FFI Norwegian Defence Research Establishment

24/01544

FFI-REPORT

Simulation supported CBRNE accident coordination training

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Norwegian Defence Research Establishment (FFI) 15 October 2024

Keywords
CBRNE
Distribuert simulering
Trening
Spredningsmodellering
Virtuell virkelighet (VR)

FFI report
24/01544

Project number
5775

Electronic ISBN
978-82-464-3557-2

Approvers
Anders Helgeland, *Research Manager*
Janet Martha Blatny, *Research Director*

The document is electronically approved and therefore has no handwritten signature.

Summary

The utilization of computer simulations and virtual environments offers a cost-effective solution for education, training, and exercises. These platforms provide training audiences exposure to scenarios that may be too hazardous, inaccessible, complex, or costly to replicate in a live environment. Consequently, virtual training environments are widely embraced within the defence community. CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) incidents present similar challenges as those mentioned above, making virtual environments a valuable tool for CBRNE incident training and education.

The starting point for this report is the use of the CBRNE Accident Coordination Training (CBRNE-ACT) system in an exercise at the Norwegian Civil Defence Course *Interaction at a contaminated incident site CBRN/E*. The Norwegian Defence Research Establishment (FFI) has developed CBRNE-ACT to facilitate training on response and management of CBRNE incidents. Technical details about the simulation system can be found in the FFI-report 24/01122 *CBRNE Accident Coordination Training (CBRNE-ACT) System – Technical description*. The external FFI-note 24/01029 *Dispersion simulation for CBRNE incident coordination training* describes how the high-fidelity dispersion data is computed. The system is a research demonstrator based on NATO and civilian standards and consists of military Computer-Generated Forces (CGF) and simulation components to include dispersion of a toxic gas and its effect on personnel.

CBRNE-ACT has been developed as part of the project "Strengthening CBRNE Safety and Security – Coordination and Standardization". The project, supported by the Norwegian Ministry of Justice and funded by Norwegian EEA grants ("Norway grants"), aims to enhance CBRNE safety and security through coordination and standardization. The training audience in the exercise was the emergency services – police, fire department, and health services – with their incident commanders and their second in command. After the exercise, recordings from CBRNE-ACT and self-evaluation from the actors was used to get a better understanding of what had been done and which consequences their actions had led to.

Feedback from all attendees after the exercise, along with the questionnaire responses, was used to formulate the lessons learned from this experiment. In conclusion, the successful implementation of CBRNE-ACT for training emergency service personnel represents a significant step forward in enhancing preparedness and response capabilities for CBRNE incidents. By addressing identified challenges and leveraging participant feedback, ongoing refinement of training methodologies and technological integration can further optimize training effectiveness, ultimately strengthening emergency response capabilities, and ensuring readiness in the face of CBRNE threats. There is room for improvement in the system setup and exercise execution, particularly regarding the room layout, allowing more time for the scenario to unfold and providing additional system training for participants before the exercise.

Sammendrag

Anvendelse av simulering og virtuelle miljøer gir en kostnadseffektiv løsning for utdanning, trening og øving. Disse plattformene gir de som trenes eksponering for scenarier som kan være for farlige, utilgjengelige, komplekse eller kostbare å gjenskapes i en virkelig setting. Virtuelle treningsmiljøer blir derfor benyttet i utstrakt grad innen militær trening og øving. CBRNE (kjemiske, biologiske, radiologiske, nukleære og eksplosive) hendelser presenterer lignende utfordringer som nevnt ovenfor, noe som gjør virtuelle miljøer til et nyttig verktøy for CBRNE-opplæring og utdanning.

Utgangspunktet for denne rapporten er bruken av CBRNE Accident Coordination Training (CBRNE-ACT)-systemet under en øvelse ved Sivilforsvarets kurs *Samvirke på et forurenset skadested CBRN/E*. Forsvarets forskningsinstitutt (FFI) har utviklet CBRNE-ACT for å fasilitere for opplæringen i respons og håndtering av CBRNE-hendelser. Tekniske detaljer om simuleringssystemet finnes i FFI-rapport 24/01122 *CBRNE Accident Coordination Training (CBRNE-ACT) System – Technical description*. Det eksterne FFI-notatet 24/01029 *Dispersion simulation for CBRNE incident coordination training* beskriver hvordan den høyoppløselige spredningsmodellen er beregnet. Systemet er en forskningsdemonstrator basert på NATO-standarder og sivile standarder, og består av militære datagenererte styrker og simuleringskomponenter som inkluderer spredning av giftig gass og dens virkning på personell.

CBRNE-ACT er utviklet som en del av prosjektet «Strengthening CBRNE Safety and Security – Coordination and Standardization». Prosjektet, støttet av Justis- og beredskapsdepartementet og finansiert av norske EØS-midler (*Norway grants*), har som mål å forbedre CBRNE-sikkerhet gjennom koordinering og standardisering. Deltakerne i øvelsen var nødetatene – politi, brannvesen og helse – med deres innsatsledere og nestkommanderende. Etter øvelsen ble opptak fra CBRNE-ACT og evaluering fra aktørene brukt for å få en bedre forståelse av hva som hadde blitt gjort og hvilke konsekvenser deres handlinger hadde ført til.

Tilbakemeldinger fra alle deltakere etter øvelsen, sammen med svar på spørreskjemaer, ble brukt til å formulere lærdommer fra dette eksperimentet. Konklusjonen er at bruk av et system tilsvarende CBRNE-ACT for opplæring av personell i nødetatene, representerer et betydelig skritt fremover for å forbedre beredskap og responskapasiteter for CBRNE-hendelser. Identifisering av utfordringer og tilbakemeldinger fra deltakerne gir rom for forbedring av systemet. Dette kan styrke nødetatenes kapasitet og sikre beredskapen i møte med CBRNE-trusler. Systemoppsettet og gjennomføring av øvelsen kan forbedres, spesielt med tanke på romlayout, tidslinjen til scenariet, og opplæring av deltakerne i forkant av øvelsen.

Contents

Preface

We would like to extend our thanks to the Civil Defence at Starum for their excellent cooperation by providing us with domain knowledge, helping develop the scenario, and facilitating the exercise. This work would not have been possible without your support.

Kjeller, 06.09.24
Anders Helgeland, Ole Martin Mevassvik, Cecilie Jackbo Gran, Arild Skjeltorp, Martin Asprusten og Thomas Vik

1 Introduction

The utilization of computer simulations and virtual environments offers a cost-effective solution for education, training, and exercises. These platforms provide training audiences exposure to scenarios that may be too hazardous, inaccessible, complex, or costly to replicate in a live environment. Consequently, virtual training environments are widely used within the defence community. CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) incidents present similar challenges as those mentioned above, making virtual environments a valuable tool for CBRNE incident training and education.

The starting point for this report is the use of the CBRNE Accident Coordination Training (CBRNE-ACT) system in an exercise as part of the Norwegian Civil Defence Course *Interaction at a contaminated incident site CBRN/E*. The Norwegian Defence Research Establishment (FFI) has developed the research demonstrator CBRNE-ACT to facilitate training on response and management of CBRNE incidents, including more realistic feedback on the consequences of decisions made by the users in the training environment. This has been possible with the use of computer-based training in a simulated environment with high-fidelity dispersion data. The report *CBRNE Accident Coordination Training (CBRNE-ACT) System - Technical description* describes the details of the simulation system [1], and the external note *Dispersion simulation for CBRNE accident coordination training* explains how the high-fidelity dispersion data is computed [2].

CBRNE-ACT has been developed as a component of the project "Strengthening CBRNE Safety and Security – Coordination and Standardization". The project, supported by the Norwegian Ministry of Justice and funded by Norwegian EEA grants ("Norway grants"), aims to enhance CBRNE safety and security through coordination and standardization. The Norway grants have been supporting projects since 2020, and the collaboration between Polish and Norwegian researchers received three rounds of funding from the EEA and Norway Grants. The Military University of Technology in Warsaw (WAT) is FFI's Polish partner in this project, and our mutual goal has been to develop innovative training platforms for the CBRNE community [3].

This report begins with introducing the background and overview of CBRNE-ACT and giving an overview of the demonstrator, before going into the scenario used during the exercise. The training system setup is described with the room layout and roles employed during the exercise, before going through the different steps taken in the execution of the exercise. The feedback from the users, and their answers to the questionnaire will be described in the result chapter, before discussing the lessons learned. The end of the report will discuss the main findings and propose further work.

2 Background and overview of CBRNE ACT

CBRNE-ACT is a further development of an already existing FFI CBRNE-demonstrator. The demonstrator was developed through international collaboration under the framework of the European Defence Agency (EDA) project *Common Operational Picture in Disaster Crisis Management* (COPDCM) [4, 5]. Experiments within COPDCM demonstrated how civilian and military units could be integrated into a Common Operational Picture (COP) alongside simulated units, enabling training with their actual Command and Control Information Systems (C2IS).

The Civil Defence Course *Interaction at a contaminated incident site CBRN/E* supported by CBRNE-ACT is a tactical management course that teaches how to handle a contaminated incident site across emergency services. The course consists of a combination of lessons and exercises and includes both tabletop and live exercises. Cooperation between actors from different emergency services is a key part of the course. CBRNE-ACT will complement the existing course scenarios and training with computer-based training. As a training tool, computer-based training could be considered as something that falls between tabletop and live exercises, with some distinct advantages. It will provide realistic feedback to the training audience (as everything is based on simulations), it is able to show the consequences of the decisions and actions performed by the users in handling a CBRNE incident site, and it will be less cost expensive than live exercises. A framework for emergency training is well described in DSB's training manual [6]. The accompanying methodological booklets detail the various types of exercises and how to plan, execute, and evaluate them.

The training audience in the exercise was the emergency services – police, fire department, and health services – with their Incident Commanders (IC) and their second In Command (2IC). The task of an organization's IC is to organize and lead their own personnel and communicate with collaborating actors in an emergency, as well as their operation centre. The IC is the operational manager at site for the emergency service in an area. The 2IC forwards orders from their IC to the emergency personnel and works closely with them to ensure that the planned actions and operations on the incident site are carried out. The 2IC reports back to their IC to help them have an updated situation awareness.

The training objectives for this exercise was to train communication and coordination between the actors, and to practice resource management and task prioritization. The actors were drilled in delivering a clear and concise first message on site ("vindusmelding" in Norwegian) and reading back their understanding of the first message, before establishing a command post and organizing the incident site. It was also important to welcome and brief other event managers as they arrived, as well as handling the incident site by establishing different zones and barriers. While exercises like this are normally run as tabletop exercises using a sandbox, this time the exercise was based on simulation using CBRNE-ACT. The main goal of using a simulation-based training system was to give the actors a better understanding of the consequences of their decision than a tabletop exercise can provide.

After the exercise, recordings from CBRNE-ACT and self-evaluation from the actors was used to get a better understanding of what had been done and which consequences their actions had led to.

2.1 Overview of CBRNE-ACT

The training system consisted of applications (federates) that communicated using the distributed simulation architecture and standard – High Level Architecture (HLA) [7, 8, 9]. The federates exchanged data and interactions using an HLA RunTime Infrastructure (RTI) as shown in figure 2.1. CBRNE-ACT used VR-Forces [10] for scenario simulation and VR-Vantage [11] for 3D visualization. The 3D visualization was shown on a large monitor or through the Varjo XR-3 [12] VR headset.

The unique property of CBRNE-ACT was the use of dispersion data from a high-fidelity 3D wind and dispersion simulation [2], computed as a preprocess, providing a realistic simulation of the effects of a toxic agent. A dispersion federate feeds offline dispersion data to the simulation network and the CBRNE Effects Federate controls how the gas dispersion affects the people simulated in VR-Forces. The CBRNE related data is exchanged in accordance with a NATO standard data model for distributed simulation – the NETN FOM [13]. CBRNE-ACT uses Pitch RTI [14] to connect the systems together, and the Pitch Recorder [15] to log simulation and radio communication data. In the lessons learned session after the exercise, the recording can be replayed for the training audience and the observers (after action review).

More detailed information of CBRNE-ACT can be found in the technical description report *[1]*.

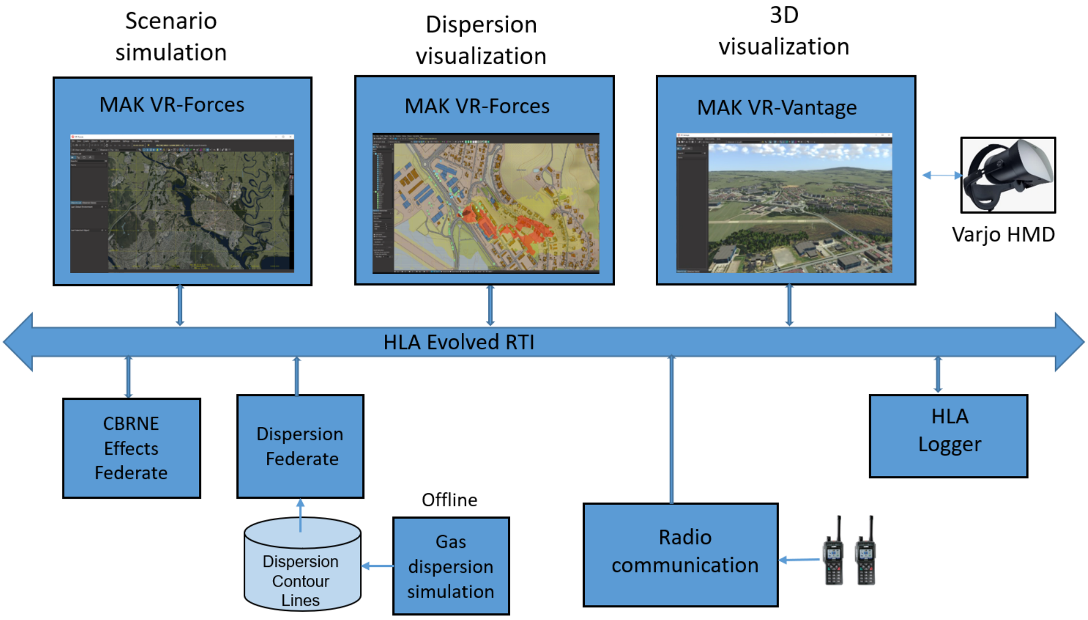


Figure 2.1 CBRNE-ACT system components and applications.

The synthetic environment databases used in CBRNE-ACT was created using Terra Vista [16] based on public geographical data for Norway. Two different terrain databases were used. A simple map-based terrain database was used for the dispersion visualization in 2D. A high-resolution database with 3D buildings, smoke and roads were used for simulation and 3D visualization. It consisted of a high-resolution area around the incident site (3.5 x 2.5 km), surrounded by areas with lower level of detail. Most of the buildings were created automatically from their footprint vector and estimated wall height. Their textures were chosen randomly from a predefined small selection. A few buildings near the incident site were given more realistic textures from photos. Figure 2.2 shows the 3D-view of buildings near the accident visualized in VR-Forces front-end.

Figure 2.2 Details in the high-resolution terrain database shown in VR-Forces front-end (3D-view).

3 Scenario

The Norwegian Civil Defence developed a storyboard, in cooperation with FFI, detailing an emission of ammonia for this exercise. This storyboard was used as a starting point when developing the CBRNE-ACT scenario. Appendix A describes the story board in greater detail.

The scenario began with a traffic accident that took place at the intersection of Fetveien (RV22) and Storgata, near the Kjeller airport. The crash involves a collision between a tank truck and a container truck, as illustrated in Figure 3.1. The tank has sustained substantial damage, resulting in a severe leakage of ammonia.

Figure 3.1 The accident between a tank truck with ammonia and a container truck. The ammonia gas leakage is visualized as white smoke in the 3D visualization.

Several individuals in the area were affected by the ammonia gas at different levels. The driver of the container truck was lying down and experiencing breathing difficulties. A police car with one officer happened to be nearby the accident at the Circle K station, outside the main dispersion area. The officer received a description of the crash from the tank truck driver, and a report of his/her perception of the incident was conveyed via radio to the emergency centre. This first message is important for all emergency services called out to the incident.

3.1 Ammonia dispersion

The dispersion federate feeds dispersion data to the simulation network. The dispersion data was calculated as a preprocess due to the computational resources needed. Figure 3.2 shows the gas plume at different simulation times (the accident is time zero). The colors show possible health effects according to the Acute Exposure Guideline Levels (AEGLs) [17]. AEGL-1 (yellow) shows the area where people could experience discomfort or irritation, AEGL-2 (red) shows the area where people could experience irreversible or long-lasting effects and an impaired ability to escape, and AEGL-3 (black) shows the area where people could experience life-threatening health effects or death.

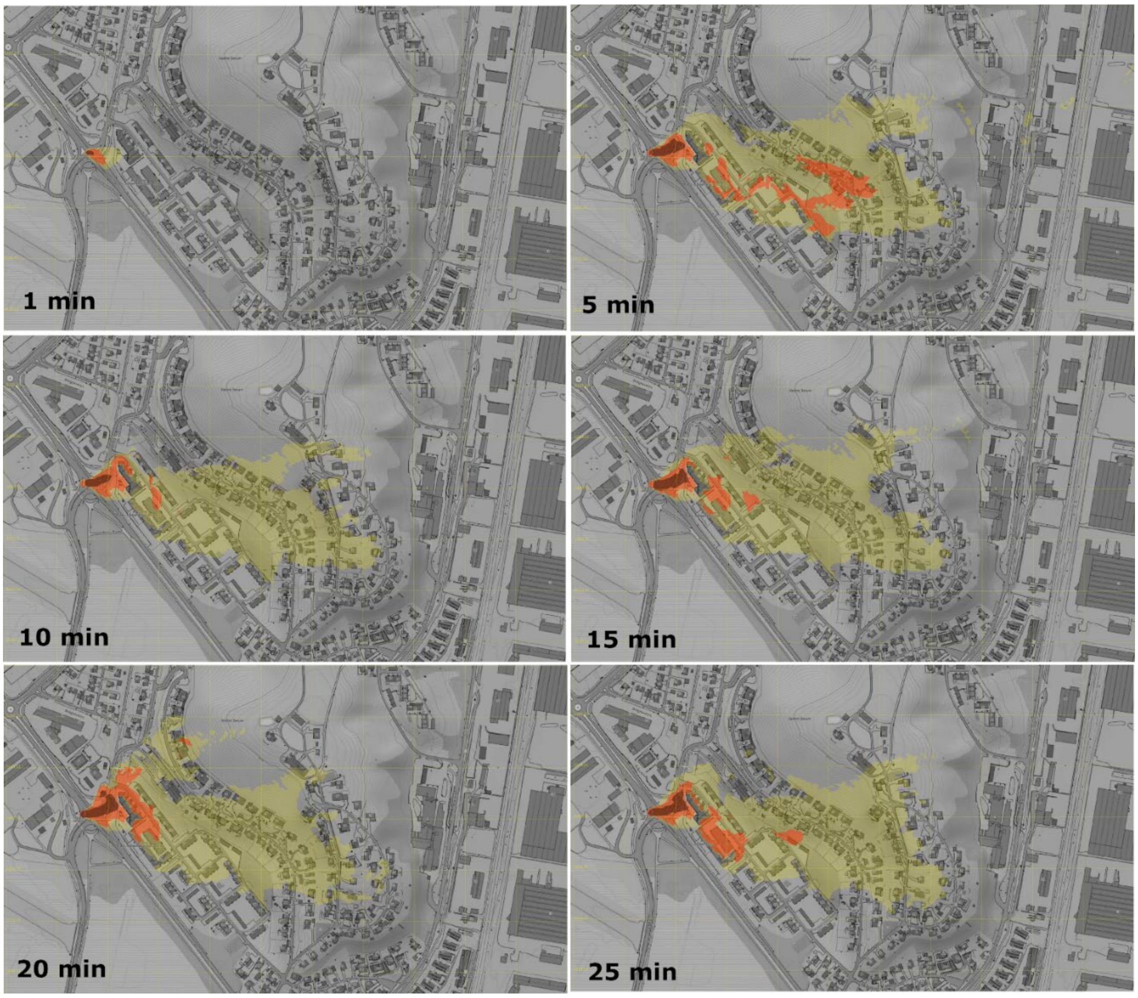


Figure 3.2 Ammonia gas plume at different simulation times. Colors are given in AEGL levels (AEGL-1 = yellow, AEGL-2 = red, AEGL-3 = black).

3.2 Scenario development

Based on the overall description of the scenario along with the details that have been developed together with the instructors, we made a scenario in VR-Forces with pre-programmed behaviour for many of the simulated units. VR-Forces has support for vehicle and lifeform “Patterns of Life” to enrich the scenario with entities that are not directly involved in the scenario. People can also be given the task of walking around within a limited area and vehicles can follow roads as they travel from one place to another. Since this was the first use of the system during a training session, it was decided to limit the number of entities that made up the background traffic in the scenario.

The scenario starts with the collision between the two trucks, and the gas leak are visualized as white smoke in the 3D visualization. It was decided that one police patrol car happened to be near the accident, and a police officer was given the task of reporting from the accident based on observations made by using a VR headset. These observations were reported by radio to emergency services on the way to the scene of the incident.

Based on the storyboard and suggestions from the instructors’, some pre-programmed plans were added to VR-Forces, to make it easier for the simulator operators. The emergency vehicles and some of the personnel simulated in VR-Forces was assumed to be at predefined meeting points at a predefined time. To move personnel from one location to another, they can be embarked in a vehicle and disembarked when this vehicle arrives at its destination. One important functionality in a preprogrammed plan is the use of triggers. A trigger has a condition and a block of statements that are executed when the trigger condition becomes true. One example can be that if a person receives a specific text message, for instance “evacuate”, a block of statements can order this person to run to a specific location using a predefined route.

Pre-programmed global plans were made for the simulator operators. These plans can be executed by pressing the corresponding buttons in the VR-Forces user interface. In this scenario, the following global plans was available for the simulator operators:


Evacuate people north towards Kiwi.


Evacuate people who are at the bench between buildings east of the accident, southwards towards Åråsen.


Evacuate people who are at the bench between buildings east of accident, north towards Kiwi.

Incident commander cars drive on towards the McDonald's sign and the people inside are disembarked.


Block Storgata at the intersection at Vestbygata. Block Fetveien southwards after the roundabout at Kiwi.

Start flushing the driver in the container truck. Magically moved to a new position near the McDonalds sign.

Start flushing the ammonia tank.

Cover the rear of the leaking tank with tarpaulin.

Create two firefighters. Evacuate the people inside the two cars that have stopped behind the tank truck, to a predefined location.

4 Training system setup

CBRNE-ACT was developed and tested at FFI and moved to the Norwegian Civil Defence's competence centre at Starum on two occasions, first for a pretest with some of the instructors, and then again for the exercise.

4.1 System setup

CBRNE-ACT was configured on four computers before the exercise at Starum. Additionally, the system used a gateway laptop, an ethernet switch, some VR equipment, a radio recording box, one large monitor and five small monitors, as shown in figure 4.1. For the first message on site, VR-Vantage was connected to the Varjo-XR3 VR headset, and the output from the VR headset was duplicated on the large monitor. The radio recording box was used to record the BAPS communication together with data from the simulation system.

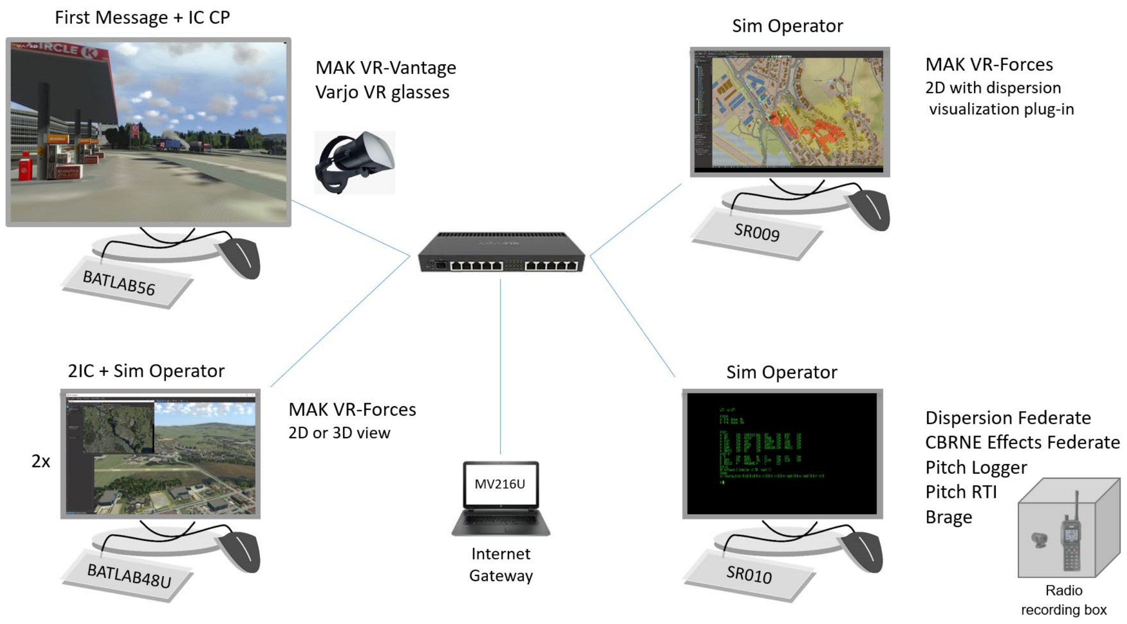


Figure 4.1 CBRNE-ACT configuration used for the exercise at Starum.

4.2 Roles

The training audience in the exercise was the emergency services with their Incident Commanders (IC) and their second In Command (2IC). As shown in figure 4.2, the ICs were supported by the instructors and the 2ICs. One experienced instructor from each emergency service participated in the exercise. The simulation system, CBRNE-ACT, was affected by the ICs decisions through the 2ICs collaboration with the simulator operators (FFI in this exercise). The instructors could also use the simulator operators to control the scenario in CBRNE-ACT to provide the ICs better learning opportunities. It was important that the ICs were not disturbed by the training technology during the exercise, as their capacity should be used to lead the effort at the scene of the incident. The IC role was set up to be as close to reality as possible during the exercise. The consequences of the ICs' decisions emerged from the simulation in CBRNE-ACT.

The 2ICs took care of the communication between the ICs and the simulation operators. Their role was to update the ICs and forward actions to be carried out at the incident site to the simulator operators (flushing, deploying barriers, and so on).

The instructors controlled the exercise so that the training goals were achieved. They did this by playing the operation center and giving the IC commands tips when needed. In addition, the instructors gave the simulation operators commands to affect the simulation according to the training goals. At the same time, the instructors monitored the ICs and 2ICs to evaluate their performance so they could provide appropriate feedback after the exercise.

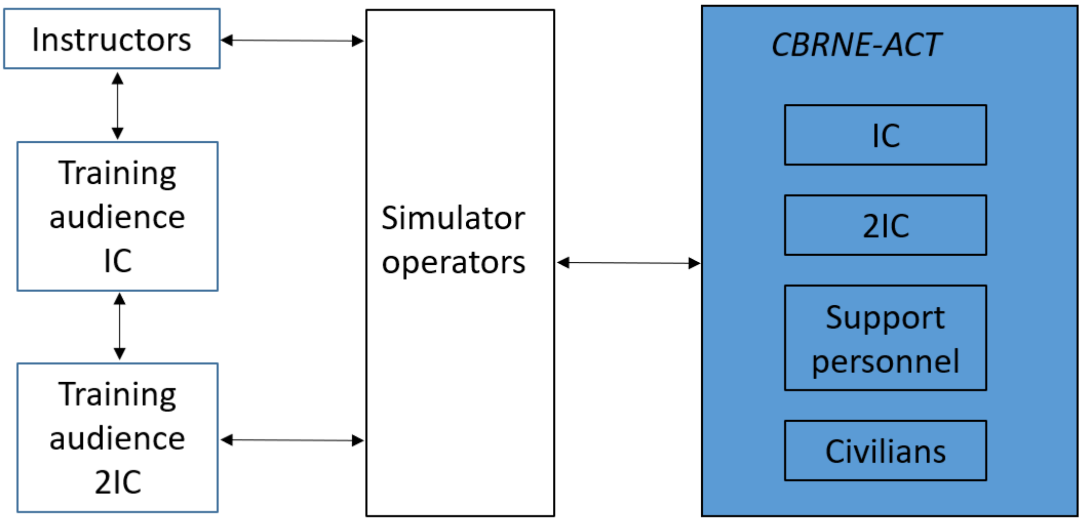


Figure 4.2 Interaction between the different role players during a training session using CBRNE-ACT.

The simulator operator role was to control CBRNE-ACT and implement actions and orders provided by the 2ICs and the instructors. The simulator operator helped the 2ICs to move around in the virtual scenario and conduct the different possible tasks as the scenario unfolded. The simulator operators also made sure that the scenario was recorded for the evaluation afterwards.

4.3 Room layout

At the pretest at Starum, we decided on the room layout as shown in figure 4.3. With many actors in a relatively small room, the observers and guests had to have dedicated areas with chairs, so they were sitting down and did not disturb the training audience. It was decided that use of emergency service specific radio channels on site, was not feasible due to the noise and audio feedback with many radios in the same room.

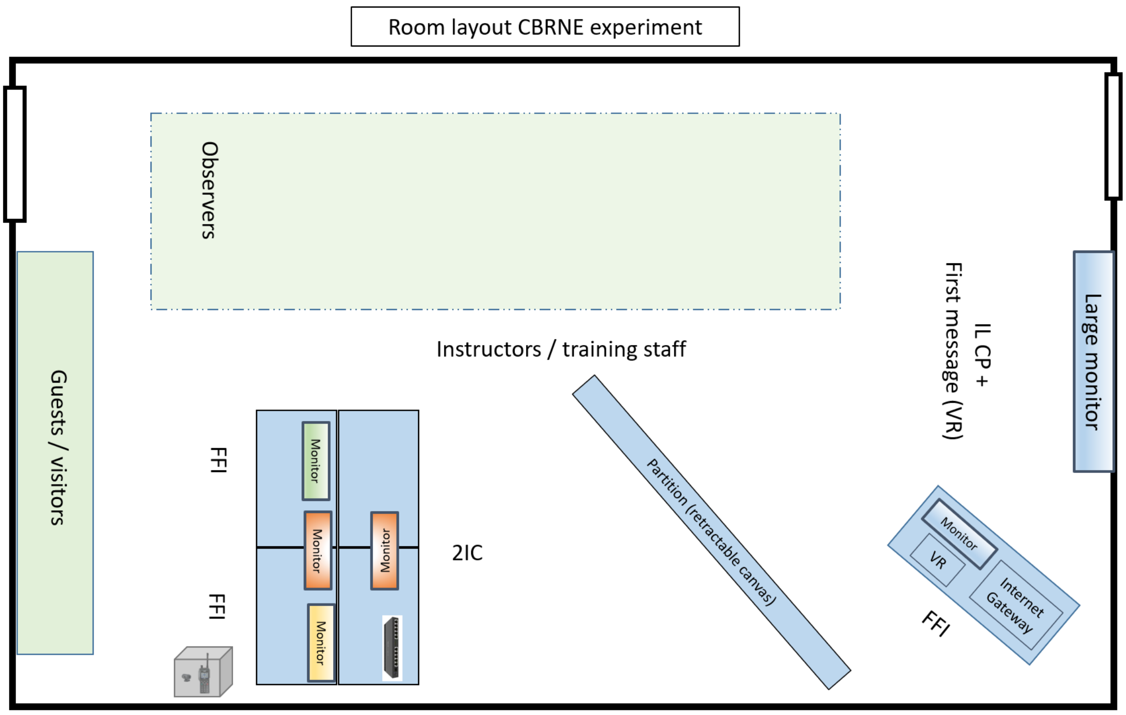


Figure 4.3 Room layout and setup used during the experiment with CBRNE-ACT at Starum.

The training audience started the exercise outside the classroom, to simulate that they were driving to the place of the accident. The person arriving first at the incident site was placed on a chair in the front of the room with a VR headset and used the VR view to create the first message on site. This message was sent to the other emergency services, which were still outside the room at that point, using a real *Nødnett* radio. The observers and guests could watch what was shown in the VR headset on the big monitor.

As the different emergency services arrived at the incident site they came into the classroom and gathered in front of the large monitor, where they established their Command Post (CP). A virtual CP was also established within the simulation system, and the big monitor showed the view from this virtual CP. Both the VR experience and the CP view could be altered by the simulator operator.

Partition walls were set up to physically separate the command post from the simulation operators. When the 2IC was given a command, they would have to walk around this physical division and ask the simulation operators to perform the given task in the simulation systems. This emulated how the 2IC would have to leave the command post to talk with emergency responders in a real operation.

5 Exercise execution

The conceptual model shown in figure 5.1 explains the overall course of action for the users during the scenario training with the CBRNE-ACT system. The main objective of the scenario was to train emergency services in handling a contaminated incident site and involves traveling to the scene of the incident, establishing a command post and handling the incident. Cooperation between the actors from the different emergency services was a key part of the course. The trainees that participated were three representatives from the police, two from the fire department and two from the health services.

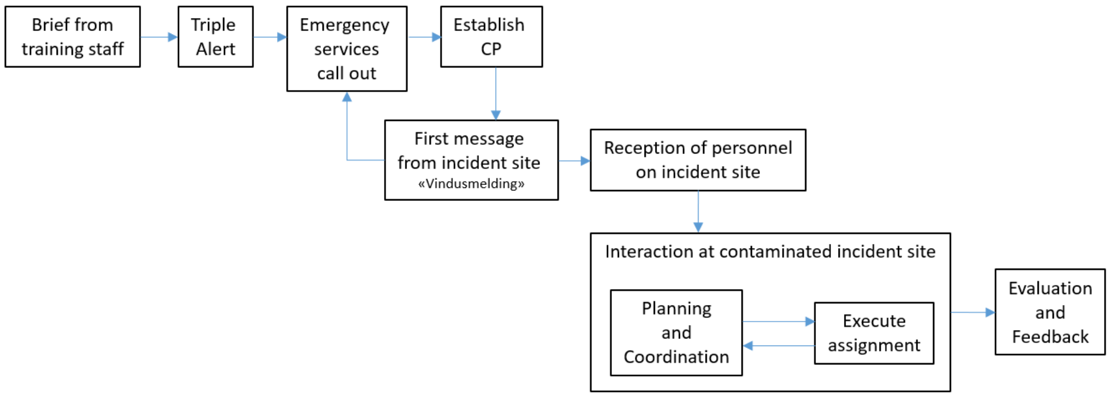


Figure 5.1 Conceptual model of the course of action for the users during the scenario training with the CBRNE-ACT system.

When the instructors decided that the trainees had gone through the main learning points, they ended the exercise. The instructors then gave the trainees an evaluation of their work, and the trainees gave the training staff feedback on their experience of the exercise.

5.1 On the way to the scene of the incident

The exercise started with a brief from the training staff with an introduction to CBRNE-ACT. Then each emergency service went to separate rooms to wait for the triple alert call.

The first phase of the training session is when the emergency services get the triple alert message and are virtually on the way to the scene of the incident. Some of the emergency services will likely arrive the incident cite before others so this phase will overlap, in time, with the next phases of the exercise. Until all actors are on site, the communication between the actors goes through the *Nødnett* radios on a BAPS channel.

BAPS is a set of dedicated shared voice groups for the emergency services only. Every incident gets a dedicated BAPS channel. In a real emergency, this is meant to assure that all actors have an updated situational awareness regardless of when they arrive, as described in figure 5.2. In addition to BAPS, the different emergency services have their own *Nødnett* channels on a separate radio for communication with their own operation centre (110, 112 or 113).

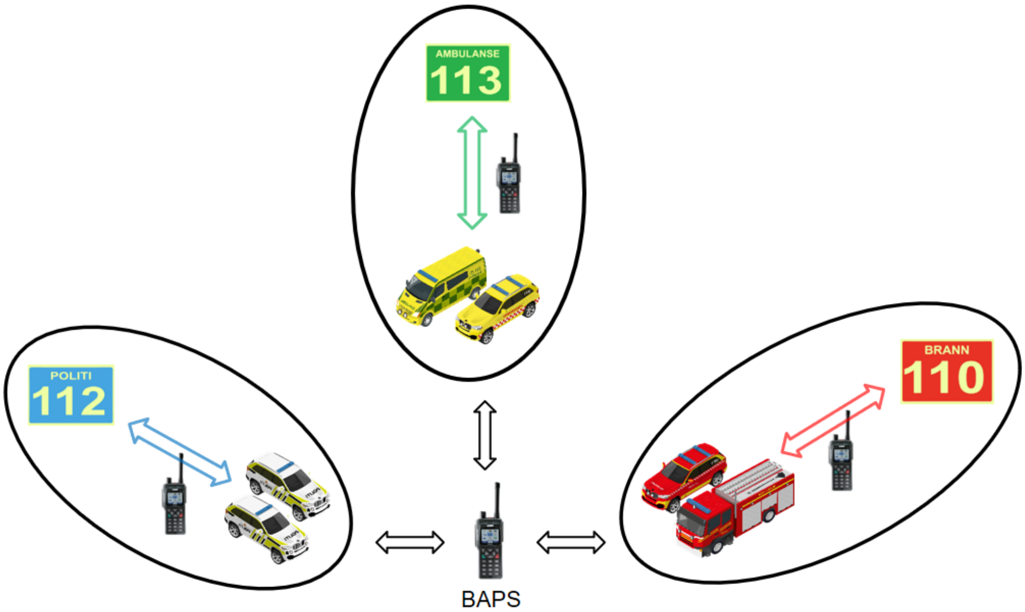


Figure 5.2 Joint radio communication on Nødnett radios using a BAPS channel, on the way to the scene of the incident until all actors have arrived.

Each emergency service got a printed map when they were on the way to the incident. The map gave the users an overview of the incident site. They could draw on the map to mark where the incident had taken place and get a grip of the wind direction and where they thought the dispersion would go, based on the messages given on the BAPS channel. This information could be useful to establish the CP.

5.2 First message

One of the main training objectives in the course was to deliver a clear and concise first message on site ("vindusmelding in Norwegian"). To get a better feeling of being at the incident site, the actor who arrived at the accident first had the opportunity to observe the accident through a VR headset as shown in figure 5.3. In this scenario, the first emergency service on site was a police officer that happened to be nearby the incident site. The glasses could be worn like a set of binoculars, allowing the user to get a closer view of the accident while still maintaining a safe distance as shown in figure 5.4. The purpose of the VR view was to give the user a more realistic basis for delivering an adequate first message. After using the VR headset to obtain sufficient situational awareness, a first message from the incident site was given to the other trainees trough BAPS.

Figure 5.3 The police officer arriving first at the accident uses a VR headset to investigates the scene of the incident.

Figure 5.4 Image capture from the VR headset recording taken during the experiment.

5.3 Establishing the command post and scene management

The first incident commander arriving the scene established a command post and started the scene management. In the execution of this exercise, it was the fire department. An important part of the early phase of the scene management is to give the other actors, which had not yet arrived, an updated description of the situation, and keep them updated until they arrive, so all have a joint situational awareness.

Finding out what kind of toxic emission that was involved and the direction of the wind was critical. That would be decisive considering where to establish the different zones at the incident site and where to place the areas for personnel and other involved actors, as shown in figure 5.5. The tools available on site, in addition to the simulation system CBRNE-ACT, was a whiteboard to plan the operation, a printed map and the possibility to see a 3D visual representation of the incident area on a large computer screen.

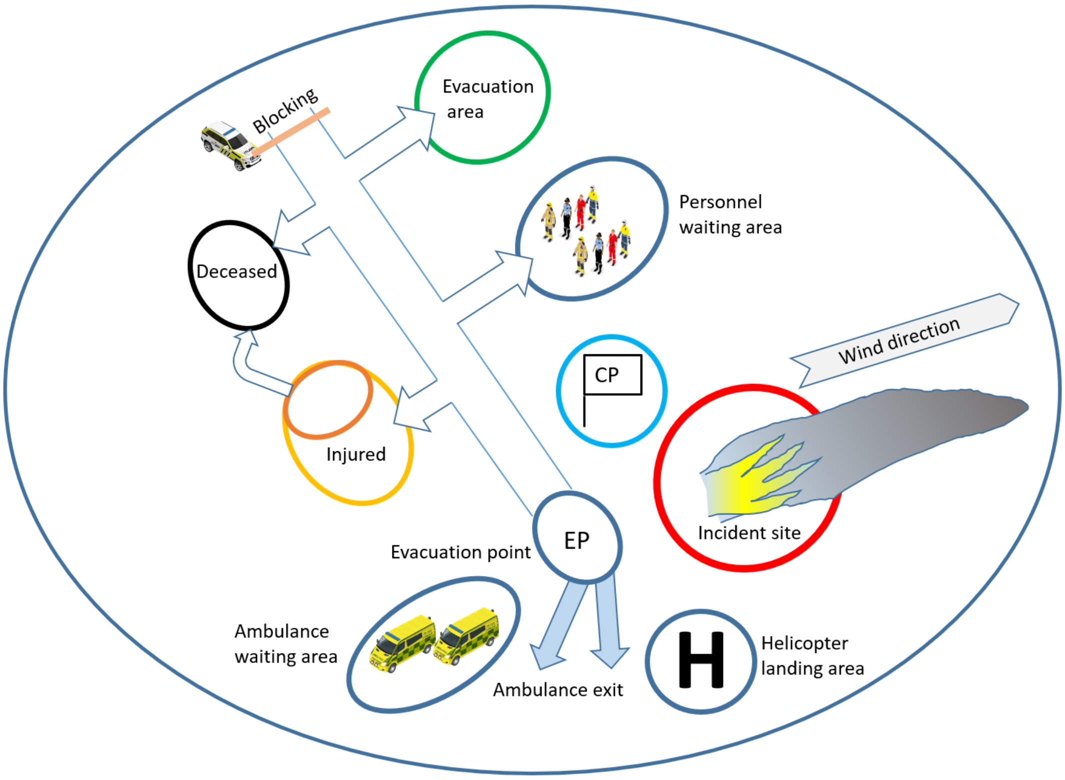


Figure 5.5 Organization of the emergency services' work at an incident site[1].

5.4 Planning and handling the incident

At the incident site, the ICs mainly stayed at the CP. From CP the ICs could communicate with and get orders from their operation centres, played by the instructors. The 2ICs updated the ICs on the situation as shown in figure 5.6. The ICs gave orders to the 2ICs, which in turn communicated the ICs orders to the CBRNE-ACT simulator operators.

The ICs had to divide their time between coordinating within their own emergency service and collaboration with the other services. It was important to take time for regular short joint status meetings in such a chaotic situation. The instructors ended the scenario at a point where sufficiently time was given to the trainees to respond to the sequence of events played out in the

[1] This figure is based on a drawing from the civil defence course *Interaction on an incident site.*

scenario. After the scenario was ended the trainees received an evaluation of the overall performance in addition to individual feedback.

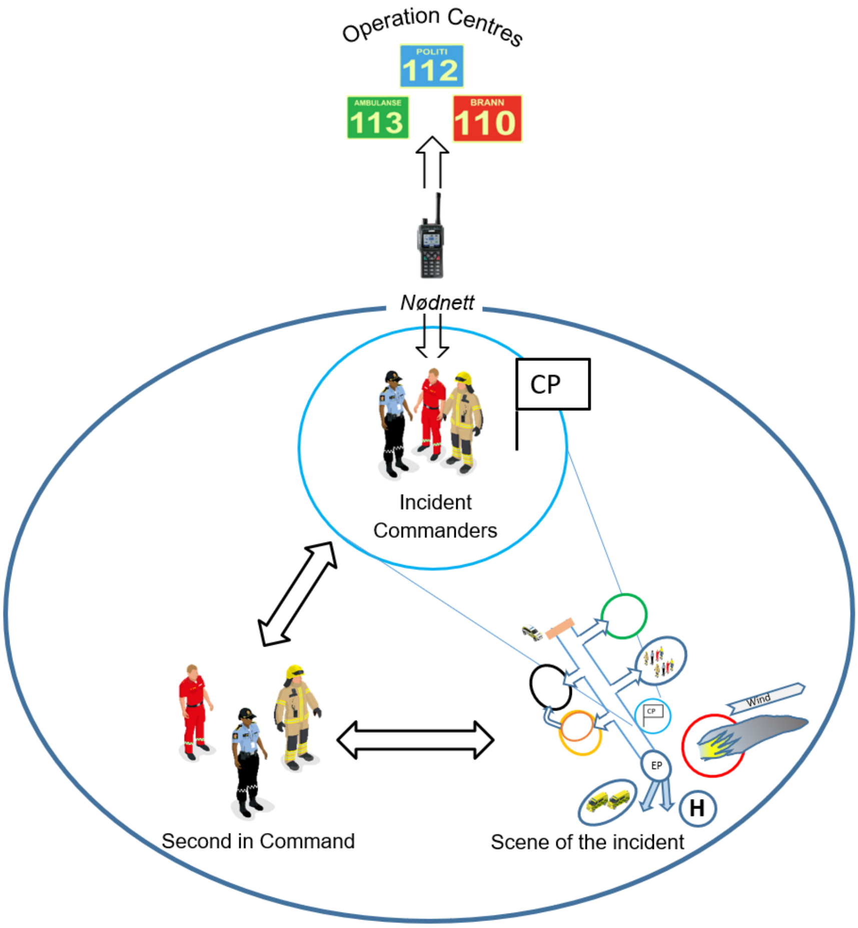


Figure 5.6 Collaboration between the incident commanders and second in command on the scene of the incident simulated in CBRNE-ACT.

5.5 After action review

The instructors lead the participants through an after-action review of the exercise as they would have done after a live exercise. They got the training audience to share their experience of the exercise, before giving them feedback on their performance.

Figure 5.7 After-action review with the recordings from CBRNE-ACT.

After the feedback from the instructors, the simulator operators played back the audio from BAPS together with the what the first policeman on sight observed through the VR headset. A map of the incident site was shown with a “ground truth” visualization of how the gas dispersed after the accident. The voice communication was played together with the two videos on the big screen in front of the room, as shown in figure 5.7. Afterwards, a new round of feedback was given by the participants based on discrepancies between what was shown from the recordings and what the actors remembered from what had happened, and the insight of how the dispersion had evolved while they were making decisions.

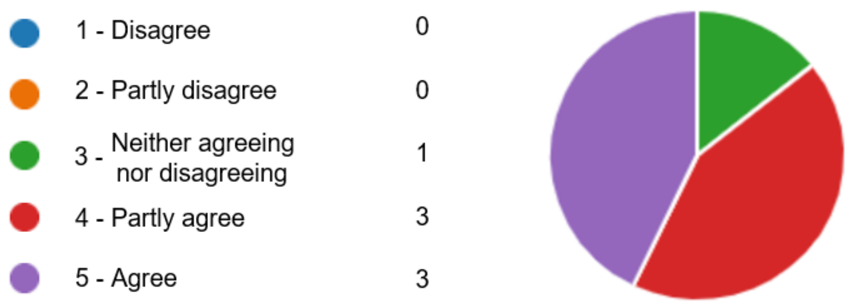
6 Results

This chapter presents the results derived from the responses provided by the seven primary participants who completed a questionnaire with 23 questions (appendix B). The feedback from all attendees after the exercise, along with the questionnaire responses, is considered when formulating the lessons learned.

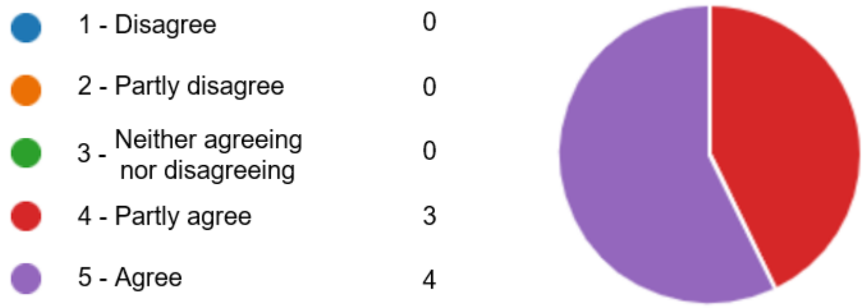
6.1 Questionnaire

After giving oral feedback immediately after the exercise, the seven trainees answered a questionnaire (given in appendix B). Three of the trainees were from the police, two from the fire department and two from the health services. All participants had over 9 years of experience, with an average of just over 15 years. They partly agreed upon that they had received a good introduction to the system before the exercise, but on an average, they were indecisive on whether they had received sufficient training in the technical systems used during the exercise. Due to limitations in time and not to reveal the scenario to the trainees, they had limited possibility to try the system before the exercise started. Even though they managed to perform the most important task they did not exploit all the functions that were available. E.g. that the IC could move the viewpoint of the 3D presentation of the accident site.

On the statement ***"The simulation of the incident was adequate for the role I played"*** they mostly agreed:



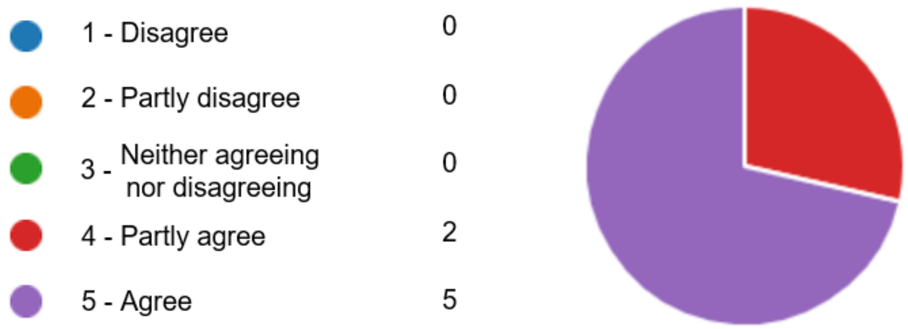
On the statement ***"I managed to complete the tasks within my role"*** all participants either partly or fully agreed:



On the question ***"Alternatively, what limitations did you experience?"*** we got the feedback:

- "The event is compressed. Things are moving a bit faster than usual."
- "Difficult to get an overview beyond the 'main picture' that only showed the accident site. It could have been useful to see more behind/around oneself."
- "When this scenario was based on fire premises, it might have been nice to have the opportunity to have a separate screen to adjust the course of events."
- "The scenario was played a bit fast; couldn't proceed with plans that would have been natural to make."

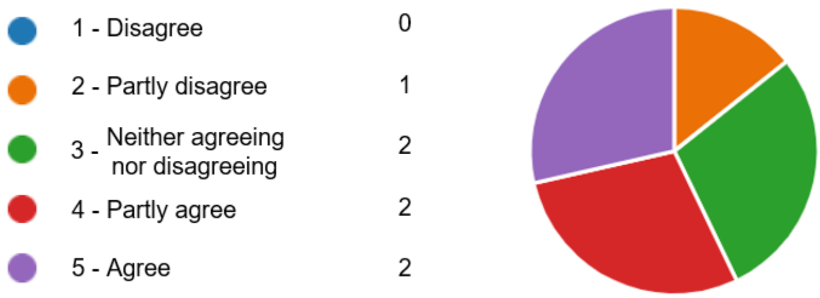
On the statement ***"The realistic dispersion of gas was important for the exercise"*** they agreed:



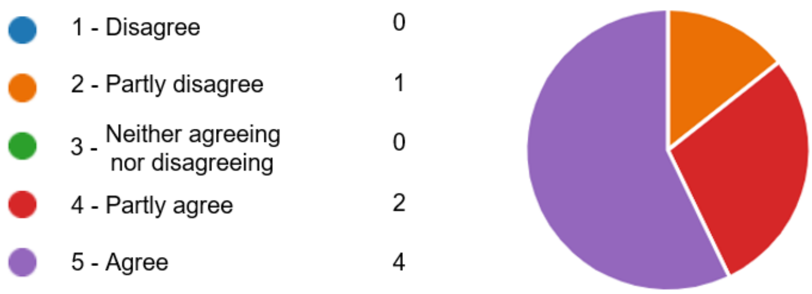
On the question ***"What did the visualization of the gas dispersion provide you with?"*** we got the feedback:

- "Had a bit of an 'aha' moment when it was shown with colours on dispersion."
- "Great utility considering evacuation."
- "Most relevant for the fire department. Slightly less for police."
- "Understanding of the characteristics of the gas."
- "An eye-opener"
- "See how the gas spread in the environment."

On the statement ***"The virtual environment provided enough realism for me to immerse myself in the work at a contaminated incident site",*** the health services gave a lower score than the other participants. Their answers ranged from partly disagree to neither agreeing nor disagreeing. The rest of the participants primarily answered partly agree to agree:

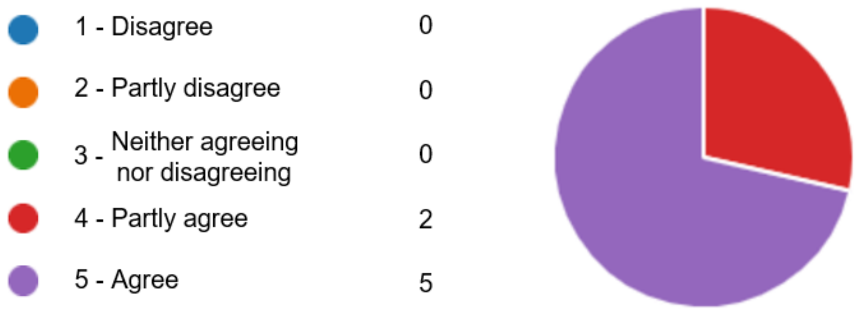


On the statement ***"The scenario used during the exercise was relevant to my role"*** one participant from health partly disagreed. The rest of the participants either partly or fully agreed:



In the follow-up question, we got the feedback that the system could have given a better overview of arriving resources and the arrangement of the resources.

On the statement ***"The ability to review the exercise afterward gave me extra learning"*** they agreed:



On the follow-up question ***"What did you learn from the recording the system made of the exercise?"*** we got the feedback:

- "It's an incredibly nice way to evaluate afterwards, as both radio use and visuals are consistent."
- "Useful to get a review of what was said and done."
- "It's nice to be able to see and hear oneself. This is good learning."
- "What was actually said."
- "It's fun to see what was said and done."

On the question ***"How do you think the room layout during the exercise worked?"*** we got the feedback:

- "Everyone who was watching should have been in another room. It created a lot of noise. During the execution in the room, only participants and those controlling the game should be present."
- "Somewhat cramped."
- "Suboptimal. It would have been preferable to have spectators in a separate room."
- "The space between the incident commander and the second in command was a bit cramped. They could have been placed in separate rooms."

- “Somewhat cramped and noisy. Hot.”
- “Could have been a bit larger, the course participants could have been in another room.”

On the question ***“How do you think the mix of using real radios, role-playing, and a virtual scenario worked?”*** we got the feedback:

- Good, from 3 participants
- “Worked relatively well. It becomes somewhat artificial when the operation centre is in the same room as oneself.”
- “I thought it worked well. Trying out a complete system would have been very interesting!”
- “More use of radios.”

On the question ***“Did the VR headset for the first message on site add extra realism to the exercise?”*** two participants answered “yes” and one “absolutely”, while the 4 others gave the feedback that they had not tested the technology.

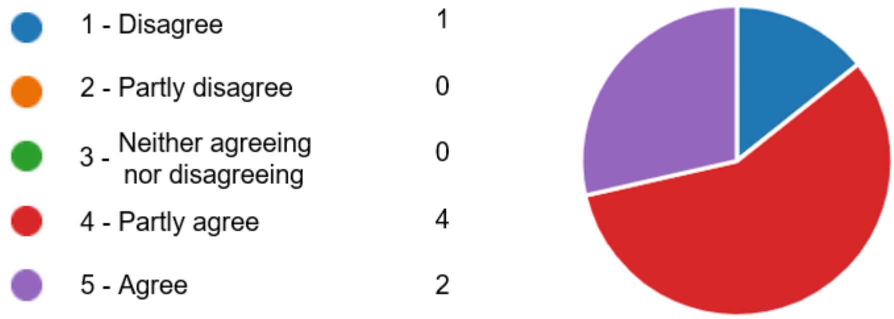
On the question ***“What advantages do you see in using such a system for training?”*** we got the feedback:

- “Endless prospects. This is the future.”
- “Incredibly significant benefits, both in terms of cost and capacity. Can immerse you in an entirely new environment, with new cases and scenarios. Provides visible feedback on the actions taken. A very good substitute for tabletop”
- “Less resources required to practice larger events.”
- “Infinite possibilities for simulation.”
- “Leadership training, as well as for personnel.”
- “Positive, modern.”

On the question ***"What disadvantages do you see in using such a system for training?"*** we got the feedback:

- "Technology-intensive/resource-intensive."
- "Limitation in overview like on a model table."
- "None"
- "Likely costly and requires instructors to conduct it."

On the statement ***"I think this system can replace live exercises in some cases"*** one participant disagreed. The rest either partly or fully agreed:



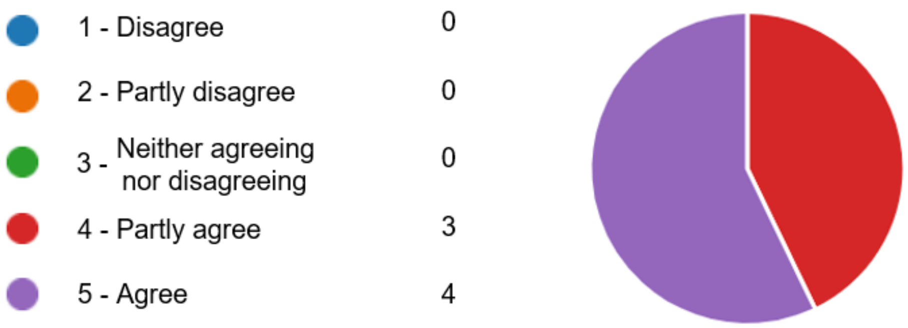
On the follow-up question ***"Where do you see such a system fitting in? Is it only in education, or could it also be used in training or exercises?"*** we got the feedback:

- "Fits in everywhere."
- "This can be used everywhere."
- "Most relevant for training and exercises."
- "Both education and exercises."
- "Everything!"
- "The optimal scenario would be to log in with a user account from anywhere in the country and use it as needed or as capacity allows."

On the last question ***"It can be time-consuming and costly with live exercises. Do you believe that a similar system to the one you have used today can increase the frequency of training in collaboration between emergency services at an incident site? Why or why not?"*** we got the feedback:

- "It can increase the frequency (of training) significantly!!"
- "With this system, there's the possibility for more frequent exercises."
- "Uncertain. I still have great faith in small "dialogue-based" live exercises/scenarios to practice collaboration between emergency services."
- "You might need dedicated individuals who work regularly with the program. If that's achieved, I believe this could be a very effective tool."
- "In an economically strained situation, this becomes the future."
- "Absolutely, can practice on a large scale with few people."

On the last statement ***"I am overall satisfied with the exercise"*** they agreed:



6.2 Lessons learned

The lessons learned is based on the feedback received from all attendees after the exercise along with the questionnaire responses and the observations done by FFI. The system got a lot of positive feedback, but the size of the rooms used and the introduction to the system before the exercise both have room for improvements.

The instructors selected the most suitable trainee candidates from the group and gave them dedicated roles in the exercise. In situations where only one run-through of the scenario occurs, it is crucial for others to learn from the top performers. In cases of multiple run-throughs, it also may be beneficial to use the best candidates for the initial run.

The scenario's time frame was too compressed compared to the actual time required to complete all tasks. More flexibility in the scenario timeline would be beneficial. One of the ICs thought that the duration of the scenario should be extended for future exercises.

The VR headset provided the first responder with a good overview of the incident and facilitated communication using BAPS. Incorporating the VR headset did not hinder BAPS usage. The option to use zoom (to simulate binoculars) in VR should have been demonstrated before the exercise. Some participants hesitated to fully utilize BAPS due to uncertainty about its reliability. Clarifying in advance how BAPS should be used is essential for future exercises.

For a next exercise, it is recommended to use two separate rooms (an exercise room and an observer room) so that the observers can be in a separate room and not disturb the exercise. It is recommended to use a sufficiently large exercise room, representing the incident cite, to ensure sufficient space between the IC and 2IC to minimize interference among the trainees. From the observer room, the observers can listen to BAPS until the channel is closed. After that, they can follow the conversations from their chosen agency's IC. The attending observers expressed that they would prefer to see the 2D-view of the incident cite with the simulated gas dispersion alongside the 3D-view on big screens. If possible, they suggested showing a video stream from the exercise room. Additionally, an instructor in the observer room could comment during the exercise to enhance the observer experience.

Those in CP were unaware that they could alter their view in the virtual environment. Briefing them on this capability in advance would enhance their experience. The whiteboard available in CP was not fully utilized, since most of the planning was done on separate paper maps. Encouraging the sharing of maps among all agencies could improve coordination. Zones were drawn on paper maps instead of within the system, potentially due to insufficient training on system functionality for the 2ICs. Providing more comprehensive training on available tasks may mitigate this issue.

The health services had relatively little work to do, perhaps mostly because they were unaware of the opportunities available to them. More system training upfront would have been beneficial. More focus on decontamination could be beneficial for the health services, but a decontamination station would maybe not be realistic to establish in the timeframe of this exercise. CBRNE-ACT should also be extended to better include transport and management of injured personnel.

The solution with screen mirroring (VR-Forces) for use by and visualization for the three 2ICs was not optimal, as they often pointed at the screen with their finger when they wanted to place or move a unit to a desired location on the map. There was some competition between the 2ICs to assign their tasks on the computer. They felt it would have been an advantage if the screen display had not changed when the same person returned after visiting the CP to convey messages to their IC. If possible, it would have been best to have one VR-Forces station per agency.

All systems and software made it through the exercise without a single serious error. After an oral review by the participants on how they felt the exercise had gone, the after-action review was conducted. The audio from BAPS was played back time-synchronized with video of the policeman's VR perspective on one half of the screen. The map with the gas dispersion was shown simultaneously on the other half of the screen. When the VR video was finished, the dispersion (with the units moving in the area) was shown on the entire big screen. This worked very well.

7 Discussion and conclusion

Feedback from the individuals who used CBRNE-ACT, the instructors, and the rest of the participants at the exercise, were overall positive. They gave responses like "*Endless prospects. This is the future.*" and on the question "What advantages do you see in using such a system for training?" one participant answered "*Incredibly significant benefits, both in terms of cost and capacity. Can immerse you in an entirely new environment, with new cases and scenarios. Provides visible feedback on the actions taken. A very good substitute for tabletop*".

There is room for improvement in future exercises with CBRNE-ACT, particularly regarding the room layout, allowing more time for the scenario to unfold, and providing additional system training for participants before the exercise. The systems and software itself performed well during the exercise and did not disturb the participants with errors, but due to lack of training the 2ICs did not use all the options available to implement the IC commands in the system. It would likely have worked better if the 2IC had one station per emergency service to perform their tasks, instead of sharing one computer [2]. If so, they would have been able to move their virtual characters around more, would not have had to wait in line, and their character would be in the same place as they left them when they returned from meetings with their ICs.

The selected scenario demonstrated how the utilization of computer simulations and virtual environments offers a unique opportunity for education, training, and exercises on handling a CBRNE incident. As an example, the participants found that the VR headset for the first message on site added extra realism to the exercise together with the realistic simulation of the dispersion of gas. The discovery that the simulation gave direct feedback on the decisions made was thought of as important for the exercise.

After action review with the audio from the BAPS channel, video of the policeman's VR view, and the map with the dispersion of the toxic agent gave many of the participants a moment of realisation. "*It's nice to be able to see and hear oneself. This is good learning*." and "*It's an incredibly nice way to evaluate afterwards, as both radio use and visuals are consistent.*" was some of the written feedback we received.

The instructors played an important role during the scenario execution. They played the emergency centres and provided tips to ICs when needed, demonstrating effective role-play. CBRNE-ACT, as currently designed, requires instructors due to its reliance on personal interaction, which is central to this training setup. For procedural training, the system that our Polish partners have developed is worth considering [3]. It features individual internet-based training with pre-set scenarios, limited decision-making to advance, and outcomes that affect the progression of the exercise.

[2] License costs for the simulation system was one of the reasons why the 2IC only had one station in total for all three emergency services.

In conclusion, the successful implementation of CBRNE-ACT for training emergency responders represents a significant step forward in enhancing preparedness and response capabilities for CBRNE incidents. By addressing identified challenges and leveraging participant feedback, ongoing refinement of training methodologies and technological integration can further optimize training effectiveness, ultimately strengthening emergency response capabilities, and ensuring readiness in the face of CBRNE threats.

Abbreviations

2IC	Second In Command
BAPS	Fire, Ambulance, Police, Cooperative
C2IS	Command and Control Information Systems
CBRNE	Chemical, Biological, Radiological, Nuclear, and Explosive materials
COP	Common Operational Picture
COPDCM	Common Operational Picture in Disaster Crisis Management
CP	Command Post
EDA	the European Defence Agency
FOM	Federation Object Model
HLA	High Level Architecture
HMD	Head-Mounted Display
IC	Incident Commander
NETN	NATO Education and Training Network
RTI	Run-Time Infrastructure
VR	Virtual Reality
XR	Extended Reality

Appendix

A Storyboard for emissions of ammonia schedule

Storyboard with emissions of ammonia (NH3) at Kjeller in the intersection Fetveien (Rv22) and Storgata, with assumed response pattern from the emergency services: police, fire department, and health services.

A.1 First, a briefing on the organization of an injury site with CBRNE event:

In rescue efforts where life and health are threatened, the police have the overall rescue management through the function: LRS (Local Rescue Centre). The operations manager takes care of the leadership inside the police operations centre, while at the same time establishing an emergency manager out at the scene of the incident who has tactical leadership of the response crews during the operation.

The police incident commander establishes a task force's command post in conjunction with the incident commanders form the fire department and health services.

The incident commander from each agency leads its own crews during the operation and has professional responsibility in their own field.
Thus, the fire department incident commander is the premise for the execution of the effort and must ensure the safety of all emergency crews regardless of agency.

Each agency communicates on its own agency communication. In addition, a common communication, BAPS (Fire, Ambulance, Police, Cooperative), is used.

In the event of an emergency alarm, the alarm receiving centre shall initiate triple notification (notify the other control centres).

On the way to the incident site, all heads of emergency units and the alarm receiving centre must be connected to a common speech group BAPS 1, where time-critical information is communicated. This could include hazards with the effort, driving routes and defined staging area for the emergency services.

A.2 Scenario description and sequence of events.

There has been a road accident between a tanker and truck. A major damage to the tank has caused a gas leak.

Several people in the area are affected by the gas plume. Some lie down and have breathing problems.

At 5 p.m. the wind direction goes from west to east into a residential area.

The timeline is not realistic but reflects practice time.

At.	Incident	Reaction	Comments
Start: 00:00:00	Notification to 110 centre about a traffic accident at Kjeller, Fetveien (Rv22)/Storgata between tank truck and container truck. The tank truck has UN1005 hazard number 268. Both drivers are out of the vehicles. White gas comes from the tanker. Several callers report itching and burning in the eyes. There is normal activity with people on site both with cars and people. The container truck has come from the main street and the tank truck has come from Rv22. The container truck has run into the side of the tanker. The damage is about 50 cm at the top of the tank.	The 110 dispatcher alerts out firefighters, at the same time as triple alerts are implemented to the EMCC and to 112.	The driver of the tanker gives his statement from the scene of the injury to a police patrol who happens to be in the area. The patrol contacts 110 and gives an explanation
00:02:30	Emergency Fire	The first units are called out from Lørenskog and Skedsmo.	Devices: 1 command car, 2 crew car and 1 tank truck
00:02:30	Emergency Police	The first units are called out from Lillestrøm	Units: 1 Command car and 2 patrol cars

00:02:30	Emergency Health	The first units move out from Ahus	Devices: - 1 Command car and 2 ambulances
00:03:00	Police patrol reported white smoke coming from the scene. Wind direction comes from west to east and towards the residential area.	110 checks information on physical and chemical properties of the substance.	Another alarm operator alerts all units that this is a hazardous substance accident (CBRNE incident).
00:03:30	Time-critical information is shared in speech group BAPS 1 (Nødnett)	Notification of CBRNE incident. Fire brigade provides information about staging area for other agencies	Information is provided about the roadway and staging area for police and health services Staging area is at Kiwi at Kjeller
00:05:00	Several calls from the public to the 110 dispatchers about unpleasant / pungent smell in the area Kjeller and especially in the areas around the airport area.	Advising those out to pull away. People in apartments are asked to close windows and shut off ventilation.	May be that someone will call 112 and 113.
00:05:30	The first unit from the fire department has arrived at the central damage site. Police and health services arrive in the staging area at Kiwi Kjeller	The fire department unit will define hot, and warm zone. Police and health services are waiting.	
00:06:00	Emergency manager from fire brigade asks for reinforcements chemical divers from OBRE (Oslo Fire and Rescue)	Briskeby fire station moves out with 1 crew car and - 1 Chemical diving car	Based on the notification to 110 dispatchers, 2 task forces would have been sent as first responders.
00:07:00	Rescue efforts are launched	Emergency crews are sent in to begin the evacuation of injured people	Only crews with proper protective equipment (respirators) can enter the area.
00:08:00	The incident commander's command post is determined outside the warm zone	Cleared for police and health services to drive to CP.	Outside the warm zone there is no need to wear protective equipment.
00:09:00	Cold sone is defined.	Police are cordoning off this area, while people who are at risk are being evacuated.	The police do not have a respirator and can only stay outside the warm zone.
00:09:30	Cleaning station established	Cleanse contaminated patients before they can be treated by health.	Undressing and washing of visible contaminants.

00:11:00	CBRNE unit to health arrives	Paramedics with simple protective equipment assist with patient care and cleansing in the transition warm/cold zone.	These are protective suits and filter masks.
00:20:00	Technical effort	After all persons have been rescued, chemical divers will start by limiting the leakage on the tank. Here you can flush water on the gas cloud and apply a tarpaulin over the leak.	The timing depends on how many people are to be evacuated.
03:00:00	Clean-up and cleaning of the accident site	Contact the carrier to transfer the fluid from the tank truck to another tank truck	You will receive heavy salvage trucks for salvage of the two trucks once the leak is under control.

Whoever plays police first on the scene can watch the scene with a VR headset. On the VR-Vantage machine, an operator can zoom in ("binoculars" function), making it easier to see details in the scene in the headset.

Hint:

- Person lying down (driver in the container car).
- Verifying UN number of tank truck.
- Look around to observe people moving around in the area.
- People between buildings located to the east of the accident.

B Questionnaire

The questionnaire consisted of 23 questions and statements. The questions had free-text fields and the statements had the following 5 answering options:

- 1 - Disagree
- 2 - Partly disagree
- 3 - Neither agreeing nor disagreeing
- 4 - Partly agree
- 5 - Agree

The questionnaire given to the participants after the exercise:

1. Which organization/role did you represent in the game? (you can choose multiple options) Options: police/fire/health/instructor/civil defence
2. How many years have you been in your organization? (number of years)
3. I received a good introduction to the system before the exercise.
4. I received sufficient training in the technical systems used during the exercise.
5. The simulation of the accident was adequate for the role I played.
6. I managed to complete the tasks within my role.
7. Alternatively, what limitations did you experience?
8. The realistic dispersion of gas was important for the exercise.
9. What did the visualization of the gas dispersion provide you with?
10. The virtual environment provided enough realism for me to immerse myself in the work at a contaminated incident site.
11. The scenario used during the exercise was relevant to my role.
12. If not, why wasn't the scenario suitable for you? What was missing?
13. The ability to review the exercise afterward gave me extra learning.
14. What did you learn from the recording the system made of the exercise?

15. How do you think the room layout during the exercise worked?

16. How do you think the mix of using real radios, role-playing, and a virtual scenario worked?

17. Did the VR headset for the first message on site add extra realism to the exercise?

18. What advantages do you see in using such a system for training?

19. What disadvantages do you see in using such a system for training?

20. I think this system can replace live exercises in some cases.

21. Where do you see such a system fitting in? Is it only in education, or could it also be used in training or exercises?

22. It can be time-consuming and costly with live exercises. Do you believe that a similar system to the one you have used today can increase the frequency of training in collaboration between emergency services at an incident site? Why or why not?

23. I am overall satisfied with the exercise.

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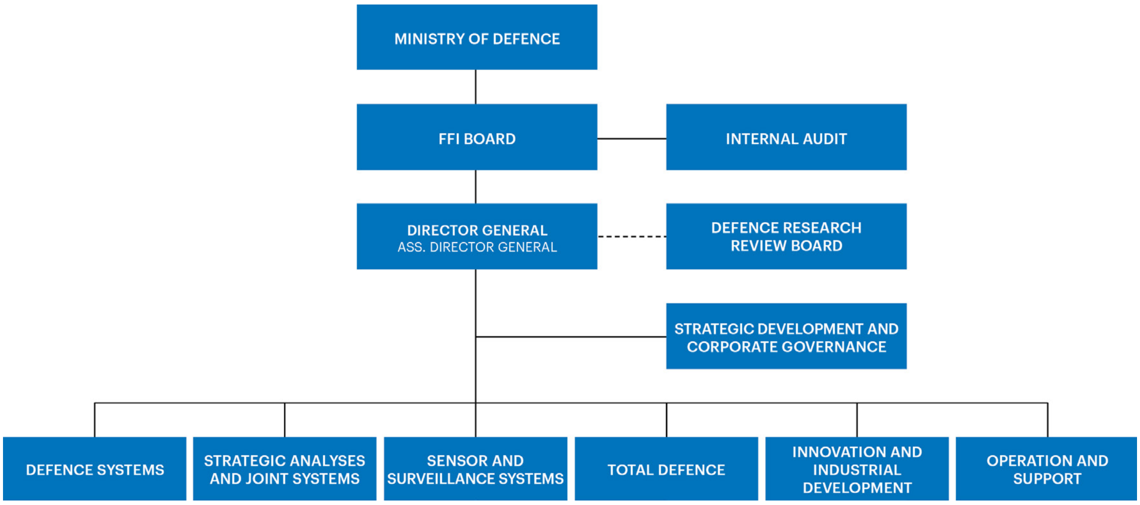

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