcement, firefighters)	*Must Have*										X			IANUS, PRO	MAESTRO	Triage Platform		
OR08	Secure and reliable communication channels shall be established during operations between:																		
OR08 .1	· Command-and-control centre(s) and First Responders on the scene	*Must Have*					x		x		x				ADS	MCX MOBILE MISSION MANAGEMEN T	XBELLO	SiVi (passive monitori ng)	

OR08.2	· Different groups of First Responders on the scene (e.g., police and firefighters)	*Must Have*					x		x		x				ADS	MCX MOBILE MISSION MANAGEMENT	XBELLO	SiVi (passive monitoring)	
OR08.3	· Command-and-control centre(s) and UxVs (e.g., drones, robots)	*Must Have*				x	x		x		x				ATM	PLANET		SiVi (passive monitoring)	
OR08.4	· First Responders on the scene and UxVs (e.g., drones, robots)	*Should Have*				x	x		x		x				ATM	PLANET		SiVi (passive monitoring)	
OR08.5	· Command-and-control centre(s) and wearable sensors (e.g., vital monitoring vest)	*Must Have*		x			x		x		x				HI	Data Logger (as emitter)		SiVi (passive monitoring)	
OR08.6	· First Responders on the scene and wearable sensors (e.g., vital monitoring vest)	*Should Have*		x			x		x		x				HI	Data Logger (as receiver)		SiVi (passive monitoring)	
OR09	The communication infrastructure used during operations shall be able to support the																		

	exchange of the data relating to:																		
OR09.1	· Text	*Should Have*								x				ADS	MC-DATA			XBELLO
OR09.2	· Voice	*Must Have*								x				ADS	MC-PTT			XBELLO
OR09.3	· Image	*Must Have*								x				ADS	MC-DATA			XBELLO
OR09.4	· Video	*Should Have*								x				ADS	MC-VIDEO			XBELLO
OR09.5	· Satellite data for location-based services (e.g., GPS signal)	*Must Have*								x				I2CAT				
OR09.6	· Virtual reality (VR) applications	*Could Have*								x								
OR09.7	· Augmented reality (AR) applications	*Could Have*								x						MCX AUGMENTED EXPERT		
OR09.8	· Alert signals	*Must Have*		x						x				HI	Data Logger			XBELLO
OR09.9	· Device metadata (e.g., metadata from sensors)	*Must Have*		x						x				HI	Data Logger			

OR10	The area in which a First Responder operation takes place shall have adequate cellular network coverage.	*Must Have*									x				ADS, NCSRD		5G system		
OR11	The communication infrastructure used during operations shall allow high-speed data exchanges.	*Must Have*									x				ADS, NCSRD		5G system		
OR12	Communication between First Responders during operations in areas with limited or no cellular network coverage shall be supported by:																		
OR12 .1	· Push-to-talk radios (e.g., VHF, UHF, HF, SIMPLEX)	*Must Have*																	
OR12 .2	· Repeaters, aerial relays	*Could Have*				x					x				ATM, SPI				
OR12 .3	· Mobile cellular transmitters, towers	*Should Have*									x				NCSRD, ATH, ADS	5G system			

OR13	Incident (call-to-action) notifications to First Responders shall be able to be communicated by:																		
OR13.1	• Phone call from civilians to emergency number	*Must Have*																	
OR13.2	• Phone call or radio notification from Emergency number operators or other First Responder organisation(s)	*Must Have*																	
OR13.3	• Email from civilians	*Could Have*																	
OR13.4	• Specialised means of communication (e.g., VTS for marine vessels and port authorities)	*Could Have*																	
OR14	The minimum necessary communication infrastructure for the deployment of mobile Command-and-Control																		

	centers shall be able to support:																		
OR14 .1	· 4G broadband cellular network coverage	*Must Have*								x				ADS, NCSRD		4G system		
OR14 .2	· 5G broadband cellular network coverage	*Could Have*								x				ADS, NCSRD		5G system		
OR15	During operations, the deployment of unmanned aerial platforms (e.g., drones) shall be supported	*Must Have*				x								ATM, SPI	DRONES			
OR16	During operations, the deployment of robots shall be supported	*Should Have*					x							VAL	DRONSTER			
OR17	The minimum necessary additional resources for the deployment of UxVs during operations shall consist of:																	
OR17 .1	· Dedicated personnel to handle UxV	*Must Have*				x								ATM	-			

OR17 .2	· 4G broadband cellular network coverage	*Must Have*				x									ATM	PLANET			
OR17 .3	· Satellite link for communications	*Should Have*				x									ATM	PLANET			
OR18	UxVs deployed during First Responder operations shall be able to support the following functionalities:																		
OR18 .1	· Image capture from incident area	*Must Have*				x									ATM	DRONES	PLANET		
OR18 .2	· Video feed from the incident area	*Must Have*				x									ATM, i2CAT	DRONES	360 CAMERA	PLANET	
OR18 .3	· Localisation (e.g., GPS coordinates) of victim(s) or infrastructure	*Could Have*				x									ATM, i2CAT	DRONES	ULTRA-WIDE BAND	PLANET	
OR18 .4	· Data feed from specialised sensors (e.g., thermal imaging)	*Could Have*				x									ATM	DRONES	PLANET		
OR18 .5	· Telemetry data transmission	*Could Have*				x									ATM	DRONES	PLANET		
OR19	The definition of the flight plan of an unmanned aerial																		

	platform during First Responder operations, shall be able to account for:																		
OR19 .1	· The altitude, above ground level (AGL) of the intended flight path	*Should Have*					x								PROBO				
OR19 .2	· The duration of the flight plan	*Must Have*					x								PROBO				
OR19 .3	· The features of the operational environment (e.g., urban environment, air traffic)	*Must Have*					x								PROBO				
OR19 .4	· The conditions of the operational environment (e.g., wind speed, temperature)	*Must Have*					x								PROBO				
OR20	On-body sensors for tracking the position of First Responders shall be available and	*Should Have*	x												I2CAT				

	functional during operations.																		
OR21	On-body sensors for tracking the vital signs of First Responders shall be available and functional during operations.	*Should Have*	x												STX, HI, VAL	wearable sensors			
OR22	Helmets with augmented reality data (AR) displays shall be available and functional during First Responder operations.	*Should Have*	x							x					VICOM (PRO) , HI, NCSRD	Casualty Health Record Display	Thermal Camera		
OR23	augmented reality headsets with augmented reality data (AR) displays shall be available and functional during First Responder training.	*Should Have*	x							x			x		0INF , HI	XR2T (MIXED REALITY TRAINING TOOL)			

OR24	Virtual reality (VR) goggles shall be available and functional during First Responder operations.	*Could Have*							x						I2CAT				
OR25	Virtual reality (VR) goggles shall be available and functional during First Responder training.	*Should Have*								x					0INF	XR2T (MIXED REALITY TRAINING TOOL)			
OR26	During First Responder operations, on-body sensors shall be able to track parameters related to:																		
OR26.1	· Electrocardiography (ECG)	*Could Have*	x												STX	Wearable sensors			
OR26.2	· Heart rate	*Should Have*	x												STX	Wearable sensors			
OR26.3	· Breathing	*Could Have*	x												STX	Wearable sensors			
OR26.4	· Breath rate	*Should Have*	x												STX	Wearable sensors			
OR26.5	· Body posture (e.g., laying, standing)	*Must Have*	x												STX	Wearable sensors			

OR26.6	· Activity classification (e.g., standing still, walking, running)	*Should Have*	x												STX	Wearable sensors			
OR26.7	· Body temperature	*Must Have*	x												VAL	Wearable sensors (Heat Stroke advice System)			
OR26.8	· Blood oxygenation	*Must Have*	x												VAL	Wearable sensors (CO advice System)			
OR26.9	· Radiological dose of the environment	*Must Have*			x										HI	Wearable sensors			
OR26.10	· Chemical contamination of the environment	*Must Have*			x										HI	Wearable sensors			
OR27	During First Responder operations, a triage system shall be able to track data related to:																		
OR27.1	· Timestamp of first contact with the victim	*Must Have*	x												PRO	Triage platform			
OR27.2	· Location of the victim	*Must Have*	x												PRO	Triage platform			

OR27.3	· Triage classification of the victim (code or colour)	*Must Have*	x												PRO	Triage platform			
OR27.4	· Vital signs of the victim	*Must Have*	x												PRO	Triage platform			
OR27.5	· Treatment(s), medication(s) administered	*Should Have*	x												PRO	Triage platform			
OR27.6	· Injuries sustained	*Must Have*	x												PRO	Triage platform			
OR27.7	· Name, age, gender of the victim	*Must Have*	x												PRO	Triage platform			
OR27.8	· Medical history of the victim	*Should Have*	x												PRO	Triage platform			
OR27.9	· Known allergies of the victim	*Should Have*	x												PRO	Triage platform			
OR27.10	· Contamination (chemical or otherwise)	*Must Have*	x												PRO	Triage platform			
OR27.11	· Aggregate numbers, statistics about the number of victims on the scene	*Should Have*	x												PRO	Triage platform			

OR27 .12	· Breakdown of victim numbers per triage classification	*Must Have*	x												PRO	Triage platform			
OR27 .13	· Breakdown of victim numbers per age group	*Should Have*	x												PRO	Triage platform			
OR27 .14	· Breakdown of victim numbers per gender	*Should Have*	x												PRO	Triage platform			
OR28	The minimum necessary additional resources for the deployment of a triage system during operations shall consist of:																		
OR28 .1	· Broadband internet access	*Must Have*																	
OR28 .2	· Integration with third party systems (e.g., VTMIS) for provision of services (e.g., location tracking)	*Could Have*																	

OR28.3	· Compliance with existing, established triage protocols of First Responder organisations	*Could Have*																	
OR29	During First Responder operations, a triage system shall be operated by:																		
OR29.1	· Medical personnel	*Must Have*		x											PRO	Triage platform			
OR29.2	· Fire fighters	*Must Have*		x											PRO	Triage platform			
OR29.3	· Other search and rescue personnel (e.g., SAR, MRCC)	*Could Have*		x											PRO	Triage platform			
OR30	Relevant smartphone applications shall be able to be used by First Responders during operations, without impeding their activities.	*Could Have*								x					VICOM, NCSRD	Localization Services	Thermal Camera	MCX augmented RealityTool	

OR31	Helmets shall be able to be used by First Responders during operations, without impeding their activities.	*Must Have*	x							x					VICOM (PRO), HI	Casualty Health Record Display			
OR32	Virtual reality (VR) goggles shall be able to be used by First Responders during operations, without impeding their activities.	*Could Have*							x						I2CAT				
OR33	Helmets with augmented reality (AR) data displays shall be able to be used by First Responders during operations, without impeding their activities.	*Could Have*	x							x					VICOM (PRO), HI, NCSRD	Casualty Health Record Display	Thermal Camera		

OR34	Real-time 360º video shall be accessible during First Responder operations	*Should Have*							x						I2CAT				
OR35	A real-time 360º video platform shall be able to provide:																		
OR35 .1	· High-quality video feed	*Must Have*							x						I2CAT				
OR35 .2	· Ability to zoom on video	*Must Have*							x						I2CAT				
OR35 .3	· Dynamic switching between different camera angles	*Should Have*							x						I2CAT				
OR35 .4	· Ability to freely explore the omnidirectional operational environment	*Should Have*							x						I2CAT				
OR35 .5	· Ability to collaboratively inspect the same video feed with other remotely located First Responders	*Should Have*							x						I2CAT				

OR35.6	· Ability to communicate via audio with other collaborators when inspecting the available video feeds	*Should Have*							x						I2CAT				
OR35.7	· Ability to access the video feed on traditional desktop-based displays	*Must Have*							x						I2CAT				
OR35.8	· Ability to access the video feed on VR displays (e.g., VR goggles)	*Should Have*							x						I2CAT				