H2020 – Secure societies - Protecting freedom and security of Europe and its citizens

SU-DRS02-2018-2019-2020– Technologies for first responders – Research and Innovation Action (RIA)

**Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations**

# D5.4 Testing of RESCUE MIMS on-board robotic platforms and drones

| | |
|---|---|
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| **Authors:** | THALIT |
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# Search and Rescue Project Profile

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| **Title:** | Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations |
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# Document History

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# Executive Summary

The Task 5.4 called "Testing of RESCUE MIMS on-board robotic platforms and drones" is an activity lead between Month 10 and Month 30 in the Project Search & Rescue.

The main scope of T5.4 is to test the robotic platform provided by DFKI with its sensors (Cameras and LIDAR), the Obstacle Detection System (ODS) provided by THALIT and the field chemical tool (RESCUE MIMS) provided by the NTUA together with the drone provided by UHasselt.

In order to share all the possible interface from Telecom, Power, Physical and Logical point of view a dedicated Interface Control Document has been developed in order to align all partners on the mutual interfaces.

Within the Task 5.4 some specific tests are foreseen, for example the ODS algorithm will be tested with some images provided by the end users, the robot will be tested with a dedicated test and the RESCUE-MIMS will be tested in lab-scale experiments.

The related deliverables foreseen in the Task 5.4 are two: the D5.4 "Testing of RESCUE MIMS on-board robotic platforms and drones" (this document) where the topic is introduced as per status of the project and the D5.8 "Testing of RESCUE MIMS on-board robotic platforms and drones, V2" that is the revision 02 of the D5.4 with the possibility to finalize all paragraphs not ready at the moment of the D5.4 release.

The main objectives and outcomes of the D5.4 "Testing of RESCUE MIMS on-board robotic platforms and drones" are the description of the platform robot with its sensors (Cameras and LIDAR), the Obstacle Detection System (ODS), the field chemical tool (RESCUE MIMS) and the drone; in particular it is described the integration and the interfaces between all these components following the activities of Task 5.4. Moreover, it is introduced the testing approach of the whole technological platform.

The milestone submission of D5.4 is at the end of Month 16 and the milestone submission of D5.8 is at the end of Month 30, moreover the Use Case where all the components will be tested together is the number 4, named "Forest fire expanded and threat to industrial zone (Corinthia, Greece)" that is foreseen the Month 29. As per resultant scheme the early revisions of D5.8 will be used in order to adjust and complete the paragraphs of the D5.4 with the information obtained during the Task period and the related Milestone revision to formalize the final Test results.

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# List Of Abbreviations

| | |
|---|---|
| AC or ac | Alternating Current |
| Cat-6 | Category 6 |
| CCTV | Closed Circuit Television |
| FAT | Factory Acceptance Test |
| FOC | Fibre Optic Cable |
| FOV | Field of View |
| GPS | Global Positioning System |
| GLONASS | Global Navigation Satellite System |
| HMI | Human Machine Interface |
| ICD | Interface Control Document |
| IEEE | Institute of Electrical & Electronic Engineers |
| IP | Internet Protocol |
| IVVQ | Integration, Verification, Validation and Qualification |
| IT | Information Technology |
| ITU | International Telecommunication Union |
| LAN | Local Area Network |
| LCD | Liquid Crystal Display |
| LED | Light Emitting Diode |
| Lipo | Lithium Polymer |
| Mb/s | Megabits per second |
| MIMS | Membrane Inlet Mass Spectrometer |
| ODS | Obstacle Detection System |
| PoE | Power over Ethernet |
| RTMP | Real-Time Messaging Protocol |
| S&R | Search and Rescue |
| SAT | Site Acceptance Test |
| SDK | Software Development Kit |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| UC | Use case |

# 1 Introduction

The following paragraphs introduce the state of the art in chemical sensors tests with robots and drones in order to have an overview of the subject matter, then the possible improvement that could inspire the S&R Project and finally the introduction of the S&R Robot and Drone Work Plan foresee in the T5.4 and the related S&R Proposal.

## 1.1 State of the art

In case of natural or technological disasters there is a strong possibility of hazardous environments formulation, not only for the affected communities and the people who are exposed but also for the first responders that are the ones who are called to mitigate the phenomenon at its early stages and limit the impacts.

Air quality monitoring in such cases can be proved vital for assessing the risk of exposure to dangerous compounds and hence, help the decision makers in the disaster management e.g. decide on the evacuation of the affected area, or for using specific personal protective equipment etc. In case of technological or fire incidents, chemical sensors or biosensors and unmanned platforms (UAVs or UGVs) could be used as a remote early warning system for the safety and security of the first responders that are engaged in the field, through detection of selective hazardous smoke components, known as Critical Key Indexes-CKIs [1-3].

Worldwide, there is a significant increase in the use of unmanned aerial vehicles (UAVs) by emergency services since they can support the rescue operation and Specific Operations Risk Assessment (SORA) [4]. According to literature, there is a possibility of recording chemical data on-line as maps of pollutants' concentrations for the areas of interest with the help of drones, as shown in Figure 1 [5] "Gas concentration map of an area monitored by a drone equipped with a photoionization detector (PID)."

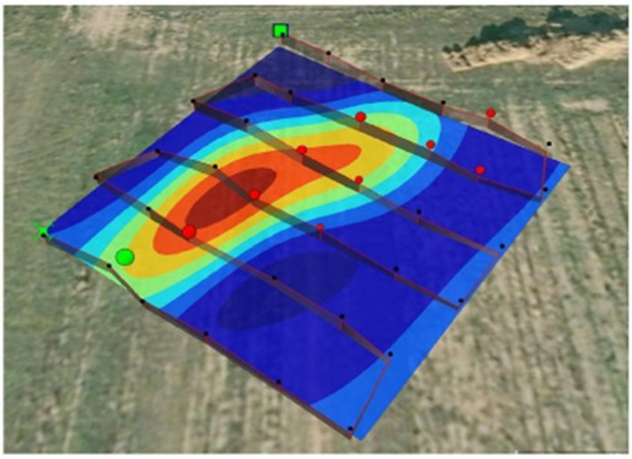

Figure 1: Gas concentration map of an area monitored by a drone with a photoionization detector.

However, there is a number of limitations in using drones with chemical sensing technologies, especially the small ones, such as their limited payload capacity and the short flying times (usually 15–20 min) that make them inappropriate for large-scale screening in settings with low infra-structure density; obstacle detection and avoidance is still not feasible in realistic scenarios [5].

Concerning the ground robots, there is a variety of them that have been used in Search and Rescue operations, such as snakes, tracks and legged locomotion [6-7]. These types of robots can be used on rough terrain, which is usually encountered in rescue missions, though they are also fairly slow. Since operation speed is quite important for searching for potential victims after disasters, these types of robots are usually used in swarms to search an entire area in coordination; it requires interconnectivity and/or sensor data fusion during the operation [6-8]. According to literature, different types of unmanned aerial vehicles and ground robots with chemical sensing have been tested together for their interoperability under a forest fire scenario [2]. It seems that robotic platforms can be assigned different missions like damage inspection, or even medical assessment of victims and for transporting equipment and first aid kits [9].

## 1.2 How to improve the State of the Art

It seems that chemical sensing on-board robotic platforms, like drones is a promising tool for a number of applications, such as environmental, or for safety and security purposes [10]. Also, drones have been used in a variety of S&R emergency services and in many research projects like INACHUS, AirBorne, DARIUS etc [11-13].

However, it has to be noted that a crucial issue when using a chemical device as a payload on a drone is the thermodynamics (turbulence), the vibrations and in general how the high altitude in terms of increased RH%, low temperature and increased atmospheric pressure may affect the response of those devices e.g. operation of pumps, sampling rate, response times etc. Also, the speed of a platform, either aerial or ground, is a critical factor for providing with spatially resolved measurements and it mainly depends on the frequency that a chemical sensor can sample [14]; a dynamic inlet system is required for monitoring dynamic changes of concentrations in time and space. Testing of chemical sensors by monitoring the above parameters could improve the state of-the-art in chemical sensing with robotic platforms.

Another important issue is the downwash generated by the propellers of Rotary-Wing (RW) drones can that can affect the concentration density of the chemicals that are monitored and hence, the quality of the measured data (false negatives) [5]. This is also an issue to be considered when using chemical devices on-board ground platforms, e.g. vehicles (roving systems) because measurements can be affected by the exhaust emissions of the vehicle providing with false positives; electric-powered vehicles are preferred for that reason.

Obstacle avoidance algorithms also seem substantial to support the robotic platforms in semi-autonomous movement operations. Search and rescue drones need to have additional requirements comparing to other generic drones. These requirements include a long flight time, a good payload capacity and a high resistance to environment and weather conditions (e.g. to 28.8km/h wind speed and more than 40°C temperature operating temperature). According to literature, Fixed Wing UAVs, capable of flying in moderate winds, can be used effectively in forest fires and especially in S&R operations [2]; according to the same study, ground robots need to be fire proof and heat resistance.

## 1.3 S&R T5.4 Work Plan

The scope of the Task 5.4 is the Testing of RESCUE MIMS on-board robotic platform and drone. The following main activities explain the related work plan in order to achieve this scope:

1. Components identification by each partner following by alignment meetings.
2. Data gathering between partners in order to collect and to compare the proposed components.
3. Organization of related technical meetings in order to introduce and analyze the all interfaces and connections from any point of view: Telecom, Power, Data and Physical.
4. ICD (Interface Control Document) submission as internal Project document.
5. Definition of the resulting architecture with the identification of each role for each partner and for each component.
6. Integration and Testing.

# 2 IVVQ Methodology

The following paragraphs describe the IVVQ (Integration, Verification, Validation and Qualification) methodology including the introduction of the theoretical approach with V-Cycle Scheme, the management of the interfaces on the Robot platform and Drone with the ICD document, the related interface Matrixes and finally the S&R Robot & Drone Integration and Verification Plan.

## 2.1 The V-Cycle Scheme

The V-Cycle scheme is a model usually considered in the IVVQ strategy that represents the theory of the systems development lifecycle within the System Engineering and Project Management disciplines in particular it is applied for complex Integration System in an industrial context.

The Figure 2 shows all the steps and the dependences foreseen on the V-Cycle scheme:

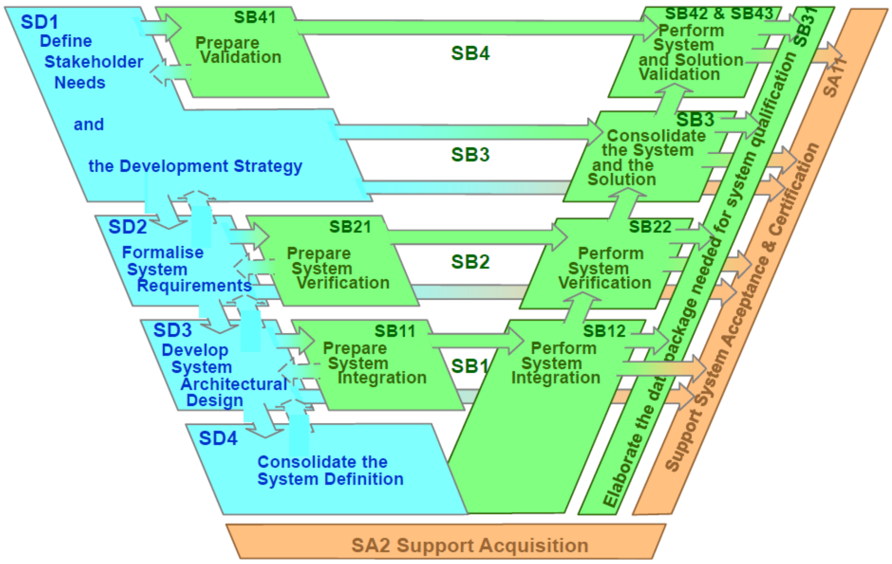


Figure 2: V Cycle Scheme

The SD1 is the step at the beginning of the Design and it is fundamental in order to well define the Stakeholder Needs and the consequent development strategy; in particular the needs can come from customer "nice to have", formal specifications and/or from experience of who is the provider of the System that will suggest the right need.

The SD2 is the second step useful to formalize the System requirements; these are not be confused with the Stakeholder Needs, in fact these are the list of the technical issues to achieve the Stakeholder Needs. Often only the system engineer knows the constrains, the performances and the activities to reach a Stakeholder Need.

After the formalization of the System requirements, the related System Architecture can be designed and developed with a block diagram (SD3) and the System definition (SD4) can be consolidated for example with the submission of a Functional Design Specification.

It is important to perform a review at the end of each step, an internal review and/or with customer in order to search eventual issues and to consider a new revision of the previous step.

At the bottom of the V-Cycle, the activity SA2 Support Acquisition is often considered the "point of no return" of the design and development, in fact this will produce the Contracts with outside companies (vendors) and the eventual manufacturing will start.

As shown in Figure 2, the parallel activities to the left side of the "V" can proceed, then for example; following the architecture the preparation of System integration (SB11) can be prepared with related document and consequently the System integration can be implemented (SB12).

"Prepare System Verification" (SB21) and "Prepare System Validation" (SB41) mean to write the documentation that will describe the related phase of testing, usually procedures are submitted. An important note is the difference between Verification, which is the test statement by statement of all requirements, and Validation, which is the test statement by statement of all Stakeholder needs.

Passed all the steps also on the right side of the "V", the activity for System Qualification (SB31) can be performed, this could push the related manufacturing. Finally, the Acceptances and/or Certifications (SA11) can also be performed. In particular, the step of the Acceptances are usually two: the first is the FAT (Factory Acceptance Test) and the second is the SAT (Site Acceptance Test), which follows the Verification and the Validation with the Customer presence.

The arrows that go from the left side to the right side of the "V" define Requirements Traceability, in fact that from requirements to preparation, are called the "Link to Design", that from requirements to verification/validation are called the "Link to Test". The Test Procedure will be derived directly from the Requirements Traceability and developed in the revision 2 of D5.4 (this document) in Paragraph 7.1.4.

## 2.2 S&R T5.4 – Interface Control Document Results

During the first 12 months of S&R Projects several meetings have been organized in order to introduce and analyze the Interfaces of all components for the Robot and the Drone platform. Then, the Interface Control Document has been issued with the definition of all interfaces and connections from Telecom, Power, Data and Physical point of views. The ICD has contributed to define the resulting architectures, including the identification of each role for each partner and for each component. The following paragraphs report the results of the ICD document.

### 2.2.1 ICD – Components positions and related provider partners

The following Figure 3 shows the mutual positions of single components:

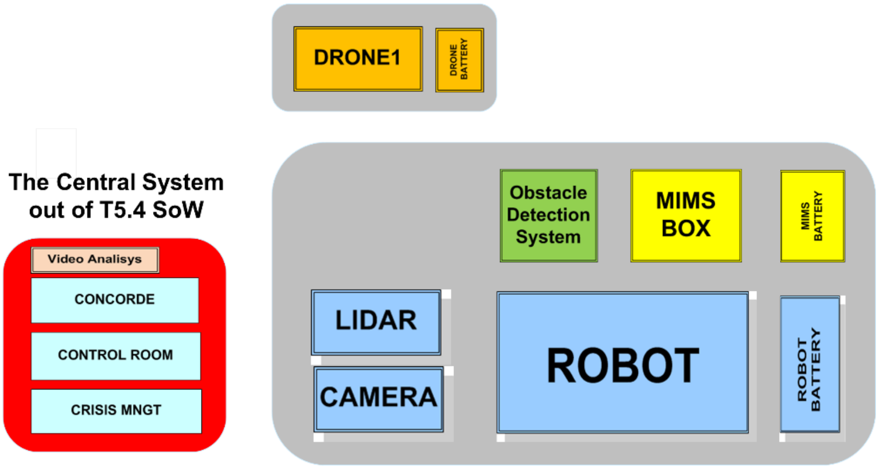


Figure 3: Components mutual positions on Robot and Drone platform

In particular, LiDAR sensor, Camera, Robot and its battery are provided by DFKI and the Robot will host the Obstacle Detection System provided by Thales and the MIMS with its battery proved by NTUA. The Drone with its battery provided by UHASSELT will be independent from Robot platform and the related Video Analysis provided by Aideas will be installed on the Central System (out of T5.4 Scope of Work).

### 2.2.2 ICD – Telecom connections Block Diagram

The following Figure 4 shows all Telecom connections foreseen in the Robot & Drone platform:

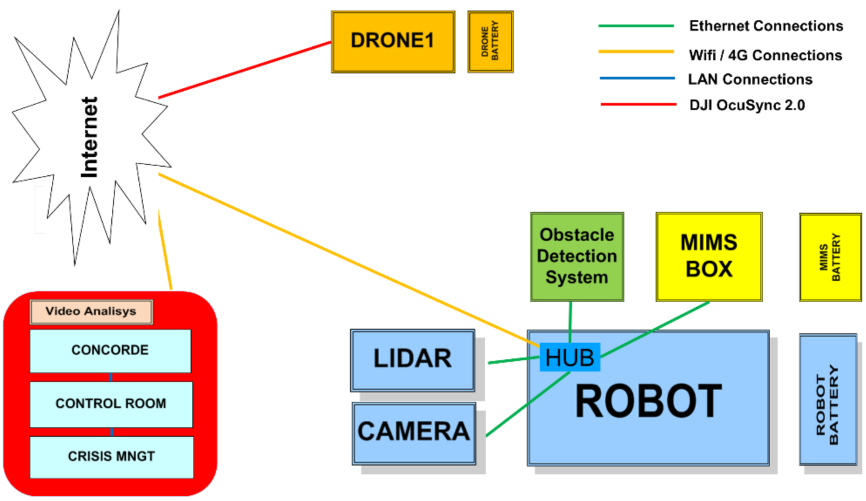


Figure 4: Telecom preliminary Block Diagram

In particular, all sensors (LiDAR sensor and Cameras) and devices ODS and MIMS box will be connected together with an HUB provided by DFKI which will be connected to the Control Room via

WiFi or 4G connection, the Drone will be connected to Control Room with a specific telecom connection. For details on the architectures refer to the paragraphs 4.2 and 5.3.

### 2.2.3 ICD – Power connections Block Diagram

The following Figure 5 clarifies the power feeding of the single components on Robot and Drone platform. In particular, the MIMS and the Drone will have the own batteries, while the Obstacle detection System will be powered by the Robot battery.

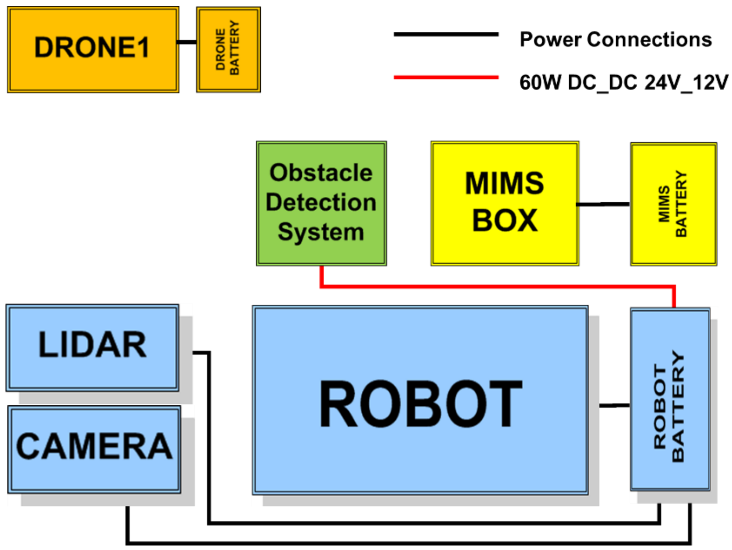


Figure 5: Power Connection Block Diagram

### 2.2.4 ICD – DATA connection Block Diagram

The following Block Diagram provides an idea of all data exchanged within the Robot and Drone platform:

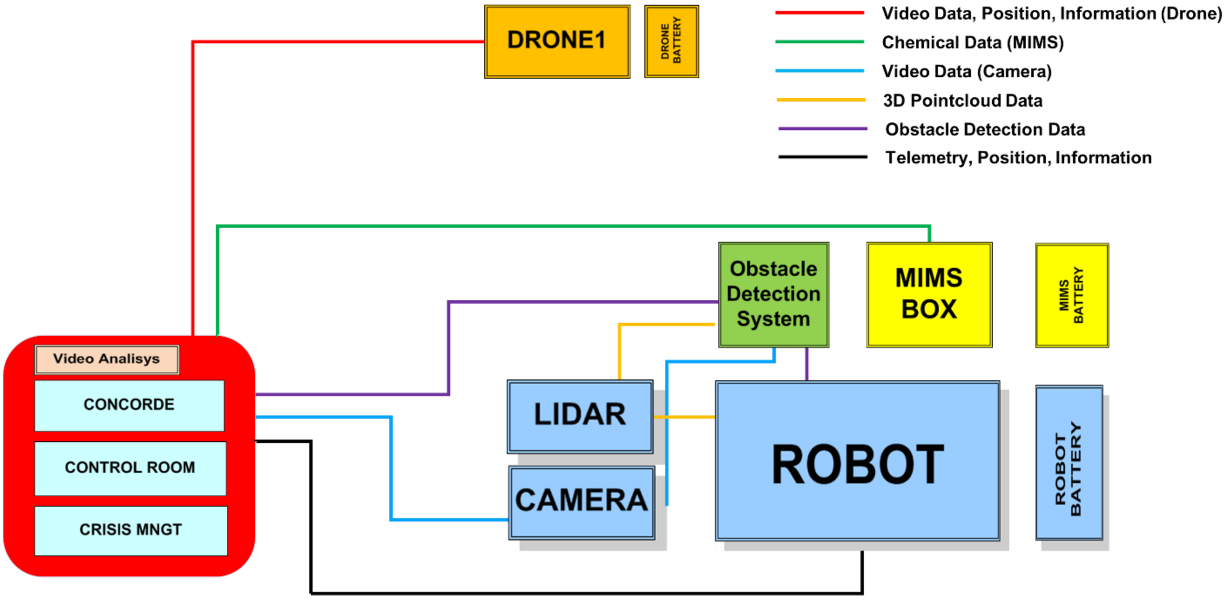


Figure 6: Data Connection Block Diagram

### 2.2.5 ICD – Physical connections Block Diagram

The last figure of this chapter explains the physical connections to be organized on the Robot and Drone Platform, for example the connection between Obstacle Detection System and the Robot will be through metal brackets (the same possibly for the MIMS):

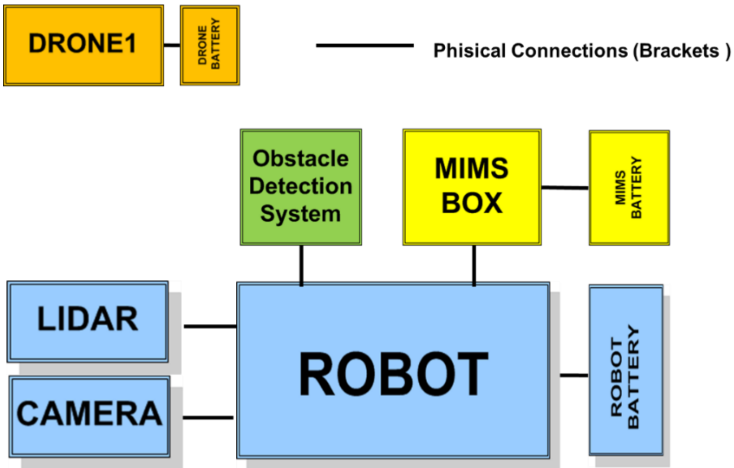


Figure 7: Physical Connections Block Diagram

## 2.3 S&R T5.4 - Integration and Verification Plan

The Integration and Verification strategy takes into consideration the V-Cycle scheme with the adaptation on the context of the S&R Project. In particular, the project is characterized by several partners that have the responsibility of a single component.

Following a lean approach, the strategy is to anticipate as much as possible all feasible test in house and to consider the integration test of the Robot as the key point of verification of the integrated design to de-risk the validation phase on site in the Use Case 4.

Refer to the following flowchart integration and testing plan, where the FAT is a preliminary preparation test (refer to 6.1 and 6.2) for each component, the i-FAT is integration test in the Robot platform while the SAT is the final test during the Use Cases:

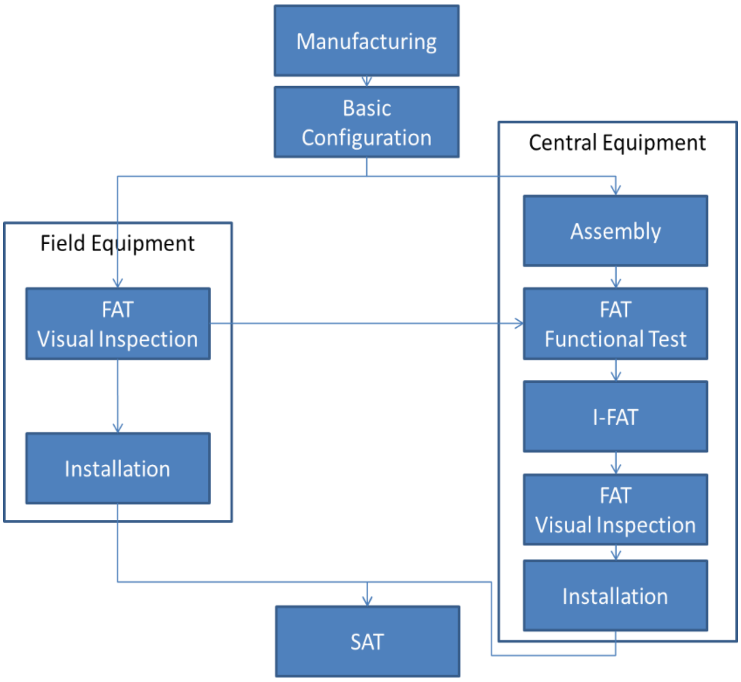


Figure 8: Integration and Testing Flowchart

Moreover, to anticipate any integration SW issues, an additional remote test is foreseen between Robot, Obstacle Detection System and MIMS box to test for example the robot inputs from Lidar and Camera towards ODS or the output of ODS toward the Robot.

# 3 Solutions Composition

## 3.1 End-Users opinions (from WP8)

In the context of the WP8 in S&R project the questionnaire "Need for use cases' technologies" has been launched between the End Users, hereafter the main statements about the Robot Platform and Drone are listed in order to have the important point of view of the End-Users:

*Question: Are there any components/technologies that are missing that you would like to have?*

*Reply: No, everything that is going to be used or not used from the proposed solutions came up after serious consideration*

*Question: What are the main constraints (i.e. obstacles that these technologies could pose during use cases) that you think these technologies could entail in the use cases?*

*Reply: Wi-Fi network and 4G might pose a constraint. Also weather might be an obstacle and flying of drones might not be feasible.*

*Question: Is it required special maintain costs or efforts for the selected technology?*

*Reply: Yes. Maintenance, insurance (for the drones), batteries, data for mobile network, etc.*

*Question: Does it require a complicated bureaucracy / or legal framework for its implementation?*

*Reply: In some cases yes. We need special permissions to fly the drones.*

*Question: What real change will it bring to Search and Rescue Operations?*

*Reply: Saving time. Supporting a more efficient way on carrying out the Search and Rescue operation.*

*Question: Is there a component could be improved in the selected technology in order to be more efficient and what reason?*

*Reply: Chemical sensors, since we are involved in UC where there is a chemical risk and robots to assess the risks before FRs interventions.*

*Question: What is the combination of technologies that are envisaged in each use-case? (i.e., Rescue MIMS combined with robot and obstacle avoidance system; drones with artificial intelligence, etc.).*

*Reply: Chemical sensors in combination with robots and drones. Six gases monitor in combination with drones and robots.*

*Question: What technologies are most and least important to you/your organization?*

*Reply: Most relevant: Rescue MIMS, Emergency Response health condition monitoring device (especially for us as EMS), drones/robots (for data gathering e.g. of hard to reach places)*

*Question: Is the select technology easy to use?*

*Reply: The use of robot and obstacle avoidance is depending on an external pilot*

*Question: Is there a component could be improved in the selected technology in order to be more efficient and what reason?*

*Reply: The weight and the volume of the MIMS could be improved in order to be transferred more easily from a drone. The new tools could be communicated before the UC to be known from the teams before the use case.*

## 3.2 Operative Scenario (from WP8)

As introduced in the paragraphs above, all the components of T5.4: the robotic platform provided by DFKI with its sensors (Cameras and LIDAR), the Obstacle Detection System (ODS) provided by THALIT and the field chemical device (RESCUE MIMS) provided by the NTUA together with the drone provided by UHasselt will be tested together during the Pilot UC4: "Forest fire expanded and threat to industrial zone (Corinthia, Greece)".

The pilot will take place in an urban area mixed with forest that is situated nearby an industrial zone. It has to be considered that wildfire disasters may rapidly change their nature into technological disasters, e.g. in the mixed areas of forest and residential, heavy industrial, or recycle zones.  This pilot is based on a real scenario that took place in Industrial Zone; Greece were a refinery was indeed in danger during wildfires occurred in July 2018 in Greece.

The main objective of the pilot is to test the remote sensing technologies proposed in the S&R project for the safety of first responders; alarms for early warning of toxicity or radiation exposure and generally inspection of the hot zone area; use of rescue robots and drones to facilitate the SAR operations.

The estimated time for the implementation of UC4 is November 2022. The pilot will take place a Weekend during the daytime, at 8.00 a.m. and last 8 to 10 hours, in a region called Lecheo close to city of Korinthos. The place of the pilot will be the LECHEO (LEH), Military airport, Corinthia. Longitude: 22o 51' 40.15" E. Latitude: 37o 55' 38.37" N

All components that will be tested are:

1) Smart Glasses (SIMAVI)

2) Smartwatch (KT)

3) Emergency response health condition monitoring device (CERTH/HRT)

4) Radiation sensors (wearable)

5) Chemical sensors - Rescue MIMS (NTUA)

6) Drones (UHasselt)

7) Collaborative drones' platform (UHasselt)

8) Rescue Robots & Autonomous vehicles (DFKI)

9) Obstacle Detection System (THALIT)

10)Volunteer application (CERTH)

The representatives of Hellenic National Defense general staff will be invited, they give to S&R consortium the place where the UC4 be held and the Local stakeholders (Regional governor, Mayor, Fire department and civil protection authorities) will possibly attend the pilot as observers. However, the level of their involvement is dependent on their availability at the time of the pilot and their willingness to participate.

## 3.3 Selected Components introduction

The following paragraphs have the scope to introduce the single selected components provided by the four Partners DFKI (Robot Platform), NTUA (MIMS Box), THALIT (Obstacle Detection Software) and UHASSELT (Drone).

### 3.3.1 Robot overview

The planned robot platform to be used in this S&R project is the DFKI version of the SeekurJr. It is a very robust outdoor system which can especially be used on uneven, e.g. rocky or sandy ground, or urban environments. On heavy terrain it may struggle due to the low ground clearance. It also is not fully waterproof in the current state, so rain, wet roads and muddy terrain should generally be avoided. Originally, the system is used for the primary research tasks of autonomous self-evaluation and the detection of unspecified failures and disturbances.

The rover is originally equipped with with a SICK LMS-111 LiDaR scanner for long range mapping, and extended by a sensor tower at the front, which holds a periodically tilting Hokuyo UTM-30LX-EW LiDaR scanner for close proximity obstacle detection at an extended height, plus a pan-tilt unit with a mounted Velodyne VLP-16 LiDaR scanner and two IDS UI-5240CP Rev 2 GigE cameras for more dynamic perception capabilities including stereo vision. The peripheral components are connected via two switches using Gigabit-Ethernet or USB.

To be able to turn on the spot, the robot is skid-steered by two motors - one on each side. It has a swing radius of 52cm, a maximum linear velocity of 1.2m/s and a maximum traversable grade of 75%. The rover can run for 2-3 hours on average until the batteries are depleted. This value depends on the rover's tasks and loads. For an extended operation duration, the batteries can be hot swapped manually during a mission, as long as the white cover on the robot base remains freely accessible. The battery provides regulated power of 2A at 5V, 2A at 12V, and 1A at 24V. It also provides 20A of unregulated power at a nominal voltage of 24V which will be used for powering the ODS.

For autonomy and perception, the robot includes three PCs. Besides navigation and plan execution, the semi-autonomous control particularly includes the prediction of sensor values (generation of expectations) and the self-evaluation (detection of unexpected or unknown situations).The robot has four easy to access full stop buttons in case of emergency, which halt the entire operation of the robot. In Figure 9, the modified platform is shown in its current state.

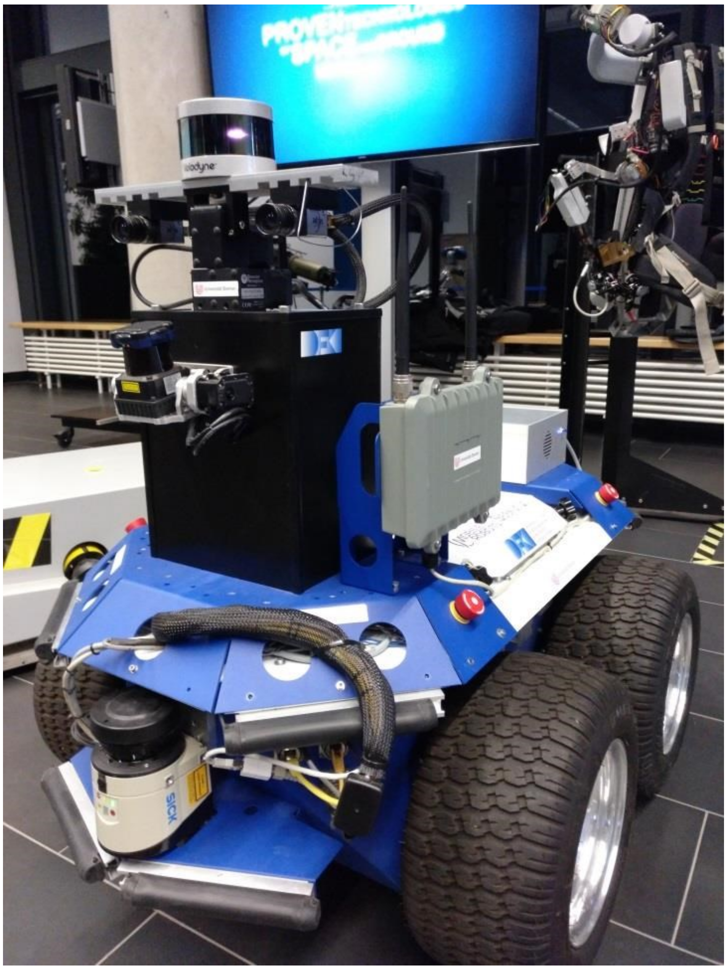


Figure 9: DFKI SeekurJr robot platform

### 3.3.2 MIMS overview

The RESCUE-MIMS device that will be delivered in S&R project is a prototype of technology readiness level (TRL) 6 that has been designed and developed in the prospect of satisfying the majority of the end-users requirements that have been indicated inside D1.2.

Figure 10. The rescue-MIMS chemical device

RESCUE-MIMS device can be used for the early detection of toxic environments for the first responders in terms of hazardous VOCs or semi-VOCs identified in the disaster environment. Membrane inlet mass spectrometry (MIMS) can generally offer high sensitivity (from low parts per billion-ppb, to low parts per trillion-ppt), fast and accurate analysis, minimizing false alarms and sample preparation requirements. It can be used for both single and multicomponent mixtures. Since it is a field instrument, it can be used either as a handheld device, or as a payload on-board robotic platforms.

### 3.3.3 Obstacle Detection System overview

In the context of S&R Project the Obstacle Detection System is a Prototype developed within the T3.4, for the detailed description refer to the D3.6. In the T5.4 ODS will be integrated in the Robot Platform, with the main objectives as following:

- Detect and track obstacles, fusing information coming from different technologies of sensors;
- Notify the pilot of a potential collision with obstacles detected in front of the robot;
- Cover different scenarios despite weather conditions and unavailable sensors.

Consequently, ODS main functions are:

- Acquire sensors (LiDAR and Camera) raw data;
- Filter and process raw data at sensors outputs;
- Detect obstacles in front of the Robot, associating information from different sensors and tracking them;
- Provide an alarm, to notice to the pilot of obstacles presence.

The ODS block diagram is represented in Figure 11. The ODS system includes two different sensors, whose data will be fused together in order to improve obstacles detection probability.

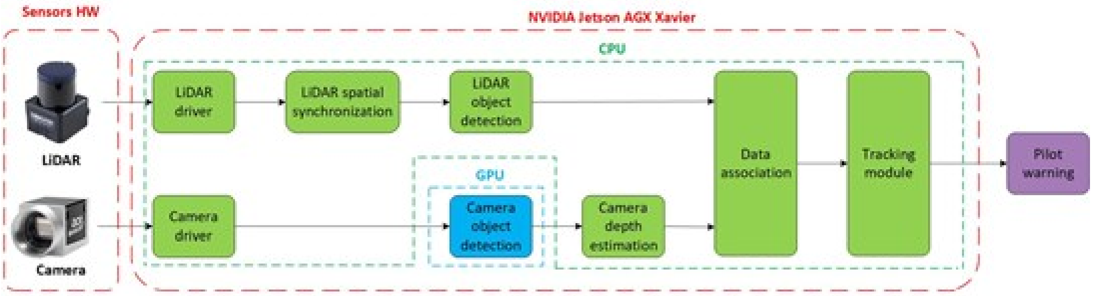


Figure 11: ODS block diagram

Inputs of the system are smart sensors: each block is composed by the hardware device and a sensor driver that is in charge of the receiving and the conversion of raw data in a suitable format.
LiDAR raw data are converted in the Cartesian coordinate reference system centered in the robot in the Spatial synchronization module.
Then objects are detected on sensors raw data. So:

- Clustering algorithm will be implemented, to aggregate LiDAR 3D point cloud.
- Convolutional Neural Network (CNN) will run on video frames, enclosing objects detected by the model in Bounding Boxes (BBs).

Later, depth estimation module represents BB information (like central point coordinates, width, and length) on the robot Cartesian coordinate reference system. At the end of this process, objects detected by LiDAR and camera are represented in the same reference system and they can be compared.
The Sensor Fusion algorithm is a fundamental and crucial stage of the ODS composed by two steps: data association and tracking. They analyze one time step the given data and decide on the most likely measurement-to-track associations. Objects detected coming from different sensors are associated using one of the analyzed algorithms:

- Global Nearest Neighbor (GNN);
- Joint Probabilistic Data Association (JPDA).

In order to increase the methods robustness, some constrained extra information can be added, e.g.: speed, obstacle width and/or length, etc.
A limited number of the associated objects can be tracked with Unscented Kalman Filters (UKFs).
Finally, the Collision Checker Module evaluates if detected objects located in the Region of Interest (ROI) could be obstacles for the robot and sends the alarm to the pilot. ROI for the collision warning will have a defined length and width.
The output information of the ODS will be the:

- Reference time T of detected objects;
- Objects position (x, y) and their velocity ($v_x$, $v_y$);
- Measure of the uncertainty of the given data;
- Objects class;

- Objects dimensions expressed as width and length of Bounding Boxes in which they are enclosed.

ODS runs in the NVIDIA Jetson AGX Xavier board composed by:

- CPU: 8-core ARM v8.2 (x64) @2.26 GHz, 8MB L2 + 4MB L3;
- GPU: 512-core Volta GPU @ 1.37 GHz with Tensor Cores;
- RAM: 32GB 256-Bit LPDDR4x (137 GBps).

The OS installed in the NVIDIA Jetson AGX Xavier is a Linux-based, in order to support the Robot Operating System (ROS).

The following figure shows the NVIDIA Jetson AGX Xavier and the related Peli Protector 1400 box which will contain it:


Figure 12: NVIDIA Jetson AGX Xavier

Figure 13: Peli Protector 1400 box

ODS prototype will present the following interfaces:

1. Metallic circular connector for the power supply at 24 V.
2. 2 x female Ethernet connector: one for the connection with the robot and the other for debug;
3. Green LED. When the ODS prototype is fed, the green LED in ON.

### 3.3.4 Drone overview

The Drone that will be provided is DJI phantom 4 Pro v2. This drone weight 1375g with the battery and propellers. It can fly for around 30min using a 6000mAh LiPo 2S battery. The drone has three speed modes (S-mode: 45 mph (72 kph); A-mode: 36 mph (58 kph); P-mode: 31 mph (50 kph)) and has an approximative max wind speed resistance of 10m/s. The DJI phantom 4 Pro v2 can operate in temperature range from 32° to 104°F (0° to 40°C) and support two satellite positioning system (GPS/GLONASS).


Figure 14: Dimension of DJI Phantom 4 Pro v2.0

The provided drone will include a camera onboard with a Gimbal of 3 axes for stabilization (pitch, roll, yaw). The Gimbal pitch could be controlled from -90° to +30° with a max speed of 90°/s.
The obstacle avoidance system of the drone with the Gimbal provides three Field of View (FOV). A forward and backward view with a variation degree of 60° (Horizontal) and ±27° (Vertical). A downward view with a variation degree of 70° (Front and Rear) and 50° (Left and Right). The vision system has an Obstacle Sensory Range of 2-98 ft (0.7-30 m).
The DJI phantom 4 Pro v2 has also an Infrared Sensing System with a FOV of 70° (Horizontal), ±10° (Vertical) and obstacle sensory range of 0.6-23 feet (0.2-7 m).
The camera integrated with the Drone provide a FOV of 84° 8.8 mm/24 mm (35 mm format equivalent). It provides pictures with three aspect ratios (3:2 Aspect Ratio: 5472×3648, 4:3 Aspect Ratio: 4864×3648, 16:9 Aspect Ratio: 5472×3078) and support different photography mode like Single Shot, Burst Shooting, Auto Exposure Bracketing (AEB) and Interval. The images could be saved in different

formats (JPEG, DNG (RAW), JPEG + DNG)). The camera also supports different Video Recording Modes including Cinema 4K (C4K: 4096×2160 24/25/30p @100Mbps) and different video formats (MP4/MOV (AVC/H.264; HEVC/H.265)). The video could be saved in the microSD of the drone which has a capacity of 128GB or live streamed to live stream platform like Facebook, Youtube, WeiBo or a customized (hosted or local) RTMP (Real-Time Messaging Protocol) server with a max live view quality of 1080P.

# 4 Robot System Integration

## 4.1 Functional requirements

To provide first responders with crucial information of the environment in form of spatial maps and gas measurements, the robot needs a proper network interface as well as hardware interface to mount the necessary tools for the job. This includes a) a 4G/WiFi router, b) the RESCUE-MIMS system case, c) the Obstacle Detection System (ODS), d) an additional voltage regulator to provide power to the ODS, and e) an ethernet hub to connect these components, so they can access the network independently as well as work as a unit for controlling the robot. The sensors of the robot need to provide the data to the Obstacle Detection System, which then provides obstacle information to the robot for semi-autonomous control as well as to the driver on the control room for manual control, in case the semi-autonomous system fails or does not lead to desired robot operation.

Ideally, the white battery cover of the robot should remain accessible after mounting all components, so the batteries can be hot-swapped during an operation.

### 4.1.1 Robot Functional Requirements

In this section the Functional Requirements of the Robot system are listed:

1. The Robot shall provide a hardware interface (like metal brackets) to mount all the additional components.
2. The Robot shall provide the proper Power to the components that requires it (ODS).
3. The Robot shall provide a dedicated internal network where all networking components are linked via Ethernet and connect to a remote control station via 4G or WiFi.
4. The Robot shall navigate with a driver or in semi-autonomous mode with a 3D-Exploration Algorithm.
5. The Robot shall Integrate the Obstacle Detection System in order to elaborate the output of the Detection SW and to decelerate/stop the movement, in particular the ODS will provide information to the onboard Robot System by outputting fused obstacles position and speed data in the robot reference system. Moreover the ODS output will be available on a ROS topic whose content describes objects position and Speed.

### 4.1.2 ODS Functional Requirements

In this section the Functional Requirements of the Obstacle Detection system are listed:

1. ODS system shall run in the NVIDIA Jetson AGX Xavier Developer Kit.
2. ODS interface with the robot shall be the RJ45 Ethernet port.
3. The ODS shall detect and distinguish the following objects categories:
   - Pedestrian;
   - Car;

- Animals like Dogs.

4. ODS system shall have an input power of 24 VDC nominal (18 VDC – 36 VDC), which is power supply of the HW prototype.
5. The HW/SW platform shall support ROS framework to transfer ROS messages between components.
6. The Sensor Fusion Algorithm shall be executed in the CPU of the AGX Xavier board.
7. The object detection SW module on camera frames shall run in the GPU of the AGX Xavier board.

To instruct the Algorithm of ODS, some video coming from End-user will be used to test the good results of the performance.

### 4.1.3 MIMS Box Functional Requirements

In this section the Functional Requirements of the MIMS Box are listed:

1. The MIMS Box shall detect the chemical hazards for the safety of the first responders; the Chemical device will be installed on the Robot Platform for remote sensing.
2. The MIMS Box shall be powered by the MIMS battery.
3. The MIMS Box shall communicate the Chemical data to the Control room. Based on D5,3 outcomes Benzene can be selected as a key compound for on-line monitoring in the pilot demonstration of UC4.

## 4.2 System architecture

The system setup of the robot is shown in Figure 15. All hardware components need to be mounted on the robot platform. While the sensors are already mounted, the RESCUE-MIMS, 4G Router, Ethernet Hub and ODS have to be mounted additionally. All components can then individually communicate with the control room over the router through an Ethernet hub.

The Control Room is where the user is located to supervise the Robot operations.

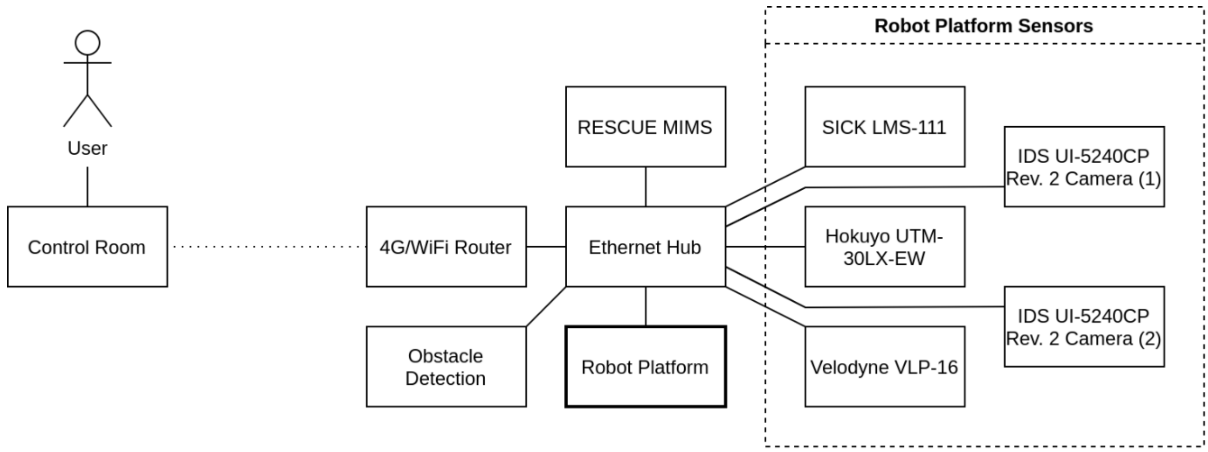


Figure 15: Robot Platform System architecture

## 4.3 Hardware architecture

### 4.3.1 Hardware architecture of the Robot Platform

As already introduced, the planned robot platform to be used in this S&R project is the SeekurJr. The rover is originally equipped with with a SICK LMS-111 LiDaR scanner for long range mapping, and extended by a sensor tower at the front, which holds a periodically tilting Hokuyo UTM-30LX-EW LiDaR scanner for close proximity obstacle detection at an extended height, plus a pan-tilt unit with a mounted Velodyne VLP-16 LiDaR scanner and two IDS UI-5240CP Rev 2 GigE cameras for more dynamic perception capabilities including stereo vision. The peripheral components are connected via two switches using Gigabit-Ethernet or USB.

To be able to turn on the spot, the robot is skid-steered by two motors - one on each side. It has a swing radius of 52cm, a maximum linear velocity of 1.2m/s and a maximum traversable grade of 75%.

The rover can run actively for 3 on average until the 3 batteries are depleted. For an extended operation duration, the batteries can be hot swapped manually during a mission, as long as the white cover on the robot base remains freely accessible. The battery provides regulated power of 2A at 5V, 2A at 12V, and 1A at 24V. It also provides 20A of unregulated power at a nominal voltage of 24V.

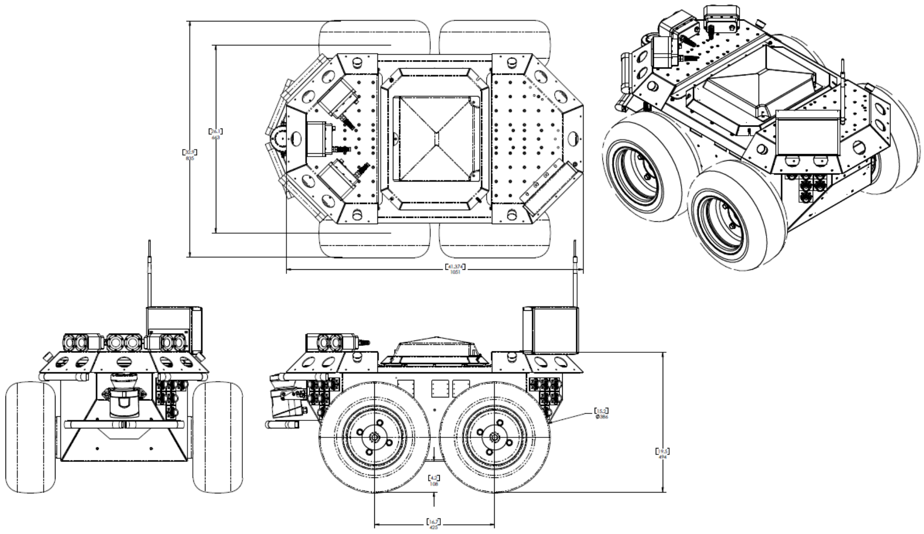

Figure 16: Robot Platform Hardware architecture (basis System w/o DFKI extensions)

### 4.3.2 Hardware architecture of the MIMS Box

The Rescue MIMS prototype comes in a configuration of a hand-held peli-box luggage about 60x50x20 cm that encloses the inner parts of the mass analyzer, in order to be robust and withstand the harsh operational environment; straps can potentially be integrated to be used as back-back equipment. The Rescue MIMS luggage can be connected with a portable PC or tablet e.g. 9”-10” or bigger, where the results of the measurements will be displayed (monitor display). In Figure 5, the 3-D graphic of the

RESCUE-MIMS device is provided. More details on the prototype TRL 6 that will be delivered inside S&R, as well as proposals for optimization in a future version of TRL7-9 are available in D5.1, M10.

Figure 17: RESCUE-MIMS device: hand-held robust peli-box luggage

The RESCUE-MIMS can also be mounted on fire-fighters vehicles (roving system) or tested as a payload on robotic platforms in order to serve as a screening tool for early warning. This configuration can protect first responders as well as canines from exposure to toxic environments.

The RESCUE-MIMS prototype is foreseen to be installed on-board DFKI ground robot SeekurJr refer to the following Figure 18, more details are provided in D5.1.

Figure 18: RESCUE-MIMS on-board DFKI robotic platform SeekurJr

### 4.3.3 Hardware architecture of the ODS prototype

The ODS prototype is composed by the Peli 1400EU Protector Case including the Xavier board and a 60Watt DC-DC convert from 24 V to 12 V, refer to the following figure:

Figure 19: ODS 60Watt DC-DC convert

The dimensions of the ODS HW prototype are presented in Figure 20 together with the three interfaces. Reading Figure 11 from left to right, the following connectors are illustrated:

- RJ45 interface, for the Ethernet connection between the Xavier board and the robot.
- Power supply interface, which is a circular 3 pins connector.
- Green LED, which is turned on when the ODS HW prototype is fed.

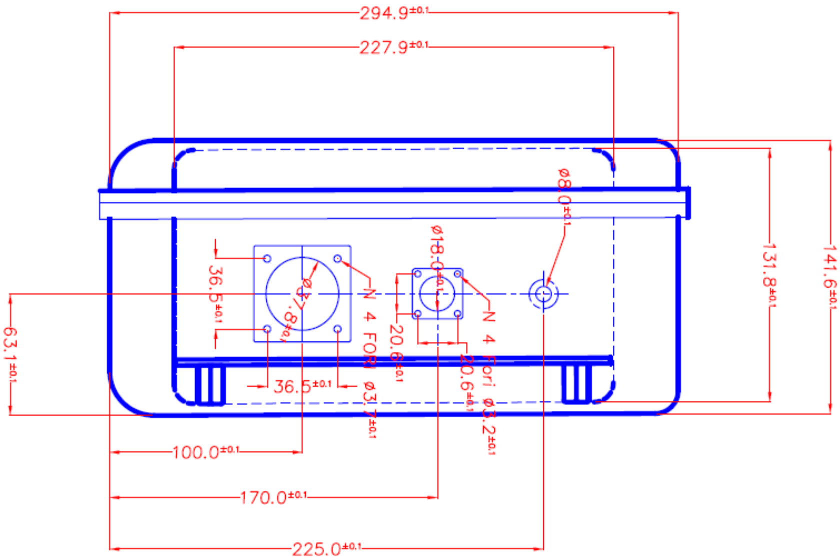


Figure 20: ODS Design of the interfaces of the HW prototype

## 4.4 Communication interfaces

The robot, the ODS, as well as the control room will communicate via ROS (noetic), which is a networking middleware to allow communication between the single components. Hereby, the sensor data will be provided by the robot in form of sensor_msgs/Image and sensor_msgs/PointCloud2 messages for the camera and LiDaR data respectively, where the camera data will be sent to the control room for observation, to the ODS for obstacle detection, and to the robot for mapping, while the LiDaR data will only be sent to the robot platform for the mapping, and to the ODS for the obstacle detection. The control room will be able to send control commands for manual operation and a map section for semi-autonomous exploration. The robot platform will use the sensor data to generate the spatial map and send it to the control room. The gas measurements can then be inserted into the map at the control room or robot directly, depending on where the respective ROS node will run. The obstacle information will be provided by the ODS with a custom message format to the robot. These messages will then be used by the robot and control room to control the robot manually and (semi-)autonomous exploration.

The communication layout is displayed in Figure 21.

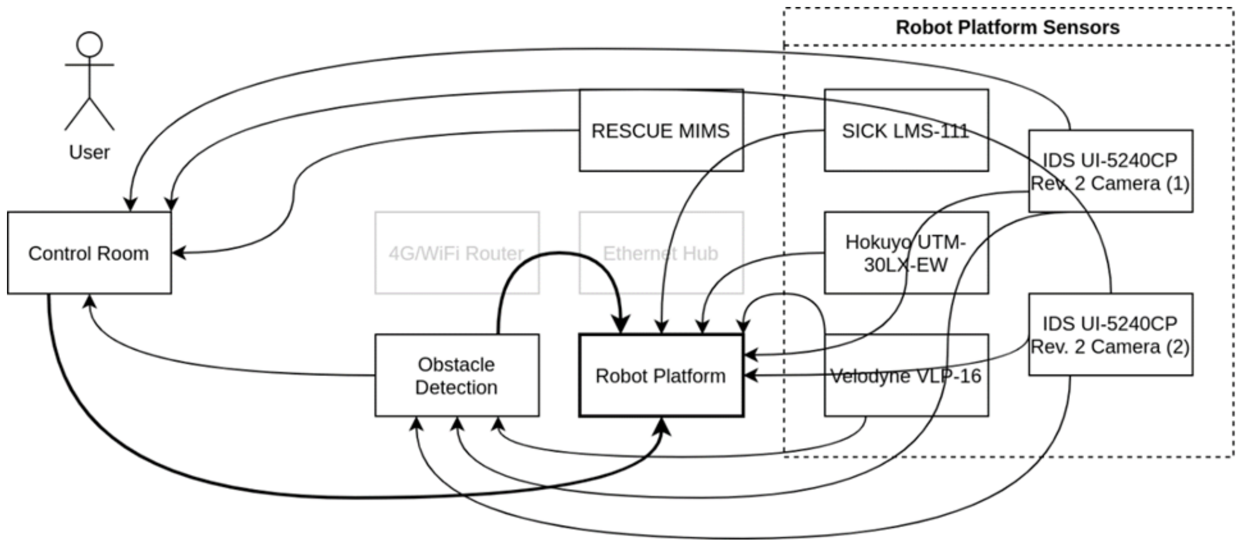


Figure 21: Communication interfaces in the Robot Platform

# 5 Drone System Integration

## 5.1 Functional requirements

The drone will mainly fly and provide video stream which could be transmitted to a steaming server from the remote-control unit or from the laptop. The streaming server will provide the video input for the video analysis module via a 4G or Wifi communication. The video could be provided from a max altitude of 120m meters following the EU Regulation (2019/947) and with a max quality of 1080P. The best quality of video is provided by the wired connection. The drone flight could last for max 25 min. The drone will also provide data about the level of its battery, the camera position and the drone GPS position. To perform these tasks, the drone must have a full charged battery and should be operated by a certified drone pilot. The main important scope of the Drone is to give an overall view of the S&R environment to the Robot driver in order to avoid dangerous area like fire zones.

### 5.1.1 Drone Functional requirements

In this section the Functional Requirements of the Drone system are listed:

1. The Drone shall fly next to the Robot Platform in order to have a top overview of the related environment
2. The Drone shall provide video stream which could be transmitted to the driver of the robot in order to support on the Rescue operations.
3. The drone flight shall last for max 25 min.
4. The drone shall provide data about the level of its battery, the camera position and the drone GPS position.
5. The drone shall be operated by a certified drone pilot.

## 5.2 System architecture

The DJI phantom 4 pro will be controlled using the remote control in which a tablet or phone could be connected via a wired connection. The tabled or phone will be setup up with a 4G connection and the DJI GO 4 mobile application will be installed in this device. This application could be setup up to stream video to a RTMP server. The video stream could also be displayed in the Windows application installed in the laptop and then the video could be streamed from the laptop to the streaming server using 4G communication.

## 5.3 Drone HW Architecture

The data from the drone will be communicated to the DJI Go 4 application. This application could transmit the video stream directly to the streaming server via 4G communication. Also, it is possible to collect the live video view from the windows application and stream the video view from the laptop to a streaming server via a 4G communication. The other data (GPS position, battery level, camera position) will be transmitted to a laptop via a wired communication. The laptop will then send the data to provide the required information to the Data Lake via a DJI SDK based application.

The following Figure shows the Drone Communication Architecture:

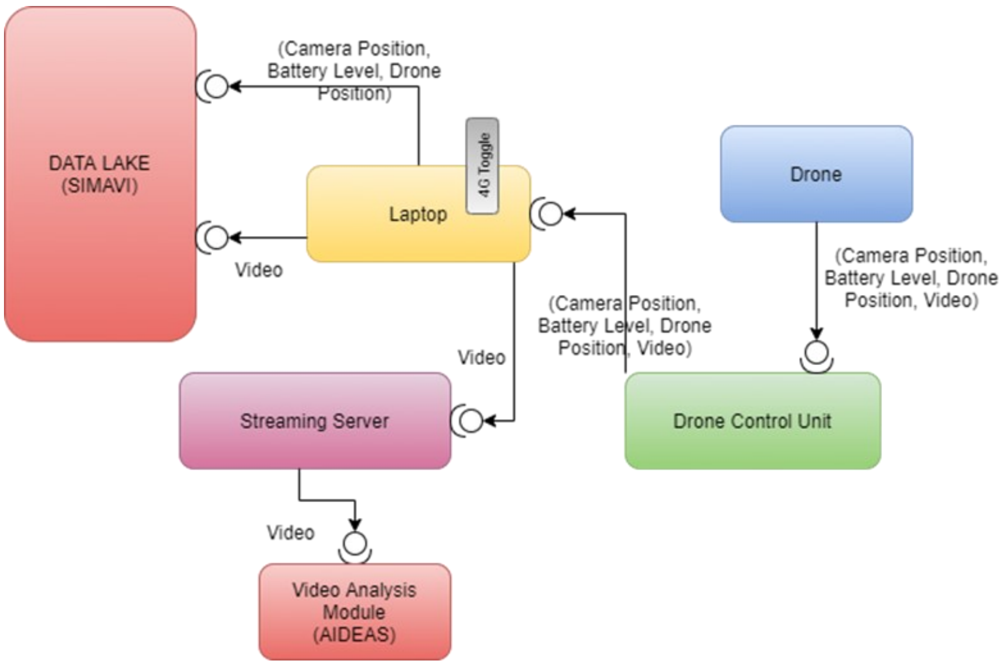


Figure 22: Drone Communication Architecture

## 5.4 Communication interfaces

The drone will send the video and the data to the drone control unit via the OcuSync 2.0 Transmission System. The DJI Go 4 application will be installed on a tablet, a smartphone or a build-in screen of the remote connected to remote control. The Tablet is equipped with a 4G or Wifi communication. The collected video stream will then be transmitted from the tablet to a streaming server via 4G or Wifi connection. The video view could also be visualized from the DJI SDK Windows application over a wired connection. The streamed video could be then retrieved by the video analysis module using Wifi or 4G communication. The DJI SDK based windows application will also transmit the data of the drone including the battery, the GPS location and the position of the camera to the Data Lake.

The following Figure shows the Communication interfaces for Drone video stream and data:

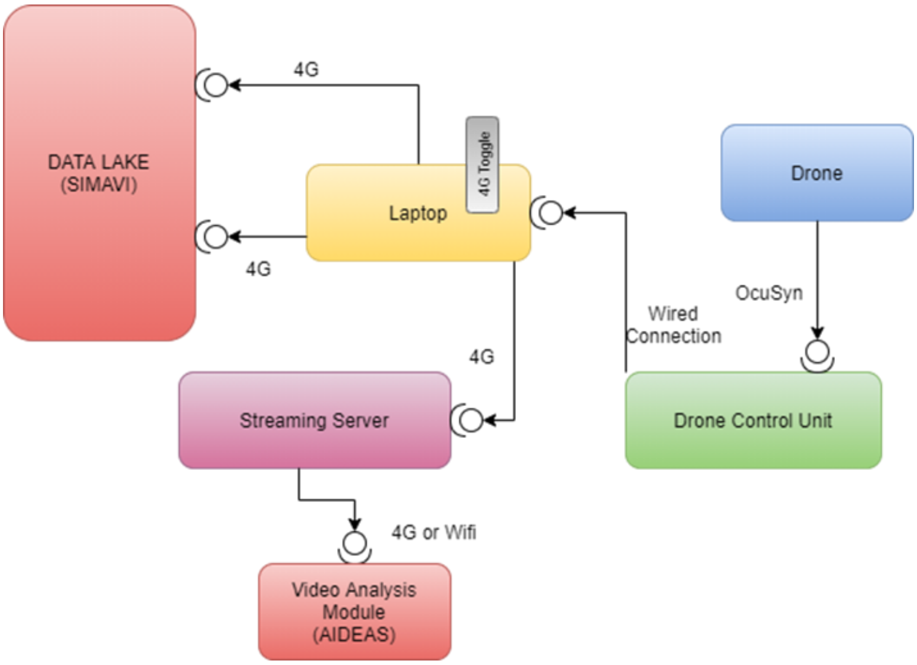


Figure 23: Communication interfaces for Drone video stream and data

# 6 Stand-alone Pretesting

Following the integration and testing strategy described in the paragraph 2.3, hereafter are listed all the stand-alone tests performed on the single components both from HW and SW point of view.

## 6.1 Hardware tests preparation

### 6.1.1 Robot HW tests preparation

Prior to testing the integration of all components on the robot, the robot will be tested with a sample payload which roughly represents the final one. This is done to avoid later complications with mounting the hardware components. To achieve this, a PeliCase of the model, which is also used for RESCUE MIMS, will be filled with weight to represent to load of the sensor box and mounted using a planned hole pattern on the robot. With this payload, the robot will then be moved around outdoors to test the motion capabilities. Since the other components already have fixed mounting patterns, they will be omitted in this test.

It also has to be tested, that all sensor data provide correct data with covariance information. For this, all sensors have to be calibrated before testing.

### 6.1.2 MIMS box HW tests preparation

NTUA who will provide the RESCUE-MIMS chemical device will organize and run a number of laboratory experiments for testing various factors regarding the performance of the device, so that to scale up its use in the field under the UC4 pilot demonstration.

Specifically, a number of different chemical compounds and their mixtures have been prepared in different concentrations and combinations in order to test response times and other analytical characteristics of the has been set including the method of the analysis that will also be used in the field, e.g. the specific masses to be monitored, the cycles of scans, etc. The RESCUE-MIMS system was evaluated by addressing the following analytical criteria: (a) response times (b) linear dynamic range within the examined concentration area, (c) sensitivity (LODs), (d) repeatability. Specifically, RESCUE-MIMS was tested and validated in lab-scale with chlorinated compounds since they are considered potentially hazardous product in case of industrial accidents and because the RESCUE-MIMS will be demonstrated in such a fire industrial incident scenario under UC4. For the same reason, Benzene was also used for testing because it is one of the core compounds of BTX (Benzene, Toluene, Xylene) that is mainly evolved in forest fires and/or industrial fires. Detailed description of the experiments is provided in D5.3.

### 6.1.3 ODS HW tests preparation

First tests of the ODS HW prototype are executed in the laboratory. Using the multimeter, a check of the electric connections within the HW prototype is required. Then, the power supply is set to 24 V and it is switched off. The two cables are connected to the ODS HW prototype:

1. Power supply;
2. Ethernet, in order to connect a laptop and verify the publication of ROS messages.

The laboratory test setup of the ODS HW prototype is represented in Figure 24.

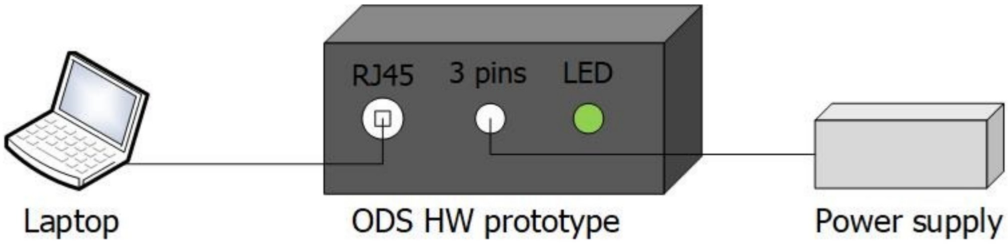


Figure 24: Setup of the tests in laboratory

Switching on the power supply, if these HW tests are completed successfully (without short circuits and electromagnetic interferences), the ODS HW prototype is ready to go on the field. It will communicate with the robot through the RJ45 interface.

### 6.1.4 Drone HW tests preparation

The following hardware should be prepared and pretested before the Pilot:

- Drone DJI phantom 4 Pro v2 Quadcopter.
- 4k Camera & Gimbal (pre-installed)
- Intelligent Flight Battery.
- Remote Control.
- Battery Charger with the cable.
- USB OTG Cable
- 4G Toggle of connection.
- Micro-USB Cable
- Remote control device: Tablet or Smartphone.
- Laptop with charged battery.
- Streaming Server (Local or Online).

## 6.2 Software tests preparation

### 6.2.1 Robot SW preparation

The robot will be first tested in a simulation to make sure the software stack is fully functional with simulated sensor data. That way the amount of integration issues can be minimized.

The simulated scene will contain the robot and a sample environment, which roughly represents a S&R scenario containing a collapsed building and rubble. The robot will be moved on the environment using the manual control and semi-autonomous exploration. This is expected to work sufficiently stable and accurate prior to doing the real integration tests with the actual robot.

### 6.2.2 MIMS SW preparation

All the SW related to the Chemical device within the MIMS box will be tested in advance respect to the pilot.

Figure 21 presents the mass spectrum of Benzene recorded by the RESCUE-MIMS prototype in lab-scale for different concentrations, by scanning in the mass range of 70 to 85 amu; 12.5 ppm (in navy), 6.25 ppm (in red), 3.13 ppm (in grey), 1.56 (in orange), 0.78 ppm (in light-blue), 0.39 ppm (in green), 0.12 ppm (in dark-blue), 0.06 ppm (in purple). It's clear that mass 78 recorded is the most abundant.

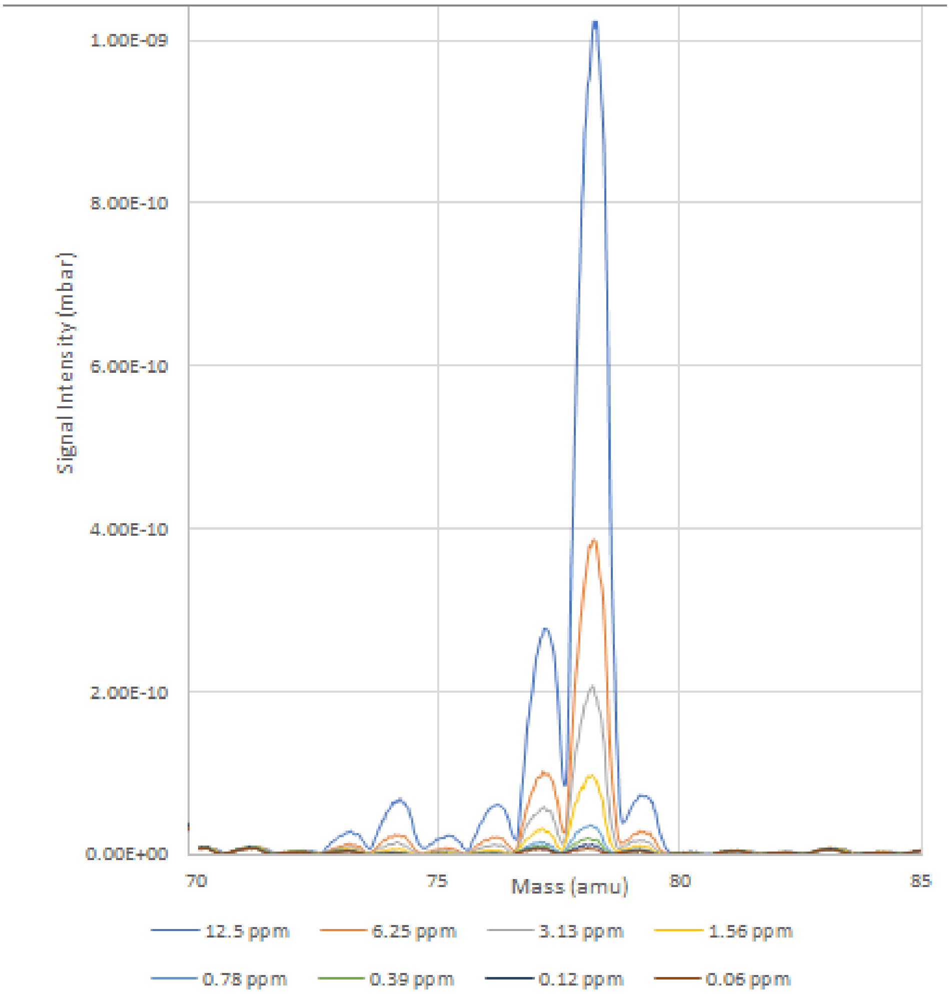


Figure 21 Mass spectra of Benzene recorded for different concentrations in the range of 70 to 85 amu; 12.5 ppm (in navy), 6.25 ppm (in red), 3.13 ppm (in grey), 1.56 (in orange), 0.78 ppm (in light-blue), 0.39 ppm (in green), 0.12 ppm (in dark-blue), 0.06 ppm (in purple)

Detailed description of the lab-scale experiments is provided in D5.3.

### 6.2.3 ODS SW preparation

All Docker containers have to be switched on. Feeding the ODS HW prototype and connecting the Ethernet cable to the robot, it is possible to check if the defined ROS topics are published and their consistency. The contents of ROS messages are under definition according to the developments of the ODS algorithms. The following preliminary stand – alone tests are foreseen in the ODS platform before the robot integration:

- Test on Camera ROS driver
- Test on Lidar ROS driver
- Tests with all Sensors on laboratory host
- Test with all Sensors with Xavier
- Test with all sensors, Xavier and ODS Algorithms

### 6.2.4 Drone SW preparation

For the test preparation the following software need to be prepared:

- DJI GO 4
- DJI Assistant 2 For Phantom
- Streaming Server Software.
- Encoder Streaming Software.
- DJI SDK based Windows application.

# 7 Test Descriptions

## 7.1 Test cases

### 7.1.1 Prerequisite conditions

In general, before performing integration tests, the described pre-tests in section 6 need to be passed, to make sure the operations of the Robot and Drone are sufficiently stable and accurate. All sensors need to be functional and calibrated. All network connections have to be established with a control computer, which represents the control room.

The robot and drone need to operate in a suitable weather conditions, no rain, no snow, a wind speed less than 9m/s and a temperature 0° to 40°C.

The devices batteries (Robot, Drone, MIMS) need to be fully charged before the test.

In the laboratory where the tests will be performed, the energy source with 220V is required.

### 7.1.2 Test input

The robot will have to be controlled using manual control and the semi-autonomous exploration algorithm in an outdoor- and indoor environment. The environment has to contain obstacles (like Pedestrian; Car and Dogs), which the ODS can detect and it has to be sufficiently safe for robots and drones to operate in, in case of malfunction. Unexpected behavior and events should not lead to personal or structural damage to the environment or devices.

The drone's mission path and the video stream server configuration will be setup in the application installed in the tablet used with the drone's remote control. The drone will then fly following the defined path and transmit the video to the DJI SDK windows application. The remote-control tablet will be connected to a windows DJI SDK based application. This application will collect the information about the location, the camera position, the camera orientation and the battery level to transmit it to the Data Lake which will send the data to the CONCORDE platform. The live video could also be stream to a server from the DJI SDK windows application.

### 7.1.3 Main expected test results

It is expected, that the robot correctly navigates in a Search & Rescue environment. At no point, there should be a collision with the environment or (moving) obstacles. During semi-autonomous navigation, the robot should never get stuck without ever completing the goal. In case of imminent collision, the robot should stop the autonomous operation.

For the Obstacle Detection System, the main expectation is the detection of three types of elements during the Robot movement: Pedestrian, Cars and Dogs. The output of the ODS Sw will be towards the Robot in order to hard stop the Robot operation moreover to show the camera images with the Detections to the Robot Driver.

The MIMS Box will be able to communicate the Chemical data to the Control Room through an Ethernet hub installed on the Robot Platform.

The Drone will provide an overall view of Robot operations providing another important information to the Robot Driver in order to navigate on a S&R environment.

### 7.1.4 Test procedure

The Test Procedure will be developed in version 2 of D5.4. As explained this will follow the requirements traceability described in the paragraph 2.1.

# 8 Test results

## 8.1 Summary of test results

To be included in D5.8 version 2 of D5.4, after the pre-testing and the pilot itself.

## 8.2 Problems encountered

To be included in D5.8 version 2 of D5.4, after the pre-testing and the pilot itself.

## 8.3 Impact on test environment

To be included in D5.8 version 2 of D5.4, after the pre-testing and the pilot itself.

## 8.4 Recommended improvements

To be included in D5.8 version 2 of D5.4, after the pre-testing and the pilot itself.

# Annex I: References

[1] Karma, S. 2018. Tools for Analyzing Risks from Human Exposure to Chemical Environments: The case of exposure to Smoke Components during Forest or Other Field Fires. Chapter 9. In: Novel Approaches in Risk, Crisis and Disaster Management. Chalaris, M., Emmanouloudis, D., Wen, J.C., and Wu. Z.P. New York, USA. Nova Science Publishers

[2] Karma, S., et. al 2015. Use of unmanned vehicles in search and rescue operations in forest fires: Advantages and limitations observed in a field trial. International Journal of Disaster Risk Reduction. Vol. 13: 307-312.

[3] Booze, T.F., Reinhardt, T.E., Quiring, S.J., and Ottmar, R.D. 2004. A screening-level assessment of the health risks of chronic smoke exposure for wildland firefighters. Journal of Occupational and Environmental Hygiene. Vol. 1, Issue 5: 296-305.

[4] Janik, P.; Zawistowski, M.; Fellner, R.; Zawistowski, G. Unmanned Aircraft Systems Risk Assessment Based on SORA for First Responders and Disaster Management. Appl. Sci. 2021, 11, 5364.

[5] Javier Burgués, Santiago Marco, Environmental chemical sensing using small drones: A review, Science of The Total Environment, Volume 748, 2020, 141172

[6] Murphy R.R. et al. (2008) Search and Rescue Robotics. In: Siciliano B., Khatib O. (eds) Springer Handbook of Robotics. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-30301-5_51

[7] Tadokoro, S. (Ed.). (2009). Rescue robotics: DDT project on robots and systems for urban search and rescue. Springer Science & Business Media.

[8] G. -J. M. Kruijff *et al.*, "Rescue robots at earthquake-hit Mirandola, Italy: A field report," *2012 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR)*, 2012, pp. 1-8, doi: 10.1109/SSRR.2012.6523866.

[9] Fakhrulddin SS, Gharghan SK, Al-Naji A, Chahl J. An Advanced First Aid System Based on an Unmanned Aerial Vehicles and a Wireless Body Area Sensor Network for Elderly Persons in Outdoor Environments. Sensors (Basel). 2019 Jul 4;19(13):2955. doi: 10.3390/s19132955. PMID: 31277484; PMCID: PMC6651807.

[10] Tullio Joseph Tanzi et al. TOWARDS "DRONE-BORNE" DISASTER MANAGEMENT: FUTURE APPLICATION SCENARIOS, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume III-8, 2016 XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic

[11] INACHUS project, Available at: ttps://www.inachus.eu

[12]AirBorne project, Available at: https://www.airborne-project.eu/

[13] DARIUS project, Available at: https://cordis.europa.eu/project/id/284851

[14] Emran, B.J., Tannant, D.D., Najjaran, H., 2017. Low-altitude aerial methane concentration mapping. Remote Sens. 9, 823