ROCSAFE

Remotely Operated CBRNe Scene Assessment & Forensic Examination

ROCSAFE Remote Forensics

European Commission

HORIZON 2020

www.rocsafe.eu

ROCSAFE: Remotely Operated CBRNe Scene Assessment & Forensic Examination

ROCSAFE's overall goal is to fundamentally change how CBRNe (Chemical, Biological, Radiation/Nuclear including those with explosive dispersal) events are assessed, and ensure the safety of crime scene investigators, by reducing the need for them to enter dangerous scenes to gather evidence.

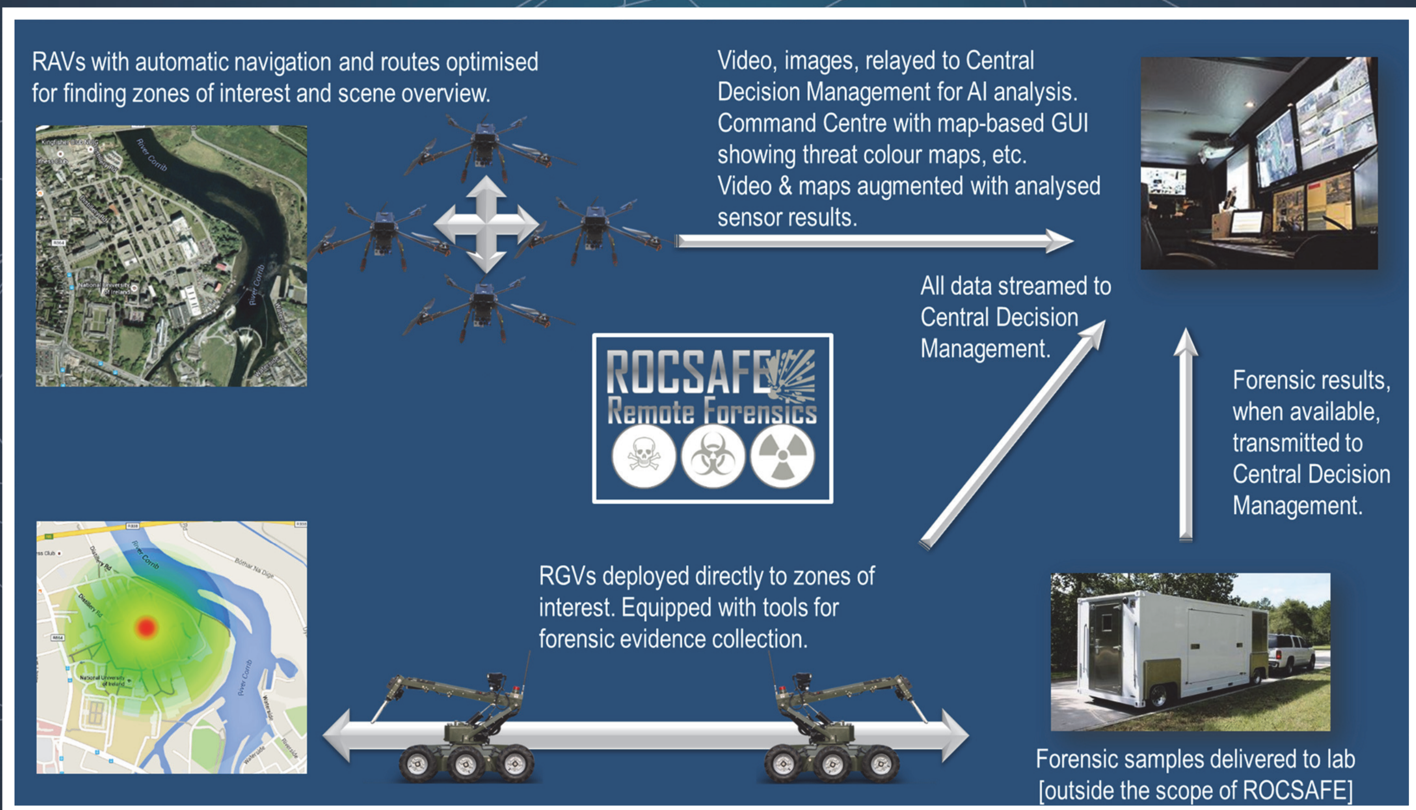
This will help to protect human life, reduce threats, and ensure that the crime scene is processed in a more efficient manner.

To achieve its goals, ROCSAFE will make use of cost-effective modern remotely-controlled robotic air and ground vehicles (RAVs/RGVs). First, RAVs will assess the scene. These will have cameras and can carry an array of innovative new high-performance and rugged miniaturized sensor systems for RN, chemical and biological threats.

To reduce the crime scene manager's cognitive load, ROCSAFE will include new Central Decision Management software and a Command, Control and Communications Interface (C3I). All images and data will be streamed to this, where they will be analyzed and displayed on a sophisticated and intuitive interface with maps and video, showing results of analytics and giving readings geographical context.

After the scene is assessed, RGVs will be dispatched to collect forensic material/evidence. They will have innovative new equipment for forensics collection that will automate best practices. Forensic material will be collected, bagged, tagged, documented, and stored by the RGV.

Overall, ROCSAFE aims to ensure that CBRNe scenes are assessed more rapidly and thoroughly than is currently possible, and that forensic evidence is collected in a manner that stands up in court, without putting personnel at risk.



Some of the major components of ROCSAFE and how they interact with each other.

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The End-User Perspective

Minimise the Threat to Crime Scene Investigators

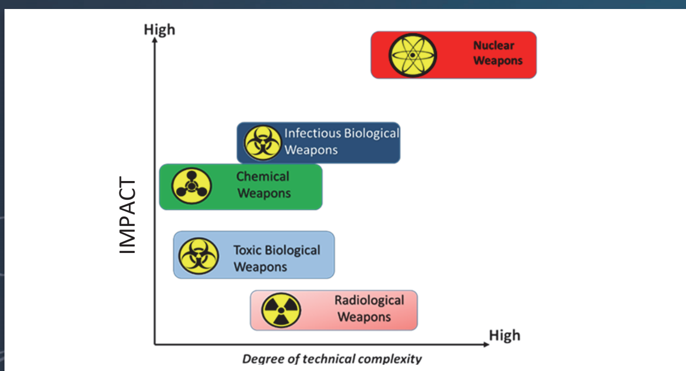
One of the key findings in establishing the end-user perspective was that early scene assessment and exploitation of a potential CBRNe attack has a critical role to play in response at strategic and political levels.

Understanding the balance between securing forensic evidence and gaining actionable intelligence is crucial in devising the detail of the remote technology.

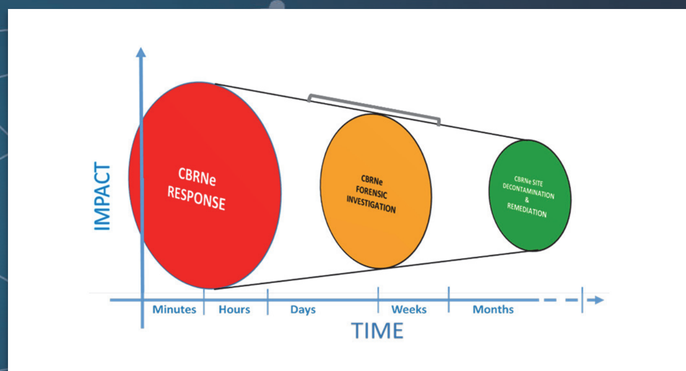
The perspective of the end-users is essential to the successful outcome of ROCSAFE. A significant effort was made to gather an analyse end-user data in the context of ROCSAFE.

The end-users highlighted specific issues. Firstly, a piece of evidence, including a sample intended for evidence, needs to be collected by a known person, from a known position at a known time and date, and be identified by a unique identifier. Secondly, it also requires context, meaning where that piece of potential evidence sits in the overall crime scene.

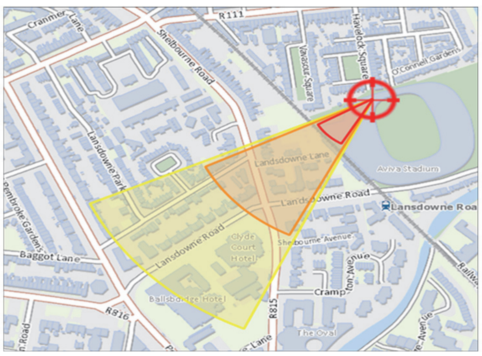
Finally, there was general end-user agreement that the SIBRCA methods and procedures as set out in the current NATO Allied Engineering Publications (AEP-66) should be followed.



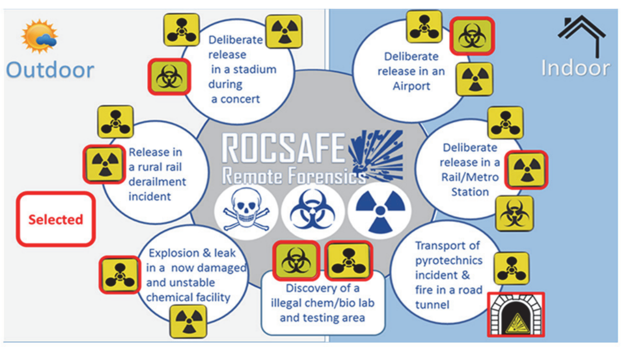
Understanding the weaponisation of CBR material gives guidance for type of material that may be found at the scene of a CBRNe attack.



Understanding the position of ROCSAFE in the CBRNe response timeline is essential to the overall understanding the user requirements.



Understanding the size of potential CBRNe crime scenes is essential to defining parameters acceptable to the users.



Selecting representative scenarios is key to a mutual understanding between ROCSAFE and the end-users about what is expected and what can be delivered.

Robotic Ground Vehicles for Remote Evidence Collection in ROCSAFE

Reacher, which is a 450kg Explosive Ordnance Disposal Vehicle with adaptable payload drawer, is being utilised for remote evidence collection within ROCSAFE.

Reacher is operated remotely through a command control station. Operator pre-set commands allow the Reacher 7 DOF arm to semi-autonomously utilise the forensic evidence containers.

Tool container units designed for remote evidence collection are utilized from the robot's payload drawer.

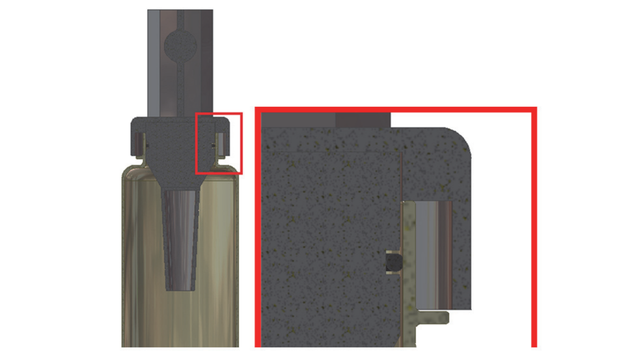
The tool container unit consists of three parts: (1) Tool holder cap; (2) Disposable sampling tools: and (3) the evidence container itself. The tool holder cap will have a grip that will allow it to be utilised by the robot manipulator. The cap forms a sealed unit with the evidence container.

The unit accommodates specific sampling tools such as soil sample collectors, swabs and a loose gravel-debris scoop.

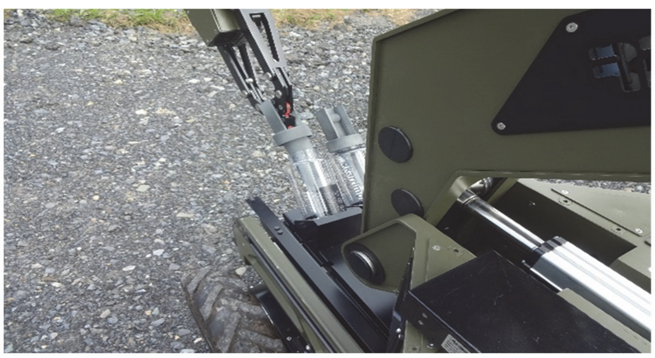
Reacher's gripper can then grasp the tool, obtain its sample, replace the tool in its container, and the sample is then ready to be further processed for transportation to the laboratory for analysis.

Larger samples are collected by direct usage of the robot gripper and deposited in specifically-made forensic sample containers incorporated into the ROCSAFE landing platform trailer.

Robot-Specific Forensic Sample Containers



Tool sealing mechanism with rubber seals (push seal)



Reacher robot utilising forensic containers

Reacher robot with forensic payload drawer

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ROCSAFE Robotic Aerial Vehicles for Assessment of CBRNe Events

The Robotic Aerial Vehicle (RAV) platform will automatically survey the scene and assist in the location of CBRNe hotspots.

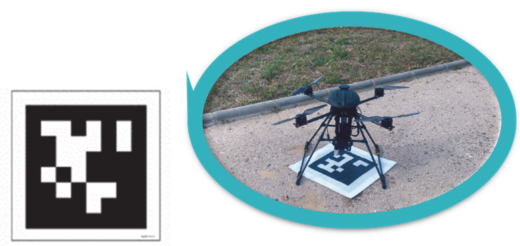
According to end-users' requirements, the RAV hardware and software elements have been develop to perform an autonomous and safe flight.

The **autonomous navigation** allows the RAV to perform several missions in the CBRNe event. During the flight, images of the event are collected and sent in real time to the Central Decision Management.

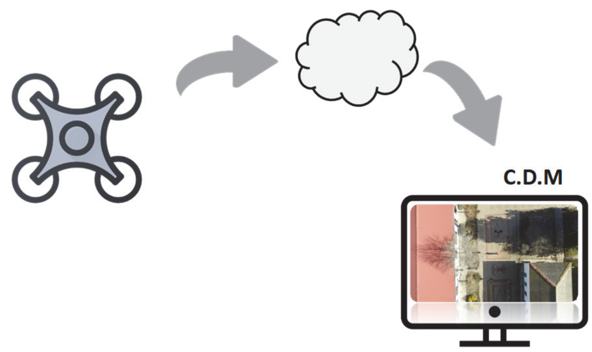
For the **obstacle detection and mapping**, every RAV runs a software component that prevents the vehicle from moving to specific locations by identifying the space occupied by physical objects. Once the samples are collected, the drone will take them to the landing POD platform for analysis. This maneuver requires high precision. In this respect, AR codes and computer vision-based techniques are used to perform a **precision landing**.

AUTONOMOUS NAVIGATION SYSTEM
- ⇒ *RAV manoeuvres*
- ⇒ *Real time*

OBSTACLE DETECTION & AVOIDANCE SYSTEM
- ⇒ *LIDAR based object detection*
- ⇒ *Avoidance algorithm*



PRECISION LANDING
- ⇒ *AR codes*
- ⇒ *Computer vision based*



REAL-TIME VIDEO

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ROCSAFE Turret for Aerial Sampling & Sensing: Description and Features

The ROCSAFE Turret is a sensor-based R&N, Bio and Chemical remote controlled sample collection system connected to a RAV.

This device performs initial analysis on R&N and Chemical by being winched close to the target area or ground. It also collects Bio samples for later analysis in the Landing Pod.

The Turret contains sensors and sample gathering features for use by CBRN analysis and forensics. Multiple samples can be collected by air-draw from the ground or target area with GPS and vision tagging as part of the evidential trail. The connected RAV lowers the Turret to the desired height via a controlled winch in the Turret. The latch connection between the winch wire and the RAV is electrically controlled. The Turret can be raised/lowered to a target area or dropped off the RAV for collection by the Reacher vehicle of ROCSAFE. The used Turret is delivered to the Landing Pod trailer where it is robotically collected and presented to the B and C analysis modules in the Landing Pod. The system operator can wirelessly control the type of Turret that is presented to the analysis modules or as a fresh Turret to be uploaded to the landed RAV. The Turret can be configured to have multiple samples capacity or a single purpose sample acquisition. The Turret also acts as a RFID tagged sample holder to be stored for use by a laboratory or evidence protection for later use.

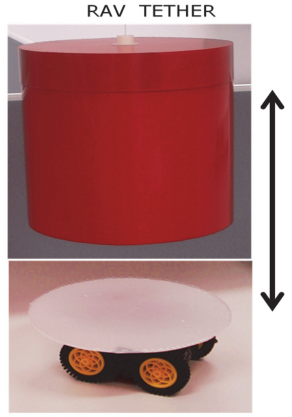
R&N Turret for fast radio-activity scan of area using RAV and winch.

Chemical Turret with in-built C module and subsequent delivery to the LP C module for detailed analysis.

Bio Turret designed to collect B samples and deliver to the B module in the LP.

Multi Turret designed to take multiple samples over the event site in B & C and monitor R&N at all sites.

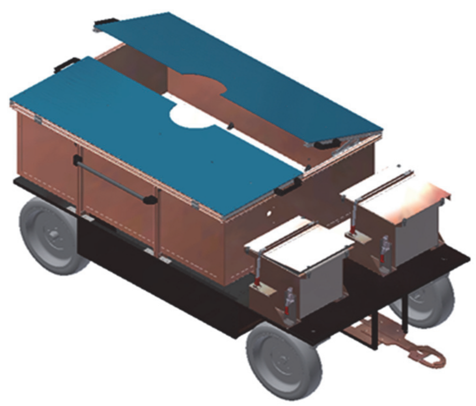
Turret Type Options



Turret Being Lowered onto the 4-Wheeled Buggy Inside the Landing Pod, Via the Hole on Top

A Turret can be lowered close to the ground or dropped to collect samples and be later recovered by REACHER RGV.
Turrets are stored in the LP after use, RFID tagged for evidential trail protection. A wireless connection is on the Turret and in the LP with a connection to the remote operator.
The Turret winch controls its descent and a short collapsible air snorkel is mounted on the base of the Turret. The B sample is via a sample collector and a pre-loaded liquid. The C sample is via a sorbent tube. R&N monitors and analyses in real time.

Turret Operational Features



Landing Pod Showing Top Hole for Turret

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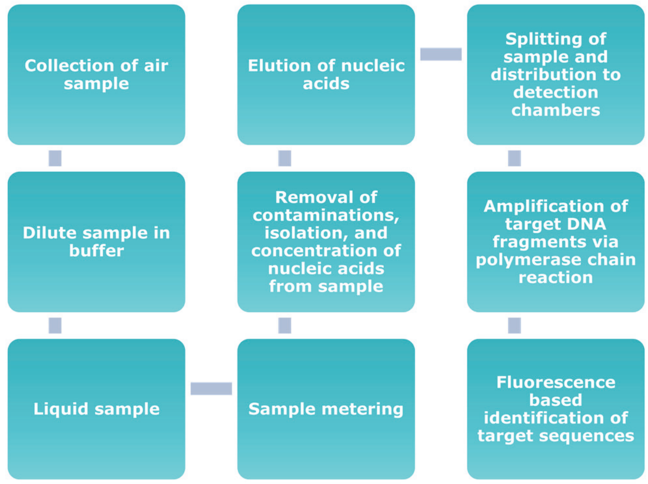
Lab-on-a-Chip Analyser: Detection of Biological Threats in ROCSAFE

The Lab-on-a-Chip Analyser is used for molecular biological analysis of air samples in the ROCSAFE system. The setup consists of two components, the microfluidic chip and the associated operating device. The complete analysis process is covered by the chip which contains all required reagents in order to build a "sample in – result out" system.

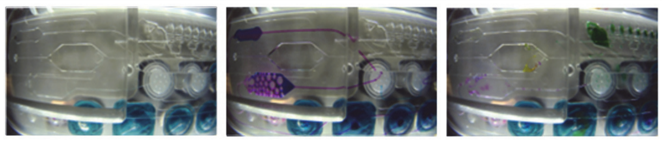
The molecular identification via Real-Time Polymerase Chain Reaction covers eight typical CBRNE-related pathogenic organisms: *Yersinia pestis, Francisella tularensis, Burkholderia mallei, Burholderia pseudomallei, Brucella melitensis, Brucella abortis, Coxiella burnetti, and Bacillus anthracis.*



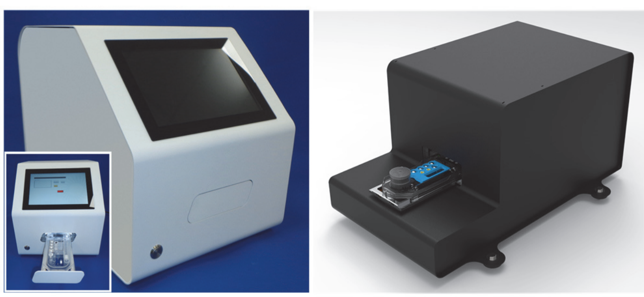
Flow chart of the detection process for the eight ROCSAFE target organisms in air samples.

The microfluidic cartridge with all functional elements. Reagents are stored in blister pouches directly on the chip, turning valves and the integrated syringe pump control the fluidic process.

Chip inserted & ready	DNA-Isolation	Amplification and analysis



The picture shows a shortened illustration of the micro-fluidic protocol on the ROCSAFE cartridge. The chip is used for the complete process sample metering over DNA isolation to target amplification and analysis.



The Lab-on-a-Chip Analyser instrument. The left picture shows the manual controlled "desktop version" for protocol development and system evaluation. The right picture shows the remotely controlled instrument for integration on the ROCSAFE Landing Pod.

Performance Indicators	
Size	W: 31cm; L: 43cm; H: 30cm
weight	Approx. 11 kg
Power input	12V DC; 10A
Detection	2 fluorescence dyes
Actuators	2 turning valves motors; 6 blisters motors; 1 syringe pump; 1 chip tray
Heaters	PCR; sample preparation

The table shows the main performance indicators of the Lab-on-a-Chip Analyser. Turning valves, blisters and syringe pump are used for control of the fluidic protocol, a detector for two fluorescence dyes (Excitation: E470/ 625 nm Emission: 520/680 nm) is used for target analysis.

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microfluidic ChipShop

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Lightweight Chemical Sensor for Robotic Aerial Vehicles

A lightweight and cost-effective C sensor for mini-RAVs, based on pre-concentration and dispersive IR analysis of vapours, suitable to detect and identify with ppm sensitivity and low false alarm rate a wide range of volatile threats, including low-mass molecules that commonly go undetected by IMS sensors.

Size (case included): < 25 x 15 x 10 cm.

Weight: < 0.5 Kg
< 1 Kg (case included).

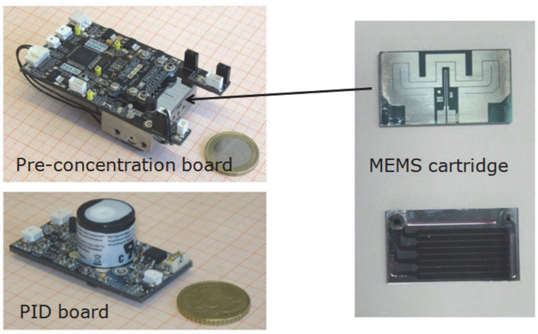
Power needs (average): < 7 W.

Targets: a wide range of volatile toxic compounds (NH_3, PH_3, H_2S, …).

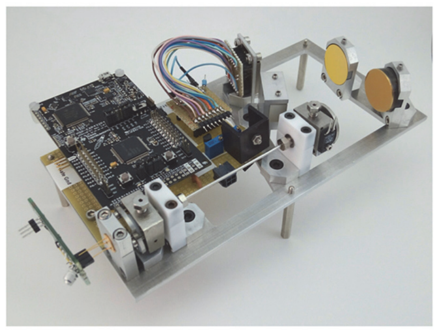
Detection range: 1-1000 ppm.

Sensing cycle-time: < 3 min.

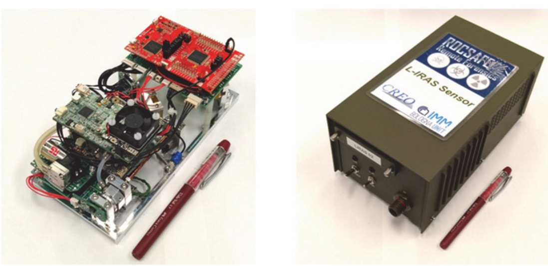
Warm-up time: < 1 min.



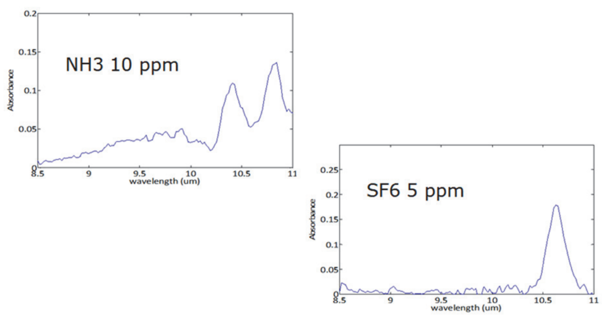
Vapor phase preconcentrator



InfraRed analyzer



Lightweight C sensor prototype



Measured IR absorption spectra

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Trace Chemical Sensor for Robotic Ground Vehicles and Dirty Environments

A portable and rugged C sensor for RGVs, based on FAST Gas Chromatography and Quartz Enhanced Photo Acoustic Spectroscopy, suitable to detect and identify with trace sensitivity and fast response a wide range toxic compounds of higher and lower volatility, even in the presence of interferents like gasoline, detergents, and paints.

Size: < 45 x 40 x 20 cm.

Weight: < 10 Kg.

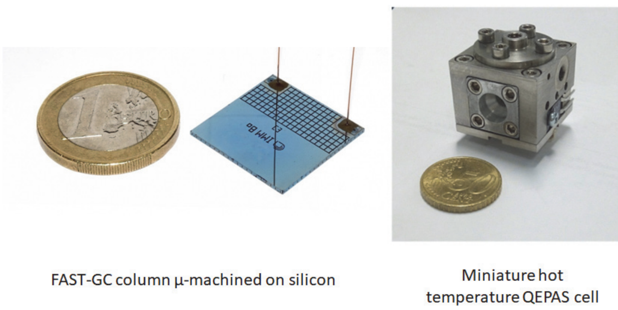
Targets: tested successfully with a variety of CWA simulants and drug precursors (DMMP, DPGME, Methyl Salicylate, safrole, …).

Robustness: tested successfully with targets in the presence of higher concentrations of gasoline, gasoil, and paints.

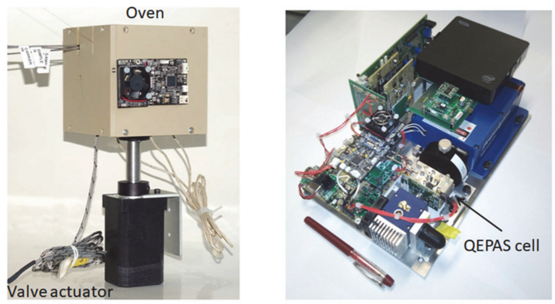
Detection range: tens ppb-1000 ppm.

Sensing cycle-time: < 7 min.

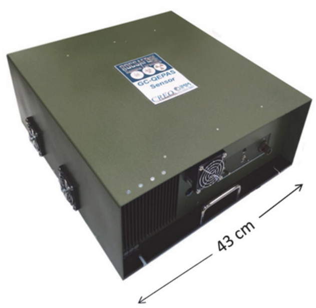
Warm-up time: < 10 min.



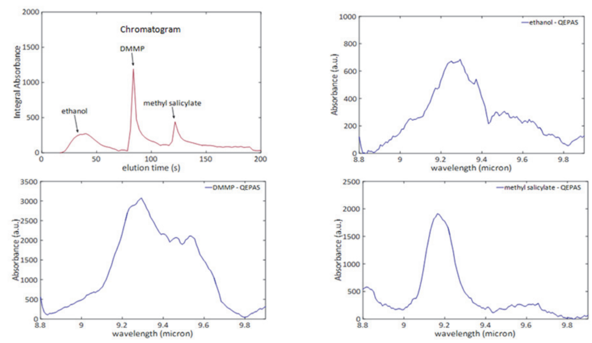
Miniaturized components



Modules for pre-concentration and FAST-GC separation (left), and for QEPAS analysis (right)



Trace C sensor prototype



Measured chromatogram and QEPAS spectra of a mix of ethanol, DMMP, and methyl salicylate

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Radiation Detector Module

The Radiation Detector Module is integrated with the ground and aerial vehicles. It detects increased levels of gamma radiation and identifies radionuclides.

The detection principle is based on scintillation (conversion of high energy gamma rays into lower energy visible photons by a scintillator) and subsequent conversion into an electronic signal by a photo detector.

The Radiation Detection Module is comprised of the radiation detector (scintillator optically coupled with silicon photomultiplier - SPM), associated read-out electronics, and firmware. The SPM acts as a photo detector and replaces legacy photomultiplier tube. The heart of read-out electronics is a Multi Channel Analyser (MCA), which processes and analyses the detector output signal to generate the radiation spectra. The module is supported by the application software and communicates in real time with the ROCSAFE platform. The module facilitates both detection of radiation levels and identification of radionuclides.

Module concept, dimensions, and cross section are shown in Figure 1. Figure 2 shows the implementation and test setup in Tyndall's laboratory. Spectra obtained from radioactive sources Am-241, Cs-137, and Co-60 with photo peak energy resolution are presented in Figure 3.

In accordance with the relevant standard IEC 62637, the module can detect 0.5 μSv/hr of Am-241, Cs-137, and Co-60 above user specified threshold, as shown in Figure 4.

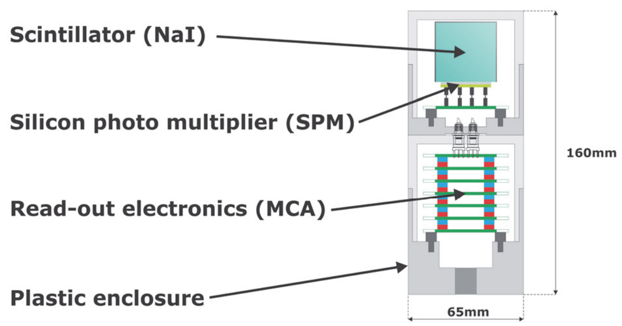

Figure 1: Radiation Detector Module cross section.

Figure 2: Radiation Detector Module implementation and test setup.

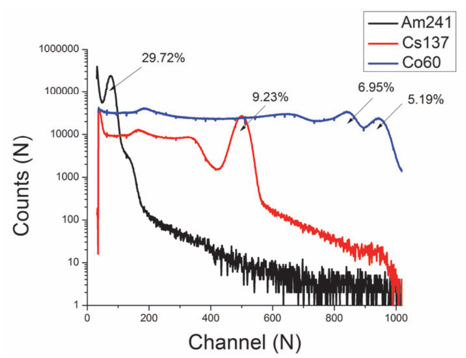

Figure 3: Am-241, Cs-137, and Co-60 spectra and their energy resolutions.

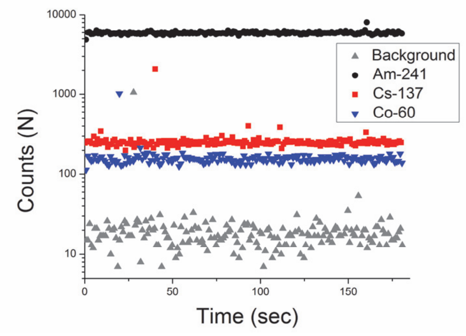

Figure 4: Radiation Detector Module count rates at dose-rate of 0.5 μSv/h (as per IEC 62637) for three radionuclides tested. Background counts are also shown.

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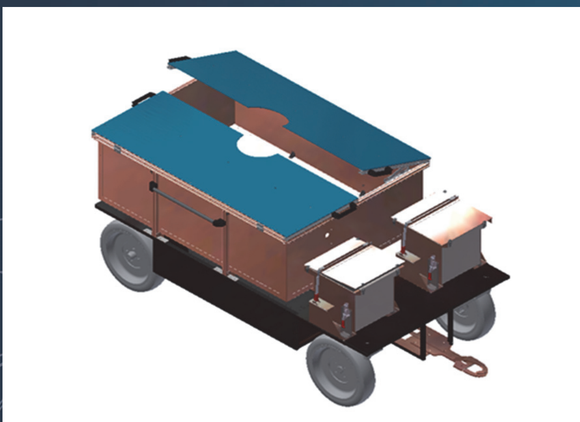
The ROCSAFE Landing Pod

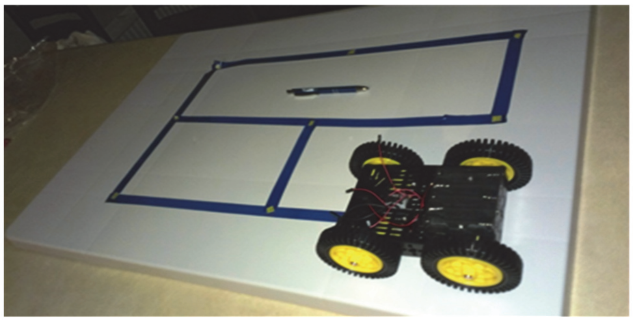
The sample handling system inside the Landing Pod (LP) manages the reception of used Turrets from the RAV on landing, the delivery of fresh Turrets to the RAV before it departs, manages the selection of multiple Turret types and their delivery to the analysis modules in the LP. It also places analysed Turrets in storage with samples 50% or more intact, identified by RFID and available later to full laboratory analysis.

The Turret attached to the RAV is landed on the top surface of the LP. Centering mechanism positions the Turret over the access hole to the LP inside. The Turret is unlatched from the RAV and captured by the sample handling systems inside the LP. An elevator lowers the Turret onto an independent 4 wheeled buggy platform that then travels a marked route as dictated over wireless by the remote operator.

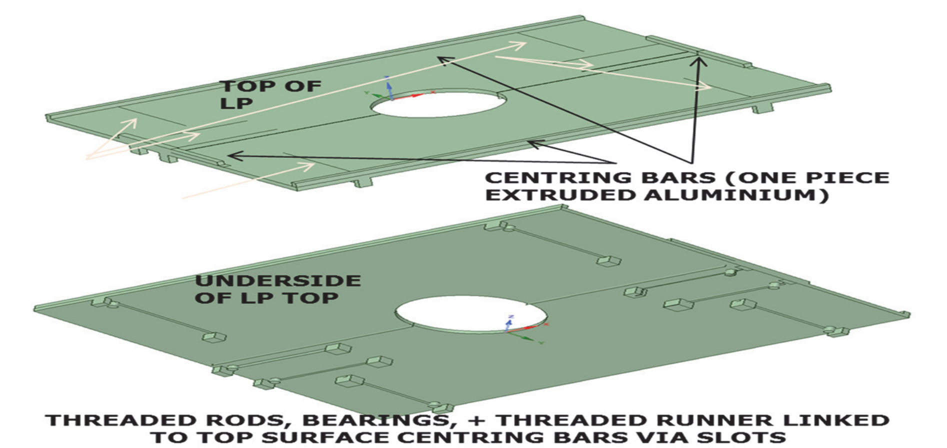
The systems inside the LP manage the elevator platform, the turntables at the B and C analysis modules and delivers the samples to these modules. The embedded processing in the LP manages the routes taken by the Turrets + independent robots, to correctly place and orient them at the analysis modules, to loop them on the track to facilitate Turret selection for uploading to the RAV and to send the used Turrets to storage in the LP. The concept allows for 5 unused Turrets to be loaded in the LP and for 5 used Turrets to be stored for later collection and used in laboratories while preserving the chain of evidence. The Bio samples are delivered to the LP Bio analysis module without touching the microfluidics collection chip. The Chemical sorbent tube sample is ejected from the Turret to the C analysis module where it is further heated for detailed analysis.



Landing Pod Trailer



4 Wheeled Buggy On Set Track. Positions 1 To 4 Unused Turrets, 5 Is Free To Accept Used Turret From Rav, A Is C Analysis, B Is Bio Analysis, C & D Plus 4 Are Storage When All 5 Are Used. 2/5/4/3 Is A Turret Type Selection Loop.



Centering Mechanism For Rav On Lp Top

The Landing Pod is box mounted on 4 wheels for towing by REACHER. It includes sample boxes on the same base. The robotic solutions inside the box present fresh Turrets to the RAV and receive used Turrets for analysis in the Bio and Chemical modules inside. The top surface is the landing area for the RAV, including the Turret access opening.

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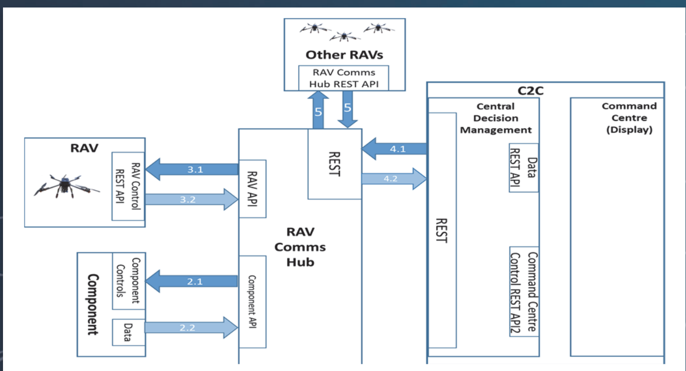
Central Decision Management: Communications, Artificial Intelligence, and Decision Support

The objective of ROCSAFE's Central Decision Management (CDM) is to support the people on the scene by providing timely and relevant information.

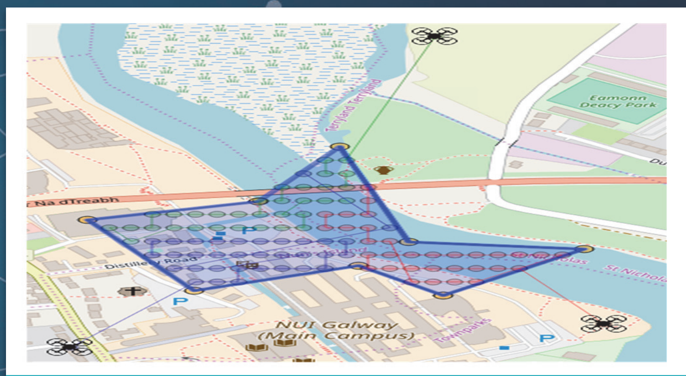
It reduces the cognitive load on the investigators by providing advanced decision support and by coordinating the operation of robotics, sensors and analysis systems.

The functions of the Central Decision Management include:

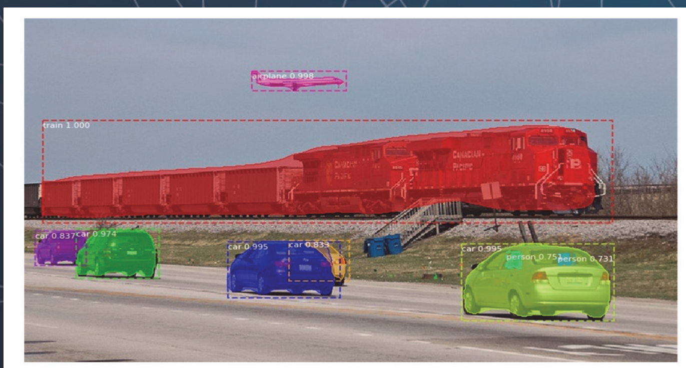
- Design and implement a **secure communications protocol** to link all major ROCSAFE system components.
- Propose **route planning** for teams of robotic aerial and ground vehicles, taking into account their goals and sensor payloads.
- Support the scene commander by **coordinating all other aspects of ROCSAFE:** RAVs and RGVs with cameras and sensors; the C3I the where information is displayed and relayed; and ancillary information from the field.
- Provide **context-aware decision support** for assessing the scene of the crime in an optimal fashion, dispatching coordinated RAVs with appropriate sensor loads.
- Provide innovative **artificial intelligence algorithms** for data analytics and fusion of sensor data sources, including deep learning analysis of images, and **probabilistic reasoning over time** about most likely threats based on evidence.



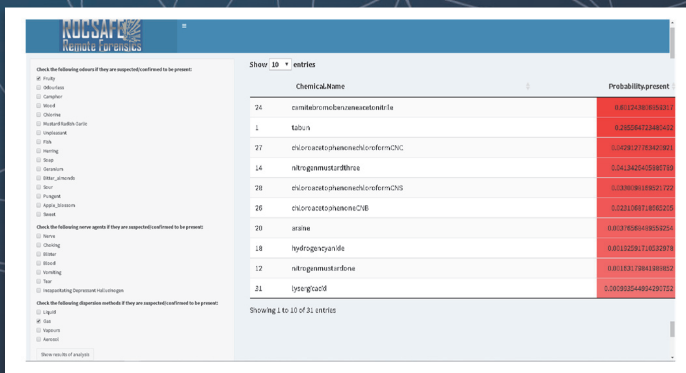
Example of Communication Flows for Messages Between Robotic Aerial Vehicle and Central Decision Management.



Multi-agent route planning for a swarm of Robotic Aerial Vehicles to assess the scene, taking into account their sensor payloads.



Example of Object Detections (Train, Car, Airplane) in a real image using a deep neural network architecture that is deployed in the ROCSAFE CDM.



Probabilistic reasoning about most likely causes of evidence observed: here, a gas with a fruity smell has been observed, and Camite and Tabun are most likely.

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C3I: Information Visualization & Knowledge Management

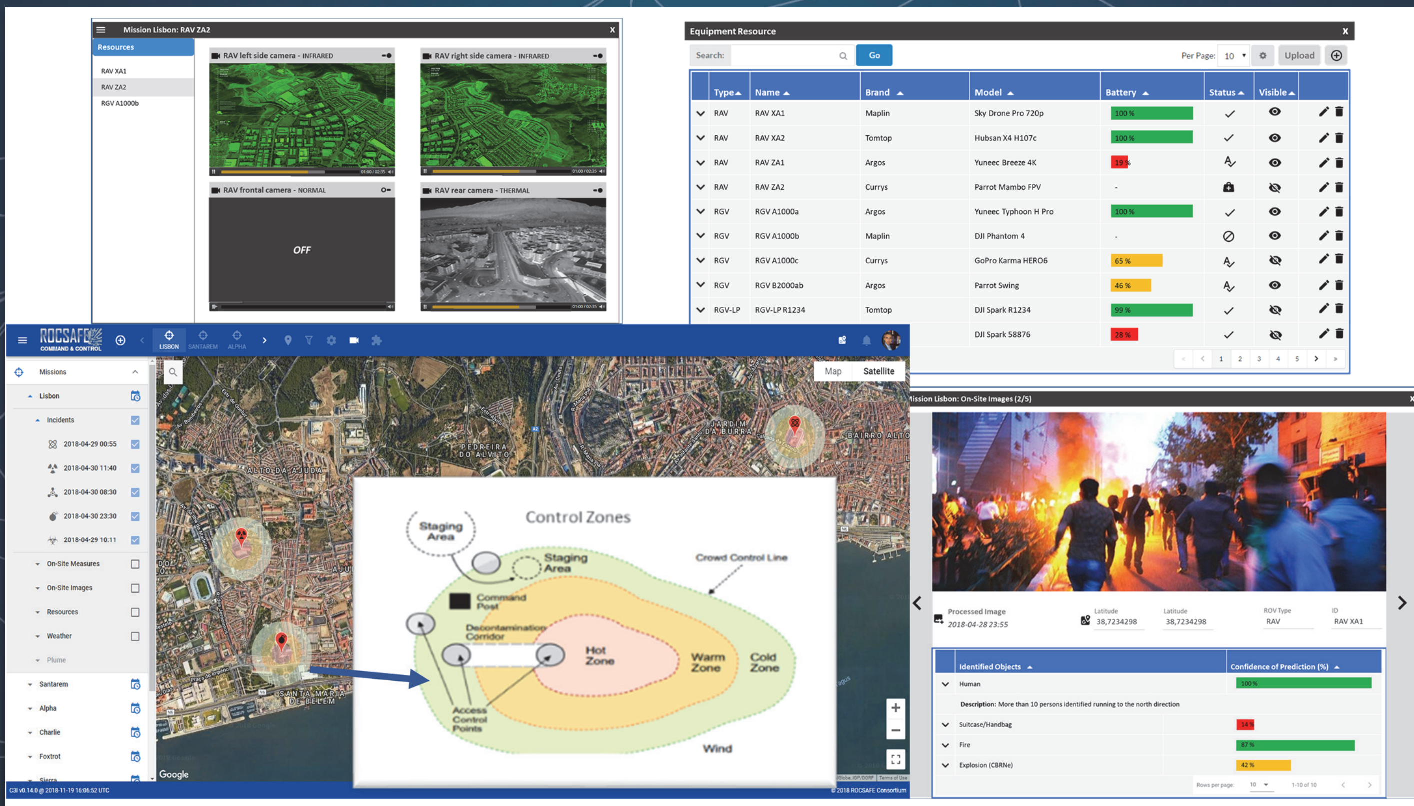
The construction of an artifact (i.e., Information System artifact) to visually represent information is associated with research in the field of Knowledge Visualization to support the decision-making process.

The C3I design issues considered the tasks that the user should be able to perform and categorizes user tasks according to whether the user is a data consumer or a data analyst.

The following questions were considered during the design of the C3I views.

- **What can the user see?** Approach on a focus-and-context (or fish-eye-view) interaction allows for the user to focus on specific information while, at the same time, getting an overview of how that information relates to the bigger context.
- **What does the user need to see?** Address a details-on-demand interaction for a visualization solution to only display details when requested by the user. This interaction reduces the amount of information by showing the user only what he/she wants or needs to see.
- **What would the user like to see?** Comply with the brushing-and-linking interaction allowing for the change in one view to dynamically change another view. Such heuristic postulates a domain information to assist the user in interpreting the visualization.

The employed methodology consists of a taxonomy of visualization formats to guide the application of visualization in knowledge management according to the type of knowledge that is visualized, the knowledge management objective and the user profile.



***On-Site Images Viewer**: visualize the gallery of stitched images & corresponding metadata identifying specific objects.*

***Multimedia Viewer**: automatically activate the viewer for video streaming*

***Equipment Resources Viewer**: Quick overview of the available equipment, access to the complete information is restricted to specific user profiles*

Virtual Environment for Testing ROCSAFE Scenarios

We have built simulations of critical incidents with a 3D physics-based game engine, Unreal Engine with AirSim.

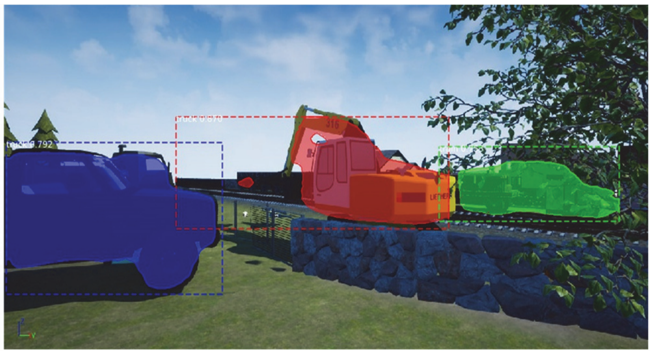
This allows us to test other ROCSAFE sub-systems in a realistic fashion, rapidly and at low cost.

It is used to test the routing, object recognition, and probabilistic reasoning.

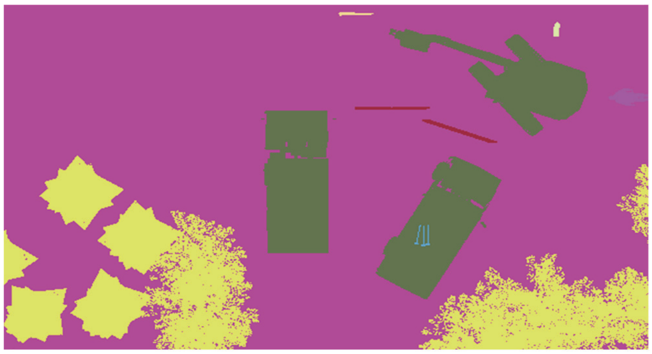
It is also used to automatically generate labelled image data for training AI algorithms.

Image from a derailed train scene in the Virtual Environment, which is based on one of the possible ROCSAFE application scenarios identified by end users.

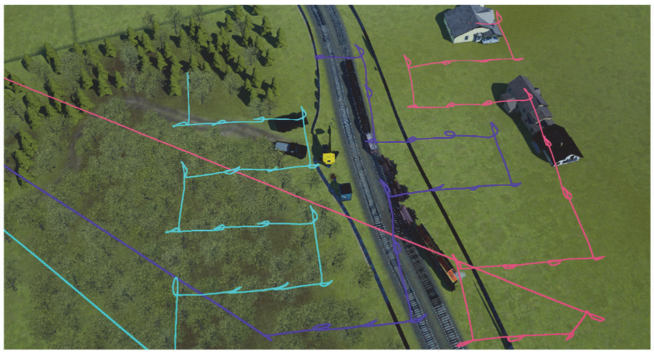
A deep neural network detects and labels the objects of interest in the images taken by RAVs in the Virtual Environment.



An example of a different view of the scene, which has again been analyzed by the deep neural network to detect object of interest.



The Virtual Environment can generate accurate ground truth data for training deep neural nets to perform pixel-level semantic annotation, as an input into RGV routing.



Here, the Virtual Environment is used to test and validate the operation of a multi-agent algorithm for routing the Robotic Aerial Vehicles.

ROCSAFE Remote Forensics

NUI Galway
OÉ Gaillimh

ROCSAFE System Integration and Validation

ROCSAFE involves the integration of a variety of complex sub-systems as well as the testing and validation of system performance as a whole. The first phase of the project was dedicated to development of such sub-systems as shown previously. The current phase is focusing on making system assemblies work at different levels sequentially.

The integration, validation and demonstration process of the ROCSAFE system and sub-systems began with the drafting of a task timeline (Fig. 1).

Integrating the system involves organising different ROCSAFE sub-systems into a series of assembly layers (Fig. 2). These assemblies are based on shared electromechanical interfaces and, at the latest one, on shared operational functionality, i.e. scene assessment and evidence collection.

The system integration procedure follows a series of steps for every sub-system and assembly: take-assemble-test-prevalidate-next. For every assembly to meet pre-validation status, system specifications and end-user requirements have to be satisfied.

Consortium and external end-users will validate ROCSAFE once the system has successfully passed tests in certified labs and undergone a final demonstration to be held at DFI facilities (Fig.3).

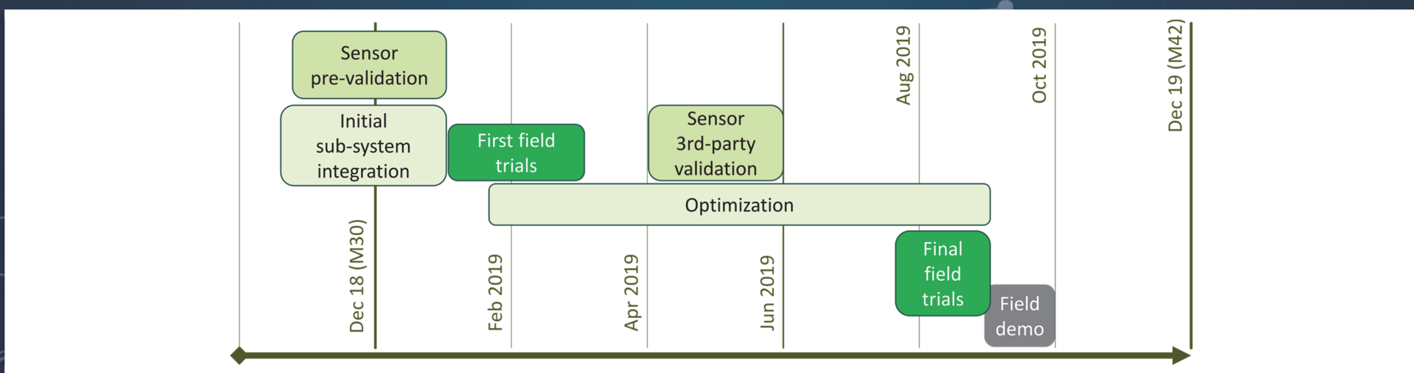


Figure 1. Calendar of ROCSAFE system integration, validation and demonstration tasks. In the current [first] phase, slated until March 2019 (Month 33), initial integration of sub-systems with subsequent testing is being performed. Before final trials and field demonstration to end users in October 2019, a phase of performance optimization will be conducted.

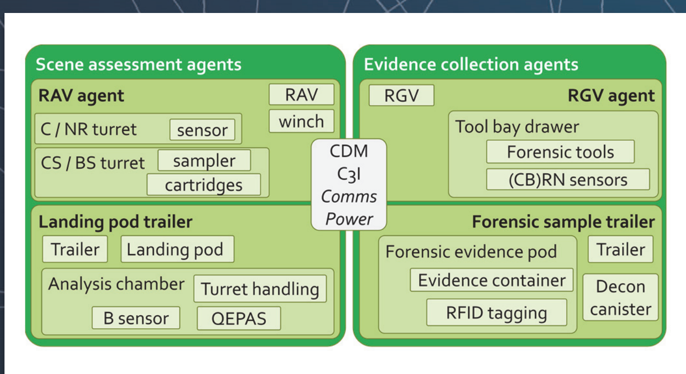
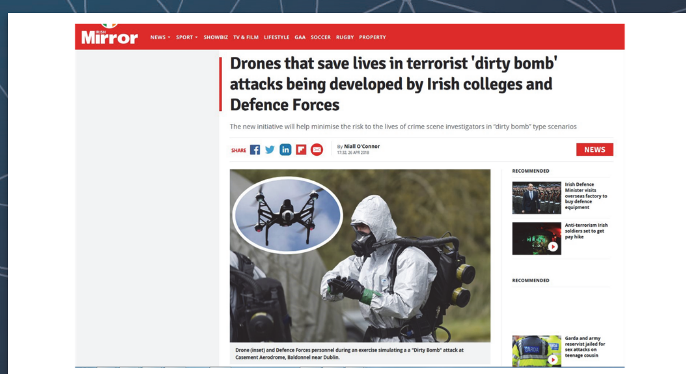


Figure 2. Scheme of ROCSAFE sub-systems (lime green) together with the sequential assemblies in which they are integrated (darker green).


Mirror

Drones that save lives in terrorist 'dirty bomb' attacks being developed by Irish colleges and Defence Forces

The new initiative will help minimise the risk to the lives of crime scene investigators in "dirty bomb" type scenarios

NEWS

Figure 3. News featuring a CBRN exercise by Defence Forces Ireland. DFI facilities will host ROCSAFE final validation exercises in conjunction with project end-users.

ROCSAFE Remote Forensics

IBATECH

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National University of Ireland Galway
NUIG, Ireland

Aeorum España S.L.
AEO, Spain

Consiglio Nazionale
Delle Ricerche
CNR, Italy

Consorzio CREO-Centro
Ricerche Elettro Ottiche,
CREO, Italy

Defence Forces of Ireland,
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