ASSISTANCE

Adapted situation awareneSS tools and tailored training curricula for increaSing capabiliTies and enhANcing the proteCtion of first respondErs

European Commission

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Deliverable D4.1

ASSISTANCE Adapted Unmanned Platforms

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[1] PU: Public; PP: Restricted to other programme participants (including the EC services); RE: Restricted to a group specified by the Consortium (including the EC services); CO: Confidential, only for members of the Consortium (including the EC services).

ASSISTANCE

Nowadays different first responder (FR) organizations cooperate together to face large and complex disasters that in some cases can be amplified due to new threats such as climate change in case of natural disasters (e.g. larger and more frequent floods and wildfires, etc) or the increase of radicalization in case of man-made disasters (e.g. arsonists that burn European forests, terrorist attacks coordinated across multiple European cities).

The impact of large disasters like these could have disastrous consequences for the European Member States and affect social well-being on a global level. Each type of FR organization (e.g. medical emergency services, fire and rescue services, law enforcement teams, civil protection professionals, etc.) that mitigate these kinds of events are exposed to unexpected dangers and new threats that can severely affect their personal safety.

ASSISTANCE proposes a holistic solution that will adapt a well-tested situation awareness (SA) application as the core of a wider SA platform. The new ASSISTANCE platform is capable of offering different configuration modes for providing the tailored information needed by each FR organization while they work together to mitigate the disaster (e.g. real-time video and resources location for firefighters, evacuation route status for emergency health services and so on).

With this solution, ASSISTANCE will enhance the SA of the responding organisations during their mitigation activities through the integration of new paradigms, tools and technologies (e.g. drones/robots equipped with a range of sensors, robust communications capabilities, etc.) with the main objective of increasing both their protection and their efficiency.

ASSISTANCE will also improve the skills and capabilities of the FRs through the establishment of a European advanced training network that will provide tailored training based on new learning approaches (e.g. virtual, mixed and/or augmented reality) adapted to each type of FR organizational need and the possibility of sharing virtual training environments, exchanging experiences and actuation procedures.

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Disclaimer

Executive Summary

This Deliverable provides a clear description of the unmanned platforms that have been selected for the pilots in the ASSISTANCE project and the required adaptations and modification, so the robots fulfil with requirements imposed for each scenario.

The main specifications of the robots, both aerial platform and ground plaforms, are described in the document, as well as the sensors that each robot mounts. This document will help the reader to understand how the robots will look like during the pilots, since it contains a detailed description of every component integrated into the robots.

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Change control datasheet

Version	Changes	Chapters	Pages	Date
0.1	First draft	All	41	31/03/20
0.2	UGV added			

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Acronyms

ASSISTANCE	Adapted situation awareneSS tools and taIlored training curricula for increaSing capabiliTie and enhANcing the proteCtion of first respondErs
C2	Command and Control
COTS	Commercial Off-The-Shelf
D#.#	Deliverable number #.# (D1.1 deliverable 1 of work package 1)
FPV	First Person View
FR	First Responder
GCS	Ground Control Station
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMI	Human Machine Interface
IR	Infrared
KPI	Key Performance Indicator
MMM	Mission Management Module
MTOW	Maximum Take-Off Weight
PC	Computer
RC	Radio Control
RTK	Real-Time Kinematic
RPA	Remotely Piloted Aircraft
SA	Situation Awareness
SAS	Sensors Abstraction Service
UxV	Unmanned Vehicle
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
WP	Work Package

1 Introduction

This document describes the physical solutions adopted by unmanned platforms providers according to task 4.1 guidelines.

Based on the information from WP2, the most suitable solutions will be selected. The choice of unmanned platforms shall be made on the basis of external conditions (such as type of terrain or space, the endurance of the platform, payload type and weight, size and weight of the platform, autonomy, etc.) and functional requirements to be met by each pilot. It is possible that the choice of the platforms will not allow complying with all the requirements and functionalities foreseen for the ASSISTANCE project, so it will be necessary to make modifications in order to adapt them to the needs of the project. These modifications may be at the mechanical level of the platforms, or at the software level, or even at the electrical integration level.

1.1 Purpose of the document

The main purpose of this deliverable is to describe the unmanned platforms selected by involved partners in order to carry out the tasks to be performed on each of the pilots. In the document, there are details of the platform choices made and the modifications required based on the scenarios described in deliverable D2.3. Two types of platform are to be defined: a ground platform and an aerial platform.

The ground platform must be equipped with the necessary interfaces to integrate the necessary sensors and other devices detailed in the document. These interfaces must be bi-directional so that the operator can control these additional devices if desired. The modifications will be made with the aim of maintaining modularity in the solution so that it is easy to change the payload if a change in the scenario or use case is needed.

As for the aerial platform, it is important to know in advance which are the functionalities that the drone must perform and what type of payload it must integrate to make a good choice of the platform. The size and weight of the aerial platform is a fundamental factor, for example, for obtaining the flight permits.

The flight of drones is an action that is increasingly being controlled by the authorities due to the risk it can pose to other airspace users as well as to people and properties on the ground. That is why European countries, as well as the European Union, are establishing rules for the operation of drones in the airspace, with a number of restrictions that must be complied with. In this deliverable, the basic configurations for the aerial platforms are going to be defined so that all the required functionalities can be fulfilled in the different scenarios.

Hence, this deliverable covers the output of the Task 4.1 Unmanned Platforms Selection & Adaptation. In this section, the scope and objectives of this deliverable and its structure are described, together with the relationship with other ASSISTANCE work packages.

1.2 Scope

This deliverable includes the description of the unmanned platforms selected for the different pilots, being one of the fundamental tasks of WP4. Firstly, it is shown a description of the ASSISTANCE architecture and how this architecture relates to unmanned platforms, according to what was explained in D2.4.

Then the selected platforms will be defined for each of the pilots or experiments defined in deliverable D2.3. All the required modifications and adaptations, as well as the sensors, will be explained in the next sections.

1.3 Relationship with other work packages

This deliverable gets information from the following tasks:

- Task 2.2 User requirements gathering analysis and tracking
- Task 2.3 Reference scenarios, pilot operations specifications and KPIs.
- Task 3.1 Sensor Abstraction Service Adapted Interfaces Definition
- Task 3.2 Sensor Abstraction Service Adapted Interfaces Implementation
- Task 3.3 Robust Mobile Communications

The output from this task contributes to the following tasks:

- Task 4.2 UAV Management and sensors integration
- Task 4.3 Robots Management and sensors integration
- Task 4.4 Wearable Sensors Integration
- Task 4.6 Mission management
- Task 5.1 ASSISTANCE SA platform adaptation
- Task 5.2 SA advanced modules development
- Task 5.3 Robust Land Mobile Communications Infrastructure Development
- Task 5.4 Advanced Modules, SAS & Communications Infrastructure Integration in ASSISTANCE SA Platform
- Task 7.1 Validation Plan
- Task 7.2 Integrated system test bed
- Task 7.3 Pilot Demonstration

2 ASSISTANCE General architecture

The D2.4 deliverable offers the high-level description of the ASSISTANCE system, with a scheme with the role that unmanned platforms or robots are going to play (see Figure 1). In this scheme, it is possible to see how the unmanned platforms (green shaded), together with the sensors they will have to mount, are a tool that through the Sensor Abstraction Service (SAS) will provide the necessary data (telemetry, images, sensor data, etc.) to the end-users through the Human Machine Interface (HMI).

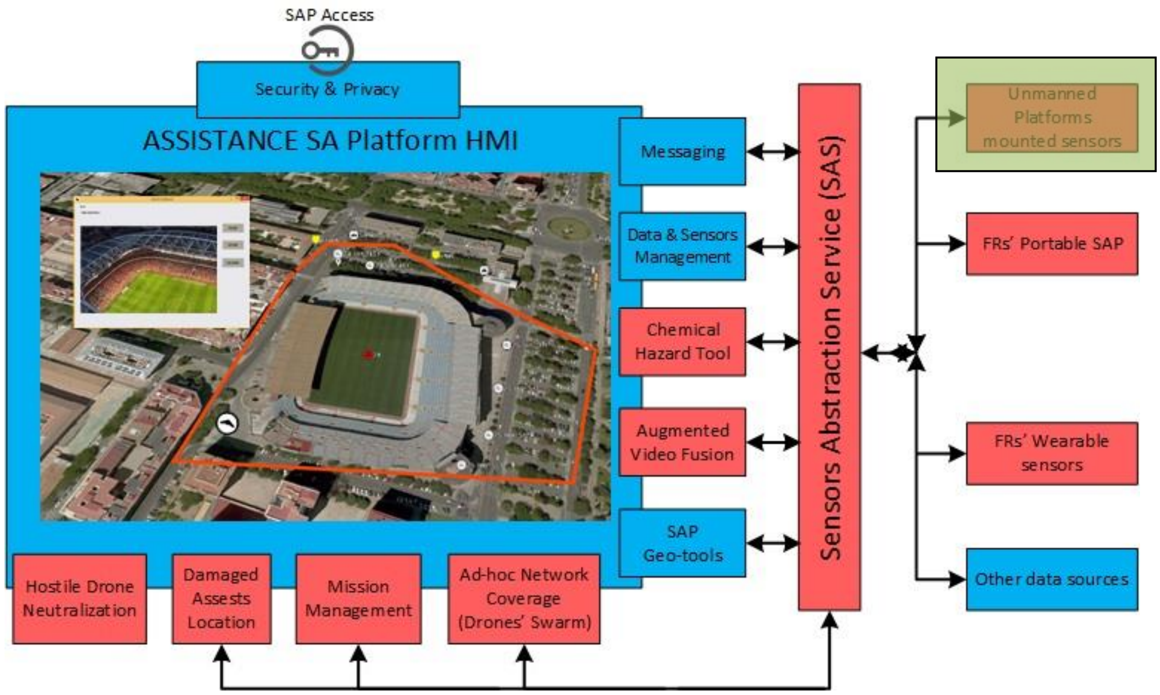

Figure 1: Platform high level design schema

As for the definition of the ASSISTANCE system architecture, Figure 2 shows the integration of all modules and components, with drones and ground robots at the top (again green shaded). In this scheme, extracted from the D2.4 deliverable, it is possible to observe the general interfaces that these unmanned platforms must have in order to exchange with the SAS, which will be the communication link with the rest of the ASSISTANCE system modules. These main interfaces are:

- Sensors data: the main sensors that the unmanned platforms will mount are:
  - Cameras: video images of the situation to the end users
  - Thermal cameras: thermal sensor to detect
  - Gas sensors: sensor to detect CO & CO2 concentration
  - Weather station: meteorological sensor for wind, temperature, humidity, etc.
  - EMF sensor: to measure electromagnetic fields
  - Gamma detector: to detect possible incoming gamma rays
- Mission data: it is necessary to exchange the flight path that the platform must go through and receive telemetry data:

- Flight path: list of waypoints that the robot must go through. This flight path is received in the robots through the SAS, from the Mission Management Module (MMM).
- Telemetry data: status data of the robot, such as position, velocity, attitude, etc. This data will be sent to the MMM through the SAS.

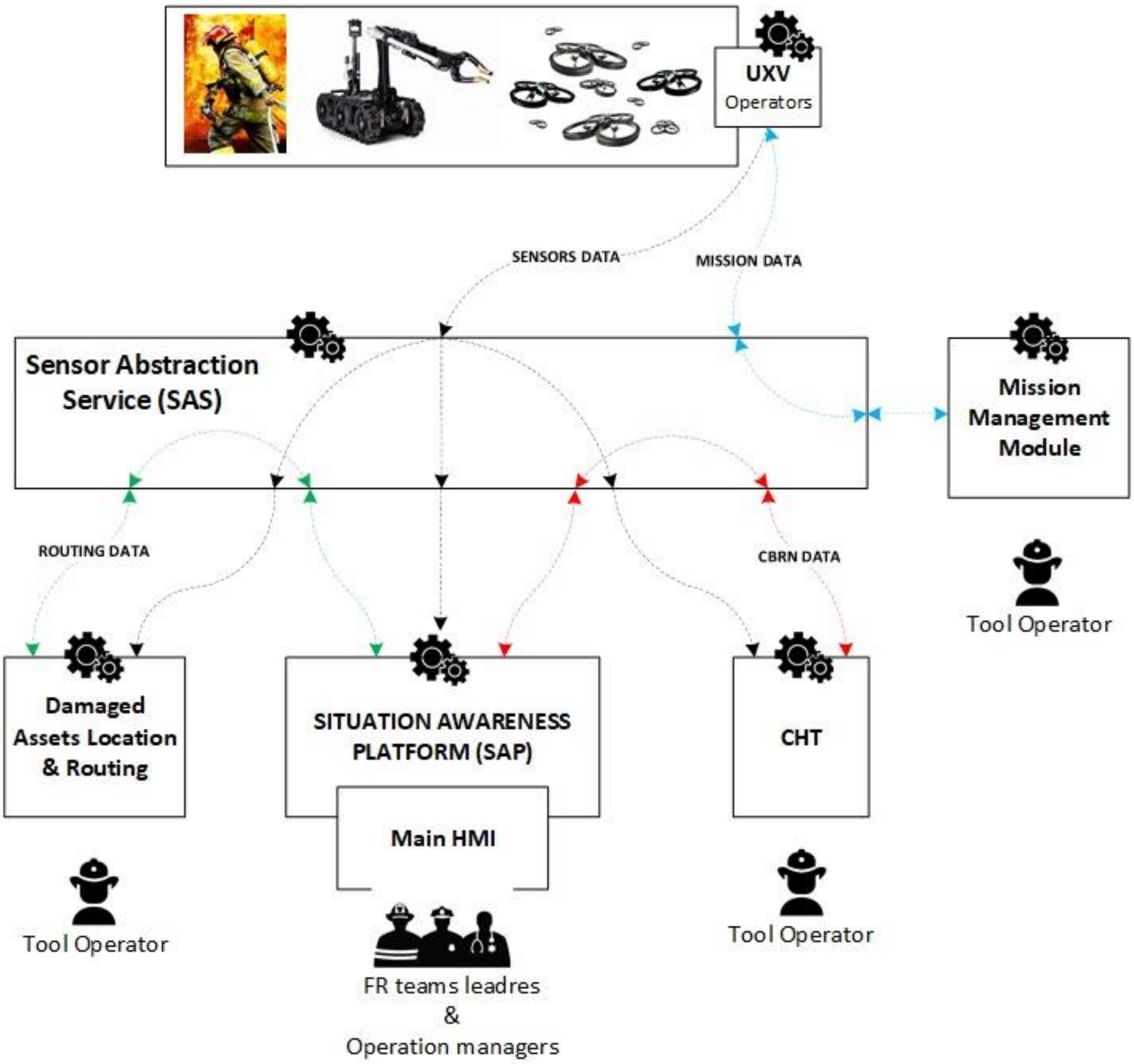

Figure 2: ASSISTANCE Architecture Scheme

Apart from what has been rescued in this section from the D2.4, it is also important to highlight as input for this deliverable the use cases and functionalities described for each of the robots being considered: ground (UGVs) and aerial (UAVs).

In the following subsections, a generic description of these two types of platforms will be made, so that the components that are basic to the operation of each one of them will be defined. That is to say, the essential elements necessary to operate a UGV and a UAV will be shown.

2.1 UAV Generics

An unmanned aerial vehicle or RPA (Remotely Piloted Aircraft) is, in general terms, an aircraft that flies without a pilot on board. The aircraft is controlled by a pilot on the ground or by an on-board computer. The very fact that the pilot is not on board means that it is necessary to have other technical mechanisms to make up for this, such as a cameras, communication link and/or a navigation system.

In the operation of a drone, three fundamental components can be distinguished: air segment (drone), ground segment (Ground Control Station – GCS) and communication link between both segments. Figure 3 shows a scheme of these components required for the operation of the drone.

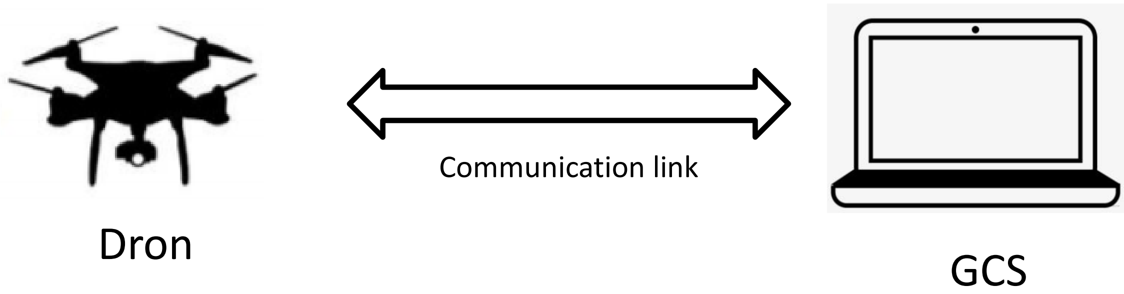

Figure 3: Main components in the operation of a drone

Air segment

The air segment (UAV) consists of three main components:

- Platform: it includes the structure, engines, servomotors, landing gear, etc.,
- Avionics: made up of all the electronic systems that allow the UAV to fly autonomously (the communications link module, the flight controller or the navigation system)
- Payload: composed of one or several sensors needed to execute the UAV's mission. The most common payload is the cameras, but there may be others such as radars, lidars, environmental sensors, etc. In this part is where the onboard PCs, sensors and the cameras required for the different scenarios are included.

The avionics, in turn, is composed of:

- The navigation system, which allows the UAV to fly autonomously, determining both its position and its attitude to fly along the pre-established route.
- The communications links enable wireless communication between the UAV and the ground control station. It is common for there to be separate communications links for command and control (commonly known as C2 - Command and Control link) and for payload. In addition, it is also important to note that these communications can be ground-to-air (direct) or via satellite (indirect).
- The flight control is in charge of controlling the active elements of the UAV (engine/s, ailerons, rudder, stabilizer, etc.) to follow the trajectory demanded by the navigation system. The autopilot is the element in charge of maintaining stability and controllability of the aircraft.
- Some examples of flight sensors are: GNSS receiver, inertial sensors, altimeters, pressure sensor, etc.

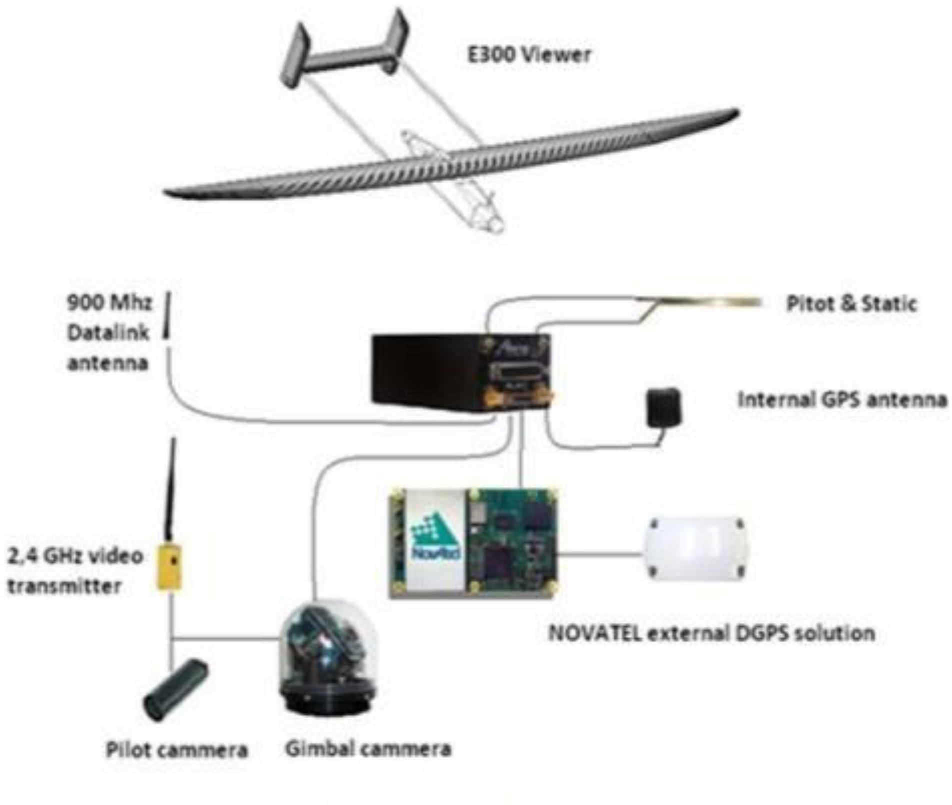

Figure 4: Example of aerial segment of a fixed wing drone

Ground segment

The ground segment consists mainly of the GCS, as well as the communications module that establishes the link with the air segment. This GCS serves as an interface for the pilot to interact with the drone by displaying telemetry (status of the drone, position on the map, speeds, attitude, etc.) and by commanding the actions that the drone must perform (execute a mission using a route of waypoints, fly in an assisted manner giving position increments or with commands in speed, command in attitude maintaining altitude, etc.)

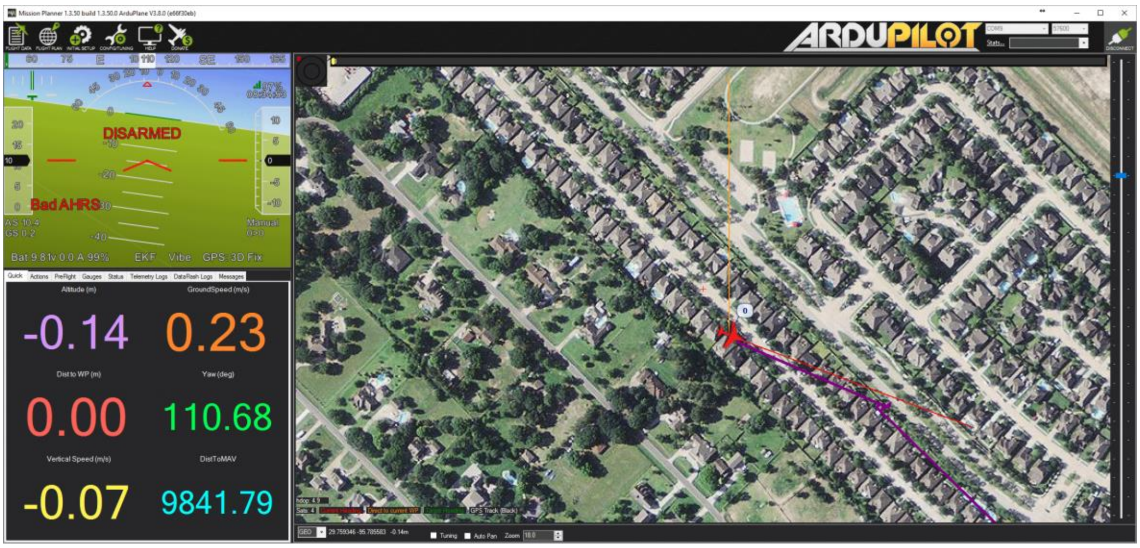

Figure 5: Example of GCS interface for the drone pilot

Communication link

Finally, the communication link between the drone and the GCS is bidirectional:

- Uplink: mission commands from the GCS to the drone, so the drone flies through the commanded list of waypoints or commands from the remote pilot. Through this link, it is also possible to send commands to the payload.

- Downlink: telemetry with the states of the drone (position, velocity, attitude, etc.), video stream from the payload camera and also data from the payload sensors.

2.2 UGV Generics

Unmanned Ground Vehicle (or UGV) have many possible applications. From security and military tasks like explosive ordinance disposal, to factory floor transport means. Wide variety of applications means wide variety of sizes, form factors and propulsion systems. With smallest UGVs weighting much less than 1kg and large ones that can weight up to several tones.

Most basic usage of UGV requires three components:

- Unmanned ground vehicle itself
- Communication link
- Human machine interface (HMI) used by operator to control robot

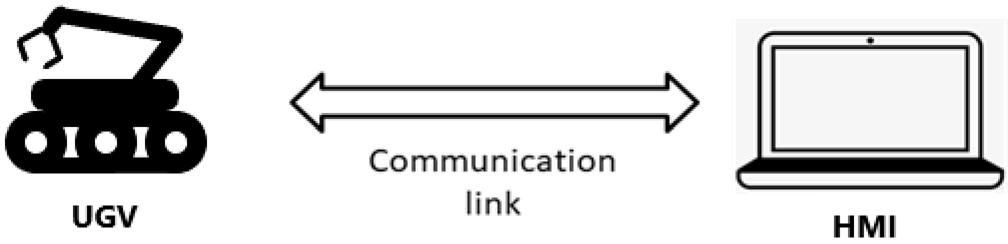

Figure 6: Main components in the operation of UGV

Most basic form of remote control is called teleoperation (or telemanipulation) and classically means constant control of operator of all robots movements (both UGV base and manipulator). For that purpose operator uses video cameras as feedback. Using direct teleoperation is feasible in some scenarios but can be time consuming and tiresome for robot operator. This is why UGVs can be equipped with additional sensors and software algorithms for achieving higher level of autonomy. Instead of constant control by joystick, operator can just set goals for UGV to obtain.

UGV

Unmanned Ground vehicle can be divided into following components:

Base platform: mechanical and electrical components that allow platform to be teleoperated. Including motors, batteries, and cameras.

Autonomy module: sensors and processing units required for autonomous operation.

Sensors required for autonomous operation can be divided in two main groups. Division comes from basic operating concept: in order to go somewhere UGV has to know where it is, and how to move safely:

- Positioning sensors – GNSS, IMU
- Obstacle avoidance sensors – LIDAR, RADAR, cameras (visible light or other), depth cameras (time of flight or structured light), stereo vision cameras.

There is some overlap between this groups, as lidars and cameras are often used in positioning.

Additional payloads: mission specific payloads, like manipulator, specialized sensors (like radiation sensors), or specialized actuators.

Figure 7 PIAP Gryf® robot taking samples, with additional payloads on the back of UGV.

HMI

Human machine interface can have various forms, basically can be defined as a screen with some input device (touchscreen or joystick). This interface can be mobile (in form of tablet of smartphone) or stationary, in form of vehicle or container.

Figure 8 Human machine interface example.

Figure 9 Control station used in FP7-SECURITY TALOS project founded by European Union. Contains HMIs for mission management and operation of two UGVs.

Communication Links

Communication link for UGV is usually proprietary solution, but in demonstration scenarios WiFi network can be used. This is due to complexity of requirements and spectrum allocation regulations. This link need to be bidirectional. Low latency might be required for teleoperation. Uplink is used to send commands to UGV and payloads. Downlink is used to receive telemetry, video feeds and sensor readings.

3 Scenario 1: Earthquake in urban environment pilot scenario

3.1 Specific functionalities/Requirements and related sensors

The first scenario is considered an earthquake in an urban environment so it becomes necessary to make an initial assessment of the disaster by taking images with cameras mounted on drones and UGVs.

As for the deployment of a drone swarm to establish ad-hoc communications coverage in the affected area, due to the complexity of this operation in the Turkish area, it has been agreed at the consortium level that this functionality will be tested in Spain, in ATLAS, where the available airspace allows this type of operation to be carried out more easily.

From the requirements established in deliverable D2.2 on the ground robot and on the drone, together with the use cases defined in deliverable D2.3, it is possible to make a list of the sensors that are required to be integrated into the unmanned platforms. The sensors identified to be integrated on the unmanned platforms in this pilot are the following:

- GPS,
- Cameras mounted on UxV.

The following subsections will show which unmanned platform and sensors have been chosen. Since there is still time left for the end of the project, it is possible that these are not the final sensors or platforms; however, they will have similar specifications, so the implementation, integration and modifications will not vary from one sensor or platform to another.

3.2 Proposed UAV Platforms and modifications

This section will detail the UAV platforms to be used along with their capabilities (flight time, control distance, flight conditions) and characteristics (weight, size, payload, etc). It will also address what modifications and adaptations must be made to the platform to integrate the sensors that must cover each of the different functionalities of the scenario.

In this phase of the project, it is recommended to use for this scenario a COTS platform that can be acquired/rented in Turkey where the pilot will be carried out. The arguments to justify this choice are the following:

- to avoid customs problems in the shipment of the drones,
- to avoid problems of shipment of batteries in airplanes, which is a usual complication when drones are sent from one country to another,
- to facilitate the process of application for flight permits in the sites chosen for the experiments.

This last point is key as it can be the major constraint when performing the exercises. The fact that the Turkish partner AAHD will be able to supply the drones and can arrange the permits with the Turkish civil aviation authority will make it much easier and faster to carry out the pilot.

The following section shows the drone proposal that is made where the necessary equipment can be integrated to fulfil the functionalities required by the unmanned aerial platform.

3.2.1 Proposed UAV platform

The drone proposed for this scenario is a COTS solution: the Phantom 4 from the manufacturer DJI. It is a 4-motor multirotor, powered by 15.2V LiPo batteries. Below is a table with the technical specifications of this platform.

Technical Specifications	
MTOW	1380 g
Diagonal Size (Propellers Excluded)	350 mm
Maximum velocity	Up to 72 km/h (depending on flight mode)
Maximum attitude	Up to 42º (depending on flight mode)
Maximum height	5000 m
Maximum allowed windspeed	10 m/s
Maximum Flight Time	28 min approximately
Operating Temperature Range	0ºC to 40ºC
Satellite Positioning Systems	GPS / GLONASS
Payload capacity	300 g
Operating frequency	2,4 GHz (RC transmitter with mobile device support)

Table 1: Technical Specifications of Phantom 4

Figure 10 shows a picture of the Phantom 4.

Figure 10: Phantom 4 drone from DJI manufacturer

Several types of flight control modes are available depending on the level of assistance to the pilot provided by the autopilot.

The control modes are as follows:

- Mode P (Position). The autopilot stabilizes the aircraft in attitude and position, using the GPS to fix the position. The pilot will be able to command position variations. The autopilot will automatically select between three states within this mode, depending on the quality of the GPS signal and the data received by the optical sensor:
    - P-GPS: GPS and optical sensor data available. The aircraft will use GPS for positioning.
    - P-OPTI: Optical positioning available but GPS signal weak. The aircraft will use positioning information by vision.
    - P-ATTI: Neither GPS nor optical sensor signal available, so only the barometric sensor will be used for positioning. Only the height will be stabilized.
- Mode A (Altitude Hold). GPS and vision not used for stabilization. The aircraft will only use the barometric sensor to maintain altitude, and it moves according to attitude commands from the pilot. The aircraft will still be able to use the system back home if the signal is lost and the Home point was correctly established.
- Mode F (Function). In this mode, the Intelligent Positioning Control (IOC) is activated.

3.2.2 Platform modifications and integration of sensors

The main functionalities that the aerial platform must fulfill in this scenario are to send the images taken by a camera for the evaluation of the affected area, as well as to exchange telemetries and mission commands for the drone. Figure 11 shows a scheme of how the integration will be in this scenario.

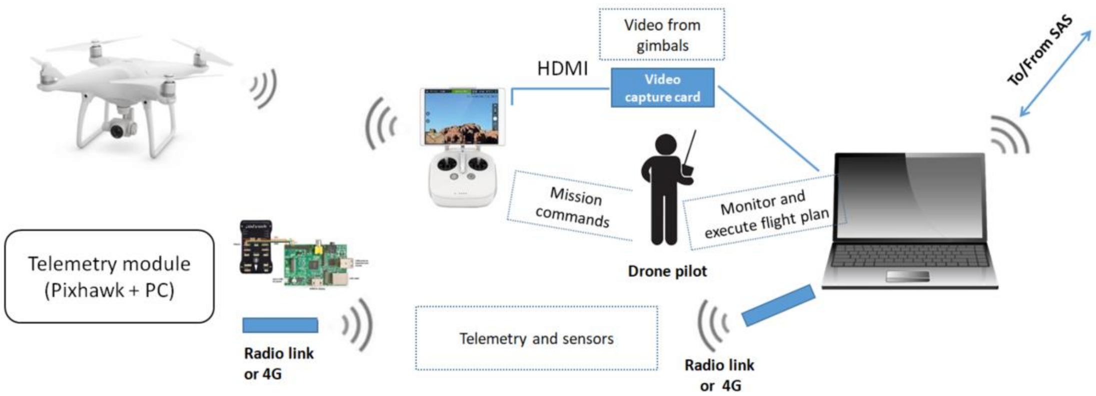

Figure 11: Integration scheme of pilot 1 scenario

In this case, it is possible to take advantage of the camera that is integrated into the drone from the factory so that it is possible to use those images for video transmission. On the other hand, to make use of the drone's telemetry, it will be necessary to mount a telemetry module to be able to access these data and integrate them with the ASSISTANCE system, since the phantom 4 telemetry data cannot be easily accessed in real-time to be processed externally.

Telemetry module

Module that is integrated into the air platform to receive the drone's flight telemetry in a computer on the ground and be able to integrate it into the ASSISTANCE system. This module is mainly composed by:

- a small autopilot that has sensors and provides information about the aircraft's status: position, speed, attitude, flight height, etc., an example of this is the Pixhawk mini autopilot as can be seen on the right side of the Figure 12;
- a small board connected to the autopilot where there is a software running for the transmission of these data, an example of this is the Raspberry Pi as can be seen on the middle part of the Figure 12;
- a communication link to the ground, either through 4G or a dedicated link, an example of this is a USB 4G modem as can be seen on the right part of the Figure 12;
- a small battery to power this module, as can be seen in the middle part of the Figure 12.

Figure 12: Components of telemetry module to be integrated in the drone

All these systems can be encapsulated in a small box printed on the CATEC premises, with maximum dimensions of 120x70x40 mm, and maximum weight of 300g. This module can be easily integrated into the drone, attaching it with tape to the top of the platform.

GPS

The GPS that normally integrates with this type of autopilot is a module recommended by the manufacturer, which includes a ublox® Neo-M8N receiver along with an HMC5983 compass. The main characteristics of this GPS module are:

- Concurrent reception of up to 3 GNSS (GPS, Galileo, GLONASS, BeiDou);
- Industry leading –167 dBm navigation sensitivity;
- Security and integrity protection;
- Supports all satellite augmentation systems;
- Advanced jamming and spoofing detection;
- Product variants to meet performance and cost requirements.

Figure 13 shows a picture of this GPS module to the Pixhawk mini used in the telemetry module. It can be seen that this GPS module is even smaller than the autopilot and its weight is 20g approximately.

Figure 13: GPS module connected to Pixhawk mini

Camera and video streaming

The aircraft itself has a three-axis gyro-stabilized gimbal with an integrated camera for 4k quality video recording and 12.4 Mpx image capture. This camera has a Sony EXMOR 1/2.3" sensor and a FOV 94° 20 mm.

Figure 14: Camera payload of the aircraft

Technical characteristics of the camera:

- Sensor: Sony EXMOR 1/2.3”; effective pixels: 12.4 M (total pixels: 12.76 M).
- Lens: FOV 94° 20 mm (Equivalent format to 35 mm) f/2.8, focus at ∞.
- Range ISO: 100-3200 (video) 100-1600 (foto).
- Shooting speed: 8s -1/8000s.
- Maximum image size: 4000x3000

Video modes:

- UHD: 4096x2160p 24/25, 3840x2160p 24/25/30.
- UHD: 4096x2160p 24/25, 3840x2160p 24/25/30.
- UHD: 4096x2160p 24/25, 3840x2160p 24/25/30.

Supported file types:

- Fat32/ExFat.
- Foto: Jpeg, DNG.
- Video: MP4, MOV (MPEG-4 AVC/H.264).

The video taken by the camera is transmitted via the drone's own link to the GCS. In this case, the GCS is composed of the RC transmitter to which a mobile device is connected, where through an app it is possible to view this video in real-time, as well as manage the payload (recording, gimbal control, etc.) Apart from visualizing the video, it is possible to capture it by using a capture card or framegrabber in a ground computer, and send the video via streaming to the SAS. Figure 15 shows a scheme of these components connected.

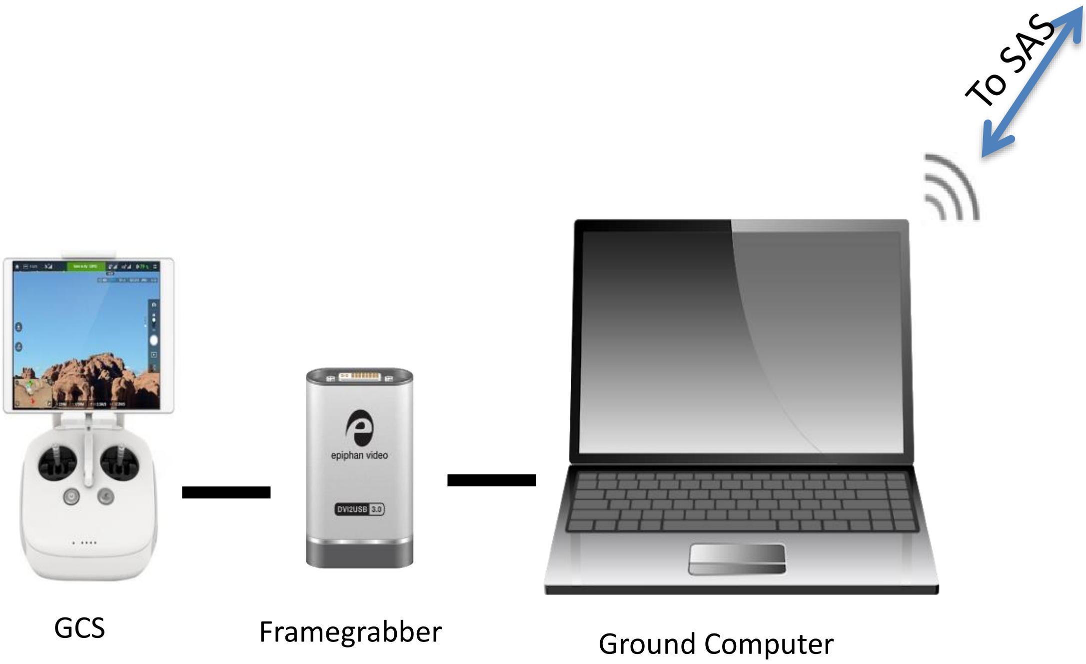

Figure 15: Streaming of video to the ASSISTANCE system

3.3 UGV Platform and modifications

For pilot scenario 1 the need for use of UGV has been identified and described in D2.3. It requires GPS and video camera and during scenario should be used for providing additional information for operators.

During project development a risk has been identified and put into ASSISTANCE Risk Register concerning issues with sending UGV to outside EU, in this case Turkey. The risk is based on PIAP's previous experience in sending UGVs and specifically concerns possible delays or stoppage by either EU or Turkey customs.

Due to selected choice of adapting and using one platform for scenarios 2 and 3 (described in detail in chapter 4.3), sending the same platform to Turkey could result in unavailability of UGV for not only scenario 1, but also other two scenarios.

This risk together with very limited requirements for UGV has led whole consortium to agree that main adapted UGV should not be sent to Turkey for this scenario.

As an alternative it is possible for a different UGV to be sent to Turkey. Smaller UGV that is only equipped with required features – GPS and video camera. This possibility will be further investigated using COTS solutions that could be available for the project partners.

4 Scenario 2: Chemical plant explosion scenario

4.1 Specific functionalities/Requirements and related sensors

The second scenario is considered an industrial accident, so it becomes necessary to make an initial assessment of the disaster by taking images with cameras mounted on drones and UGVs and also take samples of possible presence of toxic gases. This scenario will be tested in the training area of GB, where there will be simulations of a disaster in a factory.

From the requirements established in deliverable D2.2 on the ground robot and on the drone, together with the use cases defined in deliverable D2.3, it is possible to make a list of the sensors that are required to be integrated into the robots. The sensors identified to be integrated in this pilot are the following:

- GPS;
- Gas sensors;
- Video cameras mounted on UxV;
- Infrared (IR) cameras mounted on UxV;
- Wind speed sensor mounted on UGV.

The following subsections will present the unmanned platform and sensors chosen. Since there is still time left for the end of the project, it is possible that these are not the final sensors or platforms; however, they will have similar specifications, so for implementation, integration and modifications will not vary from one sensor or platform to another.

4.2 Proposed UAV Platforms and modifications

This section details the UAV platforms to be used along with their capabilities (flight time, control distance, flight conditions) and characteristics (weight, size, payload, etc.) It will also address what modifications and adaptations must be made to the platform to integrate the sensors that must cover each of the different functionalities of the scenario.

The same reasoning is used in this case to justify this decision as in the previous scenario, in addition to the fact that the platform available to GB is very suitable for the purpose of this scenario. The following section shows the drone proposed and the necessary equipment to be integrated to fulfill the functionalities required by the aerial robot.

4.2.1 Proposed UAV platform

The drone proposed for this scenario is a COTS solution: the Matrice 210 from the manufacturer DJI. It is a 4-motor multirotor, powered by 22.8V LiPo batteries. Below is a table with the technical specifications of this platform.

Technical Specifications	
MTOW	6,14 Kg
Diagonal Size (Unfolded)	886 mm
Maximum velocity	Up to 81 km/h (depending on flight mode)

Maximum attitude	Up to 30º (depending on flight mode)
Maximum height	3000 m
Maximum allowed windspeed	12 m/s
Maximum Flight Time	28 min approximately
Operating Temperature Range	-20ºC to 50ºC
Satellite Positioning Systems	GPS / GLONASS
Payload capacity	1,34 Kg
Operating frequency	2,4 GHz (RC transmitter with mobile device support)

Table 2: Technical Specifications of Matrice 210

Figure 10 shows a picture of the Matrice 210.

Figure 16: Matrice 210 drone from DJI manufacturer

Several types of flight control modes are available depending on the level of assistance to the pilot provided by the autopilot. The control modes are as follows:

- Mode P (Position). The autopilot stabilizes the aircraft in attitude and position, using the GPS to fix the position. The pilot will be able to command position variations. The autopilot will automatically select between two states within this mode, depending on the quality of the GPS signal and the data received by the optical sensor:
    - P-GPS: GPS data available. The aircraft will use GPS for positioning.
    - P-ATTI: GPS signal not available, so only the barometric sensor will be used for positioning. Only the height will be stabilized.
- Mode A (Altitude Hold). GPS and vision not used for stabilization. The aircraft will only use the barometric sensor to maintain altitude and it moves according to attitude commands from the pilot. The aircraft will still be able to use the system back home if the signal is lost and the Home point was correctly established.
- Mode M (Manual). In this mode the remote pilot controls attitude and throttle of the engines, this is the least assisted mode.

4.2.2 Platform modifications and integration of sensors

The main functionalities that the aerial robot must fulfill in this scenario are to send the video obtained from the onboard camera for the evaluation of the affected area, as well as to exchange telemetries and mission commands for the drone. In addition, it is also required to send the video obtained from the IR camera integrated into the drone and also the data captured from the gas sensor. Figure 17 shows a scheme of how the integration will be in this scenario.

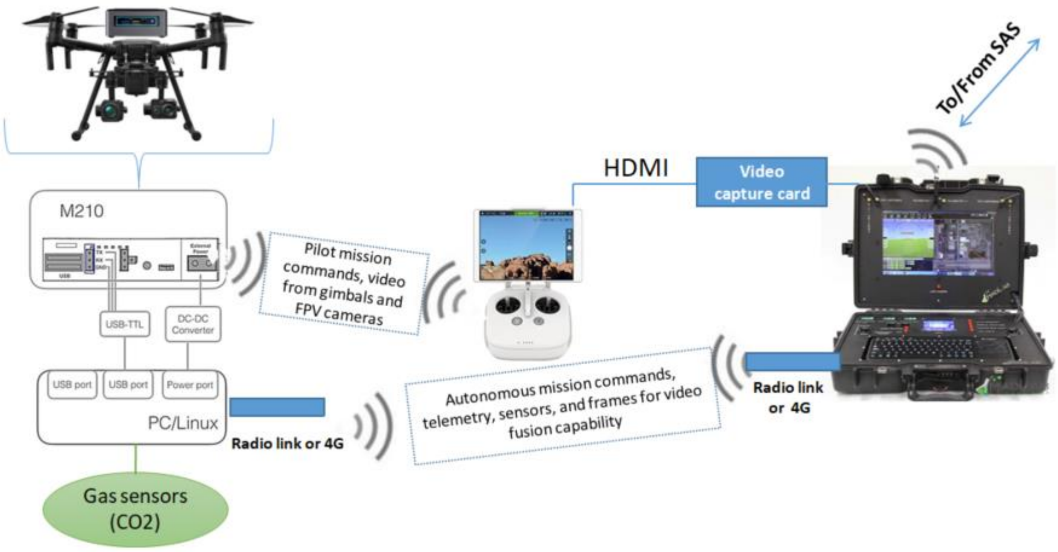

Figure 17: Integration scheme of pilot 2 scenario

In this case, the adopted solution is different from the one in the scenario 1, since the Matrice 210, which is the platform provided by the GB partner, is one of the DJI aircraft that supports the Onboard SDK to be able to interact with the drone through an external PC. This allows us to take telemetry data from the autopilot in real-time, as well as to be able to interact with it by sending missions or changing flight modes. Also, it allows access to images from cameras that are integrated into the drone. In addition, the manufacturer DJI recommends a set of cameras to be integrated into this drone that are the ones GB has and will be described in the following sections. Finally, it should be noted that since a PC is needed onboard the aircraft, the gas sensor required to take samples from the disaster area can be connected to it.

GPS

The GPS used in this case is the internal one that DJI mounts in their drones at the factory. This GPS has protection against external attacks from spoofing. It supports the reception of 2 different GNSS: GPS and GLONASS, although the RTK version also supports Galileo and Beidou.

With regard to the performance of this GPS receiver, the manufacturer's website states that it can reach an accuracy of 2 meters. On the other hand, the RTK version has an accuracy of ±0.1 m in the vertical axis, and ±0.1 m in the horizontal plane.

Gas sensor

As for the gas sensors, two alternatives will be shown below and will be tested in the experiments. A first option is a low-cost sensor that can be used as a proof of concept, and the second is a high-cost professional sensor provided by the company CNBOP-PIB.

MG811 sensor

This sensor module has an MG-811 onboard as the sensor component. There is an onboard signal conditioning circuit for amplifying output signal and an onboard heating circuit for heating the sensor. The MG-811 is highly sensitive to CO2 and also sensitive to alcohol and CO. It could be used in air quality control, ferment process, in-door air monitoring application. The output voltage of the module falls as the concentration of the CO2 increases.

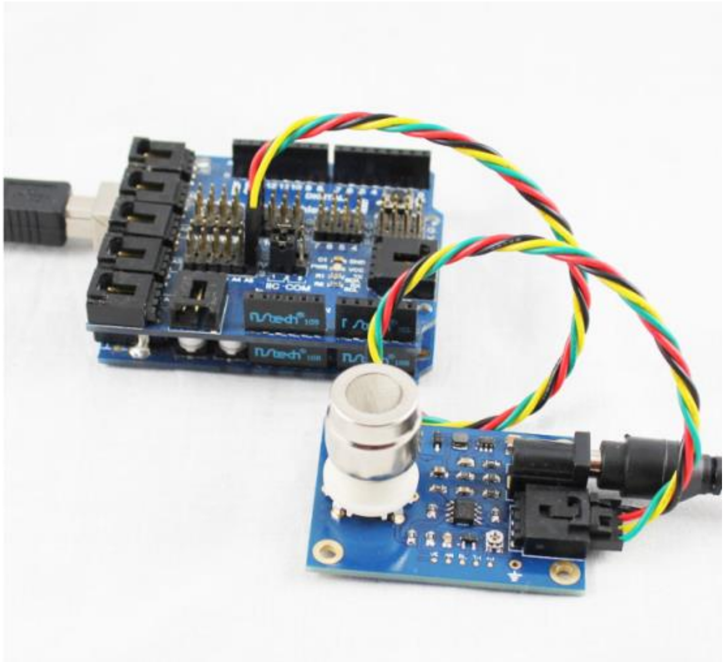

Figure 18: MG811 module

Its small dimensions (5cm the largest size) and small weight (not more than 30g) makes the integration into the drone quite easy. The main features of the sensor are:

- Analog and digital output;
- Onboard signal conditioning circuit;
- Onboard heating circuit;
- Sensor jack eliminates soldering the sensor and allows plug-and-play;
- 4-pin interlock connectors onboard;
- 4-pin interlock cables included in the package;
- Compact size.

Figure 19 shows the gas sensor sensitivity curve.

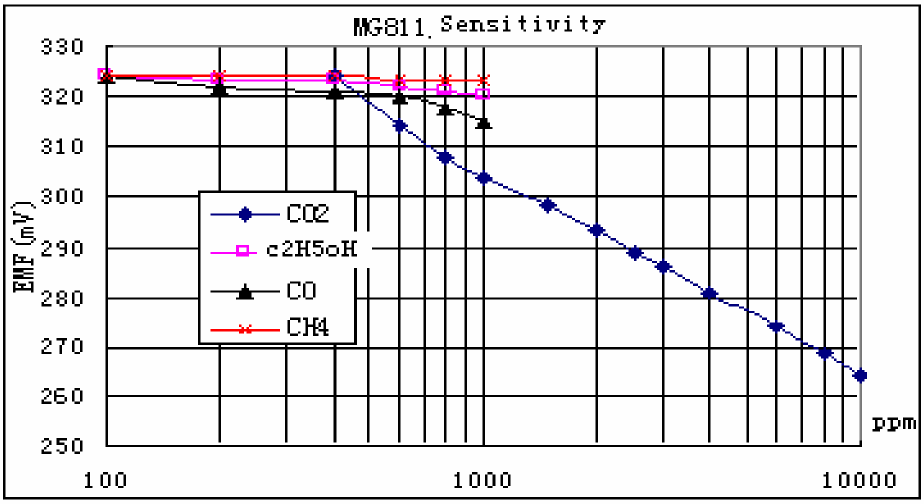

Figure 19: Sensitivity curve of the sensor

ATMON sensor

ATMON FL is designed to control and measure the concentration of hazardous gaseous substances in the air and suspended dust. ATMON FL is dedicated to monitor the air condition and gas concentrations in open spaces and semi-closed facilities, which can be accessed by drones. It sends all measurements to the Operator's PC, allowing them to be read at any time using a dedicated application. Thanks to its lightweight construction, the device can be easily transported for a long time on light flying drones.

	Atmon FL
Measured substances	Fixed sensors - PM2,5 PM10 Replaceable sensors – HCHO, CO, SO_2, NO_2, O_3, H_2S, Cl
Additional features	Temperature and humidity measurement
Mass	About 350g - depending on the number of sensors
Dimensions	covers Ø 125 mm height in the support core up to 100 mm
Maximal number of additional sensors (besides PM2,5 & PM10 sensors)	4
Type of mounting to UAV	From above, through the glued mounting rail
Communication	The measuring system connected via a 433MHz radio to the receiver. The receiver is connected to the computer via the USART protocol. The data frame is described later
Working range	Up to 1600m – in perfect conditions really about 800m
Precision of position determination	compatible with GPS, Glonass, Galileo accuracy +/-2,5 m reciever gain -167 dBc
Battery	Internal, working time up to 5h
Measurments	measurement in forced mode measuring period = 1s

	each measurement includes a time stamp and a position measurements saved in *.csv (excel) format
Operating conditions	temperature -20°C - + 50°C humidity 10-95% RH

Table 3: Specifications of ATMON FL gas sensor

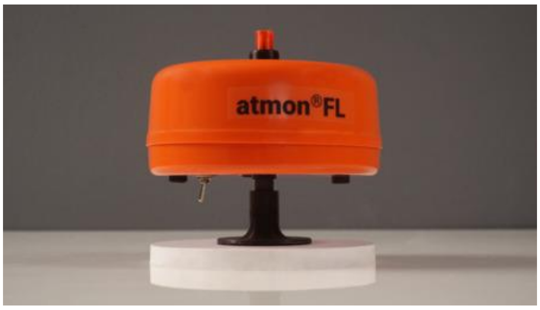

Figure 20: Front view of the ATMON FL device

Video Camera

A video camera is integrated into the drone for the purpose of visualization the images in the GCS and sending them to the SAS. The aerial camera selected in this case is the Zenmuse Z30, which is a system easy to install and very easy to use. It's compatible with any new model DJI drone, specifically with the DJI Matrice 210. One of the main features of this camera is its optical zoom up to 30x and digital up to 6x. It is a video camera that allows the user to capture the information from a greater range, making image data collection significantly faster.

The camera's quality is more than enough for industrial use. HD 1080p is plenty to see small details during inspections or search operations. The array of flight modes the camera is compatible with are impressive. "Point of Interest" makes getting a 360° view of the target a snap. The integration of the camera with the mobile device is quite easy via the DJI Go App, and it's quite easy to control. The user can tap where the camera to take aim, and it does so automatically.

Figure 21: Zenmuse Z30

The main features of this camera are:

- Camera with up to 30x optical and up to 6x digital zoom integrated;
- Automatically adjusts the focal length to give a magnified view;
- 2.13 Megapixel sensor;
- Angle of view ranging from 63.7º to 2.3º.

This camera is integrated in the drone in the gimbal provided by the DJI manufacturer, as can be seen in Figure 21. Its total weight (together with the gimbal) is 556 g.

IR Camera

As for the thermal camera, GB has the Zenmuse XT2 camera. The FLIR Zenmuse XT2 cameras integrate a high-resolution thermal camera and a 4K visual camera with DJI stabilization and intelligence technology. The advanced thermal camera of the FLIR Zenmuse XT2 provides high-sensitivity images for structure monitoring, power line inspection, fire detection, search and rescue missions and much more.

DJI's Spotlight Pro technology uses both HeatTrack and QuickTrack flight modes to automatically track objects while the operator focuses on incoming data and flight operations. As with the previous camera, it is possible to view the images on a mobile device connected to the station via the DJI Go App.

Figure 22: Zenmuse XT2

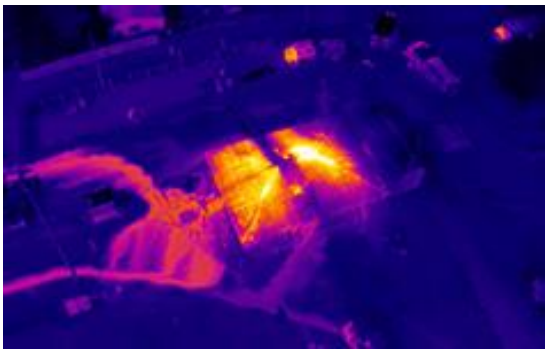

Figure 23: Structure Fires detection by thermal camera

The main features of this camera are:

- Features dual 4K, 12MP, 1/1.7" CMOS visual sensor and FLIR Tau 2 thermal sensor;
- IP44 rating for dust and water protection;
- Compatible with the DJI Matrice 200 and 600 Series;
- Thermal sensitivity of <50 MK;
- Available in 9 or 30 Hz with a range of lenses to choose from;
- Built-in visual and thermal data storage.

This camera is integrated in the drone in the gimbal provided by the DJI manufacturer, as can be seen in Figure 22. Its total weight (together with the gimbal) is 588g.

The same configuration for sending the images received in the GCS to the SAS as in scenario 1 is used in this case. So, Figure 15 is also valid in this case even if the camera is not strictly the same.

Video frames for data fusion

The images from the two cameras described above (Zenmuse Z30 and Zenmuse XT2) are mainly used for streaming to the ASSISTANCE system via the SAS. However, it is necessary to have images tagged with timestamps and synchronized with flight telemetry for the video fusion capability. For this purpose, the images need to be accessed on the onboard PC in order to add that timestamp and synchronize it with the drone telemetry, which is also received on the on-board PC via the Onboard SDK from DJI.

Figure 24: FPV camera of the Matrice 210

The main specifications of this video camera are its resolution 608x448 and the possibility to adjust the tilt of the camera via the transmitter.

4.3 UGV Platform and modifications

UGV specification will be exactly the same for both scenario 2 and scenario 3. Scenarios will individually potentially not require all of payloads, but together they make use of every feature.

4.3.1 Proposed UGV platform

Platform that was selected for ASSISTANCE project is PIAP GRYF®.

PIAP GRYF® platform was chosen based on combination of evaluation of user requirements in D2.2 as well as technical requirements for excersising use-case scenarios from D2.3.

Requirements were roughly split into 3 categories of importance – evaluated above 4.0, 3.7 to 4.0 and lower than 3.7. This resulted in split of 6/10/9 items in respective categories. This was basis for prioritization of requirements.

Approach for these categories was:

- highest category requirements must be completely covered and can impose required modifications on platform or payloads both existing as well as new components,
- medium category are requirements that should be covered and should be taken into account when making adaptations, but should not be prioritized over higher category,
- lowest category is mostly provided as-is and should not have major impact on platform choice, except when the difference between requirements and provided is very significant.

Requirements evaluated by end-users in D2.2 above 4.0				
Req. ID	**Description**	**Type**	**User rating**	**Selected platform comment**
ROB_017	Control system should be user-friendly.	Usability and humanity requirements	4.5	To operate UGV a dedicated operator training is required, however due to this requirement being very important for users, additional user interface and user experience optimizations will be introduced to HMI.
ROB_007	Robot should have the mobility to traverse terrain, like debris, stairs, etc.	The scope of the product	4.4	Robot is equipped with applied drives that allow it to traverse hillso f 45°, move on stairs and with use of manipulator perform advanced movement manevours.
ROB_020	Robot has to have the capability to carry multiple sensors.	Operational requirements	4.4	Due to importance of this requirement for end-users robot capability for sensor connection has been increased to 4.
ROB_002	Robot should be protected from the environment (dust and water) according to IP67.	The scope of the product	4.3	Robot is not IP67 certified, but operationaly it is capable of operating in dust and rain. All adapted payloads will be modified for increased environment resistance.

Requirements evaluated by end-users in D2.2 above 4.0				
Req. ID	**Description**	**Type**	**User rating**	**Selected platform comment**
ROB_010	Robot should be equipped with a monitoring system for: battery level, radio link quality, robot orientation	Functional and data requirements	4.3	Selected robot platform includes required functionality
ROB_022	Robot can transfer sensor results to the operator using its datalink.	The scope of the product	4.2	Robot can transfer sensor results to operator and SA application.

Table 4: UGV requirements evaluated by end-users in D2.2 above 4.0

Requirements evaluated by end-users in D2.2 between 3.7 and 4.0				
Req. ID	**Description**	**Type**	**User rating**	**Selected platform description**
ROB_005	Robot should have the capability of changing batteries without tools.	The scope of the product	4.0	Yes, changing batteries does not require any tools and can be done without uninstalling any parts
ROB_008	Minimal operation range 400m.	The scope of the product	4.0	Operation range is up to 800m in open field. Minimal range is dependant on signal interference.
ROB_012	Robot setup time should be lower than 10 minutes.	Operational requirements	4.0	Robot setup is quick and does not require any tools.
ROB_021	Sensors can be mounted quickly without any tools.	Operational requirements	4.0	All existing and adapted payloads will prioritize modularity and easy mounting / swapping.
ROB_023	Robot has to be equipped with multiple cameras	The scope of the product	4.0	Robot is equipped in total with 4 video cameras.
ROB_024	Robot can be teleoperated/telemanipulated by remote operator or work in automatic mode.	Operational requirements	4.0	Operator can perform every action on robot remotely, robot has capability of autonomous movement and accepting externam missions.
ROB_001	Robot should be capable to operate in a temperature range from -40C to 60C.	The scope of the product	3.9	Robot has been tested for operation in temperatures -30C to 60C.
ROB_018	Control system should have low latency.	The scope of the product	3.9	Robot connects to control system using wifi network, which even with heavy interference should still be under required 150ms.
ROB_014	Robot has to be localised on the map with accuracy lower than 1m	Functional and data requirements	3.8	Robot is equipped with powerful GNSS antenna and UWB pozyx localization system for increasing global localization accuracy.

Requirements evaluated by end-users in D2.2 between 3.7 and 4.0				
Req. ID	**Description**	**Type**	**User rating**	**Selected platform description**
ROB_025	Sensor can connect to the robot using a specified open standard.	Functional and data requirements	3.8	Sensors connect to robot using CAN protocol. Those messages are then transfered to control system using JAUS standard.

Table 5: UGV requirements evaluated by end-users in D2.2 between 3.7 and 4.0

Requirements evaluated by end-users in D2.2 lower than 3.7				
Req. ID	**Description**	**Type**	**User rating**	**Selected platform description**
ROB_009	Robot control should be protected by an authentication system.	Functional and data requirements	3.6	Robot control unit has basic authentication system available.
ROB_013	Control system should be operated in multiple languages.	Usability and humanity requirements	3.6	Robot control is only in English. Manuals are available in more languages.
ROB_019	Robot data link has to be secured.	Security requirements	3.6	Robot data link uses standard wireless transmission secure protocols.
ROB_011	Robot should be operated by one person.	Operational requirements	3.5	Robot only requires one person to operate. Setup can be done with one person, but multiple people make it faster.
ROB_004	Robot shall have minimum work time of 4h.	The scope of the product	3.4	Operating time on one battery is approximate 2hr.
ROB_006	Robot should be equipped with manipulator maximum load of 5 kg.	The scope of the product	3.4	Manipulator has 15 kg carry capacity.
ROB_003	Robot shall have a minimum maximum speed of 4 m/s.	The scope of the product	3.1	Robot has máximum speed of 3.6 km/h
ROB_015	Robot should have a maximum weight of 25kg.	The scope of the product	3.0	Robot platform weighs 38 kg and payloads add additional weight.
ROB_016	Maximum Size 60x60x80cm (width x lenght x height).	The scope of the product	2.8	Robot’s dimensions are 59 x 51 x 90

Table 6: UGV requirements evaluated by end-users in D2.2 lower than 3.7

After initial choice next step was selection of payloads to fulfill all requirements for pilot scenarios for UGV. This was followed with definition of all required modifications and payloads that will be used. Based on selected platform’s capability to fulfill all of requirements, the choice was then finalized.

Figure 25: PIAP GRYF® base platform

PIAP GRYF® is a mobile recon robot with wide application range designed for versatility. Currently many units are deployed on multiple continents performing very broad range of tasks for variety of sectors, including military, first responders, border guards, airport security, antiterrorism security and more.

The robot is characterized by excellent maneuverability. Low weight makes it easy to transport and carry the robot, and its modular design allows for quick and easy change of additional equipment. Robot's wheels can easily be removed, which reduces width of the robot by 13cm and thus facilitates missions in tight spaces. Owing to the applied drives, the robot smoothly overcomes uneven terrain and obstacles up to an angle of 45°.

The robot can be operated remotely by a trained operator, but it can also move around autonomously while avoiding obstacles by utilizing optional autonomy module that combines several positioning sensors with state of the art software.

Technical Specifications	
Dimensions	90 x 59 x 51 cm
Base weight	38 kg
Maximum Speed	3,6 km/h
Payload capacity	4 sensors
Operating temperature range	-30ºC to 60ºC
Manipulator's maximum lift	15 kg
Manipulator's maximum range	1,9m
Maximum range (open area)	Up to 800 m

Table 7: Technical specifications of PIAP GRYF

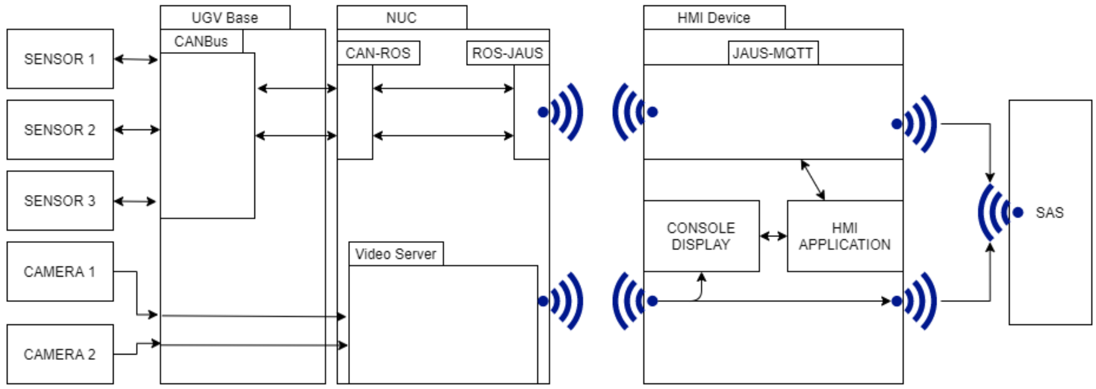

Figure 26: Detailed UGV Components and communication paths

Above is detailed UGV components and communication paths diagram. This diagram depicts only components that data from sensors/cameras has to pass through. There are two main communication paths: one for sensor data and sensor controls and one for video streams.

Sensor data and sensor controls is a bi-directional communication path – data is produced in sensors and it has to reach SAS layer of SA application. On the other hand both SAS and operator via HMI application can produce sensor control messages that have to reach sensors. Going from left to right we have sensors connected to UGV base. UGV base requires data from sensors to be sent as CAN frames and then forwards this data as well as telemetry, odometry and other produced data such as lights status etc.

Next this CAN data is received in companion computer – in this case Intel® NUC – for further processing. Since NUC requires most of received data for autonomy processing, everything received from UGV base is first converted to ROS and then any data that is required further down in the system is passed to ROS-JAUS bridge. Next device on communication path is HMI, which requires JAUS messages as input. Inside HMI device there is a JAUS-MQTT bridge for protocol translation, since both SAS and HMI application use MQTT.

For video streams it is much simpler: video feeds from cameras are forwarded straight to NUC companion computer, where video server is located. This video server then encodes video and sends it to HMI device, where it is displayed for operator, but also it is forwarded to SAS. This communication path is one way stream.

4.3.2 UGV Payload and Required modifications

There will be the same payloads configuration on the UGV for pilots 2 and 3 and it will encompass the following:

- Weather station VIASALA WXT520;
- Radioactivity sensor ZR-2;

- Autonomy module;
- Manipulator (with a camera located on gripper);
- Pan/tilt/zoom unit with a camera;
- EMF detector;
- Thermal camera;
- Gas sensor;
- Cutting extinguisher.

Additionally robot base is equipped with two inbuilt cameras.

Weather station VIASALA WXT520

Sensor VIASALA WXT 520 has been integrated with PIAP GRYF robot and tested in scope of the FP7-SECURITY project EDEN, that was completed in 2016. In ASSISTANCE the same core sensor will be used, but with evolutionary modifications.

One of objectives of WP4 as a whole has been "The proposed solution will be developed taking into account a modular approach and interoperability of payload. It will enable to configure and adjust the equipment of the unmanned platforms to meet the specific mission requirements, thus resulting in higher reliability, lesser power consumption and longer work times of the selected set of devices".

To address this objective, there have been multiple modifications. To increase sensor connection reliability existing radio connection has been removed and exchanged with cable communication. On top of increasing reliability, this change has eliminated additional power drain for radios on UGV and sensor. Usage of cable connection also allowed for switching power supply from dedicated sensor battery to utilizing battery of UGV. This change reduces weight, size and required space for mounting.

Weather station will be used to collect atmospherical data on-site for use inside ASSISTANCE Chemical Hazard Tool (CHT) module.

Figure 27: VIASALA WXT520 Weather Station

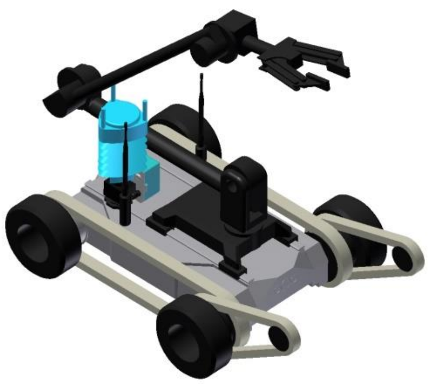

Figure 28: Render showing size comparison

Measurements specification	
Wind speed and direction	0 – 60 m/s
Air temperature	- 52ºC to +60ºC
Barometric pressure	66 – 1100 hPa
Relative humidity	0 – 100 %
Intensity of precipitation (rain)	0 – 200 mm/h
Intensity of precipitation (hail)	Hits/cm²*h

Table 8: Measurements specification for weather station

Radioactivity sensor ZR-2

ZR-2 sensor has been integrated and tested in scope of the same project as weather station. It will also undergo evolutionary modification, without changing core components. Those modifications are based on fullfiling the same objectives and are comprised of the same base concept: remove radio, connect via cable, remove battery.

ZR-2 is used as an example of how would any CBRN sensor output be integrated into ASSISTANCE SAS layer and displayed data with SA application.

Figure 29: ZR-2 Gamma detector

This sensor measures gamma radiation and outputs measurements in both uSv/h and Gray/h.

Autonomy module

PIAP GRYF® is is equipped with module containing required autonomy hardware. This hardware includes Velodyne LIDAR, Intel® NUC processing unit, Ultrawide Broadband Pozyx localization system, ubuquity radio and hydrabox GNSS antenna system.

Autonomy module will not be revamped specifically for this project. However project related autonomy optimizations will be required based on ASSISTANCE pilot scenarios and requirements.

Video cameras

UGV is equipped with 4 video cameras: a camera in PTZ unit mounted on manipulator arm, a camera is static mount located on manipulator gripper and two cameras built-in UGV base, one located at front and the other at the back.

Video streams from the cameras are encoded in hardware using h264 encoding, with optional inclusion of custom algorithms in place to control bandwidth (making sure that bitrate is constant). This can allow stream to be stable even with very low bandwidth.

All camera video streams will be broadcasted by video server and will be available in SA application.

PTZ camera

PTZ camera is a pan-tilt-zoom camera and is mounted on the manipulator with joints which can be adjusted and fixed in different angles. Therefore, the camera can be positioned in different positions and angles.

The camera is colour with 22 x optical zoom and built-in preheater. On both sides of the camera two reflectors are mounted which are conjunct together with the camera.

Camera is rotatable in two axis; the vertical by 350° and horizontal by 150°. Camera can be rotated by the operator with commands sent via gamepad.

Camera resolution	704 x 576
FOV (V x H)	30 x 60
FPS	25
GOP	50
Rotation axis	Pitch, yaw
Zoom	22x
Bandwidth	800 – 5600 kb/s (100 – 700 kB/s)

Table 9: PIAP GRYF PTZ camera characteristics

Gripper Camera

Gripper Camera is built-in into the robot manipulator. It is moving together with the gripper (that can rotate in roll axis). Camera is colour, with a built-in preheater.

Camera resolution	480/640 x 576
FOV (V x H)	28 x 60 TBC
FPS	25
GOP	50
Rotation axis	None (roll axis on gripper)

Zoom	None
Bandwidth	800 – 5600 kb/s (100 – 700 kB/s)

Table 10: PIAP GRYF gripper camera characteristics

Platform Camera

Front and back cameras built-in with platform base provide additional point of view for operator in cases when operator doesn't have clear line of sight of UGV. Those cameras have fixed position.

Camera resolution	480/640 x 576
FOV (V x H)	28 x 60 TBC
FPS	25
GOP	50
Rotation axis	None
Zoom	None
Bandwidth	800 – 5600 kb/s (100 – 700 kB/s)

Table 11: PIAP GRYF front/back platform camera characteristics

Video cameras will not be modified, except the mount on manipulator gripper will undergo mechanical modification to add an ability to swap-in the thermal camera.

Manipulator

Robot manipulator has five degrees of freedom (not including gripper clamp and option for manual extension of telescopic arm). It is able to lift up to 15kg and has maximum reach of 1.9 m.

Manipulator modifications will include possibility to swap gripper with cutting extinguisher, which are described in respective chapter. On top of that based on ASSISTANCE user requirements and pilot scenarios manipulator control software will require project specific optimizations.

Figure 30: PIAP GRYF utilizing manipulator's range for advanced movement technique

EMF detector

External sensors such as EMF detector will require full adaptation for use with UGV:

- Building mechanical chassis that will cover all components from environment hazards;
- Power converter that can supply power from UGV internal battery and convert it to power requirements of integrated sensor;
- Sampler electronics boards;
- Firmware for sampler boards dedicated to exact sensor;
- Cables and connectors.

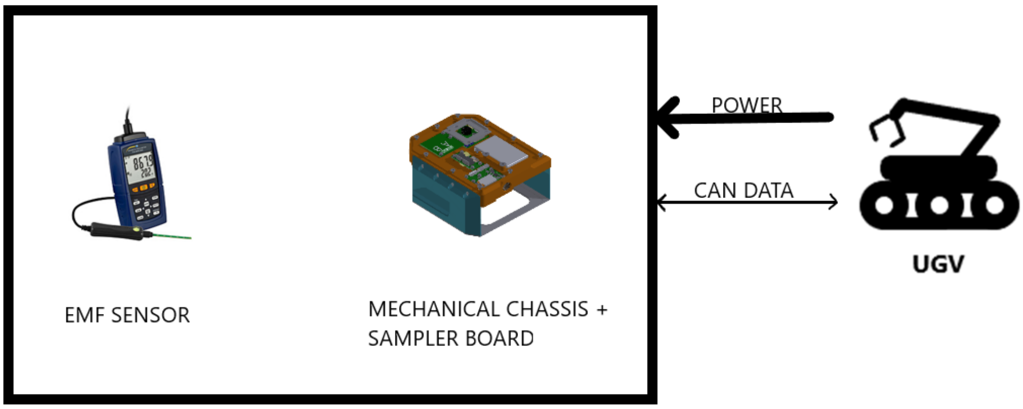

Figure 31: EMF sensor integration components

Thermal camera

Thermal camera will be used mainly for transformer building investigation use-case 6 from scenario 2.

This camera will be enclosed in the same casing as already existing gripper camera, and will be easily swappable. For this a modification of gripper camera mount located on manipulator will be required. Mount will be designed with ability to quick-swap cameras.

Figure 32: KTL-30 thermal camera module

Thermal camera parameters	
FOV	10°, 17°, 24°, 32°, 60°, 90° or other
Polarity	white hot, black hot
Digital zoom	2× and 4×
Detector type	uncooled bolometric FPA
Resolution	640 x 480 px
Pixel size	17 µm
Spectral response	8 to 12 µm
Sensitivity	40 mK
Video interfaces	Analogue (PAL), digital (BT.656, SD-SDI, MIPI CSI-2)
Voltage supply	5 to 12 VDC
Power consumption	Less than 1.5 W
Operating temperature range	–30°C to 50°C
Shutter	Yes
Dimensions	36×36×44 mm / 1.4×1.4×1.8 in
Weight	45 g / 1.6 oz

Table 12: KTL-30 thermal camera parameters

Gas sensor

Gas sensor mounted on UGV should be the same as mounted on UAV. Options include either ATMON FL high quality air analyser or lower quality prototype sensor. More description about capabilities are detailed in UAV section, chapter 3.2.2.

In case there will not be enough units of ATMON FL sensor provided by CNBOP, UGV will be equipped with MG811 sensor or equivalent, fully adapted to UGV usage in the same way as EMF detector.

Providing gas sensor readings from the same type of sensor with but located on the ground in the same place as readings from weather sensor will greatly enhance quality of CHT prediction module.

Cutting extinguisher

To showcase during demonstration ASSISTANCE objective of replacing humans in dangerous situations end-users have proposed demonstration of additional tool mounted on robot. This tool can be used in multiple of ways, but for this project demonstration will involve cutting open gas cylinders (as in dealing with acetylene cylinder) or extinguishing electrical battery fire.

This showcases important parts of ASSISTANCE project:

- robots used in field, not only provide valuable information, but can replace humans in dangerous situations;
- SA platform gives access to supervise robot operator without looking over his shoulder.

Cutting extinguisher will require mechanical integration only, and since it is an effector it will not require any integration with SAS or other ASSISTANCE SA systems. Only water cutting parts will be integrated into UGV. The rest of devices in the system will stay as they are. Control device will not be integrated into robot, as cutting extinguisher already has radio operated remote controller.

Figure 33: Temporary mount

Figure 34: Cutter extinguisher with temporary mount being tested under supervision

5 Scenario 3: Terrorist attack scenario (Pilot 3)

5.1 Specific functionalities/Requirements and related sensors

The third scenario is considered a terrorist attack in a crowded environment, so it becomes necessary to make an initial assessment of the situation by taking images with cameras mounted on drones and UGVs and also take samples of the possible presence of chemical agents. This scenario will be tested in the flight test center ATLAS, where there will be simulations of a terrorist attack with drones and other vehicles.

From the requirements established in deliverable D2.2 on the ground robot (ROB_0XX) and on the drone (UAV_0XX), together with the use cases defined in deliverable D2.3, it is possible to make a list of the sensors that are required to be integrated into the unmanned platforms. The sensors identified to be integrated on the unmanned platforms in this pilot are the following:

- GPS;
- Gas sensor;
- Video cameras mounted on UxV;
- Infrared (IR) camera mounted on UGV;
- Wind speed sensor mounted on UGV.

The following subsections will show which unmanned platform and sensors are chosen. Since there is still time left for the end of the project, it is possible that these are not the final sensors or platforms; however, they will have similar specifications, so for implementation, integration and modifications will not vary from one sensor or platform to another.

5.2 Proposed UAV Platforms and modifications

This section will detail the UAV platforms to be used along with their capabilities (flight time, control distance, flight conditions) and characteristics (weight, size, payload, etc.). It will also address what modifications and adaptations must be made to the platform to integrate the sensors that must cover each of the different functionalities of the scenario.

These platforms will be provided by CATEC with the same reasoning which is used in the previous scenario. CATEC has experience in drone operations and in the mounting of equipment and sensors on drones for specific applications. In addition, it has good relations with the Spanish Civil Aviation Authority for the management of flight permits, which are agile expedited when demonstrations are carried out in ATLAS, which has a segregated area of the airspace. The following section shows the drone proposal that is made where the necessary equipment can be integrated to fulfill the functionalities required by the unmanned aerial platform.

5.2.1 Proposed UAV platform

The drone proposed for this scenario is based on a COTS solution: the Matrice 600 from the manufacturer DJI. It is a 6-motor multirotor, powered by 22.8V LiPo batteries. Below is a table with the technical specifications of this platform.

Technical Specifications	
Weight	15,1 Kg
Diagonal Size (Unfolded)	1668 mm
Maximum velocity	Up to 65 km/h (depending on flight mode)
Maximum attitude	Up to 25º (depending on flight mode)
Maximum height	2500 m
Maximum allowed windspeed	8 m/s
Maximum Flight Time	35 min approximately
Operating Temperature Range	-10ºC to 40ºC
Satellite Positioning Systems	GPS / GLONASS
Payload capacity	6 Kg
Operating frequency	2,4 GHz (RC transmitter with mobile device support)

Table 13: Technical Specifications of Matrice 600

Figure 35 shows a picture of the Matrice 600.

Figure 35: Matrice 600 drone from DJI manufacturer

The autopilot used is the A3 from manufacturer DJI. The system consists of the following elements:

- Triple IMU: Triple redundancy of inertial measurement system that allows keeping the Matrice 600 stable in flight. Barometer with an accuracy of 0.1 meters. It is located in the internal part of the chassis.
- Triple GPS: Triple redundancy in the positioning system by GPS and GLONASS system with a positioning accuracy of 2 meters. It is located internally in the upper part of the chassis.

Several types of flight control modes are available depending on the level of assistance to the pilot provided by the autopilot. The control modes are as follows:

- Mode P (Position). The autopilot stabilizes the aircraft in attitude and position, using the GPS to fix the position. The pilot will be able to command position variations. The autopilot will automatically select between two states within this mode, depending on the quality of the GPS signal and the data received by the optical sensor:
    - P-GPS: GPS data available. The aircraft will use GPS for positioning.
    - P-ATTI: GPS signal not available, so only the barometric sensor will be used for positioning. Only the height will be stabilized.
- Mode A (Altitude Hold). GPS and vision not used for stabilization. The aircraft will only use the barometric sensor to maintain altitude, and it moves according to attitude commands from the pilot. The aircraft will still be able to use the system back home if the signal is lost and the Home point was correctly established.
- Mode M (Manual). In this mode the remote pilot controls attitude and throttle of the engines, this is the least assisted mode.

5.2.2 Platform modifications and integration of sensors

The main functionalities that the aerial robot must fulfil in this scenario are to send the video obtained from a camera for the evaluation of the affected area, as well as to exchange telemetries and mission commands for the drone. Apart from that, it is also required to receive the data captured by the gas sensor. Figure 36 shows a scheme of how the integration will be done in this scenario.

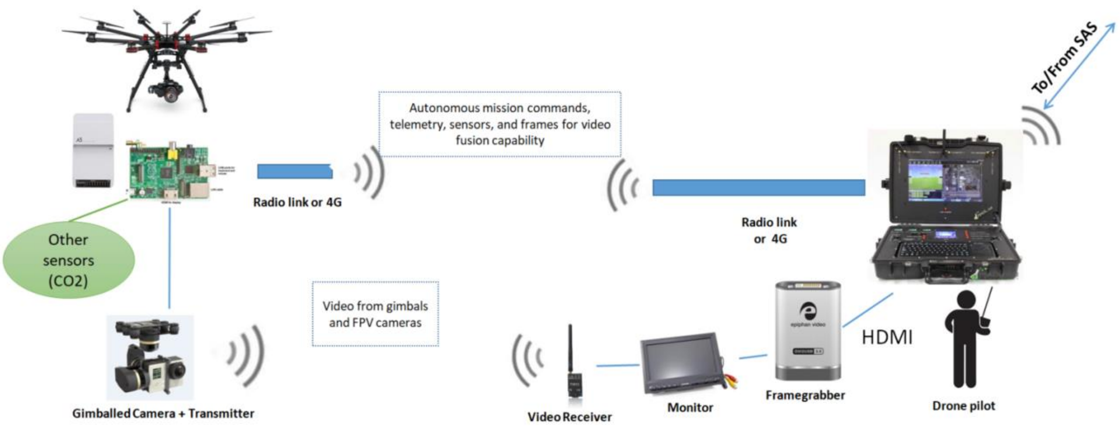

Figure 36: Integration scheme of pilot 3 scenario

In this case, the chosen autopilot (A3 from DJI) is also compatible with the Onboard SDK, so it is possible to interact with the drone through an external PC. This allows us to obtain telemetry data from the autopilot in real-time, as well as to be able to interact with it by sending missions or changing flight modes. In addition, it allows access to images from cameras that are integrated into the drone. In addition, the manufacturer DJI recommends a set of cameras to be integrated into this drone from which Catec will select one, and that will be described in the following sections. Finally, it should be noted that since a PC is needed onboard the aircraft, the gas sensor required to take samples from the disaster area can be connected to it.

GPS

The GPS used in this case is the internal one that DJI mounts in the autopilot A3. This GPS has protection against external attacks from spoofing. It supports the reception of 2 different GNSS: GPS and GLONASS.

Regarding the performance of this GPS receiver, the manufacturer's website states that it can reach an accuracy of approximately 2 meters.

Gas sensor

As for the CO and CO2 gas sensor, the same two as for scenario 2 are used. Being this platform bigger than Matrice 200 (used in scenario 2) and with a higher payload capacity, the mechanical integration of any of the two alternatives is even easier than in the previous case.

Video Camera

For the capability of video streaming to the ASSISTANCE system, the camera used would be similar to the video camera in scenario 2. One example, in this case, would be Zenmuse X5, which has its own three-axis gyrostabilized gimbal for the integration of the camera in the Matrice 600.

This camera is specifically made for aerial photography. Designed as a ready-to-fly platform, the Zenmuse X5 packs a sensor that is capable of recording 4K videos at up to 30 fps and capturing still images at 16MP. It is equipped with the standard MFT interchangeable lens mount and allows full wireless remote control over focus, aperture.

Figure 37: Zenmuse X5

The main features of this camera are:

- DCI 4K Video Capture;
- Records video and stills to micro-SDHC/SDXC cards;
- 16MP Still Photos;
- Micro Four Thirds Sensor with MFT Mount.

This camera can be integrated into the drone in the gimbal provided by the DJI manufacturer, as can be seen in Figure 37. Its total weight (together with the gimbal) is 526g.

Video frames for data fusion

For the capability of video fusion, the camera used in this case would be similar to the FPV camera in scenario 2. Another option that can be considered is to use a webcam which output is digital video frames and can be accessed directly from the onboard PC. There are already webcams with high capabilities such as the following: 4K Pro Magnetic Webcam. It has very low weight (90g) and small dimensions (3.5x10.1x2.7 cm) which allows it to be integrated easily in the drone. The main specifications of this camera are:

- Resolution:
  - at 4K Ultra HD, up to 4096x2160px @ 30 fps;
  - at 1080p Full HD, up to 1920x1080px @ 30 or 60 fps;
  - at 720p HD video, up to 1280x720px @ 30, 60 or 90 fps.
- Field of view:
  - Diagonal: 90º;
  - Horizontal: 82.1º.
- 5x digital zoom in Full HD;
- Autofocus.

Figure 38: Webcam used for video fusion capability in scenario 3

5.3 UGV Platforms and modifications

The PIAP UGV platform for scenario 3 will be the same as for scenario 2 –See description in chapter 4.3.

The same set of payloads will be available with exclusion of cutter extinguisher that would require whole system to be transported.

In scenario 3 also the UGV from Spanish National Police (MIR-PN) will participate in the demonstration. This UGV is the AUNAV Robot produced by the Spanish company Proytecsa.

Its main characteristics are the following:

- Weight: 400 Kg;
- Autonomy: 4 hours;
- Tractive force: 600 Kg;
- Elevation force:120 Kg;
- Range: 300 meters.

Figure 39 MIR-PN UGV that will be used during the third project pilot.

The UGV provided by MIR-PN will be equipped by CATEC with a telemetry module for ensuring its integration with the SAS. This telemetry module will provide the position, velocity and attitude information of the robot to the end-users. This is the unique modification that will be performed in this UGV.

The UGV will have the following sensors mounted by MIR-PN:

- Chemical Sensors CHEMPRO 100,
- Chemical Sensors QRAE 3,
- Gas detector (O2, CO2, H2S y Metano),

- Radiation detector RADIAGEN, Radiation detector COMO 170, Radiation detector NOVELEC DG 5.

These sensors have not the possibility of transmitting their measurements via any kind of wireless technology. MIR-PN has put video cameras on the UGV showing the sensors displays in order to know the measurements of this sensosrs in their real operations.

Therefore, only video streams showing both, the robot environement and the sensors displays and its telemetry information will be available in ASSISTANCE system.

Appendix A: Completion of the UAV requirements

As it was explained for the ground robot platform of PIAP (see section 4.3.1), UAVS that participate in the different pilots have been chosed after the evaluation of user requirements in D2.2 as well as technical requirements for excersising use-case scenarios from D2.3.

Below, in it is posible to find how the requirements are fulfilled with the selected UAVs.

Req. ID	Description	Type	User Rating	Comments
UAV_001	UAVs must be able to transmit visual images in RTSP 264 to the SAS platform in real-time.	Functional and data requirements	4,4	Visual images can be transmitted in real time in any format. In the different pilots, the video of the UAV is captured by a computer that it is in charge of the conversion and transmission to the SAS of the video.
UAV_002	At least in the industrial disaster Scenario, UAV must be able to transmit thermal images in real-time.	Functional and data requirements	4,5	UAVs of the scenario 2 are equipped with the Zenmuse XT2 camera, which provides thermal images in real time to the operator of the drone.
UAV_003	UAV must be capable to be equipped with a gas/smoke sensor	Functional and data requirements	4,3	UAVs of the scenario 2 and 3 can be equipped with two different gas sensors. The measurements are transmitted to the SAS.
UAV_004	UAV ground control station allows tracking the UAV during the whole operation	Functional and data requirements	4,5	GCSs used for all the drones allows to receive the position, velocity and attitude of the drone (more parameters are also received as battery level, pressure, etc).
UAV_005	UAV must have the possibility of being controlled by both pilot RC commands and unmanned waypoint navigation capabilities.	Functional and data requirements	4,4	All the autopilots implemented in the different drones allows the operator to use several flight modes. In all the UAVs, both manual and waypoint navigation are possible.
UAV_006	UAV System small enough to be transported by van or pallet, preferably with an MTOW less than 15 kg.	Functional and data requirements	3,7	Excepting the Matrice UAV that will be used in the scenario 3 and whose weight is about 20 Kg (UAV + systems associated), the weight of the rest of the UAV systems are under 10 Kg.
UAV_007	The flight envelope of the aerial vehicle has to be provided for flying and landing	Functional and data requirements	3,7	Flight envelopes for all the UAVs have been presented in their technical specifications.
UAV_008	UAV used must fulfil with the current regulation in order to obtain the flight permits.	Legal requirements	3,9	Drones used for the different scenarios fulfils with the current limitations in the regulation. The weight and dimensions of the selected drones, makes them perfect platforms for the approval of the permits.
UAV_010	UAV operation time must be at least 20 minutes	Functional and data requirements	4,5	The operation times of the drones selected for the pilots go from 28 to 35 minutes.
UAV_011	Setup time of UAV must be less than 10 minutes.	Functional and data requirements	4,2	The different UAVs will have integrated the necessary electronics at any moment(so this does not

Req. ID	Description	Type	User Rating	Comments
				suppose setup time). Due to the drones selected are ready to fly at any moment (if batteries are charged), the setup time will be under 10 minutes.
UAV_012	UAV must provide real-time video streaming and distribution	Functional and data requirements	4,6	Video from the cameras of the UAVs will be transmitted in real-time.
UAV_013	UAV must follow geofencing rules	The scope of the product	4,1	Selected UAVs have a data base that contains geofenced areas.
UAV_014	UAV must be equipped with command interface to control UAV according to simulation purposes	Functional and data requirements	3,7	Commanded missions protocols will be implemented in order the UAVs can be commanded through the commands created in the mission management module.
UAV_015	UAV must be equipped with telemetry data link connected to ASSISTANCE to provide telemetry data	Functional and data requirements	3,9	UAVs will be able to send to the SAS the position, velocity and attitude information during the whole operation. To send other parameters as the inertial information, battery level, etc. is also possible.
UAV_017	UAV can be equipped with 3D mapping capabilities depending on the type of planned mission	Functional and data requirements	3,6	3D mapping capabilities will not be performed onboard the drone. This functionality will be carried out by the augmented Video Fusion Module implemented in the SA. UAVs will be equipped for sending the necessary data.

Table 14: Completion of the UAV requirements.