COPE – COMMON OPERATIONAL PICTURE EXPLOITATION

SEVENTH FRAMEWORK PROGRAMME

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COPE Technology enabled capacity for First Responder

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Summary

Background: The present report is the final report of the human factors (HF) contribution to the COPE technology concept development. This work was accomplished in several work packages. The report provides first an overview of the usage centred design approach, the research measures taken and the outputs provided by the human factors group of the project. Then the components of the COPE technology are explained from the point of view of the three main end-user groups, the fire fighters, sector commanders and the incident commanders. The main part of the report deals with the evaluation approach used in assessing the technology during the design process, and with the results of this evaluation.

The approach: A longitudinal evaluation approach was developed for the study. Accordingly, the evaluation took place stepwise and assessment methods were adapted to the maturity of the product. Hence, in the earlier design phase, the evaluation was integrated into the technology mapping process. Design workshops were organised which each focused on singular applications. A wider scale human factors evaluation took place in the first field test. In it the wireless sensor network was tested in a realistic accident environment with end-users. In a second field test the comprehensive COPE technology concept was tested and evaluated by end-users in a more challenging accident situation. The results were used to finalise the technologies and to provide information for user training for the final examination. The most comprehensive human factors evaluation was accomplished in the final trial. It involved a challenging accident with 65 emergency responders in the live part of the trial augmented with table top exercise with about 10 participants.

Verification: The evaluation took two basic forms, i.e. verification and validation. In the verification earlier project documents were used as reference to test the fulfilment of requirements. The requirements had been defined on the basis of analysis of emergency response activity. In the verification walk through accomplished during the final trial 21 tasks were accomplished by end-users in real-like situations. It was possible to state that 17 tasks out of 21 defined for verification could be accomplished very well and the rest with slight support by the testing personnel. The majority of the end-users who used the technology during the final trial found the applications easy to use, and agreed that the provided functionalities were relevant. However, end-users found unanimously need for improvements.

Validation: In validation the focus was on testing whether the entire COPE technology concept would support emergency responders cognitive work demands, especially those connected to creation of Common Operational Picture. A new method was used that is labelled the Usability Case. It provides a systematic reasoning tool and reference for gathering data of the technology under design, and for testing its usability in the targeted work. Following this method, a model was created that defined the intrinsic work demands that are needed to maintain COP, i.e. sense making, coordination and maintaining common ground. Then the concept level requirements for the entire technology were defined. For the COPE technology these were “Forming a model of the situation”, “Presenting a model of the situation” and “Sharing the model of the situation”. Thereafter, the singular technological functionalities of the COPE applications were ordered under four main concept solutions: “Actors’ terminals for participation”, “Sensors for extending human senses”, “Semantic information system for abstraction of relevant information” and Availability of information in a Gateway on “WLAN”.

Then connections were identified concerning which singular technologies would fulfil each identified concept solution, how each concept solution would fulfil the concept requirements, and how the concept requirements would support the intrinsic cognitive demands of COP. On the basis of this reasoning, claims about the COPE technology were created. Testing of the fulfilment of these claims was the content of the validation evaluation.

All user experience and behavioural data collected during the project in different evaluation phases was pooled in a database and used as evidence to test whether the claims about the advantages of the COPE technology for creating COP could be supported. Also negative evidence was registered.

The validation results: The validation based on the Usability Case gave the following results: “Sharing of the model” of the accident situation was the concept requirement that received the most positive support. The end users felt that especially the “Actors terminals for participation” was the concept solution supported this requirement and the formation of the Common Operational Picture. End users also identified the role of the - for them invisible-gateway in creating the COP. Some evidence could even be found concerning the need for an underlying semantic structure of the task for sharing of the model and creating COP. “Forming of a model” of the situation also received positive support as a requirement that could be supported by the COPE technologies, and that is necessary for creating COP. The end users maintained that especially the “Sensors for extending human senses” was the concept solution that was considered to have a major role in forming the model. Other concept solutions were also connected to support formation of the model but not equally frequently. It was interesting to note that only little evidence could be found to support the third requirement identified by the designers and HF experts, i.e. the “Presenting a model of the situation”. This result might reflect the fact that the model of the situation is currently mainly in an implicit form, either in the minds of the responders, or in the verbal discussions among the responders. A white board in the command vehicles is used by the commanding personnel to represent the situation. The upper commanders were observed to use the board only to manage resources. According to the report of the end users, incident commanders use the white board mainly in exercises, not in real work. It may be assumed that the first responders did not clearly see the role of external artefacts and the requirement of a representing medium.

The overall opinion of the COPE technology’s potential for future work was expressed via responses to two statements. In the first case it was stated that the “Common operational picture would be enhanced if this kind of (but fully developed) new technology was used in emergency response.” Almost half of the respondents were in complete agreement with his statement and the rest agreed to it somewhat. Nobody expressed negative expectations. The other statement said that “When fully developed the system could fit well in the professional use in the future”. A majority of respondents felt that the system could fit well in professional use. Only two respondents disagreed somewhat.

According to the results future technological development should focus on further development of the semantic structuring of information, and the development of an integrated communication systems in which different media (traditional and new) and also human first responders inputs could be combined in an efficient way. The Usability Case enabled the evaluation of the potential of the COPE technology concept for the future work. It helped the end users to see beyond the disappointments that the partially immature technology in the difficult real-life environments could have brought. The method provided generic conceptual understanding of the technological features that could be useful for the end users. This information is useful for further design and innovation.

Contents

1 Introduction

The COPE (Common Operational Picture Exploitation) project is an EU project about Common Operational Picture (COP) among Emergency Response actors, that is, fire fighters, police, and medical personnel and their superiors acting at the accident site. The aim is to define and understand what is COP and how it can be developed and enhanced via technological innovations.

COPE project is focused on supporting the Incident Commander (IC). The different decision making demands of the IC during the rescue process were studied in the project. As the operational picture is obviously relevant to IC's decision making he needs to construct and maintain an appropriate understanding of the situation in order to reach the goals of the work. Te development and mediation of the common operational picture is taken place in coordination across all the personnel responsible for the incident response. In the COPE project, technologies that enable more efficient construction, maintenance and mediation of the COP were developed.

As the final part of the technology development process an evaluation process was planned. Typical to the COPE project's evaluation concept was that the evaluation was accomplished in a cumulative way and that the human factors experts participated in all phases of the evaluation. The aim of the present report is to describe the approach and results of the human factors contribution to the evaluation.

2 Usage-centred design approach in the COPE project

According to the initial plans of the COPE project the design and development should follow a usage centred approach. Fulfilling this requirement was thought to be essential for the successful development process. Indeed, the participants of the COPE project agreed from the beginning that in order to create added value to the emergency response activity and all the end users it was necessary to put sufficient effort to defining what the demands of the emergency response work are and what kind of properties successful technologies need to have in order for them to become part of the future emergency response work. We labelled this proactive perspective as the target of defining and evaluating the promisingness of the developed technologies. Hence it was necessary to construct an interdisciplinary design process with which the end user participants could be actively involved.

The design process is outlined in Figure 1. The process is depicted from the human factors usage-centred point of view. On the horizontal line the inputs of the different work packages are represented as defined in the Description of work (Annex 1). Time is portrayed on the vertical axis. The figure articulates the most important tasks that the human factors group accomplished and how these tasks were connected with the technology developers' tasks. The figure tries to make evident that in the very beginning the human factors group worked separately from the technology developers (first row in Figure 1). Soon it became clear that more interaction was needed among these two design partners representing different background disciplines. Design oriented experiments and technology mapping working groups were established to increase the interaction and joint design work (second row of the Figure 1).

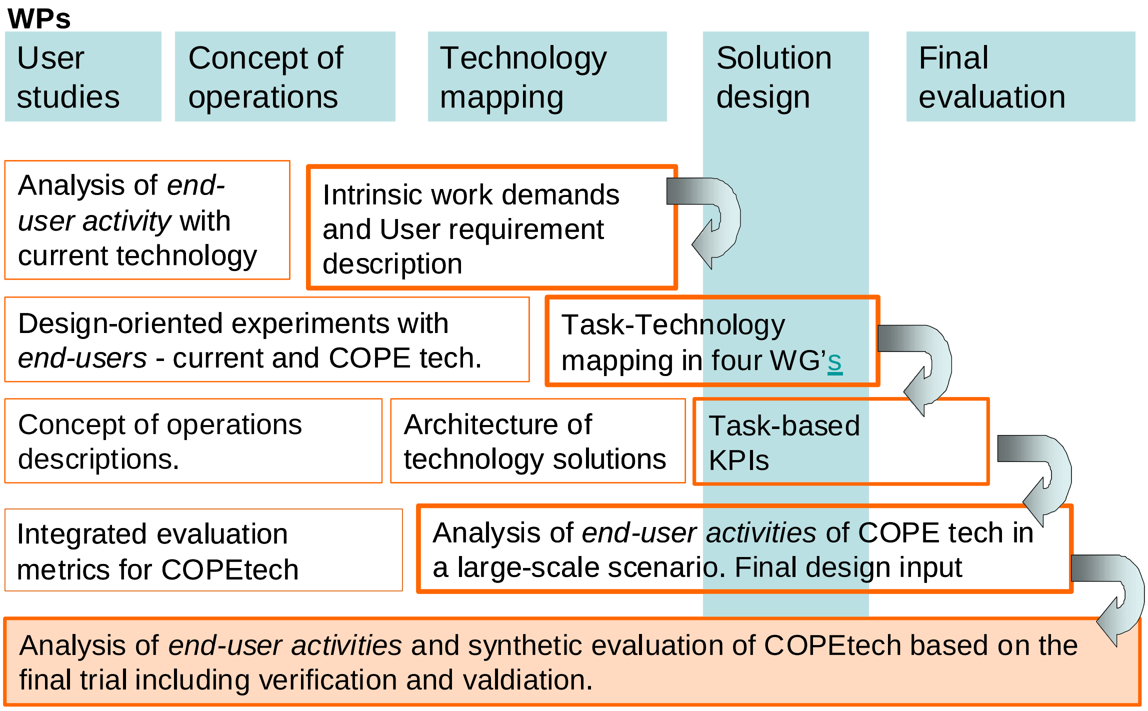

Figure 1. The usage-centred design process accomplished in the COPE project.

An important phase in the design process was when the human factors –oriented work for defining the concept of operations was found to be restricted if it were to only take into account the singular technologies that the working groups had focused on. The need for a comprehensive architecture was expressed by the human factors group. The architecture was articulated and the work for defining the quality criteria for a good system could begin (Key Performance Indicators) (third row in Figure 1). As the next step the human factors group focused on analysing the data from available end-user interviews, design experiments etc. to formulate a set of comprehensive human factors evaluation metrics. This was used in two large scale exercises with end-users and developed further. The results of these analyses were used to improve and finalise the COPE technology concept (fourth row in Figure 1). The last end-user intervention took place in September 2010 in the form of a large-scale final exercise. About 100 end-users and experts participated in the exercise and comprehensive data acquisition was organised by the human factors group concerning the activities of the personnel and their experience of the technologies (last row of Figure 1).

In the following pages we shall first describe the technologies that were provided to the end-users for use in the evaluation. The description follows the process by which the technologies were introduced to the end-users. Then an overview of the human factors evaluation concept is provided and the results of the verification and validation evaluation presented. The forthcoming pages will give an answer to the question of whether the COPE technologies which were evaluated provided any promise for future.. As will be explained, all human factors data collected during the process is pooled in the joint evidence base used in the evaluation.

3 Technological Applications developed in COPE project

In this chapter the technologies developed in COPE project are presented according to the three main first responder roles supported in the evaluation, i.e. fire fighter, sector commander and incident commander, also the upper command is tackled. Then enabling solutions are introduced. The text is based on the training material that the Human Factors group prepared for the training of end-users going to participate in the final trials. Thus the structure of the presentation differs slightly from the ones used in the technical documentation.

The final COPE system of systems consists of parts from all technology partners in Work Package 5. Each technical part or element is delivered by a partner and was developed and tested at a system level. This work was performed individually by each partner.

The technologies are presented by describing the user's tasks for which they were designed. The deliverable D3.3 (COPE Technology Evaluation Criteria) describes the use of the new technology as UML sequence diagrams, outlining the future concept of operations (CONOPS). These diagrams are used for describing the use of the COPE technology in this document. The description is focused on the technology used in field studies (trials). This means that some of the technology mentioned in the deliverable is not mentioned in this document but, on the other hand, some new technology is described here that was not described in D3.3.

The deliverable D4.4 is utilised so that all the functionalities that are defined there are taken into account from the perspective of their use in realistic activities, i.e. in the Final Trial in September 2010; hence, those functionalities that are verified and validated are highlighted.

3.1 Applications for the First Responders

For the purposes of COPE development we focussed on the fire services and specifically the fire fighters, sector commanders and incident commander who are working on the field in the incident. The tools developed for first responders are called the COPE First Responder System (FRS) and they are designed to be used in operational tasks in an acute emergency situation.

Fire Fighters' System

The system, also labelled as FRS-HW (First Responder System – Human Wearable), consists of a helmet integrated (thermal/normal) camera, position sensors and a wrist computer as an input device.

The tool can be used for several purposes; for enhancing perceptual information for the use of the fire fighter or his or her Sector Commander, for delivering situational information for Sector Commander and for delivering the location of fire fighter to Sector Commander and Incident Commander.

<u>Enhancing Observations: Thermal Camera, Helmet Mounted Display (HMD)</u>

A thermal camera was mounted on the fire fighter's helmet. A helmet mounted display (HMD) display allows the fire fighter to see the video stream for themselves. This feature is needed in smoke diving when normal visual perception is prevented and the only visual information can be acquired by a thermal camera. The advantage of helmet-mounted cameras and HMD for perceiving the image is that they enable free use of hands when sending video from the thermal camera to Sector Commander or when the fire fighter is viewing the stream sent from the thermal camera by him- or herself.

To perceive the thermal camera stream, the user shifts gaze upwards and thereby sees the video on the “brow-mounted” display (see D5.6.3 for a technical description of this technology).

Mediating of video information: video camera

There was a daylight camera located in the fire fighter’s helmet. This camera can take still images or video imagery. The fire fighter can record a video of an important object and send it to Sector Commander. The Sector Commander is free to choose when to watch the video. Additionally, the fire fighter is automatically sending a video stream; the live stream is available to Sector Commander continuously.

The fire fighter starts to record by pressing a button on the wrist mounted interface when (s)he sees something worth recording. Then, a video symbol appears on the map tab page of the Sector Commander system.

Locating fire fighters: positioning sensor

See 2.3 (Enabling Applications and Technologies), Sensors.

Not tested in Final Trial: receiving Defensive/Offensive Mode

The fire fighter is provided with an indication of tactical mode on the wrist mounted display and HMD. The tactical mode, Defensive, Offensive or Transitional Mode, is defined by the Sector Commander. This functionality has not been used in any field test as mode definition is part of the Incident command System used in the US and UK, but not explicitly expressed in Finnish Emergency Response.

Sector Commanders’ system

The system, labelled as FRS-C comprises a tablet PC which is connected to the COPE system and used by Sector Commander. The system comprises of three different functionalities (and three other functionalities that have not been tested in any field test).

Task reception: tab page ‘Tasking’ in tablet PC

Tasking is used for receiving tasks electronically, allocated by Incident Commander. Each Sector Commander receives only the tasks allocated to him/herself. This way the loading of audio-based communication is diminished. Correspondingly, the functionality serves as informing Incident Commander about the status of the tasks delivered.

For each task having appeared on the display, the Sector Commander changes its status according to the current situation. The status update is visible on the display for the Sector

Commander and the status is sent to Incident Commander to keep him informed about it as well. The first status change is performed when acknowledging the new task and it continues in several phases until the task is completed.

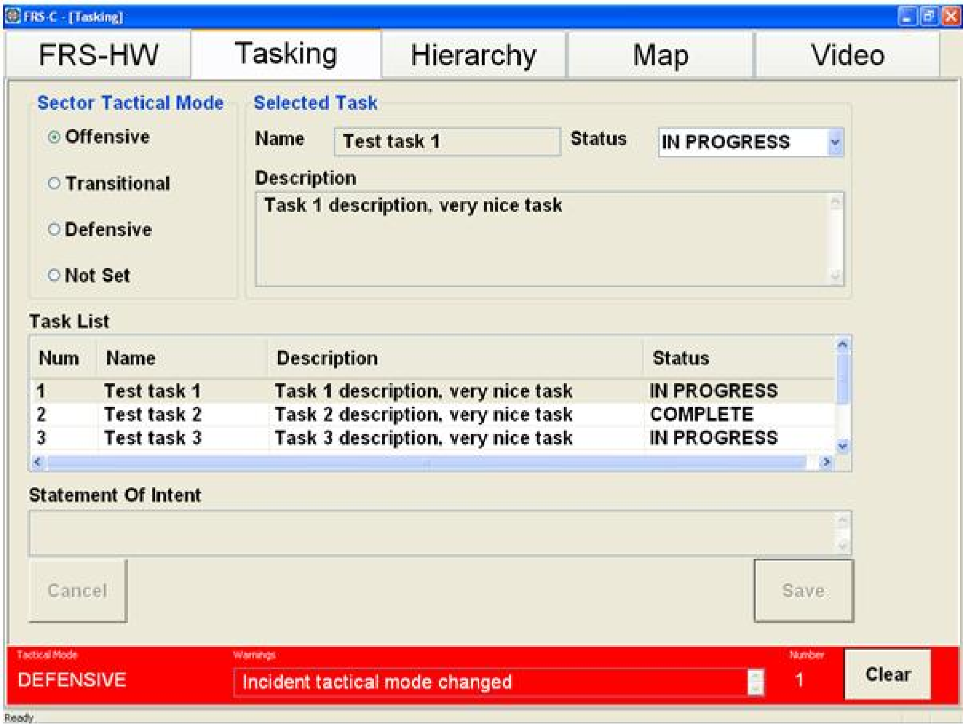

Figure 2: View on Tasking tab page on Sector Commander’s system

<u>Tool management: tab page ‘FRS-HW’ in tablet PC</u>

The Tool Management functionality is designed for maintaining the information about which the fire fighters are assigned to which technologies.

The Sector Commander first chooses a person (fire fighter) from a Personnel list and then “allocates” the tool for him from another ready-made list.

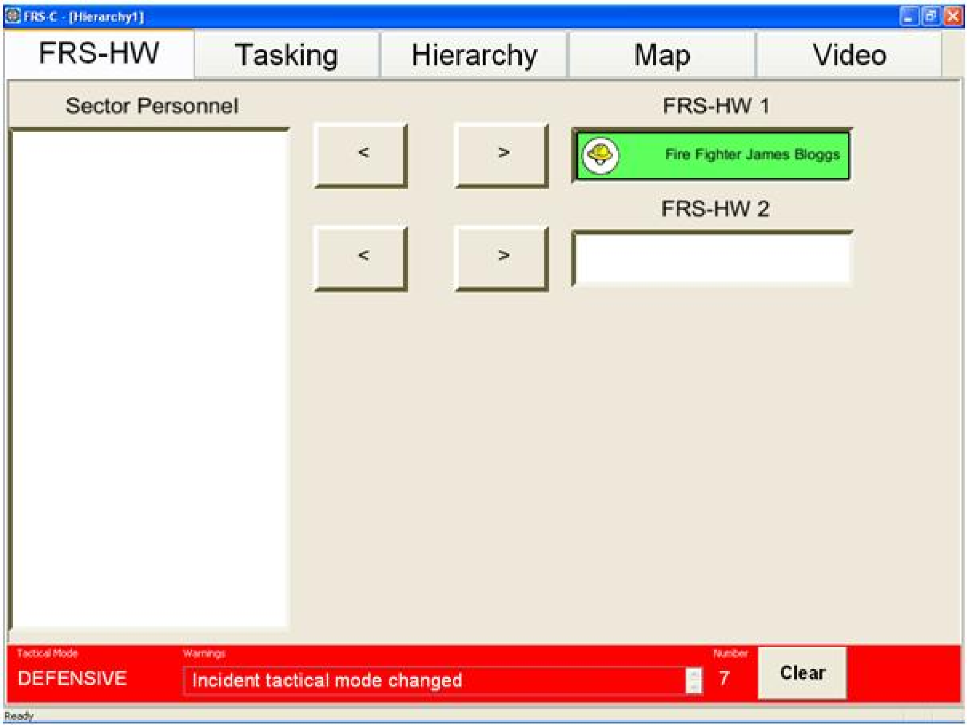

Figure 3: View on FRS-HW tab page on Sector Commander's system

Monitoring emergency response performance: tab page 'Map' in tablet PC

The map allows Sector Commander to observe the current location of the crew on the map. Furthermore, he can see emergency-response related symbols and areas on the map such as immediate danger zone, defined by other emergency-response personnel.

The map is used for viewing the current operative field where the user is located in the centre of the map. The map can be moved on the display when needed. When clicking on the symbol in the map, a new window appears containing information about that symbol.

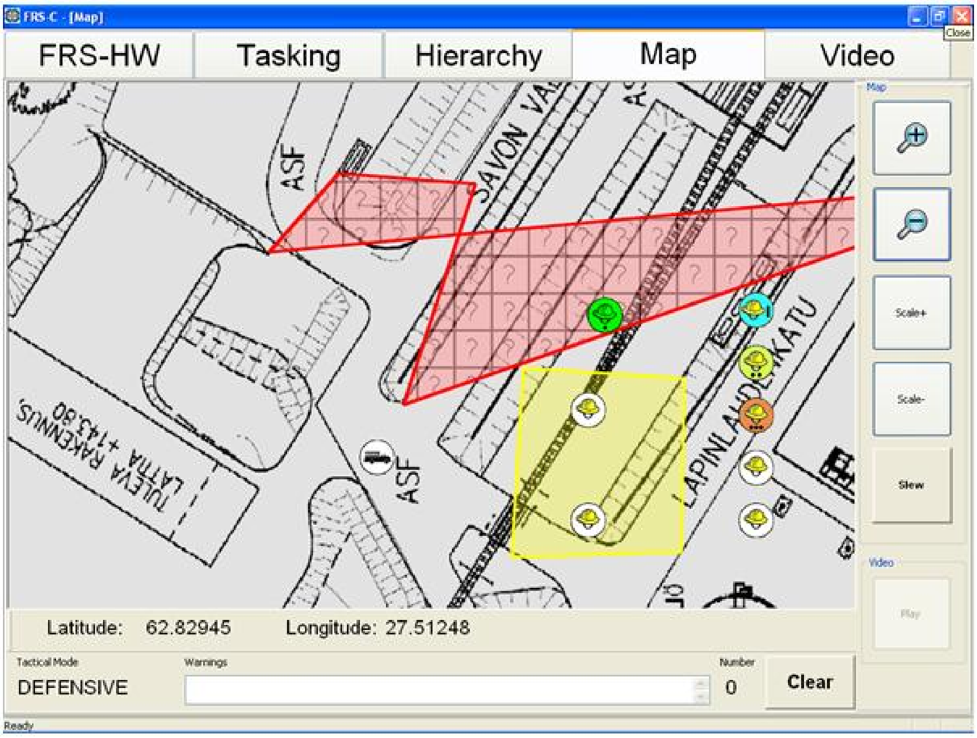

Figure 4: View on Map tab page on Sector Commander's system

<u>Receiving detailed online information from the field: tab page 'Video' in tablet PC</u>

The Sector Commander can view a video stream sent from the camera located in the helmet of the fire fighter. The video stream sent can be either from a normal or from a thermal camera.

All available video information is indicated on the display. Each video image can be opened to full-screen viewing.

<u>Not tested in Final Trial: Monitoring smoke diving</u>

The Sector Commander (or Breathing Apparatus Entry Control Officer, BAECO) is supported in his/her task by providing automatic monitoring of the time used in smoke diving by the personnel. Hence, the Sector Commander can be constantly aware of the duration of smoke diving.

Sector Commander (or BAECO) clicks the Start button when smoke diving begins and the time on the display shows how much time has passed. This functionality was not used in any field test.

<u>Not tested in Final Trial: information about the personnel hierarchy involved in the emergency response; tab page 'Hierarchy' in table PC</u>

The display shows the current personnel hierarchy from Incident Commander to all Sector Commanders.

The view dynamically updates as sectors are created and Sector Commanders are assigned. This functionality has not used in field test (Final Trial). The colouring of the currently selected Sector Commander using the functionality is blue, otherwise the colouring reflects the position in the hierarchy (Incident Commander in red, Sector Commanders in green). This functionality has not been tested in any field test.

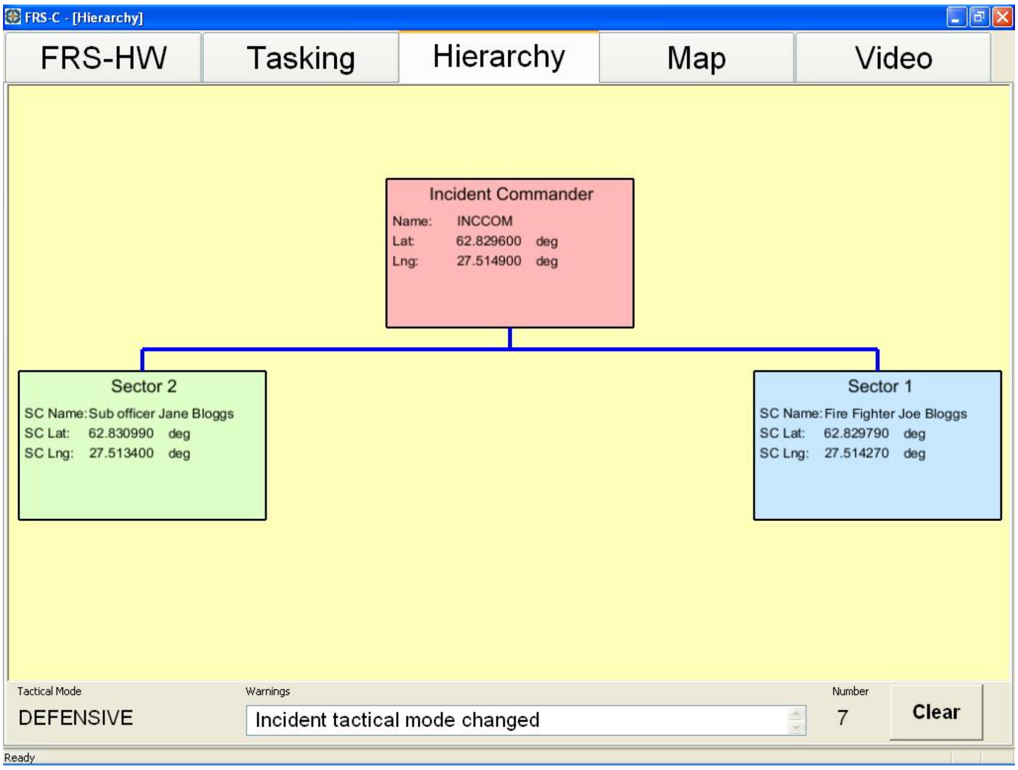

Figure 5: View on Hierarchy tab page on Sector Commander’s system

<u>Not tested in Final Trial: information about the current tactical mode; status bar in table PC</u>

The currently used tactical mode is shown in status bar of the table PC, irrespective of the tab page shown. This functionality has not been used in any field test as mode definition is not explicitly expressed in Finnish Emergency Response.

Incident Commander’s system

The Incident Commander has two separate technologies to use, one labelled Command and Control (C2), comprising of map management and task allocation, and the other the COPE Decision Support (CDS), to be used for risk analysis.

<u>Managing map-based, incident-related information to inform all parties: tab page ‘Map’ in laptop</u>

The Incident Commander visualises emergency response-related activities and accident-related elements on the map. This visualisation is delivered to all parties. Additionally, the Incident Commander can monitor chemical concentration and its spreading in a hazardous-material accident.

The Incident Commander sets symbols (ready-made symbols or areas that are drawn) manually on the map that is a standard geographical map in a digital format, shown on the display. He/she updates the visualisation when needed. However, when in a chemical accident, no updating is needed; then, instead, the Incident Commander can monitor the behaviour of the chemical cloud by its intensity/dangerousness to humans and the extent of its spreading based on data from sensors in the field.

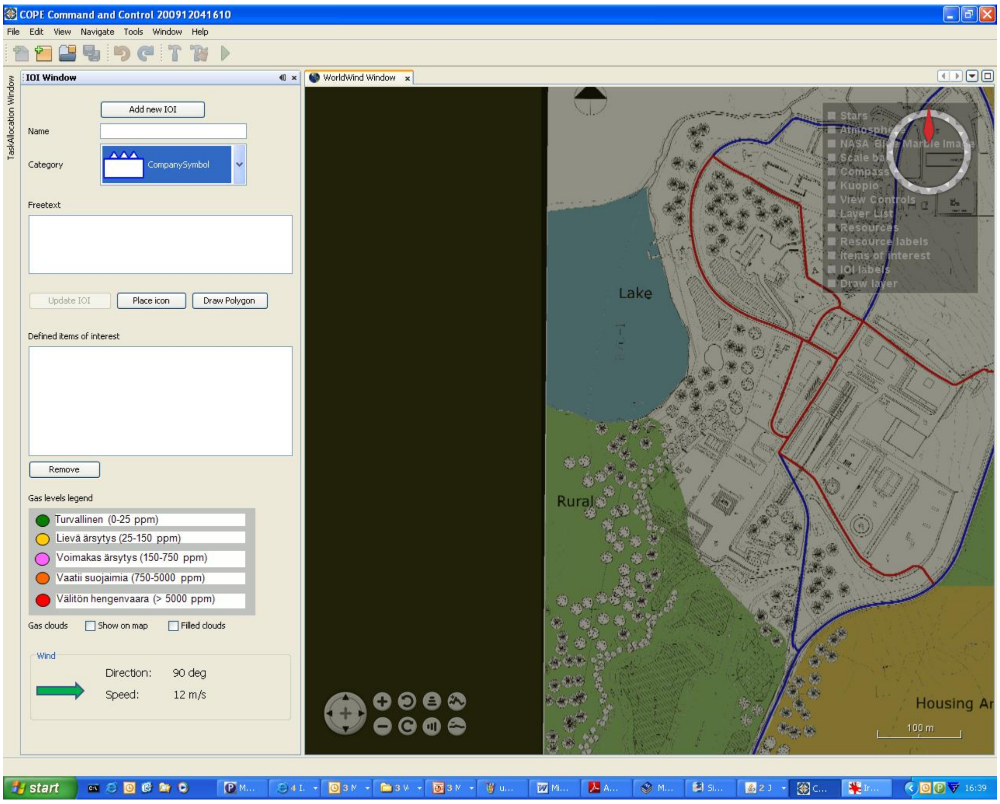

Figure 6: The View on the Map tab page on Incident Commander's system

<u>Allocating tasks to Sector Commanders: tab page 'Task Allocation' in laptop</u>

The Incident Commander allocates tasks to all Sector Commanders and monitors how task execution is proceeding by viewing the status updating performed by Sector Commanders. Also the completed tasks remain on the display so that Incident Commander can also view the history of the completed tasks.

Tasks are sent to respective Sector Commanders and task performance is followed by monitoring status updates of each task and by viewing the automatically appearing starting and finishing times of each task.

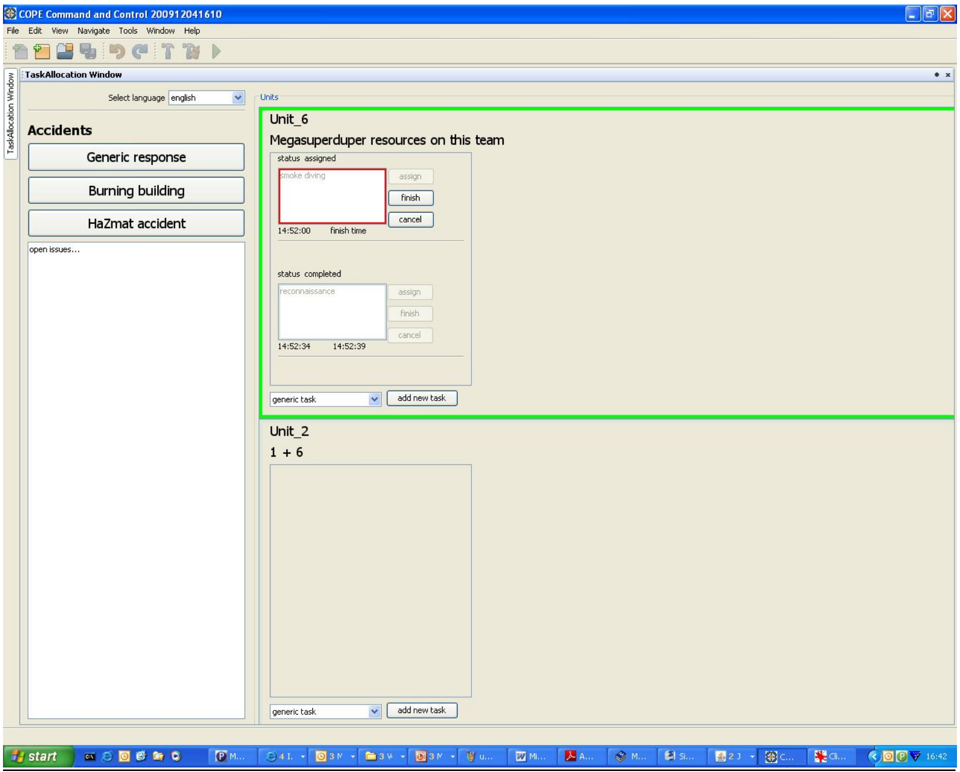

Figure 7: The view of the Task Allocation tab page on Incident Commander's system; in the figure, two units are visible

<u>Performing risk analysis: application in laptop</u>

The CDS application helps Incident Commander to find relevant risks related to the incident on hand; to evaluate the significance of the risk and to estimate the geographical location or area where one should be aware of the existence of the risk.

The Incident Commander searches the risk from a ready-made risk checklist (developed from a UK fire service checklist), evaluates its level of dangerousness numerically and places a risk symbol on the map.

3.2 Application for Higher levels of Command

Higher levels of Command had the same tools as Incident Commander; that is, the Incident Commander's system (C2 and CDS). In the final field test, i.e. the only test where Higher Command was present, Higher Command could use only the Map. This is because in the functionality of Task Allocation used in the evaluation there was no upper level for the Higher Command to contact Incident Commander. The CDS risk analysis support was used by a separate group of UK fire fighter commanders due to that fact that, in Finland, the specific risk analysis process supported by the CDS is not part of their general procedures.

3.3 Enabling Applications and Technologies

In the COPE project several applications have been developed that function in an enabling role. These applications are more or less invisible to the users. They work under the direct user interface by creating, storing and mediating information that is needed by the systems used directly by the users.

Sensors

Positioning sensor were attached to fire fighter's garments. It made it possible for the Sector Commander to be aware of the location of their fire fighters via the tablet PC.

The use of the sensors does not require any human manipulation as the fire fighter just wears the sensors and the location information is sent automatically.

Chemical gas sensors (in the trial, Ammonium sensors) can be attached permanently, for instance on vehicles used in the emergency response, and can be put anywhere on the ground. The sensors express the level of gas concentration in sensor locations and this information is used for estimating the concentration in the surrounding areas.

The use of portable chemical sensors requires human effort as the locations of the sensors has to be decided by Incident Commander and the setting of the sensors on the ground must be performed by fire fighters in the field. In order to guarantee a trustworthy estimation, local weather conditions, especially wind, must be taken into account. Therefore, a weather station has to be used in addition to the chemical sensors.

Figure 8. Chemical sensor (left), EMAS weather station (right)

Gateway

The COPE Gateway stores and mediates information provided by the COPE technology. This way the information can be delivered to all stakeholders that need it and the history of information processing can be tracked in the Gateway.

Communication technologies

Wireless Sensor Network (WSN) central unit receiver collects sensor location data, weather data and chemical gas concentration to a laptop PC used by Incident Commander (and Higher Command).

In addition to the COPE technology, the Higher Command, Incident Commander and Sector Commanders all used the **TETRA network** with TETRA radios for voice communication, as is normal procedure for the Finnish emergency-response at the incident site.

4 Framework in the Human Factors evaluation

4.1 Basic approach in evaluation

In this section we shall explain the overall approach utilised in the project for human factors evaluation of the COPE technology concept. The approach is characterised by two generic features, i.e. a phase-wise evaluation and a combination of verification and validation evaluations.

Phase-wise evaluation
As we have indicated in D4.4, evaluation of the outcome of the design is a necessary function in the design process. Evaluation takes place in all phases of the design but may take different expressions depending on the design phase and the maturity of the product. A phase-wise evaluation was realised in the COPE technology evaluation as follows:

- In the earlier design phase, evaluation took place as a *function of the technology mapping working groups*. The human factors interventions took place in smaller size design workshops among the technologists, human factors experts and end-user participants (e.g. with regard to the decision support application and the first responder applications).
- A wider scale human factors intervention and evaluation took place in the first *field test* in at the Emergency Services College (ESC) in Kuopio May 2009, the *Kuopio 1* test, in which the wireless sensor network was tested in a realistic accident environment (see D2.2).
- The next human factors evaluation took palace at ESC in May 2010. This is labelled the *Kuopio 2* test. Comprehensive COPE technologies were tested this time in a more *challenging accident situation*. The results of this test were used to a) finalise the technologies and b) provide information for user training for the final examination (design inputs to C2 and FRS-C Training material).
- The most *comprehensive human factors evaluation* was accomplished in the final trial again at ESC in Kuopio, the *Kuopio 3* test. It involved a challenging accident with 65 emergency responders in the live part of the trial augmented with table top exercise with about 10 participants. A comprehensive evaluation report is provided in D6.6.

In the analyses the results of which are presented in this deliverable all the user responses from different human factors interventions were gathered and synthesised as a comprehensive pool of evidence concerning the usability and promisingness of the COPE technology concept.

Verification and validation
In COPE deliverable D4.4. it was proposed that the COPE technology should be evaluated from two distinguishable aspects of human factors evaluation i.e. verification and validation as follows:

Verification is a quality *control* process that is used to evaluate whether or not a product, (service, or system) complies with regulations, specifications, or conditions imposed at the start of a development phase. Verification is an internal process to the development.

Validation is a quality *assurance* process of establishing evidence that provides a high degree of assurance that a product (or service, or system) accomplishes its intended purpose. This often involves acceptance of fitness for needs with end users and other product stakeholders. The question of added value is strongly emphasized in validating evaluation.

It is sometimes said that verification can be expressed by the query "Are you building the thing right?" (or “did you build what you said you would build?” and validation by "Are you building the right thing?" (or, put another way, “did what you built support the intended activities?”).

Drawing on the common descriptions of verification and validation we would like to stress that verification and validation have different *references:* Verification refers to the requirements and the design documentation (reasoning backwards). Validation refers to effective end-user activity in the future work (reasons forward, predicts, compares).

The two evaluation processes also differ with regard to the *context specificity* dimension. *Verification is rather context-independent* as the end-user requirements are defined with the aid of generic (abstract) task descriptions. These may be acquired e.g. via hierarchical task analysis measures. *In validation, the system is tested in specific contexts of use*. Realistic scenarios, test situations, or simulations are created with the help of which actual end-users activities under designed constraints can be observed.

As a result of these different perspectives to end-user performance (context independent vs. context dependent and situated) different performance evaluation metrics become relevant. In *verification it is usual to measure performance output in various specific tasks* by measuring e.g. performance time, errors, physical and mental effort etc. In *validation, the focus is on more complex cognitive and teamwork functions* and appropriate measures are for example shared understanding of the situations, proper decision making, fluent coordination, good communication etc. In validation the intention is to figure out what consequences the tested technology would have on the ways of working, acting or collaborating, sharing responsibility, and so forth, that is evaluating the entire concept of operations.

4.2 Data collection and analysis methods in the COPE HF studies

In this section we provide an overview of the human factors methods that were used in the different interventions with the end users during the entire COPE study. The overview is provided in Table 1.

Table 1: Data collection methods in the different end-user interventions. The table indicates the number of persons or emergency response units participated and delivered data. Current work refers to work without new technology, COPE work to work supported by COPE technology.

Data collection method	Initial interviews	Kuopio1	Kuopio 2	Kuopio 3	All persons/ER units
Current work: Critical Decision Method Interview	19				19
Current work: observations (video)		23	25	44	92
Present work: expert evaluations		3 units	3 units		6 units
COPE work: training feedback		2 ICs	2 ICs	19	23
COPE work: walkthrough				3	3
COPE work: observation (video)		2 ICs	2 ICs 3 SCs	upper 6 IC 4 SC 3 FRS 6	23
COPE work: Debriefing interview			2 ICs 3 SCs	upper 6 IC 4 SC 3 FRS 6	24
COPE work: Questionnaire			2 ICs 3 SCs	upper 6 IC 4 SC 3 FRS 6	24

As can be seen from the table the data acquisition focused both on “current work” (that is, the way that emergency response happens currently, without the advanced COPE technologies) and on the work with COPE technology (“COPE Work”) (that is, the envisioned ways of working with the new technologies). The former data delivered an important source of the demands of the work were as they appear presently. It also provided a reference against which the development of the future work could be reflected. As was explained in D2.2 a particular new method, called the “parallel augmented exercise” was developed to identify the zone of development when new technologies are introduced (Norros, Liinasuo, & Hutton, submitted).

More detailed descriptions of the methods were provided in D2.1 and D2.2. The Kuopio 1 study was repeated in exactly the same form in the Kuopio 2 study. The Kuopio 3 i.e. the final trial, had an even more extensive data collection and analysis approach. The overall methodology of Kuopio 3 is described in D6.6. More details are available in Chapters 5 and 6 of this report concerning verification and validation methods. The detailed qualitative data analysis concerning the emergency responders’ decision making and the communication process will take place later. The future analyses are directed to scientific publication of the results. The analyses accomplished are considered to be sufficient for verification and validation purposes.

In the following two chapters it will be shown how the collected data , after being analysed, was used in the verification and validation evaluations.

5 Verification evaluation

In this chapter the human factors verification conducted in COPE project is described.

5.1 Methods of verification – task completion and User Experience

In verification the purpose was to find out whether the developed COPE system complies with the human factors requirements developed earlier in the project. In COPE the requirements were based on extensive task analysis reported in Deliverables 3.1 and 4.4. The aim was also to ensure and evaluate apparent usability of the developed systems so that basic usability problems could be differentiated from possible concept level problems that would arise in the large scale scenario.

In order to gather data for verification purposes a walk through protocol (see Table 2) was developed by the human factors team. The aim of the walk-through method was to verify how well the task completion is in using the COPE technologies in the primary tasks. In the protocol all the tasks described in D4.4 were represented as tasks given to one of the three: fire fighter, sector commander, or incident commander.

The walkthrough was conducted with three users, each representing a specific user role. Each user was accompanied by a researcher who gave the user the task and consequently followed the successfulness of the task. A fourth researcher acted as video recorder who captured the performance of each user.

In addition to the verification walkthrough a user experience (UX) questionnaire was distributed to all the users (n=19) who had tried out the technology. In this questionnaire there were three verification related questions. These questions addressed usability and user experience from a point of view that is suitable for verification.

5.2 Results of verification

Successfulness of the tasks (walkthrough)

The task completion was evaluated in a walkthrough, in which a set of tasks (Table 2, column “task”) was given to IC, SC and FF. The success in each task was evaluated with a three digit scale in which 0 denotes failure in task, 1 success with help, and 2 success without help. The results are presented in Table 2.

Overall the success rate was very good. Only four tasks out of 21 were evaluated with a grade 1 or 0. That means that 17 tasks were completed by users alone, without help from the designers or the researchers.

Table 2. Results of the walkthorough. The succes was evaluate with a three point scale 0= unsuccesfull, 1= succes with help, 2 = success.

	Task	Role	Success	Comments
1	Assigning equipment to individual FFs	SC	2	
2	Giving reconnaissance task to a SC	IC	2	
3	Giving reconnaissance task to a FF	SC	2	
4	Checking whether reconnaissance is being conducted (checking and interpreting task status)	IC	1	User did not interpret the colour of the task frame correctly ➔ colour possible not intuitive enough
5	Conducting reconnaissance	FF		
6	Viewing video sent by FF	SC	2	
7	Recording a video	FF	0	This task had not been covered in the training at all
8	Finding location of FF on the map	SC	2	
9	Looking at a victim	FF	2	
10	Finding out where the victim is	SC	2	
11	Returning to unit	FF		
12	Letting IC know that task is completed	SC	2	
13	Checking status of the task	IC	2	
14	Marking the incident on the map (place an icon of chemical leak)	IC	2	
15	Drawing the zone of immediate danger	IC	2	
16	Finding out whether there is new information (find the icon placed by IC)	SC	2	
17	Evaluating the harmfulness of the situation	IC	1	Had difficulties operating the map in order to find the chemical concentration ➔ map operations are difficult to learn; user gets no cues if important information exists outside of current map focus
18	Evaluating spreading of the cloud	IC	1	User did not evaluate consequences of the cloud correctly
19	Changing the position of an icon	IC	2	
20	Defining sectors on the map (draw)	IC	2	
21	Writing a note for further information	IC	2	

Usability and user experience (questionnaire)

All the participants of the Kuopio final trial answered a user experience questionnaire during a debriefing session after the exercise. All 19 participants of the live exercise filled the multiple choice question sheets. Additional two CDS users of the table top exercise made a total of 21 answer sheets. The questionnaire can be found in appendix 2. Figure 9 shows the distribution of participants in different technology user groups and the length of emergency services experience. Ten emergency responders i.e. IC:s and Sector Commanders and upper commanders used the C2 system, whereas the second largest technology user group was the FRS-C fire fighter with 6 users. 40 % of all respondents and all FRS-C sector commanders had over 25 years of experience.

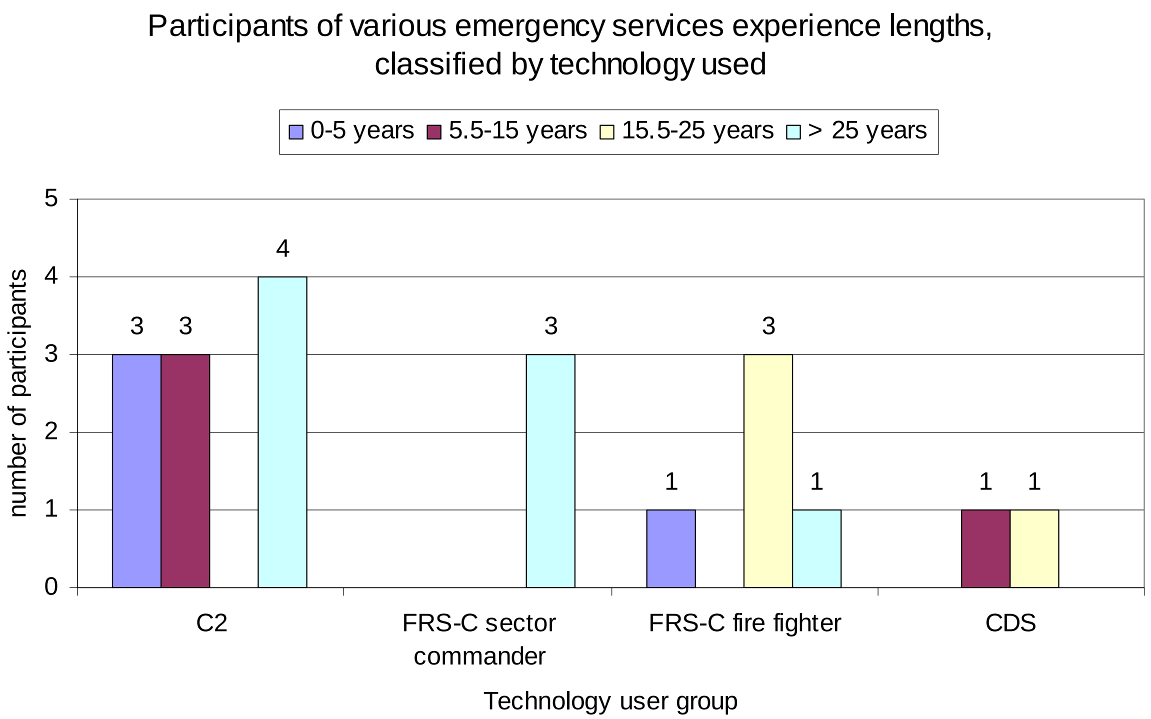

Figure 9 Number of participants that answered the user experience questionnaire (N=21) showing the technology groups and the distribution of emergency services experience length. One FRS-C fire fighter did not indicate length of experience.

The opinions about whether the system is easy to use ranged from complete agreement to complete disagreement (Figure 10). However, majority of the respondents agreed to some extent that the system is easy to use.

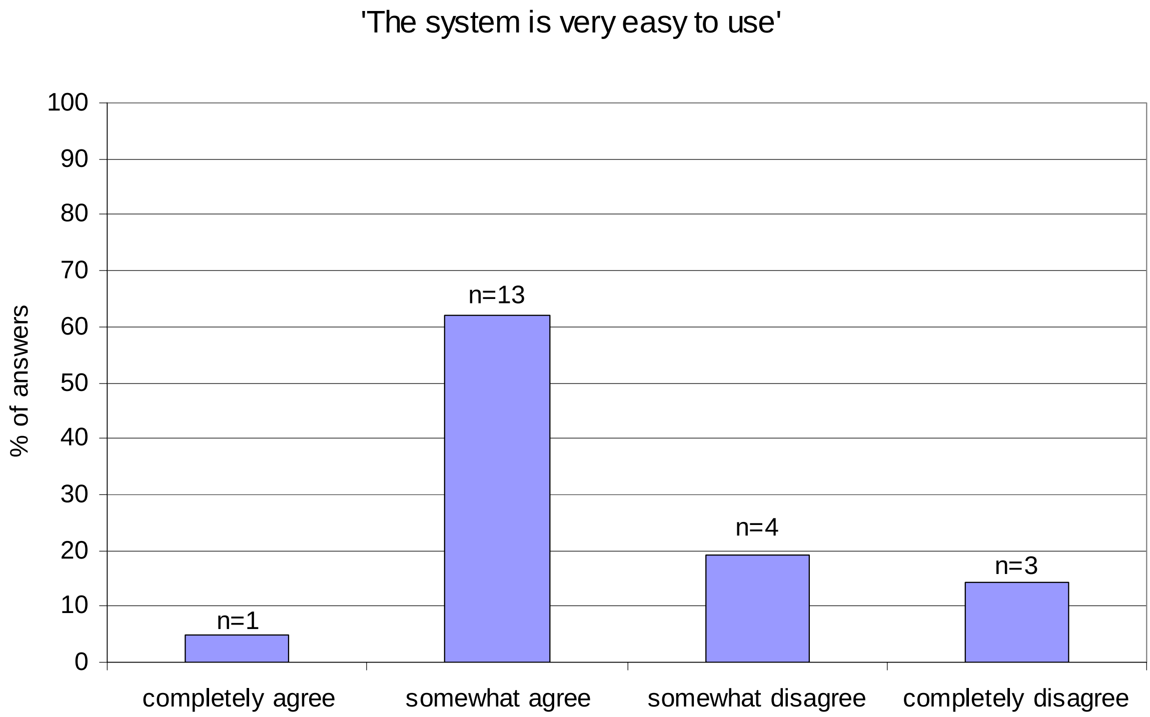

Figure 10. The percentage distribution of all answers related to the claim 'The system is very easy to use'.

The participants felt that the functionalities of the device would be usable in the field but apparently not exactly the ones needed (Figure 11). There were no strict opinions for or against the functionalities.

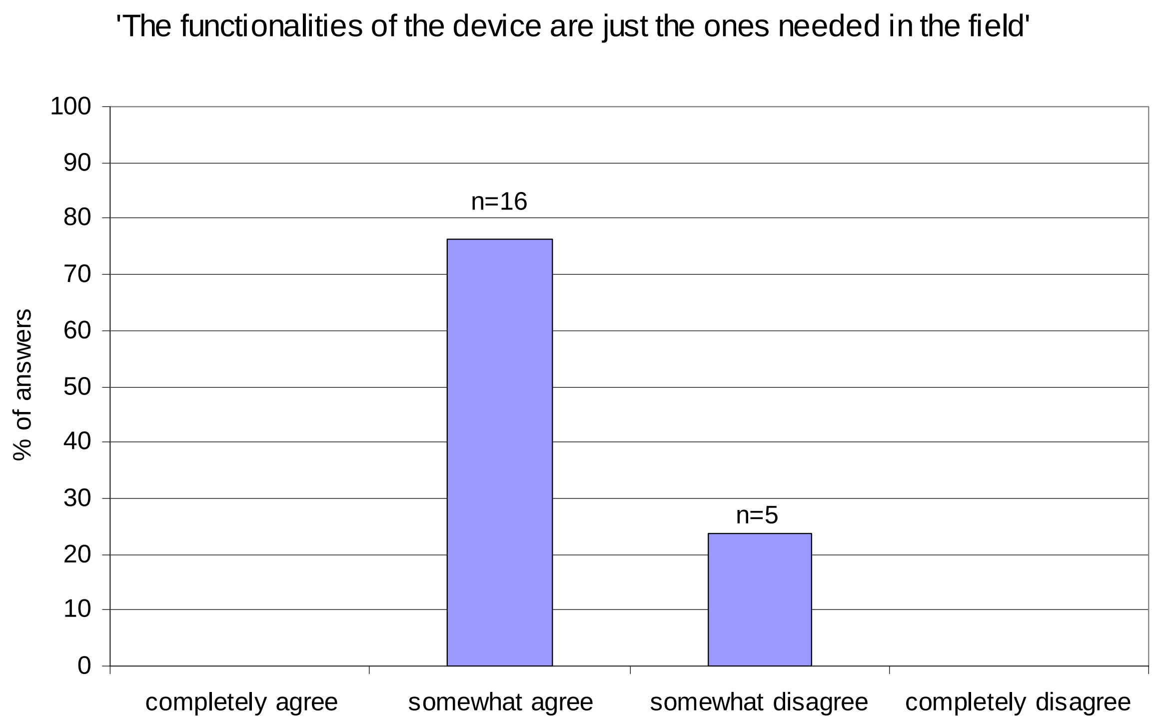

Figure 11. The percentage distribution of all answers related to the claim 'The functionalities of the device are just the ones needed in the field'.

The respondents unanimously thought the device needs improvement (Figure 12). 18 respondents completely agreed and the rest three somewhat agreed to the claim 'In the device, there is a lot to amend'.

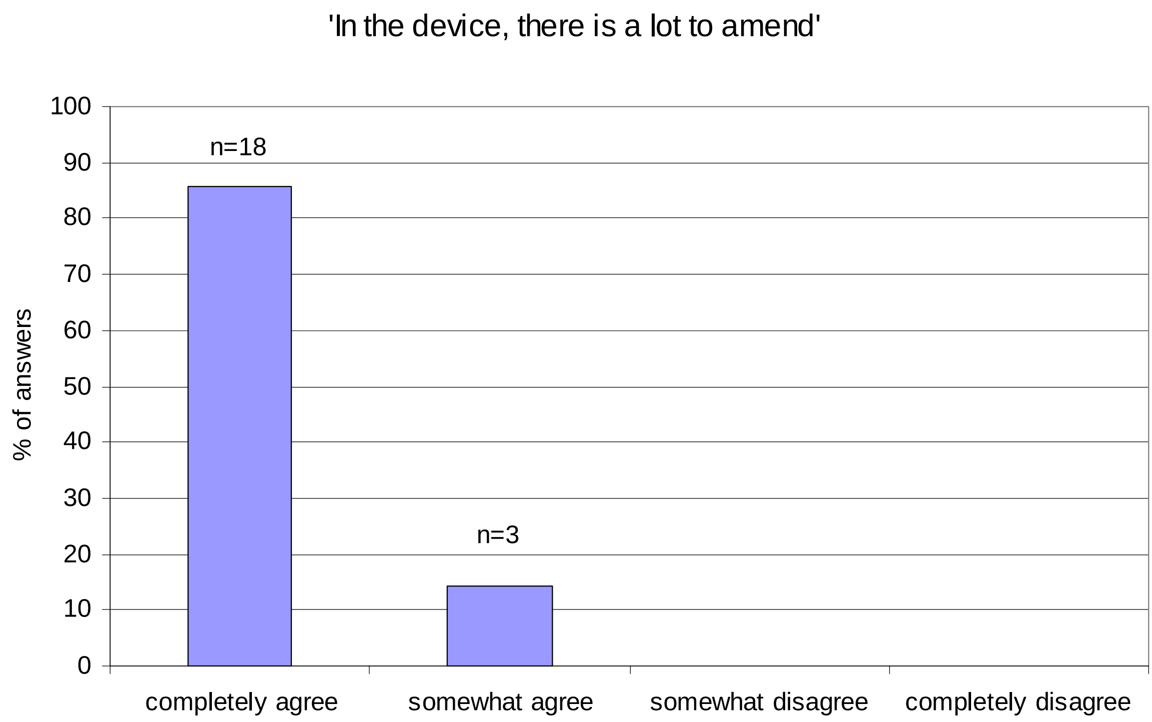

Figure 12. The percentage distribution of all answers related to the claim 'In the device, there is a lot to amend'.

6 Validation evaluation

In order to evaluate the COPE technologies and to have a basis for understanding whether the developed technologies are beneficial for the users in their work we must understand how each of the application is intended to support the core demands of their work.

According to the reasoning reported in the COPE D2.1 there are different methodologies to define the core demands of work. In the report we decided to integrate several theoretical approaches and to define what we called generic Intrinsic Cognitive Demands (ICD) of the emergency response work. The description of the ICD's was borrowed from the Naturalistic Decision Making tradition (Schraagen, Klein, & Hoffman, 2008) but corresponded, on a general level well with a more contextual methodology developed at VTT to define psychological core-task demands (Norros, 2004). Figure 13 is the description of the generic ICDs that were thought to characterise emergency responders' work.

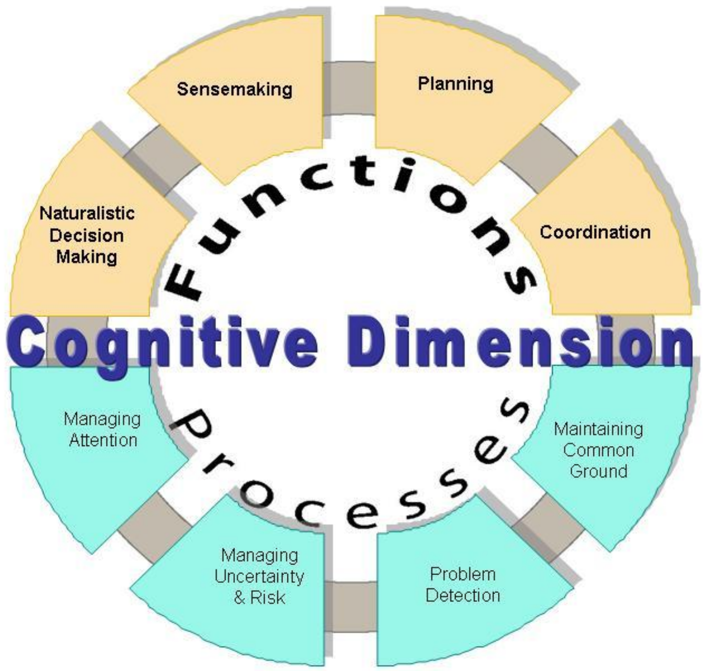

Figure 13. Macro-cognitive functions and processes.

For the COPE project it was especially important to have a clear idea of what demands the COPE technologies should support. We propose that three ICDs should be especially relevant for COPE. These are "Sensemaking", "Coordination" and "Maintaining common ground". A description of the contents of these demands (or cognitive functions) in the emergency response context is to be found in the COPE deliverable D2.1.

6.1 Common Operational Picture

From the very beginning of the project the participants did have a basic but rather intuitive understanding of what should be understood by the Common Operational Picture. It was not quite clear, first, how this concept connects to the end-user work demands and, second, what is the role of technologies to support COP. As was indicated above, the model of the macro-cognitive functions answers the first question and three ICDs were selected. Common Operational Picture is a cognitive function that needs to be fulfilled for the mastery of complex situations as a shared activity of many different actors from different agencies.

How about the second question, i.e. what is the role of technologies in COP? This issue was discussed after the Kuopio 1 study and reported in the D2.2. The definition expressed then was later shortened and finalised and discussed in a meeting just before the final trials. The Definition is given in the below box and the role of specific artefacts, i.e. information and communication technology (ICT) based artefacts is elaborated thereafter:

COP is the emergency responders' on-line conception of the emergency situation which is as coherent as reasonable, and is supported by artefacts.

In order to understand more fully the particular role of information and communication technologies in the formation of COP we made a conceptual effort to define *what functions ICT would have to fulfil and what would be the innovative features of COPE technologies* that would fulfil these functions. The approach created is an important conceptual result of the project and it will be explained in the next section.

6.2 Method of validation – usability case

The approach that we used to define the innovative features of COPE technology concept has been developed at VTT in some earlier design connections. The idea for the development of this method was borrowed from the well known case-based reasoning process used in checking the fulfilment of safety demands of complex systems, i.e. the safety case (Bishop & Bloomfield, 1998). Our innovation was to develop a "usability case" for checking the aim of systems usability demands, fulfilment of which would speak of the promisingness of complex human-system interaction concepts for future work (Liinasuo & Norros, 2007).

The original safety case concept was adapted to the needs of a usability case: Our experience in participating in design processes shows that there is a need for systematic procedures to provide evaluations and inputs into the design process. The first actual design case, in which the usability case approach was used, was when the task was to evaluate a new decision support system concept to be used in a ICT-based precision agriculture (included in Pesonen, Koskinen, & Rydberg, 2008). The next development of the usability case was made in an on-going EURATOM project MMOTION in which a pilot exercise was accomplished for testing an innovative control room design with this method (Norros et al. 2010 at http://mmotion.org.

In the case-based usability evaluation the reasoning about the quality of the system to be evaluated follows the logic proposed by Bishop and Bloomfield (1998) for safety case. In the evaluation *a case* is build and tested. The case is a documented body of evidence that provides a convincing and valid argument that a system is adequate for a given application in a given environment.

Three concepts are used to structure usability information in both safety case and the usability case. *Claims* are entities that express the quality of the system in terms of usability. The abstraction level of a claim is high but various viewpoints and levels of detail are possible. Each claim comprehends of one or more *arguments* that are instrumental descriptions supporting the claim in question. Finally, each argument is based on *evidence*, that is, various data. The representation of claims, arguments and evidence is to be as a clear and extensive way to describe the status of usability.

In the adaptation of the case-based reasoning to design contexts we made, however, some innovations concerning the formulation of claims (in Pesonen et al. 2008, MMOTION). In order to identify claims we found out that it is necessary first to develop a conceptualisation of the *innovative features of the technological system* to be evaluated. The description of the innovative features was proposed to follow a *hierarchical design logic*. The framework to be used is depicted in Figure 14.

According to this framework, at the top level we define the ultimate ends that the design should support. In our COPE case these are the Intrinsic Cognitive Demands that are associated with maintaining COP. As has been briefly indicated work for identifying the intrinsic cognitive work demands relevant to COP was accomplished in the COPE project by the HF group from the very beginning of the project, and during the project more and more data was acquired concerning the user needs.

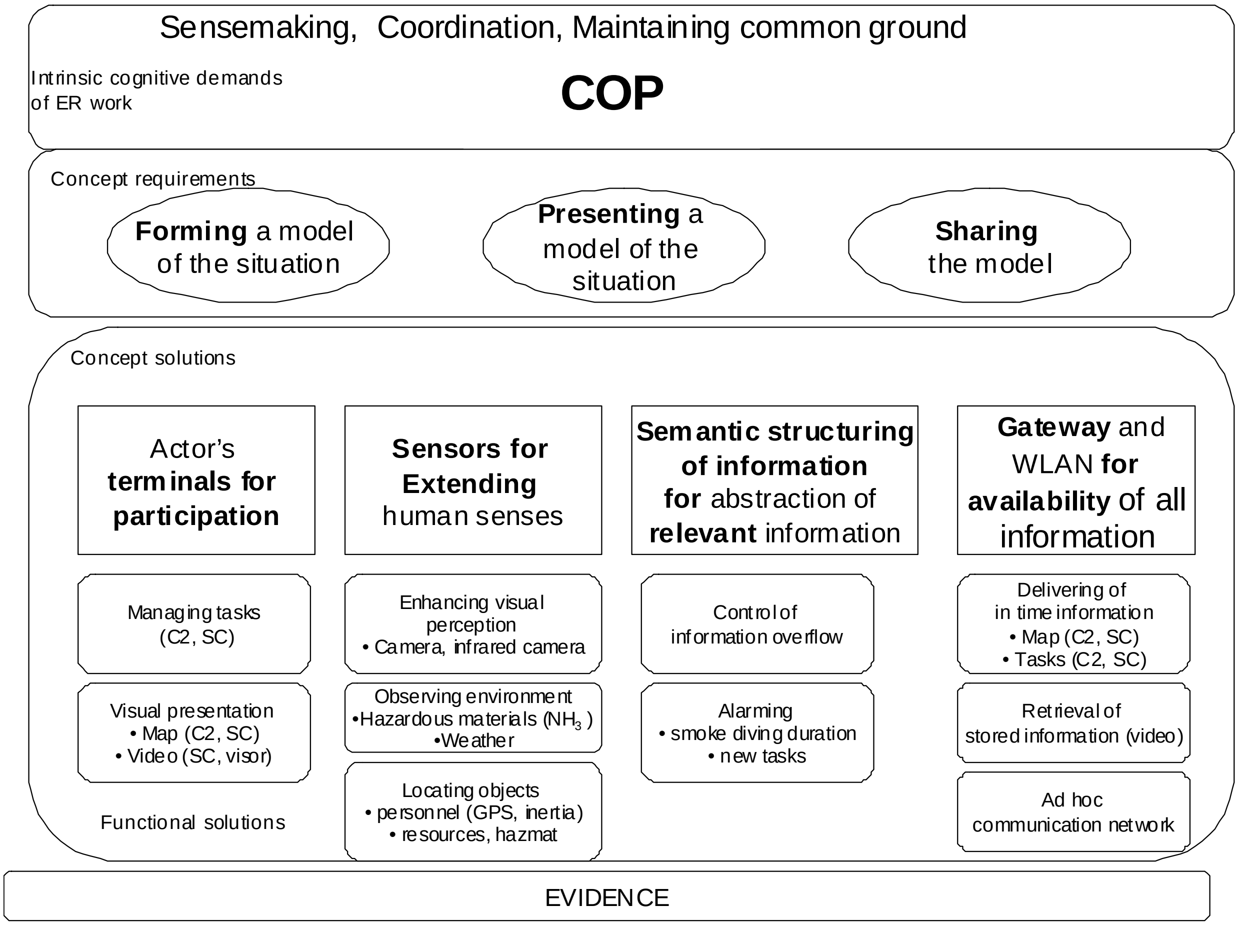

Figure 14. The framework concerning the innovative features of the technological concept used to develop claims for testing the promisingness of the technology for future usage in a usability case.

The next level of the hierarchical framework is the concept requirement level. Concept requirements were identified by the human factors group during the design process on the basis of interacting in different ways with the technology developers. Design documents also played a role here. The task for the HF group was to derive a generalisation of the concept requirements. As can be seen in the Figure 14 three generic concept requirements could be abstracted. The COPE technology concept should enable "formation of a model of the situation", "presentation of the model of the situation" and "sharing the model of the situation".

The next level below concerns the innovative features of the proposed COPE concept. These are the concept solutions that the technology should deliver. As a result of conceptual and empirical human factors analyses during the project we may propose that the key features of the COPE technology concept are: "Actors' terminals for enabling participation", "Sensors for extending human senses", "Semantic structuring of information for abstraction of relevant in formation", "Gateway and WLAN for availability of all information". These concept solutions are formulated in generic (formative) terms and should be fulfilled by any technological solutions developed for the same purposes that COPE technologies attempt to fulfil.

Then singular functional solutions of COPE project are grouped under the concept solutions as those technologies and applications that materialise the concept solutions (see Figure 14). It is usually so that the technical design is reported only on this level. This level of description is also typical in task-oriented requirement definitions and their verification that focus on certain specific technological solutions.

However, without articulating the upper levels of the concept it is not possible to evaluate technological concepts in their early phases of design, nor to connect the evaluations to the future demands of work. Making use of the more generic functional levels of reasoning about the technology enables anticipation of the potential benefits or drawbacks of the technology.

The framework illustrating the innovative features of the concept is the basis for deriving *claims*. In the cited MMOTION project (http://www.mmotion.org/) the idea was proposed that claims should be formulated as connections between the different levels of the technology concept framework which follows the hierarchical design logic. Hence, it is possible to formulate claims that state first, that

- the cognitive demands defined in the model are relevant elements of COP
- the requirements defined fulfil the described demands of the work, i.e. COP
- the concept solutions fulfil the requirements
- the functional solutions are able to materialise the concept solution.

We defined claim tables for the COPE technology solution that follow the above logic. The task then was to use the *evidence* we have available from the different end-user interventions to see whether the data supports these claims or not (see Appendix 1). In our type of data (which is not abstract measures but content laden observations or opinions) the *argument* that connects a piece of data to a claim, i.e. makes the data meaningful, is typically implicit in the data. We also anticipated that end-user activities or user experience may often be such that a connection between the concrete “functional solutions”, .e.g. managing tasks with the C2 system, is in the evidence connected directly to the added value of this system to support COP, without explicit connections to “concept solutions” or to “concept requirements”.

In order to have data available to be used as *evidence* it is of course necessary to collect data according to a systematic data collection procedures (see. table 1 in section 4.2) and careful analyses of the data. Different kinds of analyses were applied and steps taken when performance and interview data from experiments, user tests, real-life action and decision making or user interviews were developed to knowledge to be used in the evaluation. As a result statistical results or qualitative results concerning user performance, ways of working, users experience, communication etc. are achieved. Presentation of these analyses is not the focus of this report. D2.2 already explicated part of the analyses. Those analyses accomplished with regard to the Kuopio 2 and Kuopio 3 studies comprehended

- statistical analyses of questionnaires in Kuopio 2 and 3
- content analysis of the written protocols of the debriefing sessions in Kuopio 2 and 3
- review of the walkthrough in Kuopio 3
- review of the video-taped COPE-technology usage at three command levels (FF, Sc; IC and upper command) in Kuopio 3.

The results of these analyses and all the previous analyses were drawn into the claim tables as human factors evidence concerning the COPE system concept. The data comprised 270 pieces of evidence (see Appendix 1).

6.3 Results of validation

The pool of human factors evidence that is available for reasoning about the promisingness of the COPE technology concept for future use is to be found in Appendix 1.

Promisingness of COPE technology concept

The Table 3 provides an overview of the content of the claim that the evidence relates to, the type of evidence e.g. positive of negative, and the number of evidence.

Table 3. Content, type and amount of human factors evidence available of the COPE technology concept.

	positive	Negative
Actor's terminals for **participation** *supports/enables* **Formation** of an interpretation	18	7
Actor's terminals for **participation** *supports/enables* **Presenting** a model of the situation	11	2
Actor's terminals for **participation** *supports/enables* **Sharing** the interpretation	26	6
Sensors for **extending** human senses *supports/enables* **Formation** of an interpretation	42	8
Sensors for **extending** human senses *supports/enables* **Presenting** a model of the situation	12	2
Sensors for **extending** human senses *supports/enables* **Sharing** the interpretation	19	0
Semantic information system for abstraction of **relevant** information *supports/enables* **Formation** of an interpretation	12	1
Semantic information system for abstraction of **relevant** information *supports/enables* **Presenting** a model of the situation	2	3
Semantic information system for abstraction of **relevant** information *supports/enables* **Sharing** the interpretation	13	0
Gateway and WLAN for **availability** of all information *supports/enables* **Formation** of an interpretation	7	0
Gateway and WLAN **for availability** of all information *supports/enables* **Presenting** a model of the situation	1	1
Gateway and WLAN for **availability** of all information *supports/enables* **Sharing** the interpretation	29	2
Functional solution X *supports/enables* **COP**	37	9
Total	**229**	**41**

The lines of the table express how many supporting or questioning evidence could be found for the four concept solutions ("actors terminals for participation", "sensor for extending human senses", "semantic structuring of information for abstraction of relevant information", and "Gateway and WLAN for availability of all information") to fulfil any of the three requirements ("formation, presenting, sharing of an interpretation").

In addition to those evidence indicated in Table 3 there were 19 suggestions for improvement of the COPE concept. These proposals came as a side effect as the end-users were not deliberately urged to make proposals.

As one can see from Table 3, the major part of the evidence was confirmative. The end users expressed that different characteristics of the COPE technology concept were such that they could support formation and maintenance of COP.

In Figure 15 the overall result of the validation evaluation is indicted. The green arrows on the COPE technology framework demonstrate which connections between "concept solutions" and "concept requirements" i.e. respective claims have received support by the evidence collected during the project.

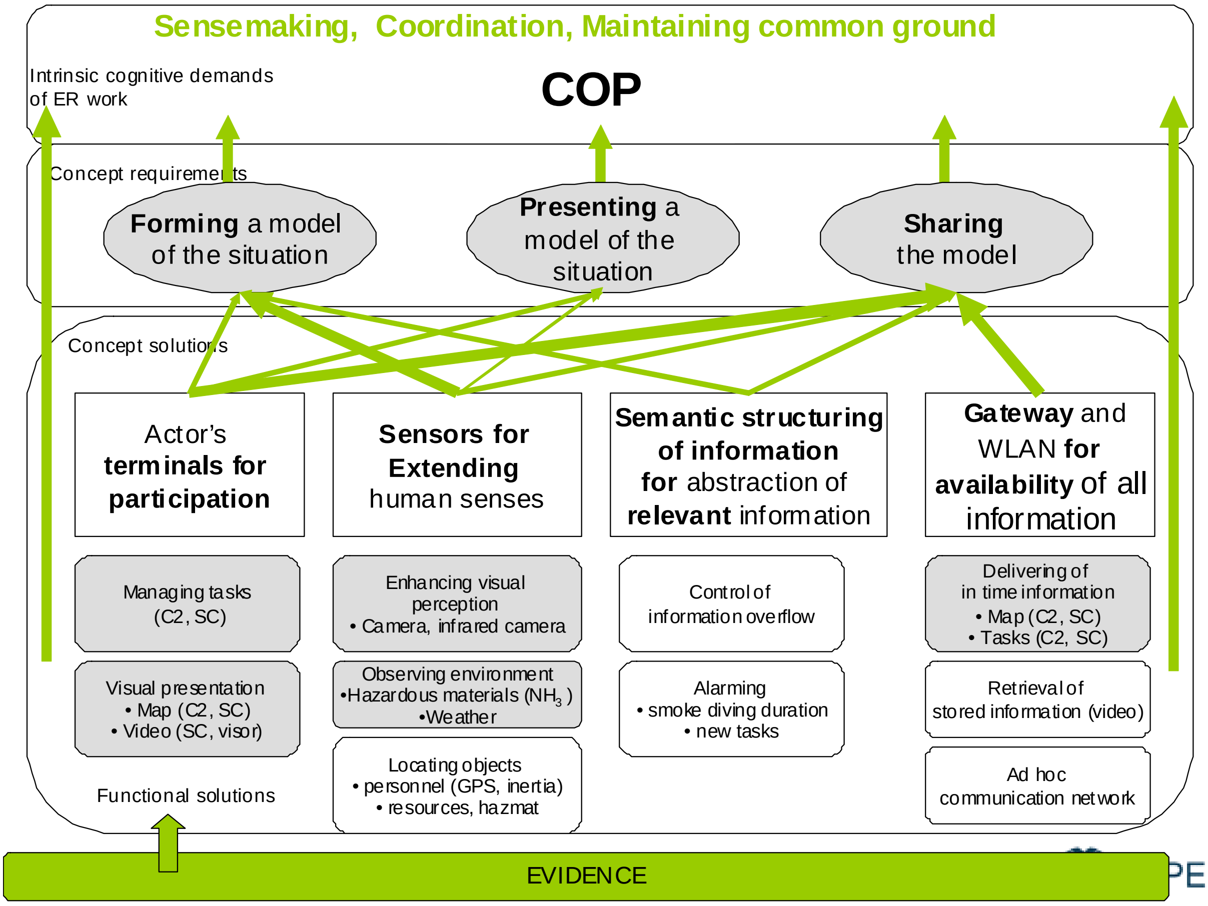

Figure 15. Evidence supporting the claims concerning the relevance of concept solutions for the concept requirements and further with regard to COP. The thick arrows indicate more that 25 pieces of evidence, the thinner lines 10-25 pieces of evidence.

When considering the evidence with regard to the four innovative features of the COPE technology concept the following results may be mentioned (direct citations to typical evidence are presented in italics):

Actors terminal for participation

The end-users had no difficulties to express their opinions about this innovative feature of the concept. It appears that the possibility to participate in the formation of COP via new kinds of equipment was welcomed in particular because sharing an interpretation would then be easier and efficiency of emergency response more efficient: *" IC: It was useful to mark the patient assembly point to the C2 map, because the ICs did not have to be separately informed of its location in order to pass the information to their units ".* The possibility for efficient tasking was brought up by ICs and SCs. This feature was not used by the upper command (and was not adapted to their needs) but upper command found the map presentation promising for sharing the interpretation, however. Otherwise upper command relied on telephone or direct verbal communication and traditional media for managing the resources during the accident.

Participation via new end-user terminals was also found to support forming an interpretation of the situation by the incident commander and the sector commander SC. One SC expressed the benefit by stating: "*It is an extremely unpleasant situation for the SC to know that the team is inside the building and self be outside. Video or thermal camera image would help make sure that everything is alright with them.*" It is evident that the safety of emergency responders could be improved if the position of the smoke divers was seen on the map.

Not that many evidences were found to connect the possibility to participation with the requirement of presentation. One IC however crystallized the benefit well when stating: "*What IC draws should be the visible for everybody!*" The lesser emphasis on presentation may be due to the fact in the present work presenting an interpretation of the situation is not that usual, rather the interpretation remains implicit or as an expression in verbal communication.

Sensors for extending human senses.

This innovative feature was the solution that received the largest amount of positive support. It was clear that the sensor information from hazardous materials application worked very well in all real-life exercises. The end-users did find the possibility to receive actual measured concentrations of gas and the interpretation of its dangerousness very helpful for interpreting the situation and for planning proper actions. *"P2 wondering about the dangerousness of the cloud: they look at the map and see red dots, interpretation: danger to life!"*

Providing a good presentation of sensor information was found important for the first responders to comprehend the information. The hazardous material application was found to have a good visual presentation in the map. The end-users particularly liked the initially used, very robust version of the presentation. At this point it may also be noted that the interfaces designed for the SC applications were generally found good due to their clarity.

The thermal camera picture and video from smoking diving were welcomed for safety reasons. It was of course seen that it increases formation of the interpretation by the individual who is smoke diving, but it was in particularly welcomed for its possibility to support sharing of the interpretation of the situation. Sharing function was also seen wider frames as one IC commented that: *"Media can be easily informed about the areas in which gas masks or the like should be used because substance concentration is so high there II2-VI3."*

Semantic structuring of information for abstraction of relevant information

This innovative feature in the Cope technology concept was the one that did not receive that much positive or negative support. It is no wonder because this solution deals with the underlying semantic structuring of information that remains invisible for the end user even though it is very important in providing relevant and appropriate amount of information for the first responders use. During the COPE project the ESC representatives kept emphasising the significance of defining the "value of information" meaning its relevance to the situation. A good solution in the semantic structuring of the data available is a key issue there. The end users did sometimes express opinions accomplish action in which we were able to interpret as signs of understanding the value of this concept solution for the forming the interpretation of the situation. This became evident in their notes concerning information needs in different situations and the need to up-date the information according to the proceeding situation: " *"Information of these sensors should be readily available to Incident Commander's digital systems so that whenever something deviating has happened, Incident Commander has immediate access to that information", or that "Combining information (GPS and units) is useful."*

There were also notes concerning the problem of overload of information during an ongoing task: *This system should analyse the information that is coming and only show what I need.* With regard to the sharing of information the end users did mention the difficult issue of defining relevant information for different partners.

Gateway and WLAN for availability of all information

End-users were well aware that the Gateway and the wireless network was an important part of the COPE technology concept. This was expressed in quite many positive remarks concerning the possibility to share information available in the gateway. It can be assumed that in the end-users' minds some of the experience technical difficulties in user terminals were compensated by the awareness of the potential of the gateway, not only on on-line activities: *"With this system operational picture that the IC has could be transferred to the sector commanders and in some situations to fire fighters*, but also for learning from experience:. *"I think in this COPE the gateway is a good thing. It is possible to archive everything."*

In the evidence listed under this innovative feature were not directly dealing with technology but expressed the end-users wide needs for communicating with other emergency responders. The currently available TETRA telephone connection was used heavily but in complex situations the commanders wanted to have face-to-face discussions. Potential for communication could be increased by an appropriate communication network with registering capabilities. *"The updating frequency was sufficient. The fact that there is a Gateway where the information goes, that is good, and that information that is used by one person would be available to everybody. Now we didn't quite reach it as we used a different system than they did."*

In conclusion, we may say that it could be verified, based on end-users interviews in three countries, and in analyses of present ER activity, that particular cognitive functions/demands i.e. sensemaking, coordination, and maintaining common ground play a central role in managing situations, and that these cognitive functions are required to maintain COP.

Our theory-based hypothesis was that there are three basic concept requirements for COP i.e. “Forming, Presenting and Sharing a model of the situation”. The experiences gained in the usage of singular technological solutions demonstrate that these requirements can be meaningfully connected to the three cognitive functions, and that the exploitation of the advantages of singular technologies is expected to support COP.

Our evidence provides support for the relevance of the four technological ”concept solutions” of the COPE concept. In those cases where less evidence was found (“Semantic structuring of information”) it is possible that due the technical immaturity of the functional solutions related to it, the end-users had difficulties to identify the relevance of the solution. It could however be found, that even though technical functioning was not good in a particular “functional solutions” (e.g. indoor localisation), the end-users were able to identify and express the relevance of the higher level concept solution (“Sensors for extending human senses”)

Technology development typically focuses on singular applications. Via the analysis of the usage of these technologies we identified the more generic functional characteristics of technologies needed in the studied environments i.e. “Actor’s terminals for participation”, “Sensors to extend human senses”, “Semantic information structuring for abstracting relevant information”, “Gateway and WLAN for availability of all information”.

Overall user experience

As a final piece of evidence to evaluate the promisingness of the COPE technology concept we shall present some of the results of the user experience questionnaire given to the COPE technology users to be filled during the debriefing discussion.

As can be seen from Figure 16 all respondents of the user experience questionnaire agreed that the new but fully developed technology would enhance the common operational picture to some extent. Almost half of the respondents were in complete agreement with the statement.

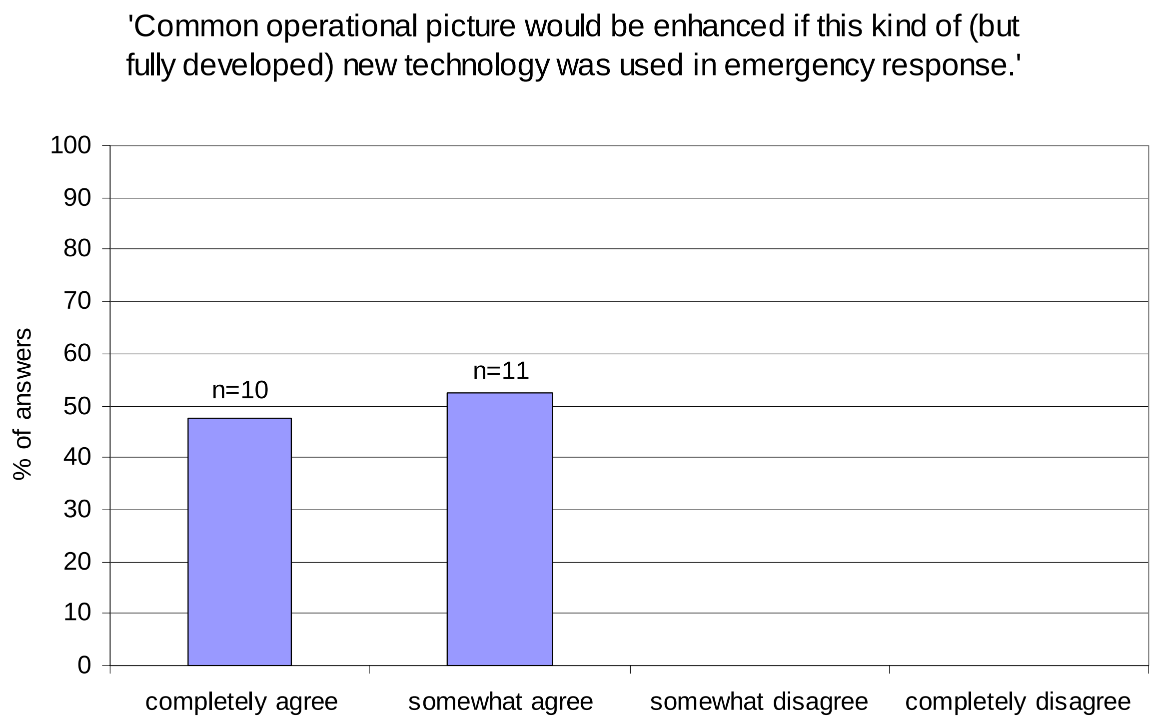

Figure 16. The percentage distribution of all answers related to the claim 'Common operational picture would be enhanced if this kind of (but fully developed) new technology was used in emergency response'.

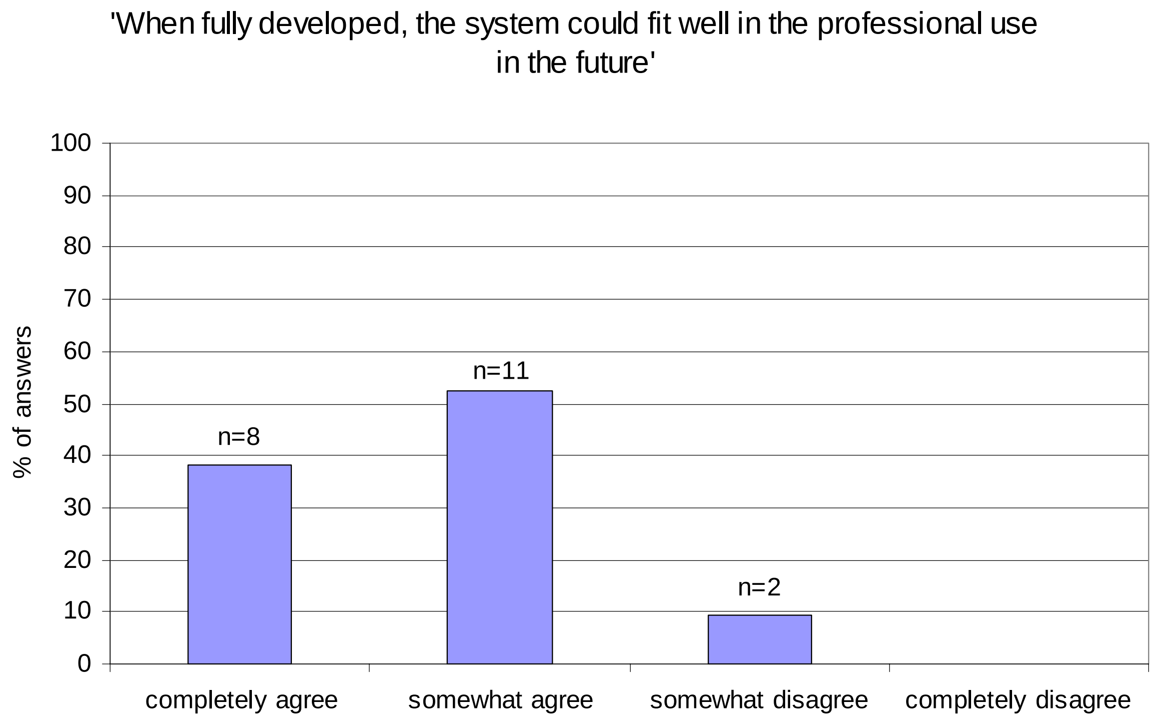

Figure 17. The percentage distribution of all answers related to the claim 'When fully developed, the system could fit well in the professional use in the future'.

A majority of respondents also felt the system could fit well in professional use (Figure 17). Only two respondents disagreed somewhat.

The end-users were also asked to give an evaluation of the technology concept using the school grading from 4-10. The average given was 6.13.

We interpret that the school grade reflects the users' experience of the functioning of the technology during the trials. From that actual perspective maturity was not very good. The other two questions were most likely interpreted to deal with the potential this technology was judged to have in the future, and there the assessment is higher. The end-users seem to look beyond the still immature technical realisation of the concept.

Finally we can see in Figure 18 that participants with over 25 years of experience were most positively convinced of the suitability of the system.

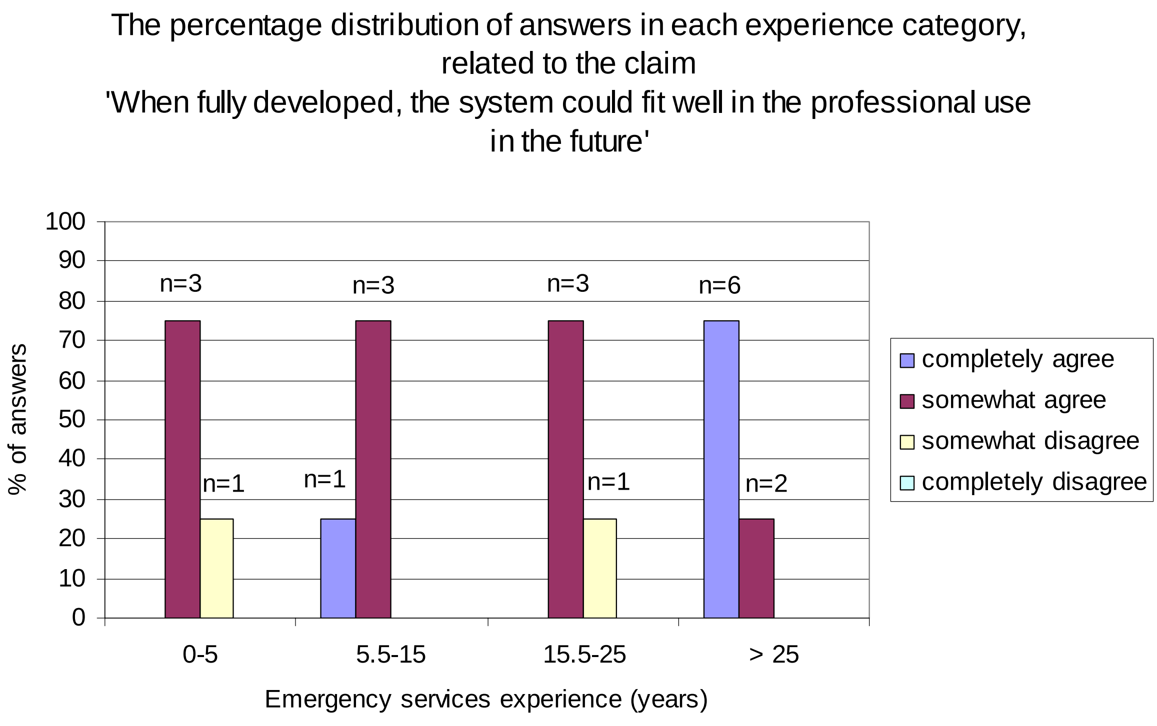

Figure 18. The distribution of answers in each experience category, related to the claim 'When fully developed, the system could fit well in the professional use in the future'.

7 Conclusion and Final Remarks

We have found that joint design among technical and human factor experts is important especially when designing technical solutions for highly demanding and safety-critical work. This enables early evaluation of innovative solutions.

In order to be able to accomplish this goal, a proactive evaluation during the design conceptual work is needed. In the COPE project we used and developed further a conceptual tool for defining the innovative features of the system under design. This hierarchically structured framework of the technology concept could be used as basis for developing claims concerning the designed system which can be tested in a Usability Case evaluation process.

The participation of end users is of vital importance when designing new tools for demanding work. Without substantial understanding of the domain and working practices it is very difficult to create new tools that support work in life-threatening situations. In the COPE case we organised many interventions to the end-user situation and worked together with end-users in the form of interviews, workshops, design sessions, usability tests and even on three different large scale live experiments with tens of end-users participating.

We feel that the promisingness of the COPE concept was shown in the project. The human factors input was very crucial in this regard, because the methods developed by the HF group enabled evaluation the potential of the COPE technology concept for the future work. It was possible to see beyond the possible disappointments that the partially immature technological solutions in the difficult real-life environments could have brought.

The analysis of the comprehensive data collected during different end-user interventions and used as evidence for evaluation allows us to state that the four innovative concept solutions *Actors terminal for participation, Sensors for extending of human senses, Semantic structuring of information for abstraction of relevant information, and Gateway and WLAN for availability of all in formation* could all be: a) materialised by some functional solutions and b) evaluated to promote general requirements of a system that should improve the Common Operational Picture.

It was also possible to identify some clear issues for future technological development work. These issues focus on further development of the semantic structuring of information, and the development of an integrated communication systems in which different media (traditional and new) and also human first responders inputs could be combined in an efficient way.

Finally it is necessary to say that when technologies are implemented in work processes the work demands may change quite significantly and new work demands are created. This is due to the fact that human and technology form joint intelligent systems that function as a whole in complex situations. In the present project it became clear, for example, that when communication of information by ICT based tools the entire structure of the concept of operations will change, i.e. there were signs that the traditional hierarchical (even mainly top-down) organisation of work will become more networked when communication is more interactive, available on request and distributed more widely. In a safety critical work of emergency response where procedures and well rehearsed ways of working play a central role much more effort should be devoted in technology development projects to understanding the interaction between technological tools and standard operating procedures.

Appendix 1: Evidence table

Source Key

I.int	**CDM interview before Kuopio trials**
K1	**Kuopio trial 1**
K1.UXint	User experience interview
K1.o	Observation
K2	**Kuopio trial 2**
K2.o	Observation
K2.que	Questionnaire
K2.db	Debriefing
K2.trainint	training interview
K2.focgroup	design focus group (discussion session after trial with designers et al.)
K2.designprops	design proposals (design suggestions)
K3	**Kuopio trial 3 (final trial)**
K3.o	Observation
K3.que	Questionnaire
K3.db	Debriefing
K3.vero	verification observation
K3.verint	verification interview
K3.focgroup	design focus group (discussion session after trial with designers et al.)

	Actor's terminals for participation *supports/enables* Forming a model of the situation	Source
1	Thermographic camera is used for finding the heat source. As the camera scales measuring unit according to the surrounding heat level, it can also show the location of the human being by showing also small differences between heat levels	K1.UXint
2	Apparently, thermographic camera is one of the central tools used in the emergency services. If that could be made light enough to be attached to each fire fighting gear, that would help a lot of the fire fighters' work	K1.UXint
3	Brew-FF: The wrist control unit was surprisingly functional.	K3.db
4	Brew-FF: All equipment was alright and reasonable. Using the equipment was not as unpleasant as could have been.	K3.db
5	FWF-IC: The battery life of equipment was unclear. The technology is not of much use on the way to site since emergency response centre sends a text message and they do not have similar technology and possibly cannot offer any extra information.	K3.db
6	More valuable information e.g. of the target fire. [SC]	K3.que
7	When going to a rescue mission, there's not always time to gear up with these devices. The device should be integrated to the existing equipment. It's time consuming to gear up for a smoke dive as such, and every separate device or accessory takes more time. Sometimes situations evolve so quickly that there's no extra time. [C2 user]	K3.que
	Managing tasks (C2, SC)	
8	The tasks that we wrote were picked up from the radio talking. The system was so slow it didn't support us at all, it didn't suggest anything, didn't remind us of anything, only demanded attention from us. We wrote there as many tasks as we could and Markus was sleeping when tasks of each sector were delivered. He put them all in one pile and as it was problematic to write, [even if] there were not many tasks.	K2.db

9	[Question: I was in the car of the "real" IC and there the driver assisted IC as it normally happens. The driver wrote on the wall all sectors and everything online what tasks were delivered. Could this be more efficient?] Answer: Definitely more efficient than this present [way of working]. Clicking the PC doesn't result in as an illustrative result as when writing manually. The whole [way of working] depends on the process and the present process is designed so that the system is known in advance and it is known what to write there. It is possible that if a corresponding system that would be supported by IT technology would become and you could click on the menu to choose the correct option, you could get it more quickly.	K2.db
10	Question by interviewer: If you were asked what kind of support you need for decision making, what would it be, for instance in this kind of accident? Answer by , augmented IC: In early phases of management, the task is resource allocation. The resources are limited and there is high pressure of time. So I think that the listing of the tasks related to the current process could be useful. The PC could deliver the tasks as ready-made; for instance, now we have a traffic accident, the normal tasks that are related to traffic accident would appear and the system could suggest which unit takes care of each task. Then you could outline what are the tasks that should be performed, what kinds of resources I have now and in the near future. The system would quickly calculate what the unit that could perform some specific task is or whether it is perhaps you yourself who is doing it. Then you would approve it and by one clicking the information would be delivered to the performing person. I have been dreaming about this. It is quite far from the present way of working.	K2.db
11	Design proposals for functionalities that support the forming of task-status related operational picture: accident groups to support the choice of an appropriate task, reporting of each task's status as well as their starting and finishing times.	K2.designprops
12	"It could be useful if the leader (IC) got some kind of a task list, to help him to remember his tasks. And a suggestion which sub officer (SC) should do it (for example this unit looks like they could handle this task)"	K2.focgroup
13	The system does not support "functional sectorisation" which is fundamental in finnish conops (drawing sectors on the map gives the sectors a geographical meaning) [C2]	K2.trainint
14	Task tool worked as a memory aid in the situation, IC used the concepts of the interface in managing tasks	K3.o
	Visual presentation of the situation (Map [C2, SC], Video [SC, visor])	
15	wind direction on a map covering the incident area. If the map is up to date and could be zoomed in and out as needed and if the application would be designed to estimate the spreading of the substance in the surrounding area, it could be very informative in showing the probable threat of the chemical cloud on population in these areas.	K1.o
16	it would be practical to have a map with the needed details to be readily available for rescue purposes	K1.UXint
17	It should be possible to update the visual symbols according to the situation	K2.trainint
18	When entering a building, the floor plan is very valuable information	K2.trainint
19	Brew-SC: It is an extremely unpleasant situation for the SC to know that the team is inside the building and self be outside. Video or thermal camera image would help make sure that everything is alright with them.	K3.db
20	Hazmat-SC: Video image was blurry. The tap could not have been turned off using the video image since the fire fighters' location could not be seen. If the fire fighter moved slowly, camera image was moderate.	K3.db
21	Hazmat-SC: It would be good if the camera image was actually visible.	K3.db
22	P2 kyselee mitä laitteita on miehillä käytössä, etsitään ruudulta I2-VI1 - katsovat PC:ltä: yksi mies näkyy 5:40	K3.o
23	käännetään kartta oikein päin	K3.o
24	P2 looks at the map first time at 23 min into the event	K3.o
25	The location of the wlan stations could be shown in order to position the car so that network is available [IC]	K3.o

	Actor's terminals for participation ***supports/enables*** **Presenting a model of the situation**	Source
26	Text messages on the helmet mounted display would be great as it is very very noisy in a smoke diving situation. The radio traffic is mixed with all other noise, for example a unit commander could send a message ”Go directly to the next room, there is a patient there” [EMS field]	K3.focgroup
27	In current C2 tasking hides the map, there should be separate screens	K3.focgroup
	Managing tasks (C2, SC)	
28	Question by interviewer: If you were asked what kind of support you need for decision making, what would it be, for instance in this kind of accident? Answer by , augmented IC: In early phases of management, the task is resource allocation. The resources are limited and there is high pressure of time. So I think that the listing of the tasks related to the current process could be useful. The PC could deliver the tasks as ready-made; for instance, now we have a traffic accident, the normal tasks that are related to traffic accident would appear and the system could suggest which unit takes care of each task. Then you could outline what are the tasks that should be performed, what kinds of resources I have now and in the near future. The system would quickly calculate what the unit that could perform some specific task is or whether it is perhaps you yourself who is doing it. Then you would approve it and by one clicking the information would be delivered to the performing person. I have been dreaming about this. It is quite far from the present way of working.	K2.db
29	Design proposals for functionalities that support task-status related operational picture for IC: accident groups, task allocation, reporting of task's status and starting and finishing times of a task performance.	K2.designprops
30	In the system the sectorisation should be pre-designed according to the available resources. The normal tasks should be pre-defined and modifiable when needed. [C2]	K2.trainint
31	The commander must deliver the tasks and have it clear for himself and others also who is doing what [C2]	K2.trainint
32	Hazmat-SC: With all equipment it is hard to notice an alert on the terminal.	K3.db
	Visual presentation of the situation (Map [C2, SC], Video [SC, visor])	
33	Design proposals for choosing the most important symbols or elements to use for presenting a model of the accident and emergency response at the site: operations-related information (spatial information and important functions) and accident-related information	K2.designprops
34	"What IC draws should be the visible for everybody"	K2.focgroup
35	In a geographically wide situation map is very important [C2]	K2.trainint
36	Police/highcommand: A drawing function in addition to the symbols would have been useful.	K3.db
37	EMS-hospital: It would be extremely important to see near the map edges the approaching EMS units and their estimated time of arrival.	K3.db
38	"Map needs to present resources available and on the way"	K3.focgroup

	Actor's terminals for participation ***supports/enables*** **Sharing the model**	Source
39	[What should be amended?] An order screen that can be checked and put aside. An audio signal with incoming order. Auditory communication superior -> team. Team-> superior communication using hand signals. [FF]	K3.que
	Managing tasks (C2, SC)	

40	Question by interviewer: If you were asked what kind of support you need for decision making, what would it be, for instance in this kind of accident? Answer by , augmented IC: In early phases of management, the task is resource allocation. The resources are limited and there is high pressure of time. So I think that the listing of the tasks related to the current process could be useful. The PC could deliver the tasks as ready-made; for instance, now we have a traffic accident, the normal tasks that are related to traffic accident would appear and the system could suggest which unit takes care of each task. Then you could outline what are the tasks that should be performed, what kinds of resources I have now and in the near future. The system would quickly calculate what the unit that could perform some specific task is or whether it is perhaps you yourself who is doing it. Then you would approve it and by one clicking the information would be delivered to the performing person. I have been dreaming about this. It is quite far from the present way of working.	K2.db
41	Design proposals for functionalities that support task-status related operational picture between IC and SC and between IC and higher command: accident groups, task allocation, reporting of task's status and starting and finishing times of a task performance.	K2.designprops
42	The tasks of an individual fire fighter is too detailed information and clumsy [C2]	K2.trainint
43	FWF-IC: IC and SC are situated relative close to each other and thus a communication medium is unnecessary.	K3.db
44	FWF-IC: SC terminal is more practical [than IC-SC] in the SC-FF communication. Information also from the higher level command might be useful.	K3.db
45	the system was not used at all for managing tasks during the event	K3.o
46	Dynamic re-allocation of tasks is needed in the situation	K3.o
47	IC (CSO) gave tasks to units via C2	K3.o
48	IC tries to find task status information from C2	K3.o
49	In my opinion the data transfer should be bidirectional. I find it important that sector commanders should be able to send messages to incident commanders. Currently the only information is the status (in progress, completed). The system as such does not reduce the usage of VIRVE. [C2 user]	K3.que
50	No se, että tuleeko sillä lisäarvoa, tässä tehtävien antamisessa kirjallisena, ehkä se on selkeempi, jos et saa radioviestistä selkoa, niin saat sen kirjallisena, että mitä sun pitäis tehdä. Se voi olla jossain tilanteessa helpompi. Ja no se, että jos tarvii mennä sisään kohteeseen, niin ei välttämättä ole käytännöllinen laite, mut jos oot ulkopuolella, niin voi olla lisäapuna siinä. (Tarkentava kysymys siitä missä tästä olisi hyötyä:) Vaikka ihan rakennuspalossa, tiedustelutilanne, vois olla, ja miksei kemikaalionnettomuuskin yhtä lailla. Yhtä lailla vois toimia. (SC)	K3.verint
	Visual presentation of the situation (Map [C2, SC], Video [SC, visor])	
51	"I think that in the level of SC, if the SC would receive his sector clearly marked in a map interface so that the area of immediate danger [inner cordon] is defined, that would be clearly better than an approximation of 50 metres." (augmented IC)	K2.db
52	"If a gas ventilator should be closed for instance, it is very tedious to explain how many steps the fire fighter should go to which direction before finding the ventilator. With this technology, the expert could instead stand outside the building [beside the SC] and he would see [from the display] that the ventilator is there, turn it in that location, that would be very easy. So when an expert that is not a fire fighter is needed to advise, this would be very useful." (augmented IC)	K2.db
53	"Yes yes, we have been thought and we can all draw quickly a beautiful picture of the accident site with the target accident, location of cars and buildings and so on but of course, if the same information could be delivered directly [to all parties] and it could be looked at whenever needed, instead of a drawing on a whiteboard, that would be very useful. Especially this accident with hazardous material is delicious because the area of immediate danger [apparently about the same as “inner cordon”], that is, the area in which it is not safe to be without proper protection wear is not visible at the site even if it is defined. If that could be delivered to all actors, that would be enormously useful. The same applies to forest fire. The outline of the situation can’t be perceived by mere watching the forest." (, augmented IC)	K2.db

54	Design proposals for choosing the most important symbols or elements to use for sharing a model of the accident and emergency response at the site among all stakeholders (at least IC, SC, higher command, possibly also to police and ambulance): operations-related information (spatial information and important functions) and accident-related information.	K2.designprops
55	EMS-fieldcommand: IC: It was useful to mark the patient assembly point to the C2 map, because the ICs did not have to be separately informed of its location in order to pass the information to their units.	K3.db
56	EMS-fieldcommand: Emergency services could benefit from video image from FFs to SCs or ICs.	K3.db
57	C2: käyttävät projektoitua kuvaa katsellakseen yleistilannetta I2-VI	K3.o
58	command centre appeared on te map	K3.o
59	start to draw the immediate danger zone, is not successful immediately, causes the system not to wark, neede booting	K3.o
60	Identify the function of the system to store information (earlier inserted info not lost when sytem booted)	K3.o
61	defining the gathering place for patients; intention to do immediately but was postponed	K3.o
62	the gathering place was accomplished when commaners notices that one unit was to define a second gaterhing point !!	K3.o
63	Police command centre was palced on teh map to inform participants	K3.o
64	P2: looking at the map and thinking witht eh police that that we need to gordon far enough, critical issue is the spreading of the cloud	K3.o
65	place a symbol on the map that the elak has been stopped to inform everbody 50 min	K3.o
66	P2 aseks whether any information was uploaded into the system from sectors; only one succesfull uploading; alla sectors falled out of the Gateway	K3.o
67	Users need visual representation of resources, how many men and with what equipment in a unit	K3.o
68	Map is handy as I (IC) can draw on it and it becomes visible to other parties	K3.verint
69	Map is handy as I (IC) can see where the other units are located	K3.verint
70	notice that some unit has succeeded to inform about the rinsing place by placin a symbol on the map	

	Sensors for extending human senses *supports/enables* Forming a model of the situation	Source
71	Hence, no clear overview was obtained about the local weather.	K1.o
72	Fire fighters work in pairs, completing each other's work and providing safety to one another. Furthermore, nowadays also the Sector Commander goes into the burning building with his crew, holding the thermographic camera to secure and assist the work of his fire fighters	K1.UXint
73	From a hardware point of view the camera has a lot of potential	K3.focgroup
	Enhancing visual perception (camera, infra red camera)	
74	"Thermal camera in a helmet is a very good idea, it is very useful, especially if you see it yourself on the display but the device must be developed (…)." (augmented SC)	K2.db
75	Comment on thermal camera: idea is good, realisation is not yet functional	K2.que
76	The normal video is important in larger situations in which the higher command levels arrive after wen operations have started. The video could be used in briefing them what has happened already [FF system]	K2.trainint
77	In a smoke diving situation with the thermal camera it is very easy to detect the patient and get an overview of the situation for example about temperature differences and location of doors etc. [FF camera]	K2.trainint
78	Brew-FF: The equipment did not bother too much although radio had to be left off.	K3.db
79	Heat camera feature very good. [C2 user]	K3.que

80	Joo ehdottomasti, se olis pelkästään toimintona se lämpökamera vaikkei se lähettäis videokuvaa minnekään niin kun mennään tuolla savuisissa tiloissa ihan umpipimeään niin totta kai siit on hyötyä. Kun ihminen sit kuitenkin säteilee lämpöä sen löytää sieltä. Me käytetään muutenkin lämpökameroita niin totta kai se on hyödyllistä. (FF joka käytti palomiehen varusteita)	K3.verint
	Observing environment (hazardous materials (NH_3), weather)	
81	What is the actual concentration and spatial spreading of the substance	K1.o
82	Aiding comprehension of - What is the needed level of protection of the first responders II2-VI1	K1.o
83	Aiding comprehension of - Emergency medical service was not told to be properly protected so that when they started to take care of the patients, they were affected by ammonia, which would have lead to ammonia-induced symptoms if real ammonia had been used	K1.o
84	Aiding comprehension - What is the working area where it is possible to work without breathing masks When on the way to the incident site, IC ordered the danger zone by defining the location for the vehicles where they should park. Danger zone was set to 25 m to all directions from the leak	K1.o
85	Aiding to - Planning of the protection zone and the protection of the population	K1.o
86	If sensors were able to identify several substances, they could be used in many incidents where hazardous material is involved. They could be used both for identifying the substance and, if several mobile sensors were used, for evaluating the diffusion of the identified substance.	K1.o
87	substance identification was rapid so that the new technology would not have had any effect on it	K1.o
88	WSN technology could have shown reliable information about the chemical and its concentration at and near the accident if mobile sensors were used. This would have shown directly what the extension of the danger zone is.	K1.o
89	a minor improvement, the new technology could have shown the level of ammonia concentration on the injured people, helping in deciding what protection should be worn when treating these people	K1.o
90	WSN technology shows real concentrations so that protection zone could be defined according to the real situation when using the new technology	K1.o
91	No effect of the new sensor technology on current activities. If WSN technology would be used, mobile sensor spreading could be monitored by looking at the map interface, where the sensors are (and what is the chemical concentration at that location)	K1.o
92	What is the direction and speed of wind, and the temperature and humidity of air WSN technology has weather unit attached so that local weather is known when using it. This is important when hazardous substances are involved as local weather condition can be different from generally known, officially delivered weather information	K1.o
93	uncertainties than experience-based estimations. WSN technology shows local wind direction, helping in these estimations. In this study, the direction of wind was constantly changing, so WSN technology could have provided useful information for decision making	K1.o
94	in specific locations. That information, combined with the information of wind, also provided by WSN technology, offers better possibilities of population protection when efforts could be focused on locations that really need protection	K1.o
95	The use of the computer software was very easy: it was easy to start to use and while using it, there was nothing that the user should remember. This was found very important as in the hasty and demanding situation, no more load in the form of secondary tasks (operating the tools) should be put on	K1.Uxint
96	Sensor spreading required here the use of two fire fighters. The less human resources are needed the better so the optimal way of delivering the sensors to the field has to be II2-V1	K1.UXint
97	Sensor spreading should be started as early as possible so that sensor information would be available already in the beginning of the rescue services. In the study it took 7 min for the fire fighters to start sensor spreading II2-VI1	K1.UXint
98	real information about substance concentration in various locations	K1.UXint

99	Substance information is correct; it does not require contrasting the use of one option to use in current operations. C37 the possibility of human error is diminished with the use of sensors A39	K1.UXint
100	The level of protection needed for The fire fighters is easily evaluated. B39	K1.UXint
101	The greatest bottleneck in the use of the WSN technology was that its use employed human resources in a situation where every fire fighter is valuable.	K1.UXint
102	It delivered immediately valuable information as it showed wind direction and speed, both important as they affect the procedures to be done.	K1.UXint
103	The delivering of the gas sensors was perceived by Johannes (IC) as an additional task. The unit from which the delivering person belongs to was heavily loaded; if that were a real situation, nobody would have gone to set up sensors by no means.	K2.db
104	For instance, if the direction of the chemical cloud would have been estimated, in accordance with wind direction, and drawn in a map, [and the application would have suggested an area of immediate danger ["inner cordon"]], that information would have been needed. Now the application didn't support us at all.	K2.db
105	Even if the sensor would have been attached to the vehicle, it would have provided information only of that point and below the wind. IC would know about the danger in other areas only if somebody would go there with the protection wear and put the sensor there – this doesn't sound usable.	K2.db
106	If the sensors would provide information about chemical concentration continuously, that would be information (but at the moment the technology was so clumsy that information arrived sporadically).	K2.db
107	Thinking about how to make things work smoothly; if the sensors would be so small that the normal protection wear for chemicals could include them, without a need to put them separately on, and the measuring could be followed while men are walking so that it would be known what is the identity of each sensor wearer and this information would be traceable also afterwards, then this all would provide added value. At the moment we are quite far from that.	K2.db
108	Setting sensors on the ground took place so late and the sensors were located quite close [to the accident site]. They would be useful only if they would be a kilometre away or so. That requires the use of a car.	K2.db
109	Now we don't have any idea of what the cloud did when further away, in the distance of one kilometre or so.	K2.db
110	Quite soon we saw that the concentration is zero here near. Of course it would have helped, IC could have announced that the area of immediate danger is now only 1 metre and the protection wear could have been used accordingly.	K2.db
111	When you are at the site you don't know how far the cloud actually is as you don't know for how long the chemical has been leaking.	K2.db
112	That's nice if management system would include also the prediction of [chemical cloud] spreading; current systems don't have it.	K2.db
113	ER wonder about the information from gas sensors	K3.o
114	P2 wondering about the dangerousness of the cloud: they look at the map and see red dots, interpretation: danger to life !	K3.o
115	commanders notice that the gas symbols change colour- facilitates decision to clear the danger zone	K3.o
116	(Kysymys:) Mitkä ominaisuudet ovat mielestäsi vähemmän tärkeitä? (Vastaus:) No nyt me käytettiin niin vähän noita ominaisuuksia… En mä tiedä… Jos tää kaasumittari liitty siihen niin sitä tulee käytettyä niin vähän et ei se ainakaan voi tossa olla vakiona, se otetaan sitten mukaan vaan jos sitä tarvitaan.	K3.verint
	Locating objects (personnel [GPS, inertia], resources, hazmat)	
117	Comment on GPS localisation, portable laptop: One should think carefully what really benefits emergency work	K2.que
118	It is hard to concentrate and notice what is relevant when there is very much detailed information	K2.trainint

119	The fact that one could observe the location of the FFs in the building was a good idea	K3.focgroup
120	The indoor positioning would be magnificent.	K3.focgroup

	Sensors for extending human senses *supports/enables* Presenting a model of the situation	Source
	Enhancing visual perception (camera, infra red camera)	
121	The use of helmet camera is difficult. One cannot move around in a space with that information only.	K2.trainint
122	Brew-FF: The visor display would have been excellent, but could not be used in the current position.	K3.db
123	FWF-IC: Thermal camera integrated to the equipment would be a very good feature.	K3.db
	Observing environment (hazardous materials (NH_3), weather)	
124	WSN technology shows the grade of the substance in specific locations by indicating the harmfulness of the concentration level on the display on a map interface.	K1.o
125	This resulted in not taking into account the possible consequences of the spreading of the substance to people in the surrounding areas not shown on the map (kindergarten locating at about 500 m from the accident) II2-VI2	K1.UXint
126	On the other hand, the correctness of the location is immediately apparent and it can be corrected if needed as the location is shown in a map interface	K1.UXint
127	Substance information is readily available, also in changing situation, so that only a glance to the map interface	K1.UXint
128	User interface was found good: The impact of the dangerous substance, expressed by the colour of the sensors in the map, was found informative by experienced fire fighters (Augmented Operations team)	K1.UXint
129	roads to block can be easily evaluated when looking at the map interface with sensor information	K1.UXint
130	With the system measurement of hazardous chemical concentration could be presented in an illustrative way [C2]	K2.trainint
131	Hazmat-CSO: The readability of the chemical sensors was poor. The chemical sensor information was not of much use, things could have been presented in some other way.	K3.db
132	Company lead: The ammonium leak could be monitored very well using the sensors which showed the concentrations at different locations. The problem with mobile sensors is usually to have persons move in the field with the sensors in order to stay up to the situation.	K3.db
	Locating objects (personnel [GPS, inertia], resources, hazmat)	
133	For SC [in Finland, P4] it is important to see the location of each of his crew members.	K2.focgroup
134	Danger zone could be presented very illustratively with this system [C2]	K2.trainint

	Sensors for extending human senses *supports/enables* Sharing the model	Source
135	Decision for ways of protecting population for chemical II2-VI3	K1.o
136	Fire fighters work in pairs, completing each other's work and providing safety to one another. Furthermore, nowadays also the Sector Commander goes into the burning building with his crew, holding the thermographic camera to secure and assist the work of his fire fighters	K1.UXint
137	Information exchange seems to be quite effective with the exception of talking in the burning house. (in-direct . Something else is needed)	K1.UXint
138	for knowing how long each fire fighter has been inside the building so that he knows when to call them back to get more air and at least after 15 minutes working	K1.UXint
139	Telling colleagues about the general condition of a fire fighter: Movement detector	K1.UXint

140	Media can be easily informed about the areas in which gas masks or the like should be used because substance concentration is so high there II2-VI3	K1.UXint
141	When the leak is blocked, it is known how substance concentration decreases and an appropriate timing can be given regarding the duration of area isolation.	K1.UXint
	Enhancing visual perception (camera, infra red camera)	
142	"…in reality it could be very useful. I could have informed by radio – now I didn't even have radio – if the fire fighter would have passed a person in the building." augmented SC	K2.db
143	In post operative situation this could be used for investigation purposes to discover the initial reason of the situation [FF video]	K2.trainint
144	Safety in smoke diving is increased when information about his position is recorded [FF positioning]	K2.trainint
145	Brew-FF: There would not have been much to see through the thermal camera since the dolls were cold and wet.	K3.db
146	No oikeestaan tämmösissä pelastussukellustehtävissä, savusukellus- tai kemikaalisukellustehtävät, missä tilanteen johto eli pelastustoiminnan johtaja ei voi olla, tai ei näe sitä tilannetta eli kun mennään sinne kohteeseen, tarvitaan erityiskalustoa. Paineilmalaitteet tai vastaavat. Siinä ainakin tosta kamerayhteydestä, tai videoyhteydestä, olisi suuri apu. Mutta miksei joka tilanteessa missä me ollaan. Sehän se suurin ongelma monta kertaa on, että pelastustoiminnan johtaja ei nää sinne kohteeseen. Mä näkisin et ihan tyypillinen rakennuspalo tai vastaava niin siitä olis eniten hyötyä. (FF joka kokeili päällepuettavia palomiehen välineitä)	K3.verint
147	No mitä nyt tässä testissä käytettiin niin kyl se on toi video-ominaisuus eli saadaan sitä tilannekuvaa sieltä kohteesta sinne pelastustoiminnan johtajalle. Ja toki jos esimerkiks toi potilaan paikkatieto saadaan tarkasti, ensinnäkin ylös jonnekin ja vielä nähdään muitten yksiköiden toimesta niin onhan se kauheen hyödyllinen tieto. Mut…niin…hyödyllisiä noi kaikki on. Mut top ykkönen jos pitää valita niin se on ehdottomasti toi videokamera. (FF joka kokeili päällepuettavia palomiehen välineitä)	K3.verint
148	No joo, varsinkin jos on videokuvaa, videokuvaa saa käyttöön, niin heti tiedustelutilanteessa helpottaa, ei tarvi esimiehen kiertää kaikkia kohteita, voi käyttää sitä miehistöä siihen kiertämiseen, tiedustelutehtävien tekoon. Vois olla tämmönen ainakin nyt äkkiseltää, missä helpottaa. (SC)	K3.verint
	Locating objects (personnel [GPS, inertia], resources, hazmat)	
149	"There are also men in the unit that don't wear compressed air devices – if everybody wears a sensor and that is shown on a display, it improves occupational safety. " (augmented SC)	K2.db
150	"If one receives normal image or image from thermal camera; thermal camera is needed in smoke diving but normal camera could be sometimes be very good when entering narrow locations, he can guide others and tell that only one person can go there. He can send the image from his camera and he can then advise others [by TETRA radio]. " (augmented SC)	K2.db
151	"That could be important for you [referring to Incident Commanders] to know as well, to know whether there are some fire fighters near." (augmented SC)	K2.db
152	"I don't necessarily need information about a single fire fighter but perhaps later, if a log is created, it could be checked if somebody is left in smoke." (augmented IC)	K2.db
153	"Factories are large buildings and it's easier to get lost there. With localisation information it would be easier to fetch somebody from there. I understood I should have had a floor plan of the building with which I could have guided where to go but I didn't get it. Just a moment ago some floor plan existed but I don't know where it is now. So in this exercise this device didn't bring any benefit. This could be useful; SC wouldn't look at this all the time but if it were available when needed, that would be really good." (augmented SC)	K2.db

	Semantic information system for abstraction of relevant information *supports/enables* Forming a model of the situation	Source
154	During this episode the immediate ammonium threat was solved but further problems arose	K1.o

155	TETRA radio informing of toxic symptoms by children at the nearby kindergarten. This sign was considered to denote a minor health problem and the IC advised to take the children inside and shut down the ventilation system. The driver was anticipating more severe problems and need for more focused attention but this idea, which becomes evident in his attempts to consult maps and guide books to clarify local area and possible measures for warning population, was not considered by the	K1.o
156	His or his driver's task is to find crucial information related to the incident in question	K1.UXint
157	In some instances it would be highly beneficial to have a structural drawing of a building so that ways out and possible locations for people could be immediately identified	K1.UXint
158	It would be very helpful if all relevant information related to a specific type of an incident (forest fire, structural fire) were easily available in one location: map	K1.UXint
159	(HazMat information) should be combined to present digital management system	K1.UXint
160	Information of these sensors should be readily available to Incident Commander's digital systems so that whenever something deviating has happened, Incident Commander has immediate access to that information III	K1.UXint
161	This system would create added value in a big and complex situation	K2.trainint
162	Combining information (gps and units) is useful	K3.o
	Control (filtering) of information overflow	
163	Monitoring on-going response activities III1-VI1	K1.o
164	This further understanding of the size denotes the need to do something about it but this understanding is not mediated further because IC action is disrupted for a while	K1.o
165	currently relevant and irrelevant issues are all portrayed in the system [C2]	K2.trainint
	Alarming (smoke diving duration, new tasks)	
166	Better awareness of smoke diving duration is good for SC because in the end he is responsible for the safety [FF positioning]	K2.trainint

	Semantic information system for abstraction of relevant information *supports/enables* Presenting a model of the situation	Source
	Control (filtering) of information overflow	
167	This system should analyse the information that is coming and only show what I need. [C2]	K2.focgroup
168	Situational command: It should be made possible to choose the level of information shown [e.g. videoimage in C2].	K3.db
169	User profiles were missing and higher command were forced to use the same C2 as ICs.	K3.db
170	Situational command: The system should check that a user does no accidentally change the entries for example by placing a symbol on top of another. Or develop an easier way to add a new symbol. A smart board would be practical for the higher command because then the entries could be directly inserted using a smart board pen.	K3.db
171	[What should be amended?] It should be made impossible to overwrite without warning. [C2 user]	K3.que

	Semantic information system for abstraction of relevant information *supports/enables* Sharing the model	Source
172	The object is isolation but no mention of the second object of preparing a cleansing place is mentioned by either the IC or the unit 041 even though this second objective was included in the initial command by the IC.	K1.o
173	It becomes slowly evident that the object of transportation has been comprehended too narrowly both with regard to the extent of service and also with regard to the protection needed to handle patients. IC, ESC and 194 all share the need to elaborate their conception of the situation	K1.o
174	In practice, they (movement detectors) are generally not used. They are experienced futile or maybe even adding work load unnecessarily as fire fighter may stand still long times without being in trouble; then, IC should dedicate time unnecessarily in checking the reason for each alarm (indirect: need to receive relevant info and share it)	K1.UXint

175	System is good because information can be gatherer, processed and shared [C2]	K2.trainint
176	Operation command: It should be made possible to expand the system organization from botton up.	K3.db
177	IC gets information about the location of the higher command location in the map	K3.o
	Control (filtering) of information overflow	
178	Situational command: The video image should be mediated to the higher command as well.	K3.db
179	Higher command would benefit from seeing video or still image from the overall situation, not necessarily the view of a single FF.	K3.db
180	[What should be amended?] Operational high command should have a possibility to give orders through system. [C2 user]	K3.que
181	[What should be amended?] Feedback sector commander->incident commander [SC]	K3.que
182	[What should be amended?] Information flow team->command. Image to command if needed. [C2 user]	K3.que
183	[What should be amended?] Image from the field to the command centre. [C2 user]	K3.que
	Alarming (smoke diving duration, new tasks)	
184	Also need alarm type information about patients (location and status), info must be dynamic, as patients are being transported	K3.o

	Availability of information in a Gateway on WLAN *supports/enables* Forming a model of the situation	Source
185	The object is elaborated as the hand book available in the truck is consulted by the driver, and the substance in the truck tank is identified to be ammonium and a possible leak may be expected as a consequence of the collision	K1.o
186	Being informed about buildings: Information card There is information available for rescue services about all public buildings at least. These information cards are not necessarily in the form of a card but can be in any format. The card contains information relevant to rescue activities such as floor plan, the existence of dangerous substances, matters requiring specific attention etc	K1.UXint
187	I think in this COPE the gateway is a good thing. It is possible to archive everything.	K2.focgroup
188	identify the function of the system to store information (earlier inserted info not lost when sytem booted)	K3.o
	Delivering of in time information (Map [C2, SC], Tasks [C2, SC])	
189	It is very important for the IC to know these kind of operative changes. He must as fast as possible eliminate possible new threats. With this he can change strategy when needed and new information is delivered to him [C2]	K2.trainint
	Retrieval of stored information (data, video)	
190	C2 system, from a practical view, should be focused more on a lower level because all incidents start at a lower level, so when if it escalates into a bigger one there will already be information available.	K3.focgroup
	Ad hoc communication network	
191	When the tool is to be used in challenging circumstances, it should be easy to use and reliable so that it is functional in all situations if possible. This means that it gets connection to other devices when needed and the information should be transferred from that device to the other one without difficulties	K1.UXint

	Availability of information in a Gateway on WLAN *supports/enables* Forming a model of the situation	Source
185	The object is elaborated as the hand book available in the truck is consulted by the driver, and the substance in the truck tank is identified to be ammonium and a possible leak may be expected as a consequence of the collision	K1.o

186	Being informed about buildings: Information card There is information available for rescue services about all public buildings at least. These information cards are not necessarily in the form of a card but can be in any format. The card contains information relevant to rescue activities such as floor plan, the existence of dangerous substances, matters requiring specific attention etc	K1.UXint
187	I think in this COPE the gateway is a good thing. It is possible to archive everything.	K2.focgroup
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	Delivering of in time information (Map [C2, SC], Tasks [C2, SC])	
189	It is very important for the IC to know these kind of operative changes. He must as fast as possible eliminate possible new threats. With this he can change strategy when needed and new information is delivered to him [C2]	K2.trainint
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	Availability of information in a Gateway on WLAN *supports/enables* Sharing the model	Source
194	These actions manifest that ERC, IC and all the units (018, 031, 041) shared the same understanding of the situation VI3- TETRA	K1.o
195	This objective is further shared with the unit 031 which is commanded for rescue and reconnaissance wearing protection clothes and breathing masks. These actions indicate the adoption of a more precise conception of the accident situation and its severity	K1.o
196	The confirmation of the IC leads triggers the driver to further confirmation which is portrayed in his further consulting the handbooks	K1.o
197	In the next phase all the three fire fighter units report being on site. These reports serve as separate signs to the IC to launch actions and define the object. Unit 031 was already commanded for rescue and has adopted it as an object. …. For Coodination	K1.o
198	At this stage the IC, driver and the unit 031 share the understanding of an ammonium danger TETRA	K1.o

199	The shared understanding of an ammonium danger is manifested by the interpretant action by the IC to announce the ammonium danger to all units TETRA - Commond ground	K1.o
200	In the last phase of this episode the unit 031 brings new information of the situation. One victim has been transported, evidently there are more, and there is a car burning. This sign indicates a need to save lives and extinguish fire but according to the action of IC this message does not appear to be mediated fully to the IC. It may be concluded that the focus of the emergency response is clearly on the ammonium danger and all units are aware of this focus. The unit 031 is acting more or less autonomously in rescue and fire fighting sectors TETRA traffic overloading	K1.o
201	a request about the hazardous substance, that understanding of the ammonium threat was not complete. The instructor returned to this issue during the debriefing and it was assumed that probably the unit was getting dressed in the chemical suits when the announcement about the ammonium danger was made, and they did not hear the TETRA mediated information. This was not known to the IC until at this phase.	K1.o
202	The complex object including all the different sectors and their interactions was not really developed. The object was represented partially in the minds of the IC and the driver. The units 194, 041, 018 had special targets but would have required better understanding of the ammonium threat in accomplishing their tasks. Unit 031 had rather good understanding of the situation and they acted independently in the sectors that were not in the focus of IC attention IV-VI3.	K1.o
203	who comes personally to IC to discuss the problem of water supply	K1.o
204	At this stage, neither of the units 031 and 041 new how the chemical divers (unit 018) proceeded in blocking the leak	K1.o
205	The formation of the object does not include the connection to the ammonium threat as no indication of this is made to the unit 194. This means that this unit is not prepared to this danger when getting ready to transporting patients.	K1.o
206	TETRA telephone was used appropriately in communicating singular messages from different sectors. It appeared however that when the object of communication becomes more complex and interactions between sectors are necessary TETRA is not sufficient. First responders tended to seek personal contact with the IC.	K1.o
207	The most central tool for communication between all public authorities dealing with an incident is radio network, based on TETRA standard .. (users also pointed out the unreliabilities of TETRA in severe conditions)	K1.UXint
208	As all important talk is mediated by TETRA, all stakeholders (IC, sector commanders, other authorities at site, Emergency Response Centre) are able to hear and know what is going on without specific measures, just by choosing the correct bandwidth and by listening the talk	K1.UXint
209	fire station’s control room may send information to the fire engine by sending data to fire engine’s computers such as graphs about the local fire hose system. Incident Commander uses computer for e.g. keeping diary of the incident and with a printer attached to the computer, a map of the incident site can be print to be delivered to Sector Commanders	K1.UXint
210	With this system operational picture that the IC has could be transferred to the sector commanders and in some situations to fire fighters [C2]	K2.trainint
211	FWF-IC: System is too sensitive if network connection is lost within a 10-m distance from a working connection of the neighbouring unit.	K3.db
212	Designer: The gateway database has been saved and it can be loaded into the gateway again by playback. Timestamps can be found in the raw database (text format)	K3.focgroup
213	[What should be amended?] The connection between systems should be developed. Connections can't fail when the system is loaded. [C2 user]	K3.que
	Delivering of in time information (Map [C2, SC], Tasks [C2, SC])	
214	"The updating frequency was sufficient. The fact that there is a Gateway where the information goes, that is good, and that information that is used by one person would be available to everybody. Now we didn’t quite reach it as we used a different system than they did." (augmented IC)	K2.db
215	If circumstances change unexpectedly it is especially important that information from the field arrives fast [C2]	K2.trainint
216	Hazmat-CSO: C2 did not support action, at least not much, because what was done with C2 lagged fairly much behind the actual live events.	K3.db

217	Company lead: The system is a good idea and good addition to the current systems. A good point is that the ICs would have already inserted information to the system when higher level command arrives or observes the situation from a remote fire station.	K3.db
	Retrieval of stored information (data, video)	
218	there are no maps about water supply	K1.o
219	FWF-IC: In large-scale scenarios it would be valuable for SC if messages and commands were saved.	K3.db
220	Operation command: It would be a good backup to have the details of the situation saved to a server where they could be retrieved even if a single computer crashed.	K3.db
221	Company lead: It is extremely important that commands given by higher command to ICs were documented as well.	K3.db
222	In support of normal functions there should be a possibility for saving information. [SC]	K3.que
223	[What should be amended?] Exportation of situational diary. [C2 user]	K3.que
224	[What should be amended?] Situational diary to the program. [C2 user]	K3.que

	Functional solution X *supports/enables* COP	Source
225	SA / Are there casualties: In Finland, Incident Commander mainly works in his vehicle, having contact with the incident site by TETRA radio talk. V-communication media needed	K1.o
226	Organising response activity in three sectors (demands for coordination and tasking were boright up)	K1.o
227	The object is in the first phases of the episode comprised of the ammonium danger and the necessary danger zone it requires. Later in the episode more aspects enter into the conception but the tactic remains focused on the ammonium danger	K1.o
228	the proposal of the driver to the IC to get more information about the ammonium leak	K1.o
229	to perform a task is expressed as a natural consequence of the situation, not as something that requires specific decision making	K1.UXint
230	the incident was divided according to major, somewhat official changes	K1.UXint
231	flow of events seems to be perceived as divided into sections roughly according to official changes in the situation	K1.UXint
232	incident-related decision points such as what to do when fire suddenly increases in power or the like were not mentioned at all as structuring the incident… "natural consequence" of the situation.	K1.UXint
233	the overall organisation and the sequence of events is known for everyone	K1.UXint
234	the nature of the incident is the criterion for responsibility – e.g., if physical violence is in question, police will be in charge	K1.UXint
235	IC is the general leader who delegates tasks to Sector Commanders. They, in turn, pass the task to their team with more detailed instructions of what to do	K1.UXint
236	Roles are changed according to incident demands (not explicit decision making)	K1.UXint
237	a hose is not only a means for transporting water into the burning building but also a security-providing tool keeping the working pair safely together as men always hold the hose when in the burning building… That way the other party knows what is the situation of the other one.	K1.UXint
238	Incident Commander often makes notes about the most important commands and the like to keep track of what has been done and for making appropriate decisions for the future. There is no official tool for that – one of the most general ones might be pen and paper, and white board in the Command Vehicle	K1.UXint

239	A wish for a tool that would identify chemicals and gas when they are related to fire was expressed. That would make fire extinction quicker, fire fighters' working safer and would make surrounding protection to be founded on sound basis	K1.UXint
240	"The most problematic in the application (Risk Analysis) is that its starting point is occupational safety, or that's at least how we understood it, and not at all in the way that it would support decision making. We found there risks and found out that now this risk has the value of 16 and then another risk was also 16, and then there was a risk of 8. But what we do with this information and now that we calculated the numbers, how does this all support us – not at all. " (IC in augmented group)	K2.db
241	"But just like said, even if you knew how to fill in the questionnaire, what is the benefit of the end result. If we think what the risk that a fire will expand is, an explosion will take place or something like that…ok we know that it's risk is 3 and if it actualises its consequences are 5, we get a factor 15, but what then? " (IC in augmented group)	K2.db
242	"I think that more important than numbers is that people are aware of the risks. Some kind of list of risks could be useful. It might be that if one is used to these numbers they would be calculated very easily, but I don't know what the benefit of it is. If an explosion gets a higher number than brewery fire, does it mean that I move my units there and forget about the brewery fire – no it doesn't." (IC in augmented group)	K2.db
243	Regarding the SC's terminal: "This device didn't bring any added value on the chemical accident. I assumed there would have appeared some sectorisation from the upper level, who does what, [chemical] sensors are in the field and what they tell…that kind of information I was waiting for but nothing appeared. Hard to evaluate what its usability is." (augmented SC)	K2.db
244	The common operational picture. If I could put some information, draw on the map, this is the area that is dangerous, if I could put it in server so that everybody could see that this is a dangerous area.	K2.focgroup
245	Most (3 out of 5) of IC's and SC´s having used the new technology (FRS-C, C2 and CDS) somewhat disagree that the functionalities of the device would be just the ones needed in the field (additionally, one completely disagrees and only one somewhat grees).	K2.que
246	The majority (2 out of 5) of IC's and SC´s having used the new technology (FRS-C, C2 and CDS) completely disagree that the tasks would be easier to perform or the result would be better if the new technology would be used in emergency response; additionally, one somewhat disagrees with the claim, one somewhat agrees with the claim and one completely agrees with the claim. Hence, 3 out of 5 more or less disagrees with the claim whereas 2 out of 5 more or less agree with the claim.	K2.que
247	Most (2 out of 5) of IC's and SC´s having used the new technology (FRS-C, C2 and CDS) completely agree or one (1 out of 5) somewhat agrees with the claim that the device would fit well in the professional use in the future whereas some (2 out of 5) somewhat disagree with that claim	K2.que
248	Average evaluation of the technologies after the trial on May 2010: 5,85 (scale: 4=poor, 10=excellent); the highest score was given to thermal camera (7), the lowest to C2 and CDS (5) (Finnish users)	K2.que
249	Brew-CSO: Initially system [C2/system in general] functioned quite well.	K3.db
250	Brew-CSO: When the system [C2/system in general] had become useful, it could not bear the load.	K3.db
251	Hazmat-IC: IC or company lead is too busy to manage technology due to radio traffic. There's need for a person who is specifically engaged to managing technology. The hazmat-CSO managed well using the computer/technology.	K3.db
252	Hazmat-SC: The progress is going to good direction [stated after commenting on camera image].	K3.db
253	FWF-IC: Using the C2 system alone is not practical. A person is needed next to IC who can manage the C2 system.	K3.db
254	FWF-CSO: The system is heavy considering the benefits. CSO was fully engaged using the system and could not keep up the live situation simultaneously. CSO was lagging behind right from the start because commands were given while CSO was setting up the system.	K3.db
255	EMS-fieldcommand: Too much effort was put to managing the devices instead of the actual situation.	K3.db

256	EMS-fieldcommand: If the technology was reliable and easy to use, it could support the traditional way of action.	K3.db
257	EMS-fieldcommand: It's demanding to use C2 in addition to several radios and mobile phones.	K3.db
258	Police/highcommand: There is no harm in having the system, but the police high command has no time to manage the system in addition to radio traffic and manual bookkeeping.	K3.db
259	Operation command: It would be good to have this system as support for PEKE system where you could see the units' locations. Those making the decisions and situational command could see who are present and form a picture of the situation immediately.	K3.db
260	Most respondents (16/21) somewhat agreed to the statement that the functionalities of the device are just the ones needed in the field. The rest (5/21) somewhat disagreed.	K3.que
261	All respondents of the user experience questionnaire agreed that the new but fully developed technology would enhance common operational picture to some extent. Almost half (10/21) were in complete agreeance.	K3.que
262	A majority of respondents (19/21) felt the system, when fully developed, could fit well in professional use . Participants with over 25 years of experience (6/8 completely agreed, 2/8 somewhat agreed) were most positively convinced of the suitability of the system.	K3.que
263	We are going to the right direction. [SC]	K3.que
264	Good idea and probably works in practice as well. A bit too imcomplete technique for "serious action". [C2 user]	K3.que
265	Keep up the good work! [FF]	K3.que
266	Thanks for developing these new technology devices. Improves safety. [SC]	K3.que
267	Confusion about usefulness. [CDS user]	K3.que
268	"C2 could be used in bigger accidents such as forest fire, chemical leak is a too little accident."	K3.verint
269	"Jos toi puhe menee pelkästään videolle elikkä se ei välity Virveen, viranomaisverkkoon, niin sitten se on kyllä aika turha suhteessa siihen et kuinka hankala sitä kaulamikkiä on pitää. Mut jos se saadaan integroitua niin et saadaan käytettyä Virveä samalla niin sithän se on erittäin hyvä." (FFjoka käytti palomiehen päällepuettavia vaatteita)	K3.verint
270	"Mutta onhan tää hieno idea ja tulee varmasti viemään alaa eteenpäin jos vaan sais edes joltain osin käyttöön." (FF joka käytti walkthrough'ssa palomiehen päällepuettavia varusteita mutta oli saanut koulutuksen muiden laitteiden käyttöön eli kommentti saattoi koskea uutta teknologiaa kokonaisuudessaan)	K3.verint

Appendix 2: User experience questionnaire to all who have used COPE technology in the trial (validation)

Answers to the questionnaire will be used for developing new technology. Answers will be handled anonymously and confidentially. Thank you for your effort!

I have worked in emergency services for _____ years.

The new technology I used: ☐ C2 (incident commander)☐ FRS-C (sector commander)
☐ FRS-C (fire fighter), tool__________________
____

In each question, choose one of the following options that is closest to your opinion.

1. The system is very easy to use

☐ completely agree

☐ somewhat agree

☐ somewhat disagree

☐ completely disagree

2. The functionalities of the device are just the ones needed in the field

☐ completely agree

☐ somewhat agree

☐ somewhat disagree

☐ completely disagree

3. In the device, there is a lot to amend

☐ completely agree

☐ somewhat agree

☐ somewhat disagree

☐ completely disagree

What should be amended specifically: ________________________________

____

____

____

____

____

____

____

____

____

____

4. Common operational picture would be enhanced if this kind of (but fully developed) new technology would be used in emergency response.

☐ completely agree

☐ somewhat agree

☐ somewhat disagree

☐ completely disagree

5. When fully developed, the system could fit well in the professional use in the future

☐ completely agree

☐ somewhat agree

☐ somewhat disagree

☐ completely disagree

6. School grade for the technology concept (4-10): ______________

7. Anything else to comment?

____

____

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