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Bridging Resources and Agencies in Large-Scale Emergency Management

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3D Real-time Emergency Support

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In November 2012 PLUS has been assigned to develop the Concept Case (CC) *Advanced Situation Awareness* (ASA). In December the BRIDGE consortium approved the PLUS proposal to optimize ASA and integrate other BRIDGE CCs developed by FIT and ALMENDE into ASA.

ASA consists of: (1) Unmanned Aerial Vehicle (UAV), equipped with video- and infrared camera, as well as multiple environmental sensors; (2) Computer-based EXPERT System (ES). ES compares incoming data with national limits and international recommendations in order to develop advice for the incident commander; (3) 3D/2D-Modelling Module (MM). MM calculates graphics depicting the impact of explosives on structures and man, and the behavior of toxic plumes due to uncontrolled release of chemicals and radioactivity. In addition, the *EU Critical Infrastructure Library* (CIL) was enlarged, enabling incident commanders to select from 85 ready-to-use 3D models of buildings typical for actually existing Critical Infrastructure (CI) in EU Members. The CIL can be used for training purposes, as well as for application on scene.

Practicability of modelling was demonstrated by SINTEF, providing the MASTER Application with a model of the virtual chemical facility CHEMCO-EXPLO through the Internet, generating a 3D model based on 2D data from the publicly available *OpenStreetMap* and elevation data provided by the SRTM project.

Functionality of the ASA system and CIL was tested twofold: (1) In the field by using a burning car and simulated car explosion in St. Gilgen (Salzburg, Austria) in September 2014; (2) In terms of system ergonomics and ruggedization, in collaboration with Austrian fire fighters in Salzburg City and St. Gilgen. FIT-Help Beacons system and ALMENDE SWARm have been integrated into the ASA successfully. ASA meets altogether 23 requirements as defined by the BRIDGE End User Advisory Board (EUAB), respectively Austrian first responders.

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1 Introduction

An *emergency* represents a sudden situation that happens unexpectedly; also, it can be an impending situation. As the situation develops further it may cause injuries among the affected person(s), death and physical damage to property. Since either of these consequences interferes with the normal activities of members of society, emergency management pays immediate attention to the situation and aims for remedial actions. Immediate action is necessary to prevent a bad situation from becoming worse.

Emergency management represents a continuum and is implemented in five phases (Fig. 1):

a. *Prevention & Mitigation Phase* (pre-event):
   Objective – Risk reduction. It includes all efforts to reduce the effects or risks associated with hazards
b. *Preparedness Phase* (before the crisis):
   Objective – Operational readiness to ensure a coordinated response. It includes all actions taken prior to an emergency to facilitate response and promote readiness
c. *Response Phase* (during a crisis, event-related):
   Objective – Integrated response in accordance with strategic priorities. It includes all actions taken during an emergency to save lives, property and the environment
d. *Recovery Phase* (post-event):
   Objective – Restored operations. It includes all actions taken after an emergency to restore and resume normal operations.

Superimposed during all phases is the aim for *Continuity*, i.e. take into account all actions needed to protect the on-site operations affected by the crisis from complete disruption.

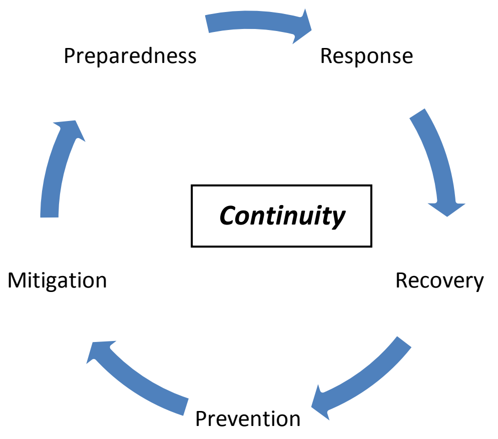

Figure 1 Emergency Management Continuum.

Initially first responders on scene face the challenge of being inundated with a large amount of information, some of which may be imprecise, possibly even erroneous. In the military soldiers face the infamous *Fog of War* problem on the battle ground, illustrating the difficulty of having to decide on incomplete information. Also civilian first responders face the problem of making decisions during emergencies being at least partially unaware of the true nature and dimension of the crisis in the initial phase of the event.

This report describes the newly developed Concept Case *Advanced Situation Awareness* and its application in the field, tested under varying conditions in collaboration with Austrian volunteer- and professional first responders.

Also, the integration of CC ASA with CC FIT Help Beacons system and ALMENDE SWARM is described.

1.1 Objectives

A new tool for facilitating the decision making process for first responders, *Advanced Situation Awareness* (ASA), has been developed.

This tool can be used in:

a) *Real-time training* by simulating complex and also hazardous environments. Thereby, ASA represents a cost-saving and risk-reduction alternative;

b) *On scene*, supporting emergency management in the complex decision making process necessary for regaining control. The output of ASA ranges from the prediction of structural stability of buildings and spatial/temporal behavior of toxic clouds, to the number and type of victims to be expected after an explosive blast and data on the toxicity in the environment.

1.2 Methodology

In order to achieve a high level of cost efficiency for first responder organisations COTS[1] technology and software was investigated with regard to its potential suitability for the ASA during training and on-scene. In case of inadequate or non-existing COTS solutions new technologies were developed for ASA (e.g., Unmanned Aerial Vehicle with environmental sensors, EXPERT System, EU Critical Infrastructure Library).

The criteria for selecting COTS were:

- Highly reliable and ruggedized hardware
- Software capable of 3D-, respectively 2D-modelling
- End user-friendly, ergonomic operation.

Based on the requirements as defined in BRIDGE JIRA, ASA was designed as a three component system:

1. A remotely controlled *surveillance component*, enabling the incident commander to obtain quickly initial information about the magnitude of the incident site in an

[1] **C**ommercially **O**ff **T**he **S**helve (COTS).

aerial overview from visual- and infrared video as well as gas- and particulate sensors;

2. A computer-based *decision aiding component*, which evaluates incoming data from the aerial overview and issues science-based advice to the incident commander;
3. A computer-based *modelling component*, offering (a) ready-to-use 3D models of EU Critical Infrastructure and the impact of explosives on these structures, (b) estimates of the number of dead and injured based on the number of persons present at the target area of the explosion, and (c) 2D models of the dispersion of toxic substances due to uncontrolled release into the atmosphere, including radioactive material.

2 Concept Case "Advanced Situation Awareness" (ASA)

2.1 General Description

The system *Advanced Situation Awareness (ASA)* was proposed by PLUS and accepted by the BRIDGE Consortium at the occasion of the Technical Coordination Meeting in Klagenfurt (Austria) in 2012. Following its validation in St. Gilgen (Austria) in August 2014, ASA was selected by the BRIDGE Consortium for further optimization in December 2014.

ASA consists of three components:

The *surveillance component* was designed as an Unmanned Aerial Vehicle (UAV) with originally eight engines (**Octocopter PLUS UAV Mk I**). In order to enable environmental gas measurements, only electric powered engines were considered suitable for the UAV, thereby avoiding any potential influence of emissions from combustion engines. This impacted on the operational flight duration, limiting it to about 20 min per battery charge. Subsequently, newly developed electric engines with higher efficiency and the increased use of carbon-fibre led to the construction of a six engine-drone (**Hexacopter PLUS UAV Mk II**). This UAV was able to carry an even higher payload than the Octocopter. With its lower gross weight it became possible to extend the flight time of the Hexacopter to approximately 30 min per battery charge. Further UAV design changes resulted in a ruggedized flying platform equipped with multiple sensors (**Dual-Quadrocopter PLUS Mk III**). This UAV is able to withstand harsh environmental conditions in terms of extreme weather (snow, heavy rain, wind speeds up to 30 km/h) and rough operational boundary conditions, typical for on scene conditions during disasters.

The *decision aiding component* was developed as a interactive database in order to: (1) Reduce the large amount of information provided by the UAV to those data essential for the decision of the Incident Commander with regard to the safety of the first responders on scene and the population affected; (2) Provide state-of-the-art information concerning the interpretation of the environmental measurements in terms of national limits and international recommendations.

The *modelling component* applied the results of the extensive review of modelling software carried out in Work Package(WP)03 during the BRIDGE Project. It took into account hardware requirements, user friendliness, and training requirements. Furthermore, it made use of the *EU Critical Infrastructure Library* (CIL) developed also in WP03.

ASA is connected via BRIDGE Middleware to the BRIDGE MASTER Table. ASA assists crisis management by providing an accurate, real-time update on the incident, strengthening the capabilities of other concept cases, such as *BRIDGE Resource Manager* and *BRIDGE Risk Analyzer*, reducing the risk for the first responder on scene and ultimately enhancing the efficiency of the management of a large crisis.

2.2 Requirements by First Responders

From the onset of the ASA implementation, requirements – as defined by the End User Advisory Board (EUAB) and Austrian first responders - were taken into account to the extent possible. The main requirements identified and the compliance by PLUS ASA are summarized in Table 1.

Requirement	BRI System No.	PLUS ASA Compliance with User Needs
ASA shall improve situation awareness by presenting relevant sensor data	98	ASA provides data on concentration of 5 gases, gamma dose rate, particle size, aerosol mass, ambient temperature and rel. humidity
UAV shall provide a live video stream & live infrared pictures	459 460 508	UAV has onboard VIS- and IR cameras with separate, encrypted 5.8 GHz downlink. VIS-camera; Resolution of 752 x 480 pixels; data acquisition frequency: up to 87 frames per seconds; IR-camera; Resolution of 160 x 120 pixels; data acquisition frequency: up to 100 frames per seconds.
UAV shall provide gas measurements and radiation measurements	461 462	UAV has onboard: (a) Electronic sniffers for: CO, CO_2, C_2H_6, CH_4, N_2O, O_2, H_2S, SO_2, NH_3, NO_2, Cl_2, ClO_2, PH_3, HCN, C_4H_{10} (butane), CH_4 (methane), C_3H_8 (propane) (b) Solid-state detector for gamma- and high energy beta-radiation
MODELLING MODULE shall present plume models, physical damage models and health-risks for people living in an area, based on UAV sensor data	467 468 469	MODELLING MODULE provides: (a) 2D plume model for toxic chemical- and radioactive isotope release for different times, (b) Dose- and risk assessment for first responders and population in affected area
EXPERT System shall provide advice on public health, safety features for first responders, and reduce information overload by enhance reasoning	474 475 476	EXPERT System provides end-user friendly information as colour-coded "dials" for safe (green), potentially dangerous (amber), and in excess of limits (red) conditions, and optionally also as numerical data. Upon request advice is given in different formats (graphics, photos, text).
MIDDLEWARE shall provide the possibility to store sensor data, models and results of the EXPERT System. Also, it shall provide the possibility to present the results of the EXPERT System to other systems in a suitable format	463 464 470 471 477 484	All ASA data output matches requirements as defined CNET (in charge of MIDDLEWARE configuration).
MASTER TABLE shall provide the possibility to show relevant sensor data	465	All output data provided by ASA can be displayed on MASTER TABLE

coming from the UAV, provide the possibility to present resulting models coming from the Modelling Module and show the results of the EXPERT System	472 485 510	
Advanced Situation Awareness system to be usable for operators after one week of training	511	(a) Full operational control over UAV by volunteer fire fighter after 15 hours of training. (b) Full operational control over EXPERT System by Incident Commander (professional fire fighters) after 9 hours of training

Table 1 Comparison of compliance with user need requirements, as defined by EUAB and Austrian first responders by PLUS ASA.

Optimization

The operable version of the CC ASA existing in September 2014, represented a laboratory version, i.e. not ruggedized, not water-proof and not sufficiently ergonomic for the rough operational conditions in routine use by first responders. Therefore, optimization of the current ASA version to meet the specific requirements of the different first responder organizations was carried out in a step-wise function:

(a) On 6 January 2015 the newly founded *Austrian ASA Focus Group* in Salzburg met for checking the feasibility of the ASA optimization approach taken by PLUS. This included representatives of the Austrian Federal Ministry of Interior, Austrian Federal Ministry of Justice, Government Salzburg Public Health, Government Salzburg Disaster Management, Salzburg Professional fire Fighters and Salzburg Volunteer Fire Fighters.

(b) On January 27-28, 2015 the *First CC ASA Coordination Meeting* took place in Salzburg, together with representatives from FIT and ALMENDE. This group jointly corroborated an *Action Plan* for implementing the different tasks in the sub-project.

(c) From 10 January to 16 February 2015 *UAV training* was carried out with volunteer fire fighter in St. Gilgen (Austria) under different weather conditions. The results showed that:

  (1) Basic UAV maintenance and entire handling of the PLUS UAV can be learnt quickly by a volunteer firefighter without any previous UAV-pertinent know-how.
  (2) UAV-required skills can be acquired within a short time period, i.e., after 15 hours of training a previously UAV-untrained volunteer firefighter was able carry out basic UAV maintenance and conduct all UAV-related flight maneuvers.
  (3) The skills acquired by the volunteer firefighter enabled him to deploy the UAV even under harsh weather conditions, including high wind speeds, snow and sub-zero temperatures.

(d) From 6–27 February 2015 professional fire fighters were collaborating with PLUS in order to corroborate the optimized *design of the EXPERT System* as end user –friendly. In altogether 9 hours the following issues were identified:

(1) PLUS Expert-System is a valuable system but needs further simplification for practical use in order to avoid information overload.
(2) Modelling Module is useful in large disasters.
(3) Modelling during crisis-response is considered an innovative methodological approach which has not been used by any of the first responders in Austria yet.
(4) Numerical UAV-data should be made available only to the "Incident Commander" on scene, whereas first responders on scene should receive colour-coded information of the "danger-level" only.

(e) On 28 April 2015 the *Second CC ASA Coordination Meeting* took place in Salzburg, further advancing the incorporation of the FIT Help Beacon system and ALMENDE SWARM into the ASA flying platform.

These results were used to modify the design of the UAV and the operation of the EXPERT System and MODELLING MODULE accordingly, as described in more detail in the following sections.

2.3 Unmanned Aerial Vehicle

Unmanned Aerial Vehicle (UAV), *PLUS UAV Mk I* (Octocopter, Figure 2), was developed in 2013 for R&D purposes and subsequently used for training of first responders. *PLUS UAV Mk II* (Hexacopter, Figure 3), a UAV with enhanced capabilities (e.g., sensor equipment onboard), was developed for deployment during the Alpine ValEDation Days in September 2014 (Figure 4). This Hexacopter has a 1.1m in diameter and a gross weight of approximately 4.5 kg. Fitted with six vertical rotors, powered by lithium-polymer rechargeable battery packs, it has an uninterrupted flight operation up to 30 min (maximum payload: 3.0 kg).

Figure 2 Unmanned Aerial Vehicle PLUS UAV Mk I.

Figure 3 Unmanned Aerial Vehicle PLUS UAV Mk II with sensors.

Figure 4 Deployment of Unmanned Aerial Vehicle PLUS UAV Mk II during field test (Alpine ValEDation Days 2014).

This prototype was further optimized into PLUS UAV Mk III (Dual-Quadrocopter, Figure 5) during the approved sub-project in order to sustain the rough operating conditions of first responders in routine operations.

Figure 5 Unmanned Aerial Vehicle PLUS UAV Mk III.

PLUS UAV Mk III has the following design features:

- **CHASSIS**
  - Compact carbon-fibre sandwich construction
  - High torsion resistance
  - Each UAV arm 90 degree flexible
  - Dual-Quadro engines, i.e., 2 engines on each of the 4 UAV arms
  - Loss of one engine can be fully compensated by remaining 7 engines
- **LANDING GEAR**
  - Additional legs
  - Larger foot-print
- **ELECTRONICS**
  - Onboard circuits with plastic seals against dust and humidity
  - Batteries and sensors 100% splash-protected (compliance with standard IP 65)
  - Voltage controls fully redundant
  - Flight controls partially redundant
  - VIS- and IR cameras with separate 5.8 GHz downlink
- **PAYLOAD**
  - On board weight reduction by replacing mini-PC und wireless-Ethernet-bridge by micro-controller and low data rate wireless link
  - Increase from 1 kg (PLUS UAV Mk II) to 5 kg

- **SYSTEM AUTOMATION**
  - Automatic routine (“plug-&-play”) for take-off and landing
- **OPTIONAL FLIGHT OPERATIONS**
  - Manually defined flight route
  - GPS & way-point defined flight route
- **FLIGHT DYNAMICS**
  - High torsion resistance allows sharp turns and high acceleration
- **USER-FRIENDLY TRANSPORT CASE**
  - Foldable, spring-loaded UAV arms
  - Chassis in folded mode is transported in small, splash-protected suitcase (Figure 6)

Figure 6 Water-protected, ruggedized transport case of complete PLUS UAV Mk III system with foldable arms.

The PLUS UAV Mk III has the following operational features:

Global Positioning System with homing mode: The UAV is fitted with a GPS-device, enabling the vehicle to proceed along a pre-established flight path. Besides the option of manual control of the UAV, it is possible to follow a predefined flight pattern using up to eight predefined waypoints. In addition, upon reaching the reserve capacities of the battery packs, the UAV automatically switches to homing mode, i.e., returning to the base station without the help of the ground-based operator.

Cameras: The UAV is equipped with two on-board lightweight EMR devices, using:

i) VIS-camera; resolution of 752 x 480 pixels; data acquisition frequency: up to 87 frames per seconds;
ii) IR-camera; resolution of 160 x 120 pixels; data acquisition frequency: up to 100 frames per seconds.

Both cameras are attached to a remotely controlled flexer, enabling the ground-based operator to change the camera-angle within 90°. The horizontal angle can be adjusted using the onboard set of rotors.

Environment sensors: Using the above flying platform the PLUS UAV Mk III is fitted with solid state sensors, enabling monitoring of the following environmental parameters:

- Electronic sniffers for O_2, CO, H_2S, SO_2, Cl_2, NH_3, NO_2, ClO_2, PH_3, HCN, CO_2, C_4H_{10} (butane), CH_4 (methane), C_3H_8 (propane);
- Environmental radiation using a solid-state radiation detector for gamma- and high energy beta-radiation;
- Aerosol number concentration to be measured with an optical particle counter (OPC), permitting the discrimination among three particle size classes (250 nm alveolar, 2.5 µm thoracic & 10 µm nasal or oral deposition);
- Aerosol mass measurement (PM with a sensitivity: >1 mg/m^3) for the spectral window up to 10µm particle diameter, using a quartz-crystal-microbalance for a first approximation of the characterisation of the aerosol.
- Standard meteorological data, such as ambient air temperature, relative humidity, atmospheric pressure. These atmospheric data enable documentation of prevailing conditions, including determination of the actual height of the UAV, and – in case of secondary detonations on site – the detection of pressure waves.

Apart from the meteorological sensors, all other sensor devices require active ventilation. This is achieved by providing a constant suction force using a carbon vein pump (mounted into the sampling line for gases and aerosols with variable pumping rate up to 1.5 litre/min).

By locking into the monitored sensor values, the on-board system enables automatic tracking of the plume propagation and – together with GPS data – determination of plume speed and plume direction. Furthermore, using aerosol information the UAV is able to keep a safe distance from hazardous plume concentrations, which could potentially damage vital parts of the aviation elements (rotors, motors). All sensors are connected to mapping data obtained from the GPS-recorder.

Sensor data are multiplexed and relayed via a wireless downlink (transponder in the GHz-range) to the base-station. Subsequently, the decoder feeds the de-multiplexed data stream into the master computer for storage (backup) for subsequent data de-convolution.

The system provides the incident commander on the ground with a visual presentation of:

- Video/photo images supplemented with IR-images
- Environmental data (gases, radiation, PM, PN, T, rH, and p).

Visualization of the data is done graphically on display units (e.g., EXPERT System, BRIDGE MASTER TABLE) in order to facilitate fast recognition of hazard threshold levels.

In summary, the flying platform contributes to situation awareness by providing the following information:

(a) Extent and architectural details of physical damage of structures on scene;
(b) Number of victims outdoors on scene;
(c) Magnitude of fires on scene;
(d) Environmental hazards due to uncontrolled release of toxic substances;
(e) Propagation of toxic gaseous and particulate effluents as a function of time (e.g., plume dispersion).

2.4 EXPERT System

PLUS Expert System is used to automatically analyse incoming data from the PLUS UAV Mk III. The data are provided via the UAV Ground Station (Figure 7).

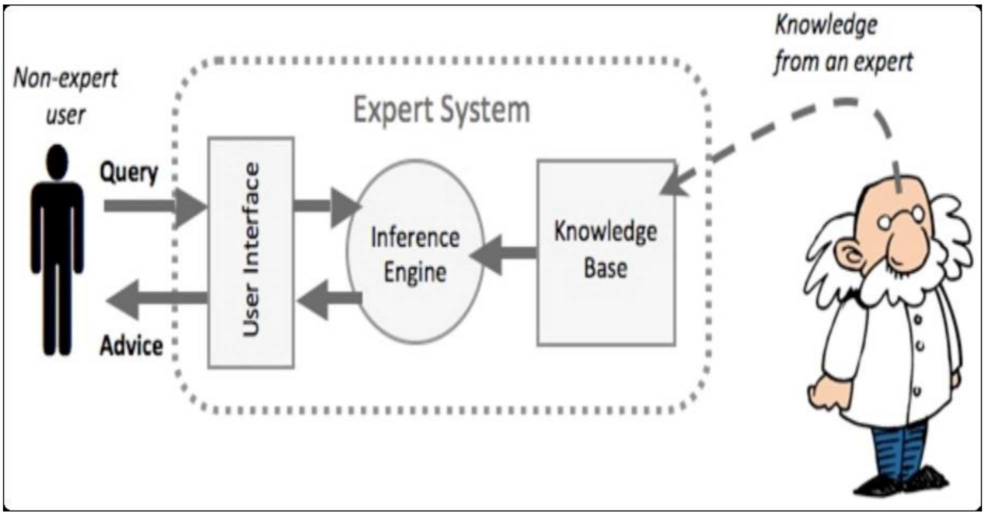

Figure 7 Data flow in EXPERT System.

Within the *Expert System* incoming data is rated and combined with expert recommendations, such as issued by WHO, ICRP, IAEA, etc. The aim is to use data on environmental measurements collected by the Hexacopter for automatic pre-analysis and data reduction in order to assist in improving situation awareness.

In addition to this numerical information, actions are recommended, based on national legislation, international recommendation and international databases (e.g., on chemical toxicity). These recommendations are categorized as information provided by different (virtual) “Experts” addressing topic areas, such as *Health*, *Environment*, *Radiation*, etc.

Collaboration with different practitioners from the Austrian- and EU first responder community resulted in multiple modifications to using the EXPERT System, such as:

- EXPERT System works also offline without access to internet;
- Reduction of information overload for UAV pilot by OSD-minimized information display at ground station;
- GIS-structure integrated into EXPERT System;
- 2D plume modelling integrated into EXPERT System;
- Colour-coded alarm signals when a certain hazard reaches dangerous levels (Figure 8);

- Virtual gauges show the measured value in addition to turning red, amber or green (Figure 17);
- Reduction of graphical information displayed on the underlying maps and focusing on essential data (Figure 9);
- Advice pops up as soon as the situation becomes life threatening on site (Figure 10);
- Additional Information on victims: (a) Registration of WLAN-based emergency calls by UAV; (b) Graphic display in separate unit at Ground Station (incl. coordinates of victim); (c) Automatic confirmation upon completed rescue operation;
- MODELLING MODULE added: Large number of completed 3D models are integrated into the EXPERT System and only a click away from the user; enables preliminary assessment of physical damage to buildings and estimation of number of victims and their injuries to be expected after an explosion;
- Touch-device allows first responders on scene to use the system with 10” tablets;
- Additional Past Incidents Analyzer, enables user to analyze the incidents at a later point in time. With the data saved in a database and a user interface being developed the user will be able to select a particular incident and view the scenario;
- Update of data repository by adding additional database on chemical toxicity (ICRP 103 with Glossary, 2007; IAEA Safety Glossary; COUNCIL DIRECTIVE 96/29/EURATOM; European CHemical Agency (ECHA) standards).

Figure 8 Improved ergonomic colour-coded display options (left: dial view; right: advice view).

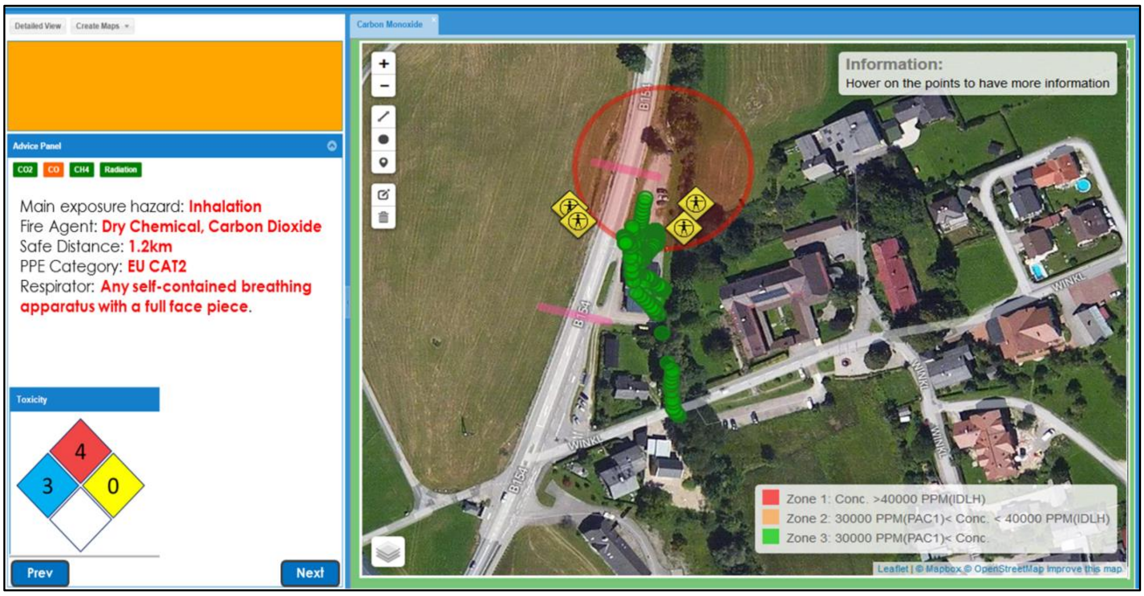

Figure 9 Optional marking of location of victims and definition of zones.

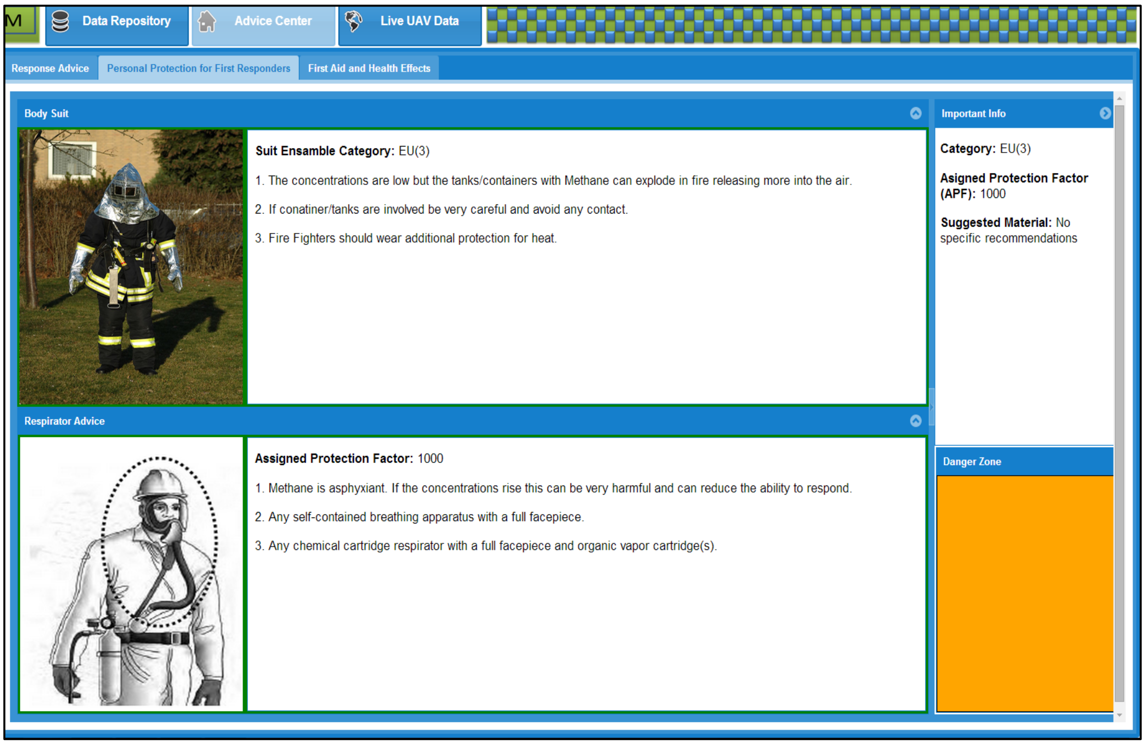

Figure 10 Virtual gauges display colour coded values measured by UAV, together with *Advice* issued by EXPERT System, issued automatically in case of life threatening situations.

2.5 3D/2D Modelling Module

PLUS Modelling Module creates computer-based models of structures on the incident site and of plumes in case of an uncontrolled release of a chemical or radioactive substance (Figure 11). Thereby, the user can predict the dispersion of toxic gases and radioactive substances resulting from an uncontrolled release, causing hazardous plumes. Also, the module enables the user to assess the physical damage to buildings due to explosions and health hazards to people after an explosion and/or uncontrolled release of toxic substances.

Figure 11 2D Plume Dispersion Model.

2D- and 3D modelling require special training of the first responder. In order to facilitate the practical application of modelling several pre-finished models have been created as input into the EXPERT System. These ready-to-use models reflect most frequently occurring threat scenarios, such as the impact of explosions due to a Vehicle-based Improvised Explosive Device (VBIED), Person-based Improvised Explosive Device (PBIED), uncontrolled release of certain toxic chemicals or radioactive isotopes. Thereby, upon clicking onto the selected threat scenario, the user has access to:

- In case of a toxic gas- or radioactivity release (Figure 12):
  - Definition of areas impacted by plume at different times;
  - Evaluation of need for evacuation or sheltering.
- In case of an explosion:
  - 3D model of damaged buildings (Figure 13);
  - Estimate of number of dead and wounded, including type of injury (Figure 14).

Figure 12 *On Scene* -Toxic Plume Model defines areas impacted (Red: Evacuation Zone; Green: Mandatory Sheltering; Black: Minor Impact Zone).

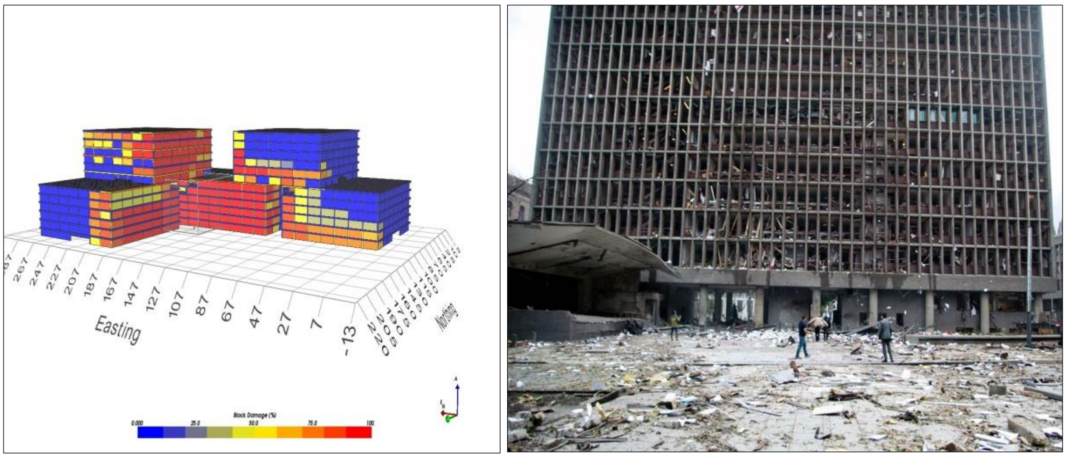

Figure 13 *On Scene* - Reality-based Modelling of Explosion Damage (Red: Do not enter; Yellow: Cautionary approach only; Blue: Safe to enter).

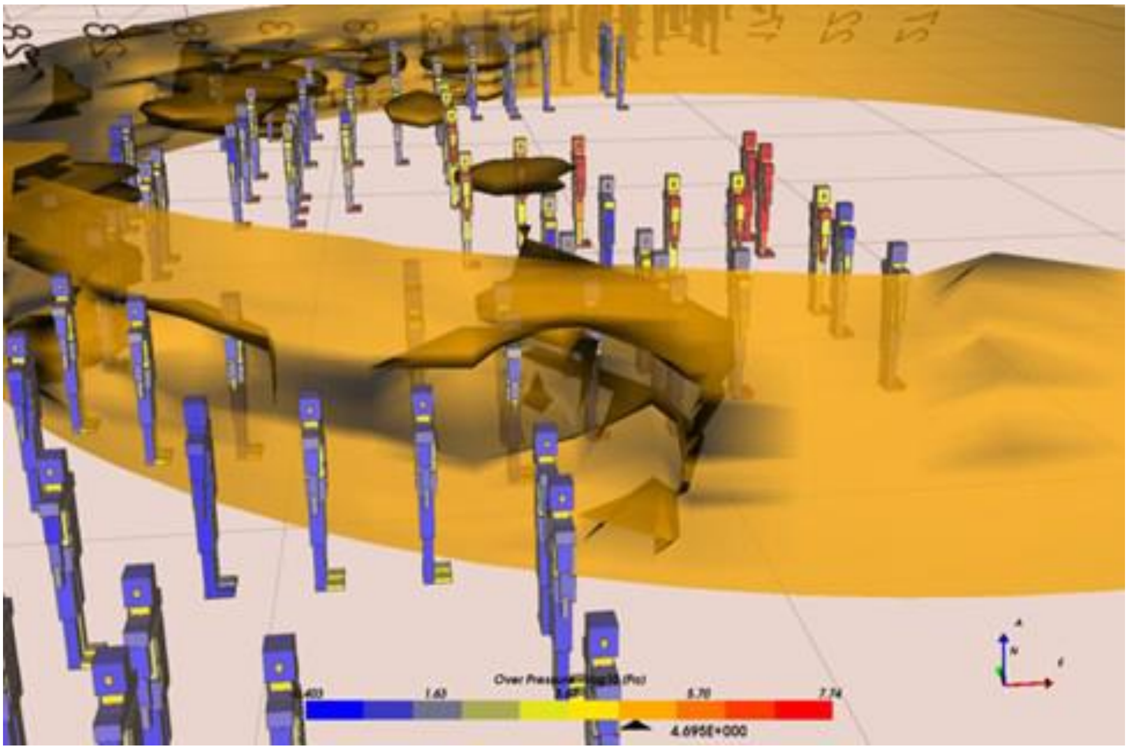

Figure 14 3D Model of Explosive Blast Wave (donut) Expanding Through Crowd of People; degrees of injury are shown in different colours (**red**: lethal; blue: uninjured).

This module draws on the pre-programmed generic models of reality-based structures contained in the *EU Critical Infrastructure Library (CIL)*, created in Work Package 3 in the BRIDGE Project.[2] Since then it has been expanded to altogether 120 ready-to-use 3D models. The models can also be populated with 3D male and female figures. Examples of the newly created models are shown in the Appendix.

2.6 First Responder Training

The ASA system has been used for on-site training of fire fighters during the period January – March 2015:[3]

- Volunteer fire fighters of the Löschzug Winkl (St. Gilgen, Austria) have been trained in the routine operation and maintenance of a UAV.
- Professional fire fighters of the city of Salzburg (Austria) were trained in the use of the EXPERT System and the 3D/2D Modelling Module.

The First Responder Training Programme on the use of the UAV had the following objectives:

- Practically applicable instructions on the UAV system maintenance;

[2] CIL has been described in detail in D 3.2 already.
[3] In January 2015 the BRIDGE Project has been granted an extension to 30 June 2015.

- Autonomous UAV system setup by trainee;
- Autonomous UAV flight operations in different weather conditions by trainee;
- Autonomous UAV flight operations in different operational conditions by trainee;
- Autonomous UAV flight operations in different operational on advanced UAV by trainee.

This UAV training programme was implemented in two phases: (1) Basic Training (Table 2), and (2) Advanced Training, using PLUS UAV Mk I and Mk III, respectively (Figure 15).

Training Programme	Weather Conditions	Remarks
Introduction to UAV setup, safety procedures and UAV system handling	Clear, 10°C, gusts of wind up to 30km/h	Basic maintenance and repair of minor damage
Exercises: flights along pre-defined route, take-off and landing	Clear, 1°C, calm	Positive feedback with regard to handling-mode.
Exercises: Flights along predefined route, take-off and landing. Use of on-board camera: focusing on objects of different sizes	Clear, 1°C, calm	
Exercise under difficult conditions (snow, wind, irritating solar radiation, line-of - sight obstruction)	Clear, 0°C, gusts of wind up to 30 km/h, snow covered ground	Complete autonomous handling of UAV

Table 2 Basic UAV training programme for first responders.

Results

Basic UAV maintenance, system setup and handling of the PLUS-UAV can be learnt quickly without any previous UAV-pertinent know-how. After 15 hours of training a previously UAV-untrained volunteer fire fighter was able to carry out basic UAV maintenance and conduct all UAV related flight manoeuvres under the support of the incorporated GPS-system.

Advanced UAV Training

Based on the previous training programme with the UAV model *PLUS Training*, training has been continued with the advanced UAV *PLUS Mk III*, a UAV suitable for real emergency use in harsh weather conditions (Figure 16, 17). In addition, training on the practice device has been continued without GPS-assistance of the system, i.e. autonomous UAV stabilisation and limitation of ground speed and climb speed.

Furthermore, training of a higher degree of difficulty could be started where the system support is restricted to autonomous retention of UAV altitude and autonomous control of tilt angle to simulate flight conditions in enclosed environments (e.g., inside cave, building) without available GPS signal (Figs. 18, 19).

Results

The advanced test series has shown that autonomous handling further autonomous practice by a trainee is feasible under the given circumstances. Also, skills acquired by using UAV PLUS Training can be adapted to fly a more professional UAV, such as PLUS UAV Mk III with similar results in terms of handling and operational challenges.

Figure 15 Flight training using with volunteer fire fighter using ruggedized UAV *PLUS Mk III.*

Figure 16 UAV training in winter conditions I.

Figure 17 UAV training in winter conditions II.

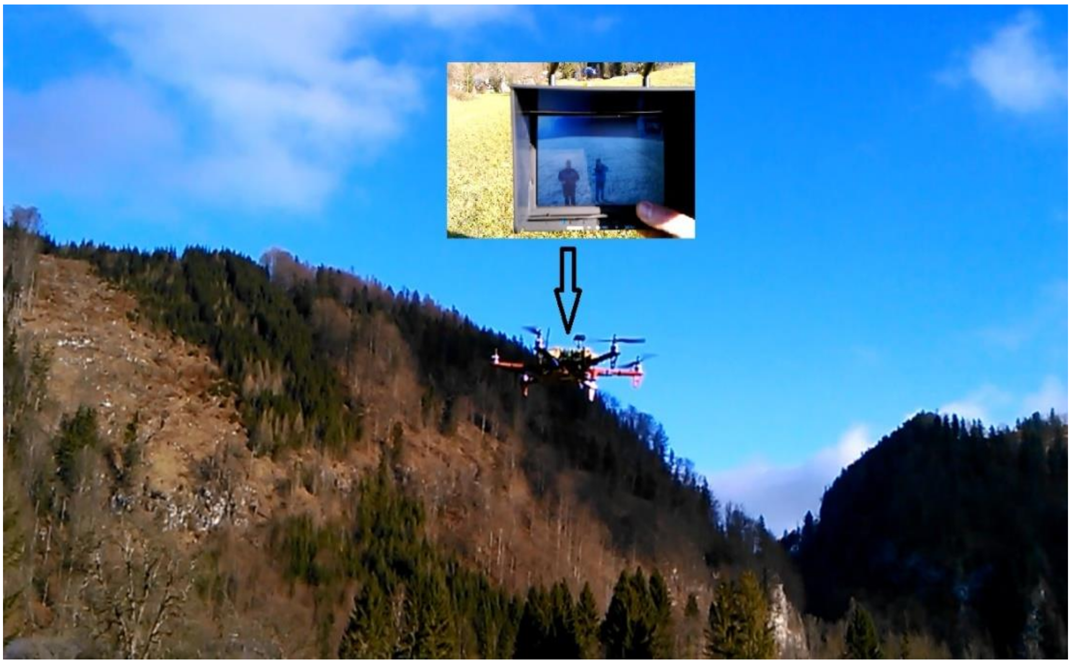

Figure 18 Training with UAV on board-video camera (arrow) and ground monitor (small picture inserted).

Figure 19 Flight control using video-screen of ground monitor only.

Together with professional fire fighters in Salzburg and experts from the Government Disaster Management Salzburg, different components of the usefulness of the practical application of the EXPERT System were corroborated. Details of this programme, lasting altogether 9 hours, are summarized below in Table 3.

Subject Area	Results
Components of BRIDGE Concept Case "Advanced Situation Awareness (ASA)"	Professional feedback of eight high-ranking first responders concerning the usefulness of ASA system in routine operations
(1) Structure of PLUS Expert-System (2) Review of content and display of information by EXPERT System focusing on ergonomics	Feedback of professional firefighters on current data depositories in routine use.
(1) Structure of PLUS Modelling-Module (2) Review of practical applicability of modelling approach and *Generic EU Critical Infrastructure Library*, focusing on ergonomics	(1) At present modelling software is not used in routine operations in Austria; (2) Practical application in disasters only; (3) Use of chemical plume dispersion models viewed as desirable in the future.
(1) Technical analysis of all measurement equipment currently used by fire-brigades in the Province of Salzburg (2) Evaluation of their future use onboard of the PLUS-UAV	(1) Identification of several sensors with the potential of integration into the onboard system of the PLUS UAV Mk III; (2) Detailed laboratory tests at PLUS.

Table 3 Corroboration of EXPERT System by professional Austrian first responders.

This included verification of the advice issued by the system, e.g., with regard to the need of personal protective equipment (PPE) (Figure 20) or the impact of a VBIED on a building (Figure 21).

Figure 20 Selection of PPE based on advice by EXPERT System.

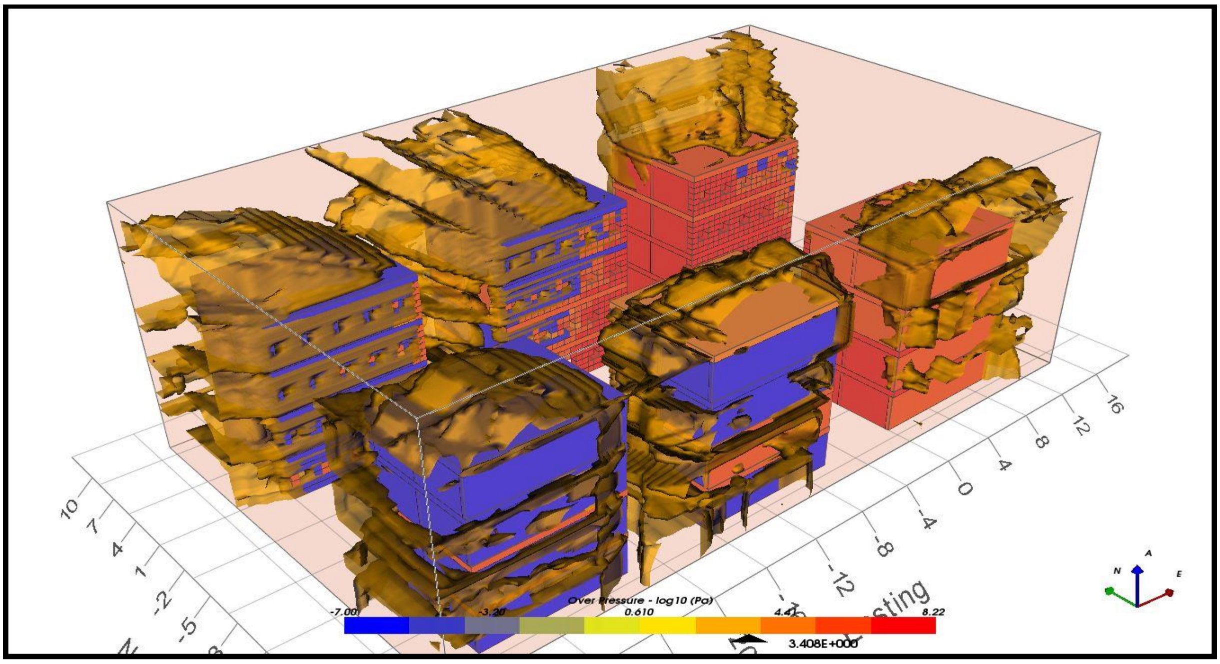

Figure 21 3D Model of Pressure Wave Expansion due to VBIED (Car Bomb).

2.7 Field Tests

The ASA system was validated jointly with the volunteer fire fighters operating at St. Gilgen (Löschzug Winkl, Austria) in September 2014 as part of the *BRIDGE Alpine ValEDation Days*. A field test was carried out with a passenger car on fire which itself triggered an explosion of the petrol tank. Four passengers were simulated to have been thrown out of the vehicle. Two of them lay only partially visible in the high grass, whilst the other two were hidden by undergrowth.[4] Using the on board video camera and infra-red camera it was possible to find all simulated victims within about 10 min.

Environmental sensors on board of the PLUS UAV sent measurement data of air pollution levels at different distances from the burning vehicle in real-time to the Incident Commander. All data were projected onto a screen in the crisis management room using the BRIDGE Middleware[5] and MASTER Table (Figure 22).

Figure 22 Sensor Data Display, together with Aerial View of Location.

The EXPERT System used the incoming data to compare the measured atmospheric concentration values with national limits and international recommended values. Furthermore, these data were used by the Modelling Module to calculate the plume, moving towards a village in about 3 km distance from the burning car. Based on the computed results, advice was issued to the Incident Commander with regard to: (a) Recommended safety equipment for the first responders approaching the burning vehicle; (b) Precautionary measures to be taken concerning the inhabitants of the village in the pathway of the plume.

[4] The field test was carried out in cooperation with the BRIDGE *HelpBeacon* System developed by FIT.
[5] Supported by CNET

3 Real-time 3D Model Creation

In order to demonstrate the practical application of 3D modelling, results of the EXPLO-CHEMCO animation (created by PLUS in WP 3 in 3ds-MAX) were adapted for display on the screen of the MASTER Table.

The “***Tinia# - module***” for the MASTER application, described in more detail in D 03.3 "3D Content Distribution", as initially developed was best suited for training purposes, where all aspects of the infrastructure can be controlled. For the second demonstration at Risavika (Norway), it was necessary to adjust the module to be better suited for use in a real-time emergency event.

The main change was optimizing the whole module to reduce the amount of bandwidth needed, and thus the power needed, whilst still giving quick responses to user input. So instead of keeping a connection to the rendering service open at all times, in this version a new image is requested only, if the user input requires it. Since the user is interacting with the 3D model, new images from the server are requested only once the previous request has been completed. In the earlier version a stream of images for any user input was requested. This stream put great strain on the data connection easily saturating the available bandwidth, with the images received only being visible very briefly. By only requesting single images, fluidity of the movement in the scene is lost, but requirements for both bandwidth and power are lower, whilst still retaining the feeling of responsiveness and showing the data the user is requesting. This has the added benefit of giving other resources and services in the MASTER application better responsiveness, when using the internet access.

Also, the approach, how user input was handled, has been optimized. By storing all user inputs until the data connection became ready to request a new image, it was possible to keep costly calculations to a minimum. This helps reduce the load on the processor, which is particularly important in the case of tablets.

Lastly, a new math library was created with just the functions needed for handling user input. This was required because the math library available on the Microsoft PixelSense table was incompatible with the math library on the Microsoft Surface tablets and vice versa.

As described in detail in D 03.3 "3D Content Distribution", a method has been implemented which generates a 3D model based on 2D data from the publicly available OpenStreetMap and elevation data provided by the SRTM project. For the second BRIDGE demonstration this method was extended by using the, then soon to be released, higher quality elevation data provided by the Norwegian Mapping Authority, thereby achieving a more accurate model covering Norway.

The following provides a summary overview of the methodological approach:

- Initially relevant OSM data are extracted for a rectangular area as defined by the minimal and maximal latitudes and longitudes. The data consists mostly of man-built structures, like roads, building footprints and public transportation routes, and consists of a 2D point defined by its latitude and longitude. In general, there is no elevation information. In rural areas there are typically few sample points, which would result in a less accurate rendering. This problem was resolved by adding additional 2D point samples.
- Subsequently, SRTM data were used to add the elevation to each of the 2D points. For Norway SRTM data were replaced by data provided by The Norwegian Mapping Authority.

- The next step triangulated the model based on the initial 2D points and wrote the triangulation to a COLLADA file. Also, roads, paths, public transportation routes and building footprints were extracted and included in the COLLADA file, where they are represented by chains of line segments. To avoid cluttering the terrain, elevation coloring was added to the shader as defined in the COLLADA file. This coloring makes it easier for the user to separate water from mainland and higher altitudes. A natural extension here would be to texture the terrain with data from satellite images, though it could make the terrain seem cluttered and hard to read in an emergency situation, which is why this route was not explored any further.

For the second demonstration the code for generating the 3D model was optimized until an acceptable performance level was reached, taking less than 30 seconds to generate a model. Working with a 10x10 km domain centered at Risavika (Norway) and using a single core on an Intel i7-2600K CPU, different optimization techniques were used, managing to reduce the runtime down to 29 seconds. The runtime includes extracting 2D data from OSM, adding elevation data from the Norwegian Mapping Authority and writing the model to a COLLADA file. It is furthermore dependent on the resolution of the model. In this case a 10x10 m grid for the elevation data was used.

The code can still be further optimized, which could make it possible to do real time terrain generation. Most of the operations for generating the model are highly suitable for parallelization and would benefit from threading to enable using the multiple cores available in today's servers.

4 Integration of FIT Sub-Project Contribution

At the occasion of the *First CC ASA Coordination Meeting* in Salzburg on January 27-28, 2015, all necessary technical details for incorporating *Help Beacons* in ASA concept case were identified jointly between FIT and PLUS. Subsequently, a device was successfully installed on the PLUS UAV Mk III, tested in the field in Salzburg city (Figure 23). All functions of the Help Beacons system could be corroborated during the flight mode in the same way as its operation on the ground.

Details are reported in Deliverable D 06.4.

Figure 23 Field test of FIT Help Beacons system installed onboard of PLUS UAV Mk III.

5 Integration of ALMENDE Sub-Project Contribution

Throughout February, March and April 2015, the BRIDGE SWARM (*Situation aWAre Resource Management*) system has been extended with resource movement simulation and ETA calculation capabilities, tested for performance and scalability towards large and very large incidents, and integrated with the PLUS EXPERT System in order to improve the awareness of experts regarding locations and estimated times of arrival of moving resources during emergency assessments.

5.1 Movement Simulation and ETA calculation

For simulation of resources and the determination of realistic estimated times of arrival, SWARM has been extended with a navigation service, based on the open-source Graphhopper suite, which makes use of OpenStreetMap data. Within the BRIDGE project, this navigation service is made accessible for the software agents that represent the various resources. Whenever a new task is given to a resource, the agent will request a route to the associated goal location. This route will contain realistic timestamps for vehicles or pedestrians. These will be used to simulate the movement of the resource towards that goal, and/or determine a realistic time of arrival estimation, potentially also including additional information about incidental road blocks and emergency related traffic queues. Through the choice for agent technology at the base of these simulations, the solution is highly scalable. On an average system up to 10.000 resources can be easily co-simulated (Figure 24).

Figure 24 SWARM scalability test simulating > 10.000 moving resources in Salzburg

5.2 Standardized integration with the PLUS EXPERT System

SWARM has been extended in order to represent both real and simulated statuses, locations and ETAs of moving resources to external parties in a variety standardized and widely accepted formats: EDXL-RM, GeoJSON, GPX, JSON-RPC, custom formats, etc. EDXL-RM provides the possibility to present status and task information, GeoJSON provides topological information, GPX is used to present tracks and routes, and the JSON-RPC format is used internally within SWARM in the communication between cloud and mobile agents.

SWARM supports both GPX and GeoJSON to present current locations and goal locations. GPX has an added benefit compared to GeoJSON, because it can place data on the path, for example timestamps on each point in a GPS track.

In the interaction between SWARM and the PLUS EXPERT System, we have chosen to use GeoJSON, given the existence of import functionality on the PLUS EXPERT System side Figure 25). As GeoJSON doesn't contain timestamps, we have omitted timed track information, but we do provide ETA information through a property on the goal location.

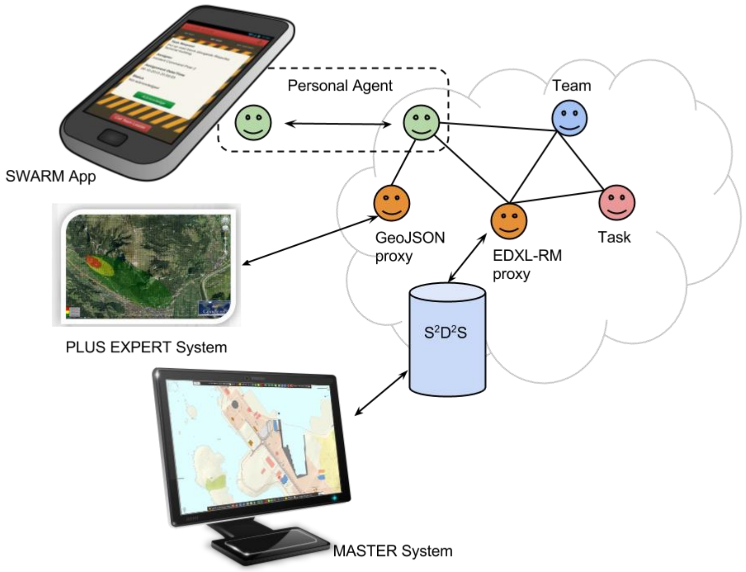

Figure 25 SWARM Architecture including integration with the PLUS EXPERT System

6 Conclusions

First responders can receive significant support in the decision making through the use of the *Advanced Situation Awareness System*. By obtaining visual and infrared information, together with characteristic data on air quality and radiation levels, the Incident Commander is able to improve risk assessment for first responders in the field. Computer modelling of plume dispersion, coupled with automatic comparison of the measured environmental data with national limits and international recommendations, ensures through the PLUS *EXPERT System* that the optimal personal protective equipment is selected for the first responders. Since this information is made available within minutes of the sensor-equipped drone being in the air, proactive measures to protect the public in the vicinity of the incident can be taken in a timely manner. As a result of the optimization process, subsequent data management by the PLUS EXPERT System has been improved in terms of user-friendliness by easier-to-read information display. Furthermore, by enlarging the already developed EU Critical Infrastructure (CI) Library in the PLUS *MODELLING MODULE*, it was possible to incorporate an additional 40 pre-modelled building damage and victim estimates into the EXPERT System. These ready-to-use models are based on typical threat situations, assuming uncontrolled release of toxic gases, respectively terror attack scenarios on CI components with explosives (e.g., car bomb, suicide bomber).

Through the development of the "*Tinia# - module*" for the MASTER application, described in more detail in D 03.3 "3D Content Distribution", the use of 3D modelling for training purposes has been extended further.

The BRIDGE *HelpBeacon* system was successfully installed onboard of PLUS UAV Mk II and Mk III. Thereby, information about the location of victims and their status reports can be used as input data for the EXPERT System as by ground-based first responders searching for victims.

The BRIDGE *SWARM* system has been extended with resource movement simulation, as well as ETA calculation capabilities, and integrated with the PLUS EXPERT System. This improves further awareness of experts regarding locations and estimated times of arrival of moving resources during emergency assessments.

All of the above information can be made available - through the use of BRIDGE *Middleware* – to the *MASTER Table*, thereby contributing to the overall BRIDGE project goal of creating a "System of Systems" in crisis management.

Appendix:
Examples of 3D Models from Enlarged EU Critical Infrastructure Library

Many examples of the “EU Critical Infrastructure Library CIL)” have already been presented in Deliverable 03.2. Since then CIL has been expanded and will still be expanded further until the end of the project for its planned use during the Demonstration No. 4.

Architectural components of modern Critical Infrastructure are designed along the same principles worldwide. This makes it possible to develop a Critical Infrastructure Library based on generic structural commonalities, even if the actual structure in a given city involved in the incidence has not been included. Basic structures, like airport arrival and departure halls, share the same architectural components, especially with regard to load-bearing structure and differ only in minor components, selected mostly only for esthetic reasons. The same applies to railway and metro stations, particularly those built in modern designs after the Second World War. Even financial centers (only partially represented in the CIL due to the fact of their enormous complexity) show the same basic components for modern high-rise buildings. Only those built more than fifty years ago have larger differences due to their historically influenced architecture.

Below eight selected examples of reality-based models contained in the CIL are shown.

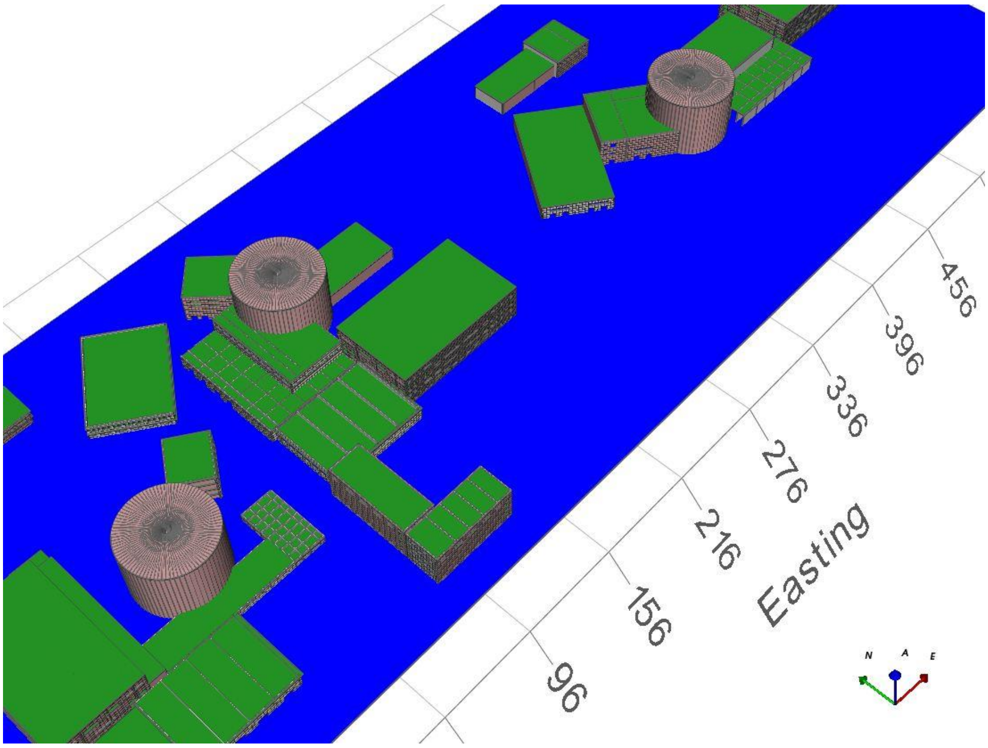

Figure App 1: Nuclear Powerplant in France

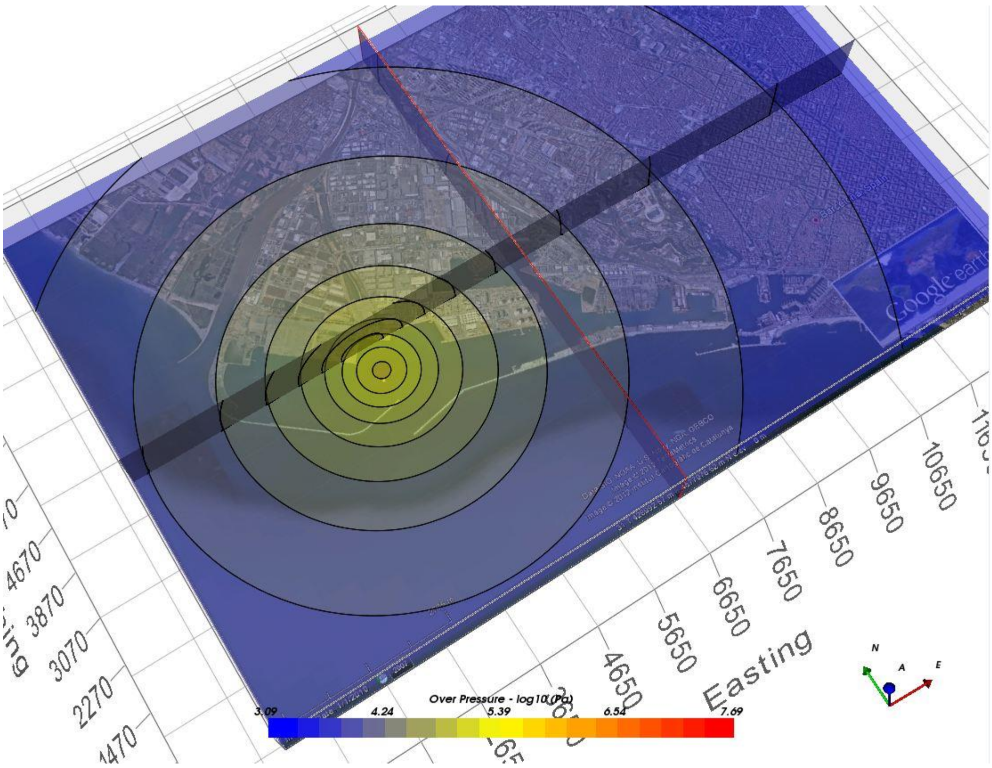

Figure App 2: Maritime Terminal in Spain – Pressure Wave Expansion due to Explosion

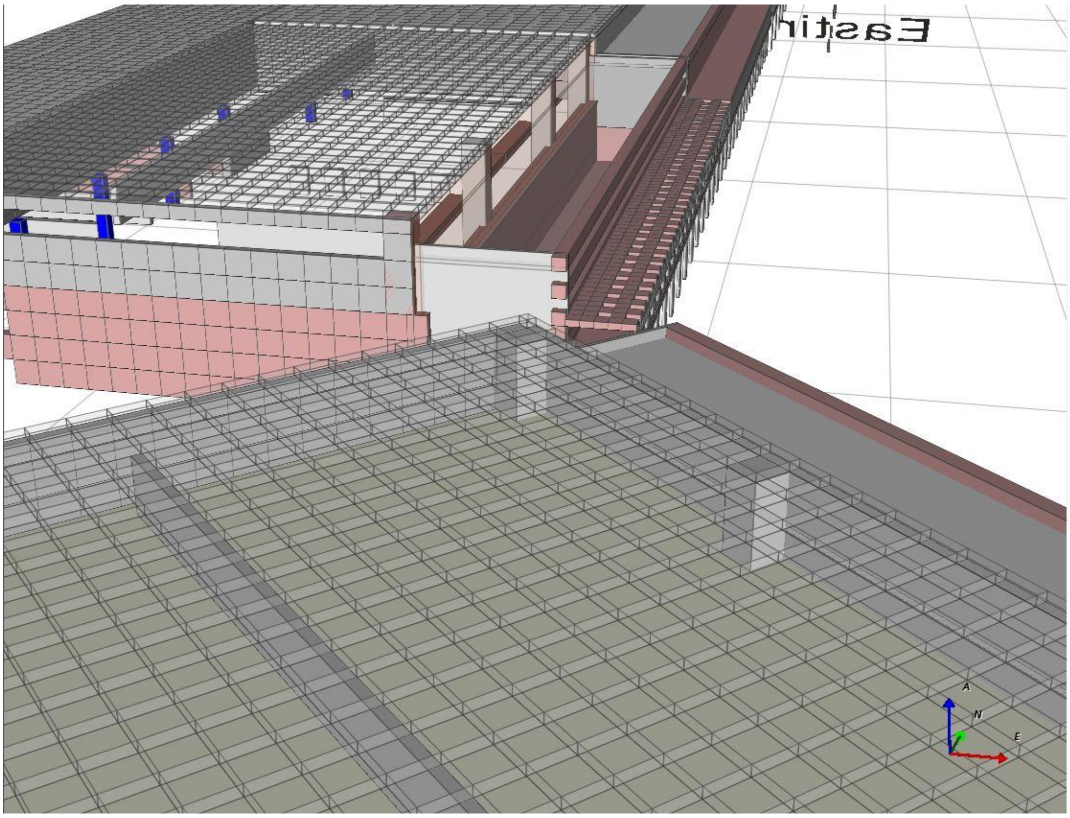

Figure App 3: Part of Departure Halls in Spanish Airport

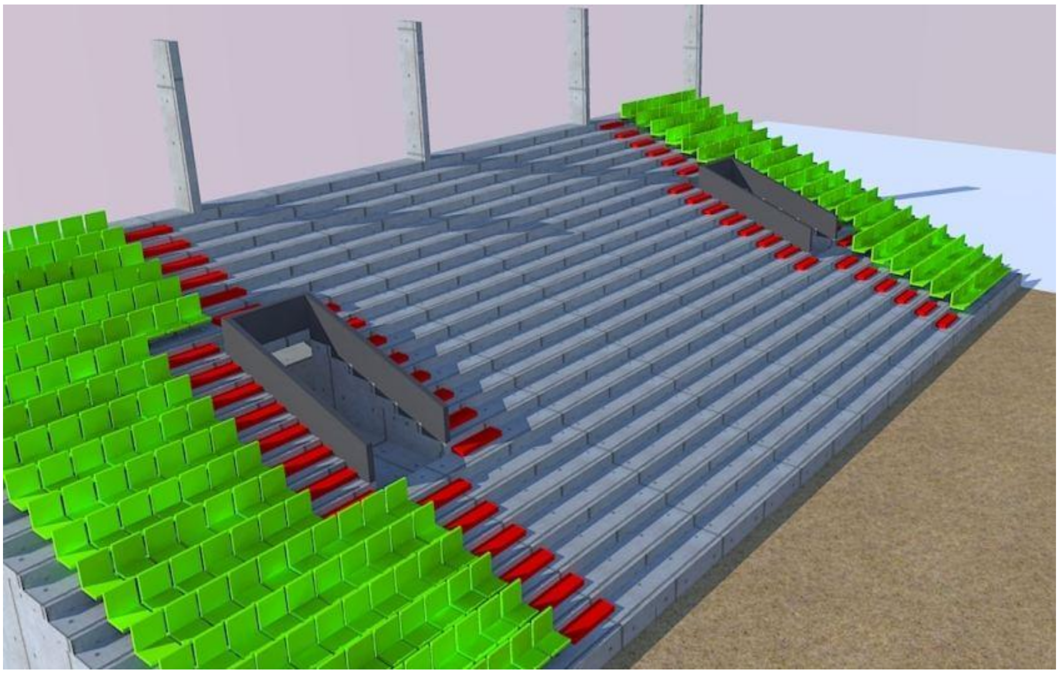

Figure App 4: Sector of Spanish Sport Stadium

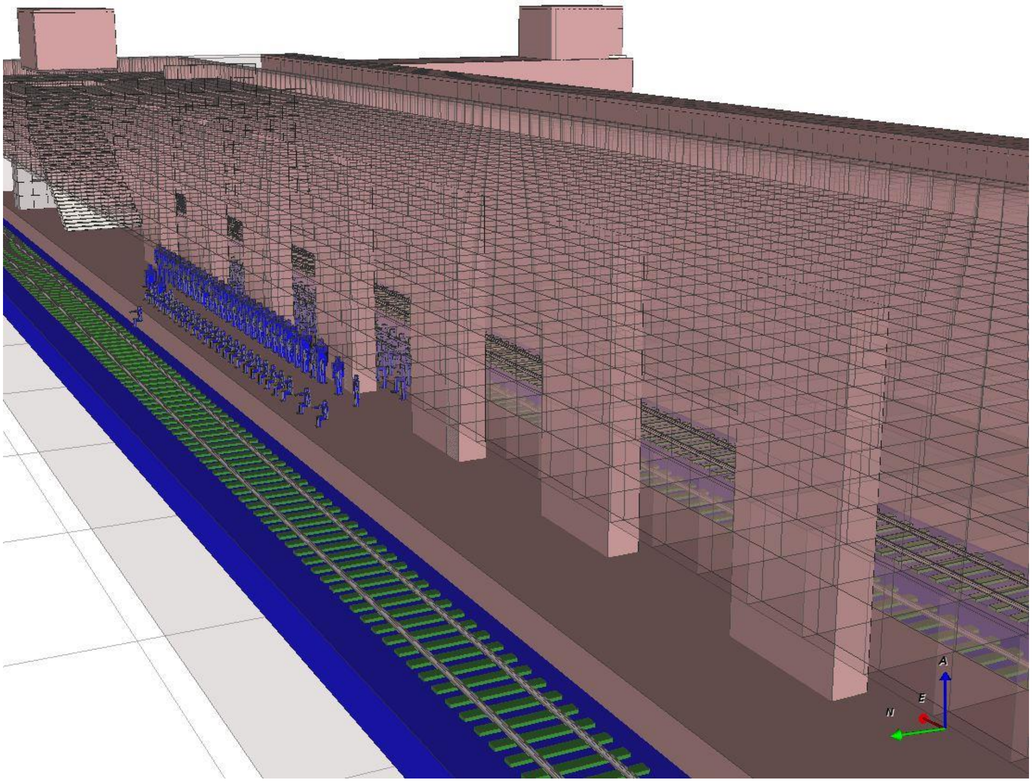

Figure App 5: Part of an German Underground Metro Station

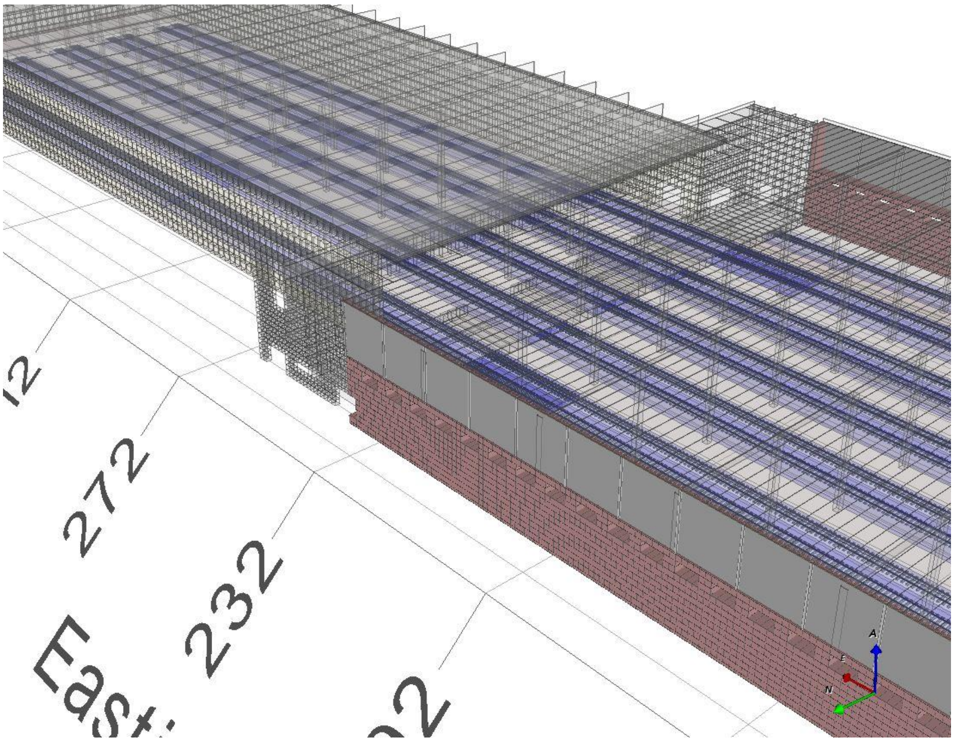

Figure App 6: Central hall of Italian Railway Station

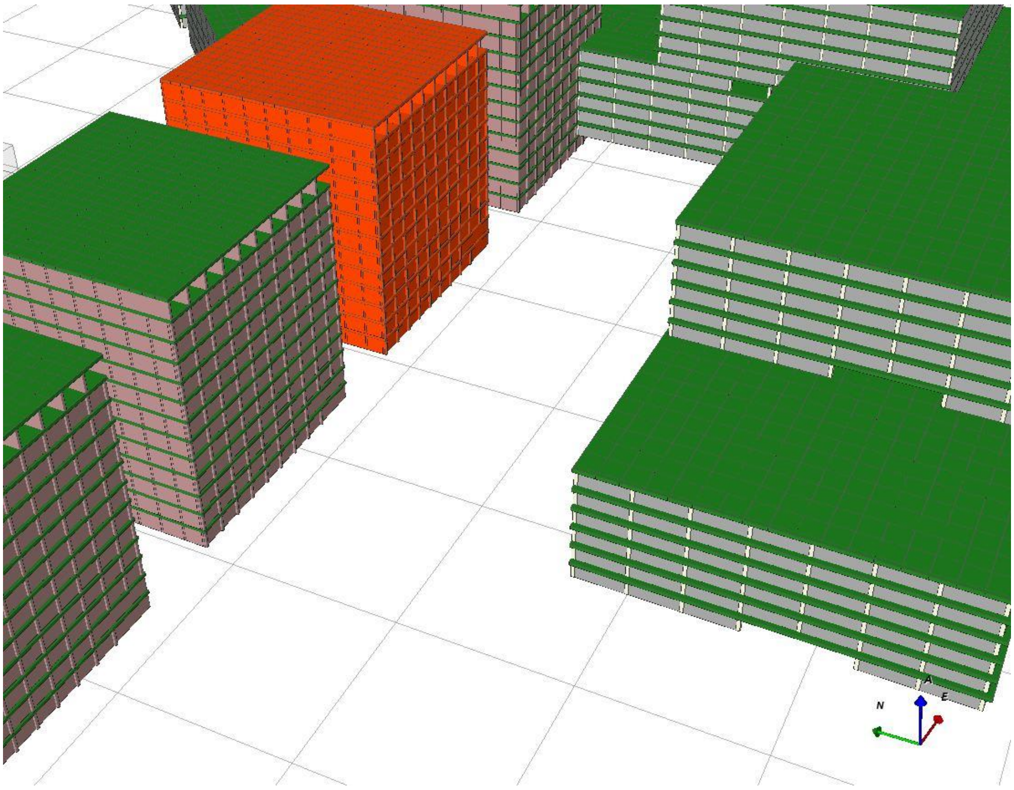

Figure App 7: Buildings near French Financial Centre (12 floors)

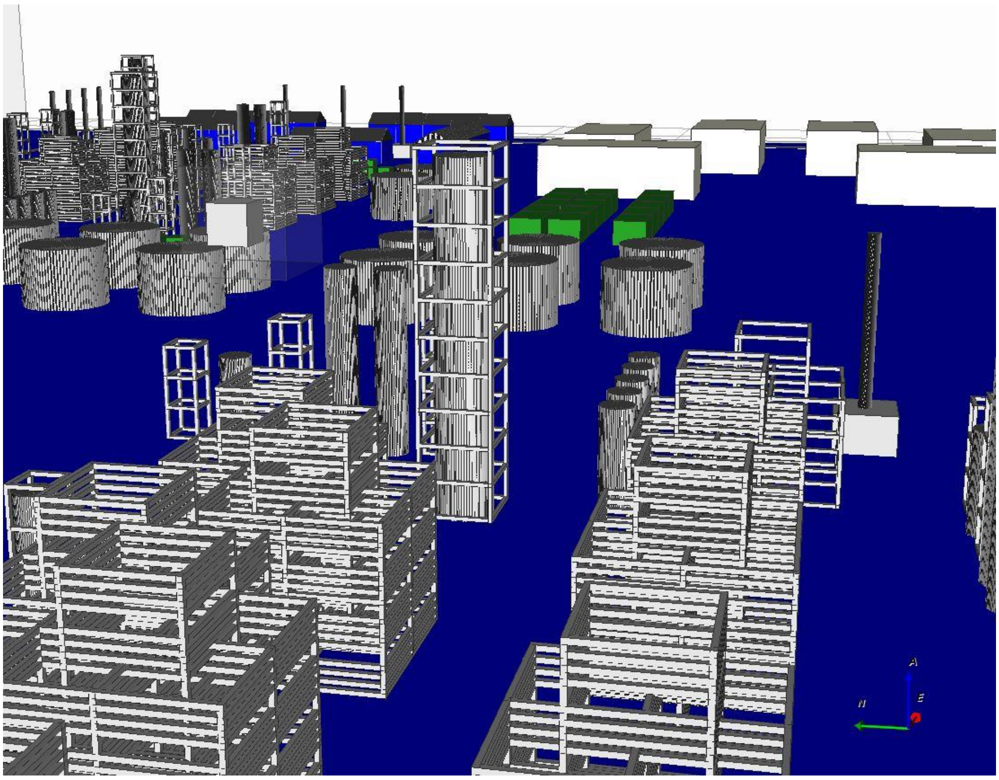

Figure App 8: Aerial View of Dutch Chemical Factory