Project number: 21743
Project acronym: Escritoire2
Project full name: Distributed Crisis Management using Remote Collaboration Technologies

Marie Curie Outgoing International Fellowship (OIF)

Deliverable D3
Design of Experiments for Asymmetric Distributed Collaboration

Period number: 2

Period covered: from Apr 2008 to Sep 2008

Start date of project: 1 October 2006

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Project coordinator organization name: Thales Research and Technology (UK)

Organization name of lead contractor for this deliverable: Thales Research and Technology (UK)

Due date of deliverable: 31 September 2008

Date of preparation: September 2008
Date of SESAM submission: -

Duration: 3 years

Revision: 3

Contents

1 Introduction

This is the third deliverable for Marie Curie Outgoing International Fellowship project 21743, "Distributed Crisis Management using Remote Collaboration technologies". The first, D1, introduced urban search and rescue as the application area of this project, and described a cognitive task analysis for the domain. The second, D2, described the technical details of a remote collaboration system containing tabletop and handheld displays for supporting that task. A tactical actor in a command centre has a tabletop display, and search units in the field have handhelds. In addition to the standard voice channel that allows all team members to speak to each other, the new system provides visual workspaces with which the collaborators can share maps, timelines, and forms.

This type of collaboration is different from a standard video conference or shared workspace because of the extreme asymmetry in the display sizes used by the collaborators, and in their roles and the situations in which they are working. We have therefore designed a set of displays and workspace awareness features that should allow the collaborators to work together in this setting, and this document, deliverable D3, describes an experiment to test how people use the displays in an urban search and rescue scenario.

Synchronous remote collaboration is dependent on the latency and reliability of the underlying network, and these aspects of quality of service are challenging to provide in a mobile context where wireless networking is required. The type of collaboration we are proposing would therefore require an investment in network technology, so we wish to qualify the benefits of truly synchronous collaboration over the more asynchronous collaboration that could be provided by a more conventional wireless network. We will use two conditions in our experiment: one with the full set of synchronous collaboration and workspace awareness features, which are described below, and another which could be implemented on a cheaper wireless network because it does not have the synchronous features. We will test how this choice of condition affects the team's performance, their process of collaboration, and their opinion of the system.

While designing the shared workspaces, we performed a usability evaluation on the timeline scheduling tool via a cognitive walkthrough. The process is described in Appendix A. That was an evaluation of an intermediate design, but the aim of the main experiment described in this document is to address a set of research questions, as described below.

1.1 Objectives

The overall objective of this experiment is, in a laboratory user experiment, to evaluate how well the collaborative mapping and scheduling displays that we have created facilitate collaborative decision making in an urban search and rescue scenario, and to quantify the difference that the use of synchronous collaboration can make to the effectiveness of a team.

This objective has three parts which explained here, and listed more explicitly in Section 2 below. The first is to evaluate the displays' effectiveness in supporting the work of the human actors: the tactical actor in the command centre using the tabletop display, and the search unit leaders in the field using handheld displays. The second is to show that the workspace awareness features that we have added to the shared workspace improve the process and product of the collaborative work, thus providing justification for investing in network technology that is able to support such real-time collaboration. The third is a more open-ended question about how people react to, and work around, the very asymmetric nature of the collaborative setting, with displays of very different sizes, which is imposed by the domain. The approach is therefore a hybrid approach of hypothesis testing and open research questions.

Our concern in this research is not about actually searching buildings and rescuing victims from them, but about the team coordination. Our findings will be more general than the urban search and rescue scenario we are using. This type of co-ordination is important in any team that performs a time-critical mission in an urban area involving navigating to different buildings, performing tasks at those buildings, and dealing with uncertainty and rescheduling on the fly.

2 Research questions

Below are the research questions that will be addressed by this experiment, which are a restatement of the ones given in Deliverable D2 Section 5.2.

1. Does the system have the right features necessary for the team to co-ordinate their task?
   a. Which information is used?
   b. Is any information missing?
   c. Which functions are used?
   d. Are any functions missing?
2. Do the synchronous workspace awareness features lead to improvements?
   a. Do they improve the final result of the task?
   b. Do they improve the process of using the displays and communicating between team members?
   c. Do they increase the users' satisfaction of the system and of their own performance ?
3. How do collaborators handle the asymmetry?
   a. Which features are most popular for communication?
   b. Does the system promote collaborative or directive communication?
   c. How do actions that can be done by either role, such as annotation and form-filling, get divided?
   d. What communication features are missing?

Question 1 essentially asks whether the system we have created fulfils the information and function requirements in Deliverable D1 Section 3.3.5, and what requirements exist that were not anticipated in that original list.

We wish to measure the product of, process of using, and satisfaction with the system (?, ?). The three parts of research question 2 reflect these three goals, which are described in more detail below.

Product measures show how changes in the system affect the final outcome of the task. This is particularly important in an emergency response scenario, such as the urban search and rescue scenario we are using here, where lives are at stake.

Process measures reveal the techniques and strategies people employ when using the system. Changes in these, as dependent measures, can be used to test hypotheses, and, being generally more qualitative, they can also be used to learn about how people use such a system, to inform future designs.

Satisfaction measures expose participants' subjective experience with the system. This is very important for consumer products where use is discretionary, but even in a critical application such as emergency response, favourable ratings from users must be conducive to system effectiveness.

Question 3 seeks to identify qualitative information about this asymmetric form of collaboration. The asymmetry in this system is an aspect that makes it different from conventional groupware and shared workspace systems, and we wish to gain insights into how people use such a system in practice.

Another perspective on the three research questions is that question 1 seeks a descriptive answer which will be obtained via qualitative responses and descriptive statistics, question 2 is a variance question (?, ?) that compares two instances of the system with slightly different features, and question 3 is a process question (?, ?) that seeks to understand the way people use the system.

3 Experimental task

To investigate the research questions listed above, a team of three participants will complete an urban search and rescue (USAR) mission, using the linked tabletop and handheld displays with which they are provided.

3.1 Task overview

Emergency response organizations generally have a fan-out of up to seven, that is, each person in the command hierarchy has up to seven subordinates. Our remote collaboration system has been designed initially to support two subordinates, to keep experiments manageable. The two search units are required to navigate around an urban area and search a set of structures (buildings). The tactical actor remains in a command centre, co-ordinating the team and passing new information to them.

In the initial test, just two participants will be used: one tactical actor and one search unit. This will be expanded in further tests.

The mission that the team must complete is as described in the Scenario Task Overview in deliverable D1, Section 3.3.1. The goal will be to search a series of structures as quickly as possible, thus the time for completion will be variable. The mission will be designed to last 20–30 minutes. Fixing the objective in this way, rather than fixing the time, enables us to measure efficiency with terms such as speed (time per task) and verbal efficiency (verbal communication per task). Instructions given to participants, that explain what is required of them, are in Appendix E.

3.2 Search unit role

Each participant taking the search unit role will use two computers: a standard PC providing a 3D simulation of an urban environment, and a handheld touch-screen computer to display information and communicate with the tactical actor. The 3D simulation is a substitute for actually navigating around an urban environment and searching buildings in a real USAR mission. The 3D simulation is based on the Risk software, described in Deliverable D2, page 13. The handheld provides a shared map, timeline, and forms for exchanging information with the tactical actor. Voice communication to the other participants is provided via a headset.

The aim of the search unit is to get to the scheduled sites as quickly as possible, search them for victims as quickly as possible, and ensure that details of the search and any victims found are reported.

3.3 Tactical role

The tactical actor has no direct interaction with the 3D simulation, as he would have no direct interaction with the outside world in a real USAR mission. He will only have the tabletop display for visual interaction, and also the voice channel for talking, via a headset.

The tactical actor, in addition to co-ordinating the search units, will control a notional rescue unit. When a victim is found, a rescue should be scheduled on the timeline, then it will be performed automatically. There is the option of having a human play the rescue unit role, in a similar way to the search unit, but currently the rescue unit is simulated by a simple algorithm that visits each scheduled rescue site in turn.

The aim of the tactical actor is to arrange the schedule of search and rescue tasks optimally, help the search unit(s) to perform their duties, and react to any external information.

3.4 Computing devices

Figure 1 shows the computers used in this experiment. There is a single server that manages the state of the shared workspaces on the tabletop and handheld devices, and that of the 3D world which is viewed by the search units. A single administration PC runs the administration programs used to configure, start, and stop the scenario. It also runs an observer client, which shows a view of the shared workspaces so the workspaces and the voice communications can be recorded with screen-grabbing software, as described in Section 6.

The tactical actor uses a single device: the tabletop display. Each search (operational) unit uses two computers: a 3D simulation PC that shows a view of the simulated urban environment via Risk, and

a handheld display that allows synchronous collaboration with the tabletop display of the tactical actor.

Figure 1 depicts the computers used in the experimental setup, and the network links between them. It shows the server on a separate machine, but we actually run the server software on the same machine as the tabletop display, to reduce the amount of hardware.
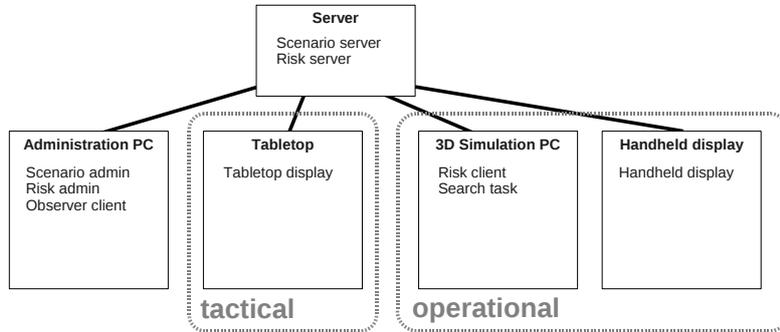

Figure 1: The computers used in this USAR scenario. The pair of computers used by each operational actor is duplicated for each search team.

3.5 Displays

The displays presented to the users on the various handheld and tabletop displays are described in Deliverable D2. The handheld display shows three types of information: a map showing structures, operational units, tasks, annotations, and various other features; a task schedule in the form of a timeline; and forms for entering the details of structures searched and victims found. The tabletop display shows the same information as on the handheld, plus the instructions for participants, and external messages that affect the mission.

The shared workspaces—map, timeline, and forms—provide various workspace awareness features (Deliverable 2, Section 2.2). These are telepointers, traces attached to the telepointers, visibility regions on the workspaces on the tabletop, feedthrough of operations such as dragging objects and clicking buttons, and shared highlighting so the common elements in different workspaces are apparent. The workspace awareness features can be enabled or disabled.

4 Experiment design

The following subsections describe the single independent variable in our experimental design (Section 4.1), the dependent variables (Section 4.2), and how the dependent variables will be used to answer the research questions (Section 4.3).

4.1 Independent variables

A major focus of this work is to investigate the possibilities for remote collaboration that arise when a reliable low-latency network is available, and to quantify the improvements that such as network can facilitate. The reliable network can support synchronous collaboration features whereas the more basic network cannot. We will therefore use two levels of features to find the difference their use makes to the team's work.

The independent variable in our experiment is the presence or absence of synchronous collaboration features, that is, the workspace awareness features described in Section 3.5 above. The two conditions are

- S0: without workspace awareness features,
- S1: with workspace awareness features.

We will use a local area network for the experiment, and assume that latency is negligible. Conditions S0 and S1 will both use a network that transmits all information with negligible delay, and is always connected, but the S0 condition will not provide all of the functionality for synchronous collaboration and workspace awareness that the S1 condition does. The differences are summarized in Table 1. The terms *asynchronous* and *synchronous* are relative, because any form of communication can be placed on a spectrum of synchronicity between very synchronous communication such as the telephone, to very asynchronous communication such as the traditional postal service.

The workspace awareness features (WA) that will not be available in S0 are: telepointers, traces, visibility regions, highlighting, and feedthrough (for dragging objects). In S0, changes to a workspace, such as dragging of an object, will only be shown to remote collaborators after the action is completed, whereas in S1 all interactions will be mirrored for all collaborators to see. Also, the over-the-shoulder view, which shows a copy of the handheld display on the tabletop, will only be available in condition S1. In condition S0 the necessary information to update the over-the-shoulder view will not be available at the tabletop. In both network conditions, location updates will be received and displayed on the map once per second when a search or rescue unit is moving.

	S0: asynchronous	S1: synchronous
voice channel	yes	yes
location tracking	yes	yes
schedule changes	shown on completion	shown continuously
map annotations	shown on completion	shown continuously
report data	shown on completion	shown continuously
schedule	without WA	with WA
map	without WA	with WA
report forms	without WA	with WA
over-the-shoulder view	absent	present

Table 1: Features provided in the different conditions. WA means workspace awareness features such as telepointers.

4.2 Dependent variables

Various dependent measurements will be made during the experiment. They are listed below, in three groups. The quantitative programmatic variables will be measured by code added to the software system which will log events to a file. The quantitative, manual variables will be measured by a human by tagging a recording of the experiment. Values for the qualitative variables will be obtained by an experimenter during an interview or provided by the subject via a questionnaire.

Quantitative, programmatic

1. Distance travelled for each search team.
2. Structures. Events related to the searching of buildings in the simulated world, which are initiated by opening the 'door' of building.
    a. Number searched
    b. Proportion of time spent searching (as opposed to navigating)
    c. Door openings. Both those that match the search schedule, and those that do not.
3. Victims. Events from victims found during search tasks.
    a. Found
    b. Rescued
4. Schedule changes, when tactical actor changes the task schedule.
    a. Allocating a task to a team
    b. Moving a task within a team's schedule
    c. Moving a task between two teams' schedules
    d. Deallocating a task
    e. Total changes

5. Route changes, when tactical actor changes a route on the map.
   a. Waypoint additions
   b. Waypoint deletions
   c. Waypoint movements
6. Report filling, when either actor fills in a report on a site or victim.
   a. Start of report
   b. Entry of data into the report
   c. Submission of a report
   d. Accuracy of the report. (Does it match the information that should have been entered?)
   e. Time between the operational actor obtaining the structure or victim information and the report being started and completed.
7. View changes, when any user changes a view of any workspace.
   a. Tactical moves own view
   b. Tactical moves S1's view
   c. Tactical moves S2's view
   d. S1 moves own view
   e. S2 moves own view

Quantitative, manual

8. Annotations. Pen strokes will be recorded automatically, but grouping those into annotations will require a person to view them.
   a. Annotation additions by each user
   b. Annotation deletions by each user

Qualitative

9. Communication Analysis. A person will look at the video of the workspaces and the listen to the recorded audio, to classify utterances and gestures.
   a. Who initiated the communication?
   b. Which communication channels were used by the initiator: voice, map, timeline, form?
   c. Who responded?
   d. Which communication channels were used by the responder: voice, map, timeline, form?
   e. What was the purpose of the communication
10. Cognitive strategies. A retrospective video review will be used to elicit participants strategies, using retrospective form of the think aloud method (?, ?).
    a. Tactical: reasons for, and information used in various events: schedule changes, waypoint changes, annotations, form entry, view changes, communication.
    b. Search: reasons for, and information used in various events: annotations, form entry, view changes, communication.
11. Questionnaires. See Appendices B, C, and D.
    a. Details about the participants and their level of experience with relevant technologies and domains.
    b. Lickert scales on the usefulness of each of the WA features.
    c. Lickert scales for subjective difficulty and effort.
    d. Choice of preference for the two conditions.
    e. Open-ended comments on various aspects of the system.

4.3 Addressing the research questions

Table 2 shows how each of the research questions will be answered.

Research question	Associated measures
1 Has the right features?	
1a Which information is used?	7 view changes
	10 cognitive strategies
	11b questionnaire: usefulness of features
1b Is any information missing?	10 cognitive strategies
	11e open-ended comments
1c Which functions are used?	4 schedule changes
	5 route changes
	7 view changes
	8 annotations
	10 cognitive strategies
	11b questionnaire: usefulness of features
1d Are any functions missing?	10 cognitive strategies
	11e open-ended comments
2 WA leads to improvements?	
2a WA improves product?	1 distance
	2 structures
	3 victims
	6d report accuracy
	6e report delay
2b WA improves process?	4 schedule changes
	5 route changes
	7 view changes
	8 annotations
	10 cognitive strategies
2c WA improves satisfaction?	11b usefulness
	11c subjective difficulty
3 How do collaborators handle the asymmetry?	
3a Which methods are popular?	9 communication analysis
3b Collaborative or directive?	9 communication analysis
3c How is work divided?	6 reporting
	7 view changes
	8 annotations
3d What communication features are missing?	10 cognitive strategies
	11e open-ended comments

Table 2: How the research questions (left) will be answered by the dependent variables (right).

5 Procedure

For each group of participants, the experiment will consist of the following steps. The timings, particularly those for the practice and actual missions, will be refined following pilot testing.

Find groups of participants
Teams of two volunteer participants will be found to do the experiment, will meet each other before moving to the separate locations of the tabletop and handheld displays. The roles of tactical actor and search unit will be assigned randomly.

For the initial experiment the participants will be employees of Thales Research and Technology, where the experiment will be conducted. A future, refined experiment will be conducted with a broader range of participants.

Pre-study questionnaire (10 minutes)
Each participant will complete the pre-study questionnaire shown in Appendix B to gather information on demographics, their experience with relevant technologies, and their knowledge of the domain.

Instruction (20 minutes)
Participants taking the search unit role will be shown the 3D simulation, how to look and walk around in it, and how to search buildings. They will be shown the handheld display, and instructed on using its features. The remote collaboration features will be demonstrated by linking the handheld to a shared workspace on the PC showing the 3D simulation, so participants can see the collaboration, and particularly the workspace awareness features, in action.

Participants in the tactical role will be shown the tabletop display, and instructed on using it's features. The collaborative features will be demonstrated via an over-the-shoulder view: a copy of a handheld display shown on the tabletop.

Each participant will be asked to read a document (Appendix E) explaining the rules of the urban search and rescue scenario, the team's objectives, and the various computer interfaces they will be using. They will be able to ask any questions of the experimenter at this stage.

Link the team (20 minutes)
The audio between the two locations will be connected, and the participants will be introduced to each other. They may or may not already know each other. They will practice using the collaborative workspace features.

Practice mission (30 minutes)
The team will complete a short practice mission that causes them to use all the features of the collaboration system. The experimenter will answer any questions they have. Time pressure in this mission will be minimal, to give the participants time to ask questions. They will perform the mission twice, once in each experimental condition, in the order in which they will experience them in the later missions.

Actual mission 1 (30 minutes)
The team will complete an actual mission, using a randomized choice of one of the two conditions S0 and S1. Their actions on the computers will be logged, video of the shared workspaces will be recorded, and the sound of the shared audio channel will be recorded.

Post-mission questionnaire 1 (15 minutes)
Each participant will complete the post-mission questionnaire shown in Appendix C to gather information on their subjective experience and proposals for improvements.

Actual mission 2 (30 minutes)
The team will complete a second actual mission, using the condition (S0/S1) that they did not use before. Data will be recorded as before.

Post-mission questionnaire 2 (15 minutes)
Each participant will complete another post-mission questionnaire (Appendix C).

Preference questionnaire (5 minutes)
Each participant will complete a short questionnaire (Appendix D) recording their preference for the two conditions.

Retrospective interview (60 minutes per participant)
An experimenter will show each participant the audio and video recording from their two missions, and ask them what information they were using, and the reasons for their decisions, wherever information is exchanged, shared data is changed, or commands are given, as described in Section 4.2. Due to the time required, this may not be performed directly after the missions, but will be performed the same day.

The total time taken will be approximately three hours per team, plus another one hour per participant for the retrospective interviews.

6 Data collection

During the mission, various data will be recorded for later analysis. The variables listed under 'quantitative, programmatic' in Section 4.2 will be recorded by the software, with timestamps. These can then be processed programmatically to produce various statistics.

The shared workspaces (map, timeline, forms) will be displayed on a separate PC during the mission, and video of them will be recorded with software such as Camtasia[1] or Frapps[2]. The workspaces may need to be displayed in lower resolution to fit on the screen. This recorded display will also contain a clock showing experimental time.

The events for the 'quantitative, manual' variables, and the communication analysis, will be tagged manually while watching the recorded video. Timestamps will be recorded.

Information about the cognitive strategies of participants will be elicited during the retrospective interviews, and the questionnaires will be given to the participants on paper.

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[1] http://www.techsmith.com/
[2] http://www.fraps.com/

APPENDIX

A   Usability Evaluation of Timeline Display

A cognitive task analysis, such as the one described in deliverable D1, provides a list of requirements for a human-computer interface, but it does not generate a design for satisfying those requirements.

The requirement to show geospatial locations of search units and structures was satisfied in a straightforward manner by a map, and the requirement for recording the results of a search fit a standard textual form, but the requirement for displaying schedule information in an easily sharable and editable form was open-ended. We therefore created an initial mock-up of an interactive timeline, then performed a cognitive walkthrough (?, ?) to evaluate it. To perform a cognitive walkthrough the experimenter first prepares a series of tasks that should be performed with the interface, and a list of actions that correctly achieves the tasks. He then asks prospective users to describe how they would use the interface, and notes any differences between the correct and observed actions, and any problems with the information that the interface presents.

Figures 2 and 3 are 'before and after' images to illustrate the changes that were made as a result of the cognitive walkthrough.
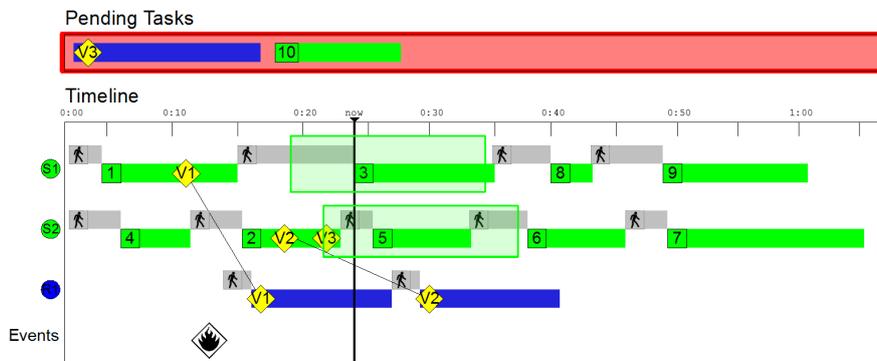
Figure 2: Initial design of timeline display. Horizontal rows contain scheduled tasks for navigation (grey), search (green) and rescue (blue).
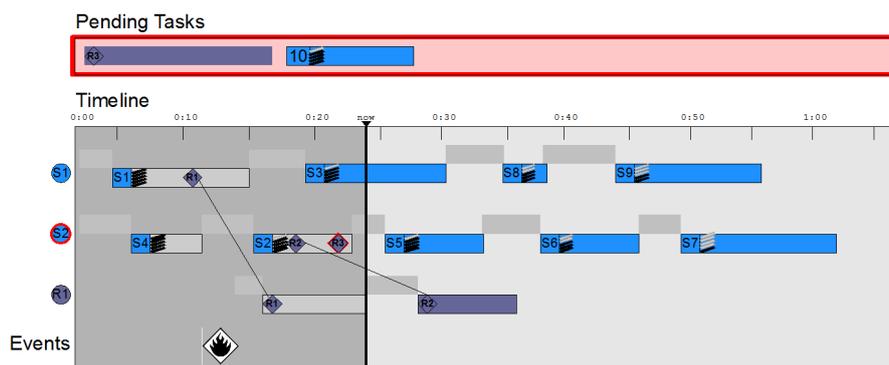
Figure 3: Revised timeline design. The display is simpler and uses more subdued colours.

B Pre-study questionnaire

Below are the pages of the questionnaire that will be given to participants before they use the technology.

Pre-study questionnaire

Participant number: _____   Date: _____

For all multiple choice questions, please choose the one answer that provides the best response.

1. Gender:
   ☐ male   ☐ female

2. Age:
   ☐ under 20   ☐ 20–29   ☐ 30–39   ☐ 40–49   ☐ 50-59   ☐ over 59

3. Handedness:
   ☐ left-handed   ☐ right-handed

4. How often do you use touch-screen handheld computers (e.g., Apple iPhone or T-Mobile G1)?
   ☐ have never used one
   ☐ have used just a few times
   ☐ use occasionally: less than once a week
   ☐ use regularly: at least once a week

5. How often do you use tabletop computers (e.g., Thales nuVa or Microsoft Surface)?
   ☐ have never used one
   ☐ have used just a few times
   ☐ use occasionally: less than once a week
   ☐ use regularly: at least once a week

Page 1 of 2

6. How often do you use real-time remote collaboration software (not just voice and webcam like Skype, but screen sharing e.g., shared whiteboard, VNC with multiple viewers, or screen sharing in Apple iChat)?

☐ have never used it

☐ have used just a few times

☐ use occasionally: less than once a week

☐ use regularly: at least once a week

7. How often do you play multiplayer online games (e.g., World of Warcraft or Second Life)?

☐ have never played one

☐ have played just a few times

☐ play occasionally: less than once a week

☐ play regularly: at least once a week

8. Do you, or have you ever, worked in an urban search and rescue or fire fighting organization?

☐ yes   ☐ no

9. How well do you know the person playing the tactical role in this experiment (the one at the tabletop)?

☐ I am playing the tactical role myself

☐ I don't know him/her

☐ we are acquaintances but I don't know him/her well

☐ I know him/her well

10. How well do you know the person playing the search unit?

☐ I am playing the search unit myself

☐ I don't know him/her

☐ we are acquaintances but I don't know him/her well

☐ I know him/her well

C Post-mission questionnaire

Below are the pages of the questionnaire that will be given to participants after they complete each of their two missions. One of of the missions will be completed in the S0 condition (without workspace awareness), and one with the S1 condition (with workspace awareness).

Questions 1 and 2 are general questions about the product and process of the collaboration. Questions 3 to 6 measure subjective workload, and are based on the relevant questions from NASA TLX. Some questions are only applicable when the workspace awareness features are enabled (S1 condition), so they are marked, and will be left blank in the S0 condition.

Following the two missions, participants will complete the questionnaire in Appendix D.

Post-mission questionnaire

Participant number: _____   Date: _____
Condition: _____

For all multiple choice questions, please choose the one answer that provides the best response.

	strongly disagree 1	somewhat disagree 2	neither agree nor disagree 3	somewhat agree 4	strongly agree 5
1. My team was successful in accomplishing its mission.	☐	☐	☐	☐	☐
2. The members of my team worked together effectively.	☐	☐	☐	☐	☐
3. I found the task mentally demanding.	☐	☐	☐	☐	☐
4. I found the pace of the task to be fast.	☐	☐	☐	☐	☐
5. I had to work hard to accomplish the mission.	☐	☐	☐	☐	☐
6. I became frustrated during the mission.	☐	☐	☐	☐	☐
7. The collaboration technology we used helped us achieve our goal.	☐	☐	☐	☐	☐
8. The ability to speak to each other was useful.	☐	☐	☐	☐	☐
9. The ability to share visual information with each other was useful.	☐	☐	☐	☐	☐

	strongly disagree	somewhat disagree	neither agree nor disagree	somewhat agree	strongly agree
	1	2	3	4	5
10. The map provided useful information for me.	☐	☐	☐	☐	☐
11. The map was useful for collaboration with the other team members.	☐	☐	☐	☐	☐
12. The timeline provided useful information for me.	☐	☐	☐	☐	☐
13. The timeline was useful for collaboration with the other team members.	☐	☐	☐	☐	☐
14. The ability to annotate the map was useful.	☐	☐	☐	☐	☐
15. The site and victim reports were useful for collaboration.	☐	☐	☐	☐	☐
16. The ability to annotate the map was useful.	☐	☐	☐	☐	☐

If workspace awareness features were enabled, go to question 17, otherwise go to question 22.

	strongly disagree	somewhat disagree	neither agree nor disagree	somewhat agree	strongly agree
17. The over-the-shoulder view (copy of the handheld display on the tabletop) was useful for collaboration.	☐	☐	☐	☐	☐
18. The telepointers were useful for collaboration.	☐	☐	☐	☐	☐
19. The traces were useful for collaboration.	☐	☐	☐	☐	☐
20. The visibility regions were useful for collaboration.	☐	☐	☐	☐	☐
21. The highlighting of symbols was useful for collaboration.	☐	☐	☐	☐	☐
22. The highlighting of symbols was useful for me individually.	☐	☐	☐	☐	☐

23. On the **map**, what extra information or ability for interaction would have helped you, or your team's, effectiveness? What would you change about the map to improve it?

24. On the **timeline**, what extra information or ability for interaction would have helped you, or your team's, effectiveness? What would you change about the timeline to improve it?

25. On the **reports**, what extra information or ability for interaction would have helped you, or your team's, effectiveness? What would you change about the forms to improve them?

If workspace awareness features were enabled, go to question 26, otherwise go to question 28.

26. The telepointers, traces, and visibility regions are examples of workspace awareness features: they let you see what another person is doing. What would you change about them to improve these features? What workspace awareness features would you add?

27. The over-the-shoulder view shows a copy of the handheld display on the tabletop. What was particularly good or bad about this feature? How would you improve it?

28. Please give comments on any other aspects of the technology you used: things that were good or bad, and what changes you would make.

29. Any other comments.

19

D   Preference questionnaire

After using the two versions of the remote collaboration technology, participants will be given this final questionnaire to capture their preference.

The two columns will be labelled 'version *without* workspace awareness features' and 'version *with* workspace awareness features', in the order in which the participant experienced those two conditions.

Preference questionnaire

Participant number: _____   Date: _____

You have completed missions with two versions of the remote collaboration technology – with and without the workspace awareness features. For each question choose one of the two versions as an answer.

	Version _____ workspace awareness features	Version _____ workspace awareness features
1. Which version of the **map** better supported your collaboration?	☐	☐
2. Which version of the **map** was easier for group work?	☐	☐
3. Which version of the **timeline** better supported your collaboration?	☐	☐
4. Which version of the **timeline** was easier for group work?	☐	☐
5. Which version of the **reports** better supported your collaboration?	☐	☐
6. Which version of the **reports** was easier for group work?	☐	☐
7. Which version did you prefer overall?	☐	☐

8. Any other comments.

Page 1 of 1

E Participant instructions

The remaining pages of this report contain the instructions that will be given to participants before starting the practice trial. The instructions will be available on the tabletop display, and on the laptop used by the search unit, and will be available as a reference throughout the practice and actual trials. Although the document shown here is paginated, it will be presented to participants as a single scrollable HTML document.

Instructions

This experiment has these steps:

1. Complete the pre-study questionnaire. You should have already done this.
2. Read these instructions.
3. Do two missions, consisting of these steps:
    a. A practice mission. You can ask questions of the experimenter during this time.
    b. An actual mission.
    c. A post-mission questionnaire.
4. Final questionnaire and interview.

These instructions will be available to all of the participants during the mission. Please read these instructions. Then you will able to experiment with the computer displays you will use, and ask questions.

The remote collaboration technology you will use has the option to use workspace awareness features, which are intended to aid communication and are described in detail towards the end of these instructions. You will do two missions, one with the workspace awareness features enabled, and one with them disabled.

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1. The Mission

In this experiment you will be a member of an Urban Search And Rescue (USAR) team. Your mission is to search a set of buildings in a city, find victims, and arrange the rescue of those victims. You will play one of two roles:

- search unit: situated in a virtual city environment, and using a small handheld display;
- tactical actor: situated in a command centre, and using a large tabletop display,

A rescue unit will be present in the scenario, but will be simulated, rather than being an actual person. The mission should take around 25 minutes.

---

2. Mission Goals

The primary goal of the mission is to find and save the victims in the buildings as quickly as possible.

Doing this, requires several sub-goals from the team members:

- Search unit
    - Get to each building as quickly as possible
    - Search each building as quickly as possible
- Tactical actor
    - Arrange the schedule of search and rescue tasks optimally
    - Inform the search unit of any new information

3. Virtual City

The search and rescue units will move around a virtual city. The person playing the search unit will see this city via a 3D view on a laptop computer. The person playing the tactical actor will not see it directly, he will only have information provided by the search unit. This section is mainly for the search unit's benefit. The virtual city contains buildings, some of which need to be searched for victims. An example view of the virtual city is shown below.
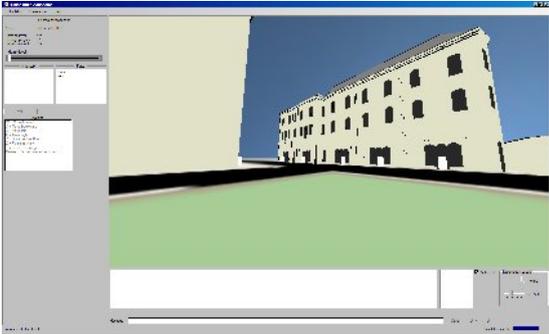
The 3D city, from the search unit's point of view. To look around, click the mouse on the view, then move it around. To walk forward, press the up arrow key to move in the direction in which you are facing. To stop looking around and use the mouse for other things, press the Escape key.
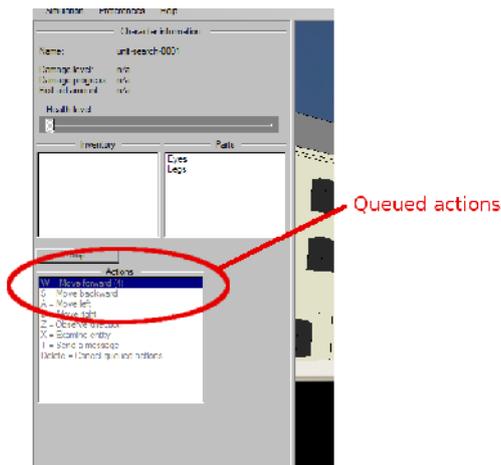
Walking around the 3D world happens in discrete steps. To walk forward a long way, press the forward button (up arrow) several times. The actions will be queued up, and indicated on the left side of the screen. To cancel the queued actions, you can press the Delete key. Apart from the queued "move forward" actions, you can ignore the other actions and controls on the left and bottom parts of the screen.
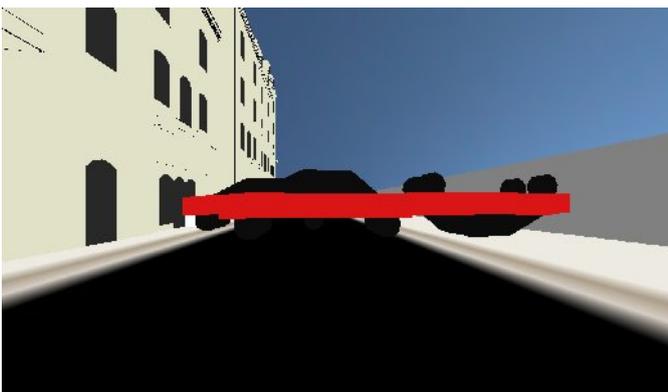
Some roads may be blocked with obstacles like the red cars shown in the screenshot above, which are not visible on the map of the city. Also, some routes through the city may be possible, even though they are

not visible on the map.
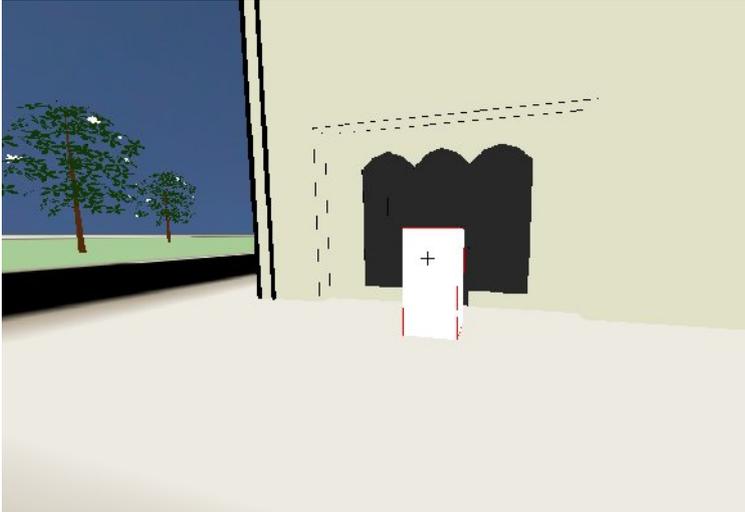
Buildings have doors, which appear as small white boxes. To search a building via a door, select the door, then press the "1" key. You must be quite close to a door to use it. The search unit should perform searches in the order specified in the timeline by the tactical actor.


Note about walking around in the virtual city. The virtual city handles collision detection by defining a rectangular box around every object. This box does not always coincide with the edge of the object. To see the box, click on an object and it will be drawn using red lines. In the picture above, the box surrounding the tree is shown in red. In this example, you cannot walk past the trees because there is no space between their surrounding boxes.

4. Searching Sites

If you are the search unit, you will be required to 'search' buildings. You start a search by selecting the door of a building and pressing the '1' key. A window will then appear in which you preform the simulated search:
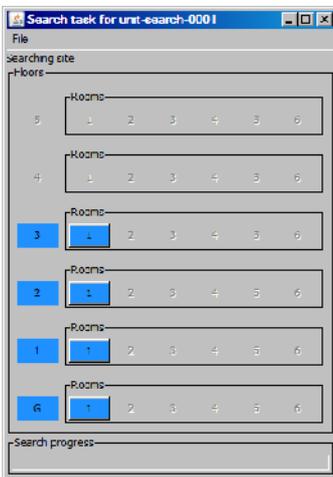
The blue buttons represent rooms to be searched. Simply click on each one to 'search' the room, after which it will turn green. If you find a victim to be rescued, a window will pop up, as shown below.
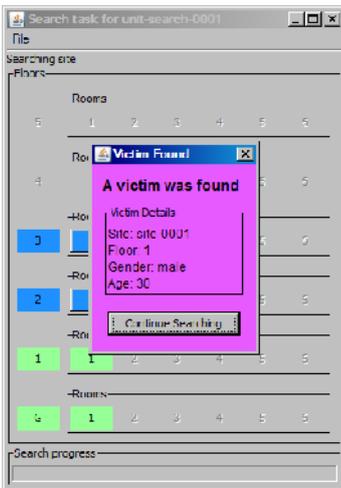
A victim report should then be completed, as described in Section 8.2. When all the rooms have been searched, the details of the site will be shown. These should be entered in a site report, as described in Section 8.1.
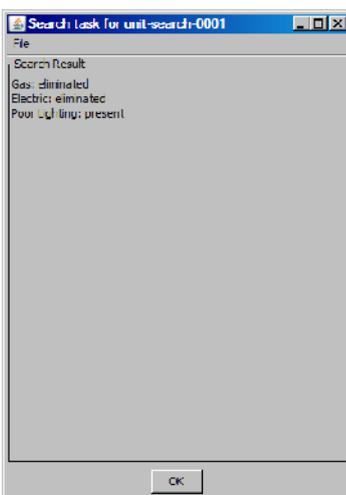
5. Devices

Each team member will have a headset like the one shown above. This is for talking to the other team member(s).

Each of the team members will use different devices to view and share visual information. These devices are shown below.

5.1 Search Unit

A laptop computer will show a 3D virtual city that you can walk around.
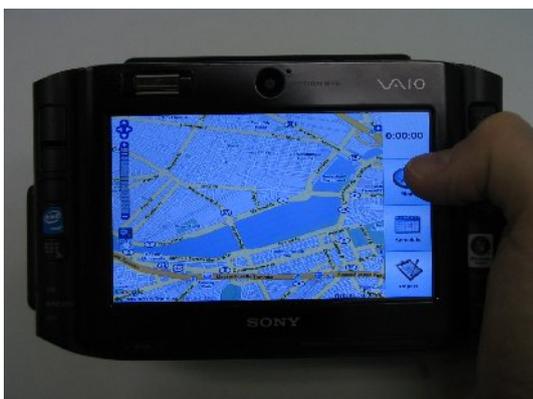
A handheld computer will be used to share visual information with the tactical actor. This handheld has a touch screen that can be operated with the fingers.
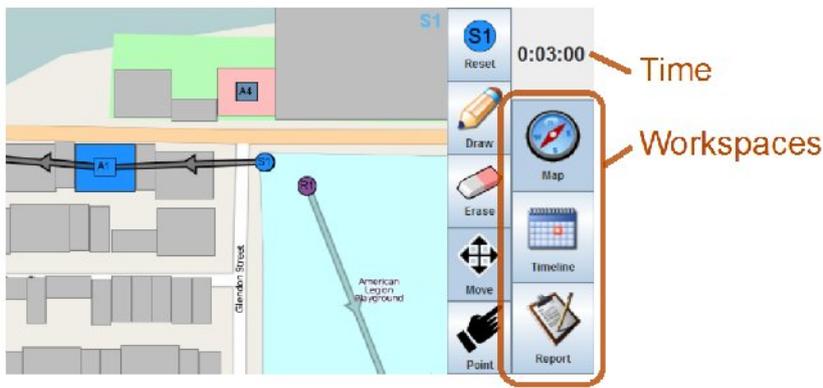
The screenshot above shows the display of the handheld device. It has a clock on the top right that shows the time since the start of the mission. On the right are three buttons that select the three workspaces that can be used to view and enter information. They are the map, timeline, and reports.

Map
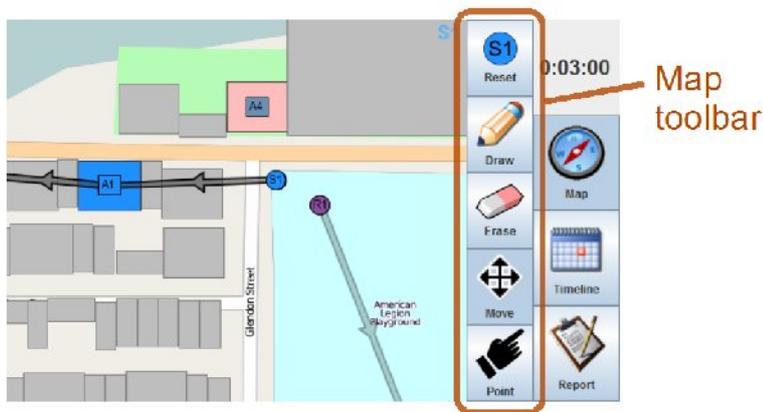
The map displays geographical information about the virtual city, and the current locations of search and rescue units. The map has a toolbar with five buttons:

- "Reset" pans the map to show your current location
- "Draw" lets you annotate the map by drawing on it
- "Erase" lets you erase annotations
- "Move" pans the map by dragging it
- "Point" simply displays a pointer when you touch the screen, so you can gesture to the tactical actor.

More details on the map are given below in Section 6.

Timeline
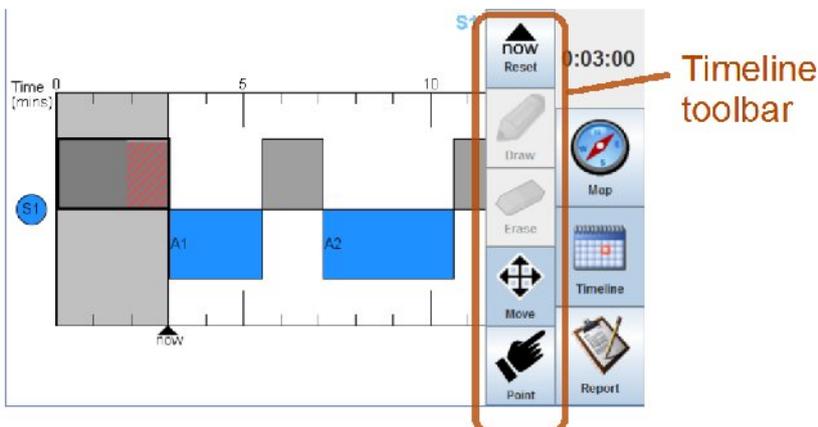
The timeline displays a schedule of search tasks that the search unit should perform. It has a toolbar with five buttons, which are very similar to the ones for the map:

- "Now" pans the timeline horizontally to show the current time
- "Draw" is disabled. Annotations are not possible on the timeline.
- "Erase" is disabled.
- "Move" pans the timeline, the same as for the map.
- "Point" displays a pointer when you touch the screen, the same as for the map.

More details on the timeline are given in Section 7.

Reports
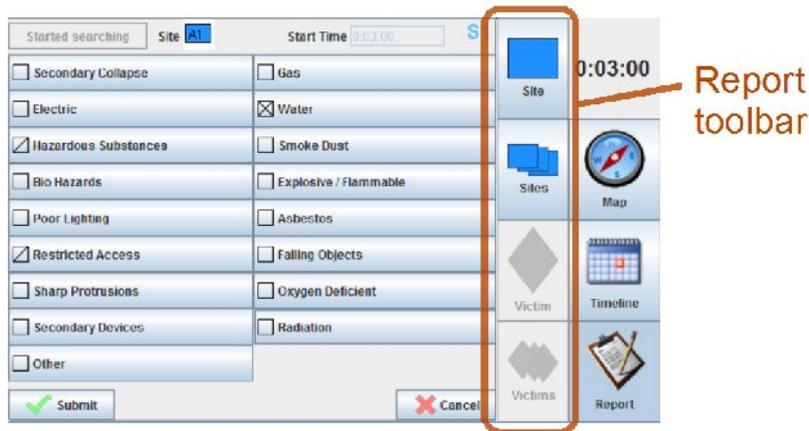
The reporting toolbar has four buttons:

- Submit a report on a site (building)
- View all submitted site reports
- Submit a report on a victim that was found during a search
- View all submitted victim reports

More details on these reports are given in Section 8.

5.2 Tactical Actor

The tactical actor will use a a single device – a tabletop display.

The tabletop displays all of the shared workspaces at the same time, unlike the handheld display which must switch between them because of its limited size. The map, timeline, and reports shown on the

Reports Messages Timeline Map Instructions Over-the-shoulder view
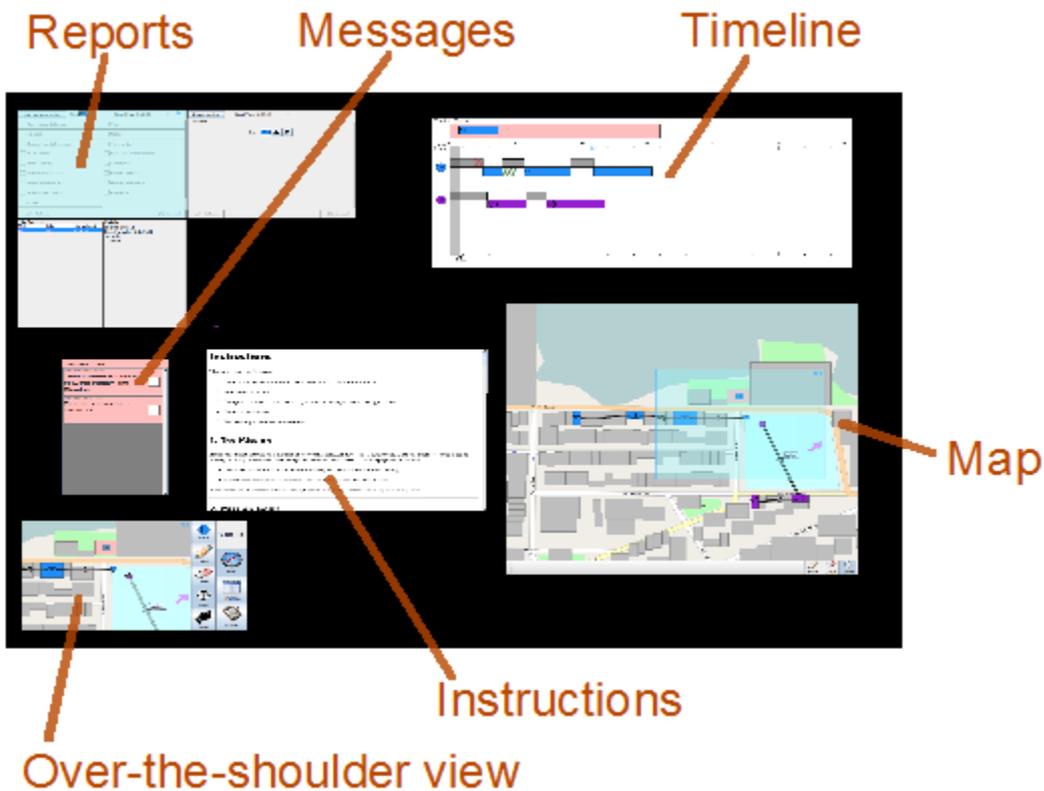
tabletop are explained in more detail in the sections below. The tabletop also displays a copy of these instructions in a web browser window, messages that will appear from time to time as described in Section 10, and an 'over-the-shoulder view': a copy of the handheld display of the search unit which is described in Section 9.

6. Map

The map, which is shared between the search units and the tactical actor, displays the city in which your urban search and rescue mission takes place. It contains various pieces of information, as shown in the picture below.

Search unit Rescue unit Waypoint Route Annotation Site to search Road Building Victim to Rescue
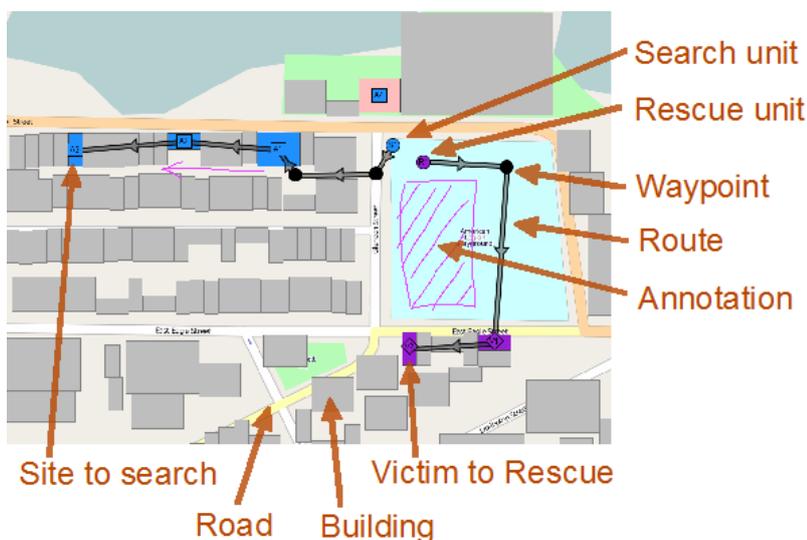
The map contains the following items.

- Roads.
- Buildings.
- Search tasks. Each site has a name e.g., "A1". A blue box is a site that should be searched,

and corresponds to a search task in the timeline.

- Rescue tasks. These are similar to the search tasks. They have names of the form "V1".
- Search units. A blue circle represent the location of the search unit as it moves around the virtual city.
- Rescue units. A purple circle represents the location of the simulated rescue unit as it moves between victims that are scheduled to be need to rescued.
- Annotations. Any user can draw on the map to annotate it.
- Routes and waypoints. Routes point from one search task to the next one. The tactical actor can add waypoints to a route be switching to drawing mode, and drawing a circle on top of a route. The waypoint can then be dragged to a new location. A waypoint can be deleted by scribbling over it.

6.1 Routes

Two consecutive tasks will automatically be joined by a direct route, represented as an arrow between them, as shown below.
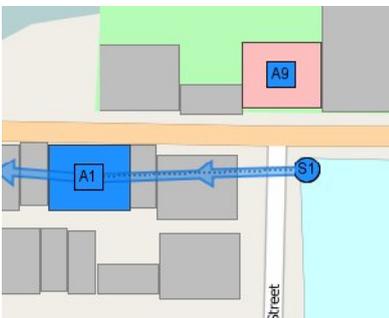
If the direct route is too simple, waypoints can be added to move the route around obstacles. To make a waypoint, draw a circle on top of an existing route, as shown below.
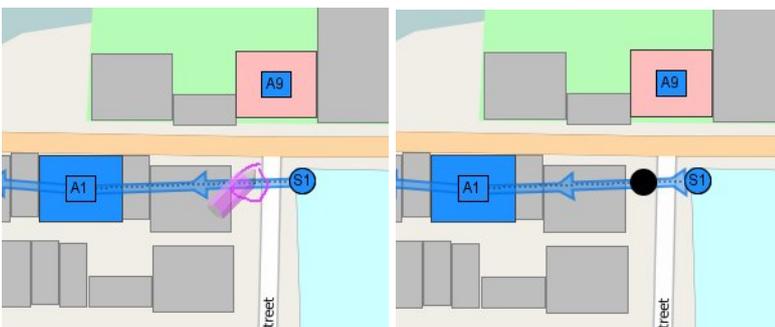

Waypoints can be moved by dragging them:
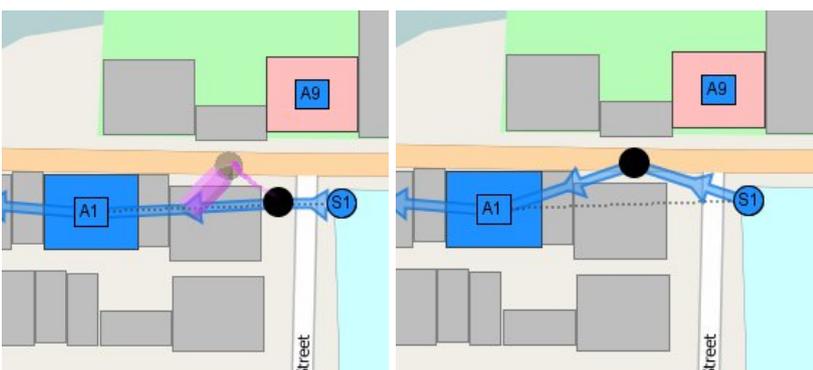
The time taken to walk a particular route is automatically calculated from it's length, and used to set its

expected duration in the timeline.

---

7. Timeline

The timeline is used to arrange the tasks of the team members. The tactical actor has responsibility for modifying the timeline. The search unit can view it to see the tasks he has been assigned. There is a row for each search or rescue unit. The "now" line is a vertical black line that shows the current time on the timeline, and moves from left to right. Only the tactical actor can modify the timeline – the search unit can only view it. Search and rescue tasks (the blue and purple boxes) can be dragged to new positions to rearrange them. The grey boxes in between tasks represent the time required to move between them. They are automatically inserted, and their duration is automatically calculated from the distance of the routes on the map.

The figure below shows the tactical actor's view of the timeline. The search unit will see a restricted view, showing just its own tasks.
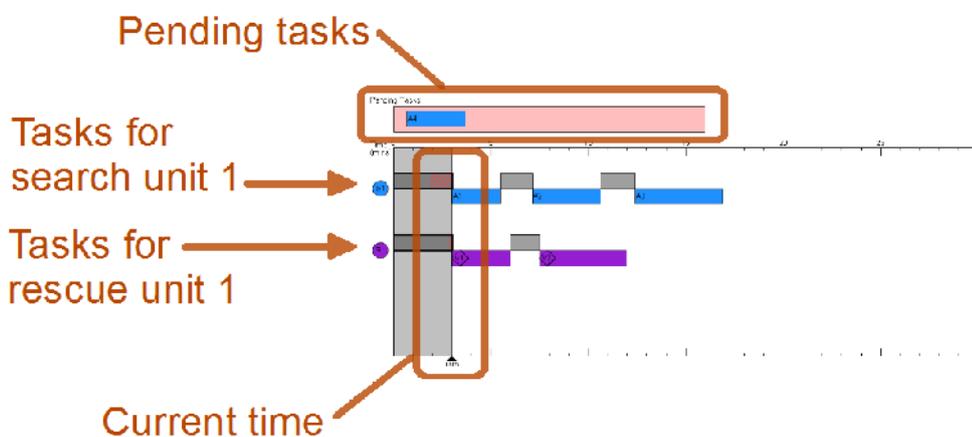
When a new task appears, it is added to the "Pending" box on the tactical actor's display, which is then highlighted in red. It should be assigned to an appropriate search or rescue unit by dragging it onto the timeline:
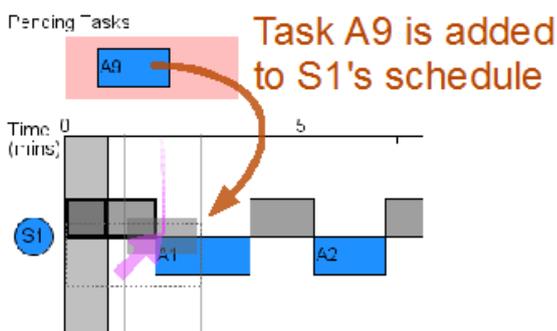
Tasks that are already partially in the past cannot be dragged to a new position, because they have already started (and may have already finished).
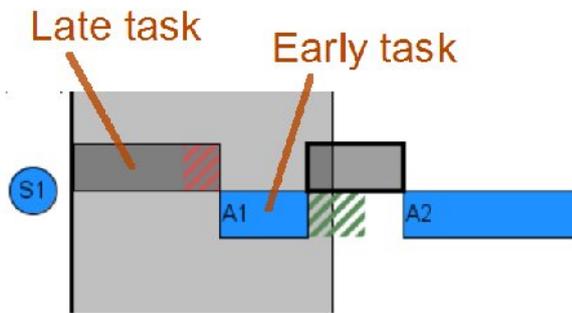
A task may take more or less time than was originally planned in the timeline. If it takes more time than planned, a red bar will appear to show the extra time taken. If it takes less time than planned, a green bar will appear and the task will overlap the following task, to show that some time has been saved.

---

8. Reports

Two types of reports must be entered. Reports on sites that have been searched, and reports on victims that have been found. The reports can be entered either by the search unit on the handheld display, or by the tactical actor on the tabletop.

8.1 Site Reports

When a search unit starts searching a site, a search report should be started by pressing the "Start Search" button. The start time is automatically recorded, and the new status of the search task is shown in the timeline.

When "started searching" is pressed, the current time is recorded, so remember to press it when you start searching a building rather than leaving it until later.
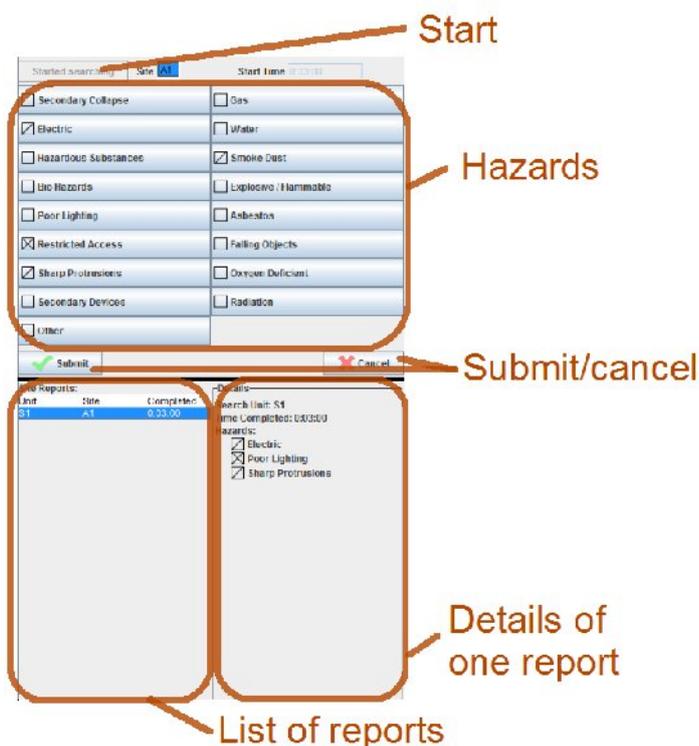
Any hazards found during the search should be entered using the "Hazards" buttons. Hazards are

classified as absent, present, or eliminated, which correspond to the following three symbols on the report:
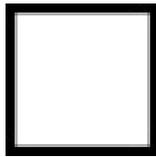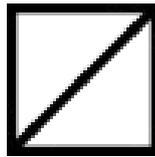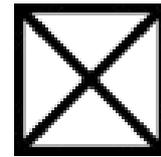
| Absent | Present | Eliminated |

When the report is finished, press the "Submit" button. The end time of the search is automatically recorded, the report appears in the list of reports in the lower part of the screenshot above, and the corresponding search task in the timeline is marked as completed.

The site to which the report corresponds e.g., 'A1', is shown at the top of the report. This corresponds to the next task in the timeline.

The information to be recorded in the report is available only to the search unit (because he is the one physically at the site). However, either the search unit or the tactical actor can enter the information into the report - they are both equally able to operate the buttons on the shared display.

Previously entered reports can be reviewed in the list of reports. Click on a report on a left, then view the details on the right.

8.2 Victim Reports

During the search of a site, a search unit may find a victim. A victim report should then be completed. This will cause a rescue task to appear on the timeline, which the tactical actor must allocate to a rescue team so that the victim can be rescued as soon as possible.

The victim reports are similar to the site reports, as shown below.
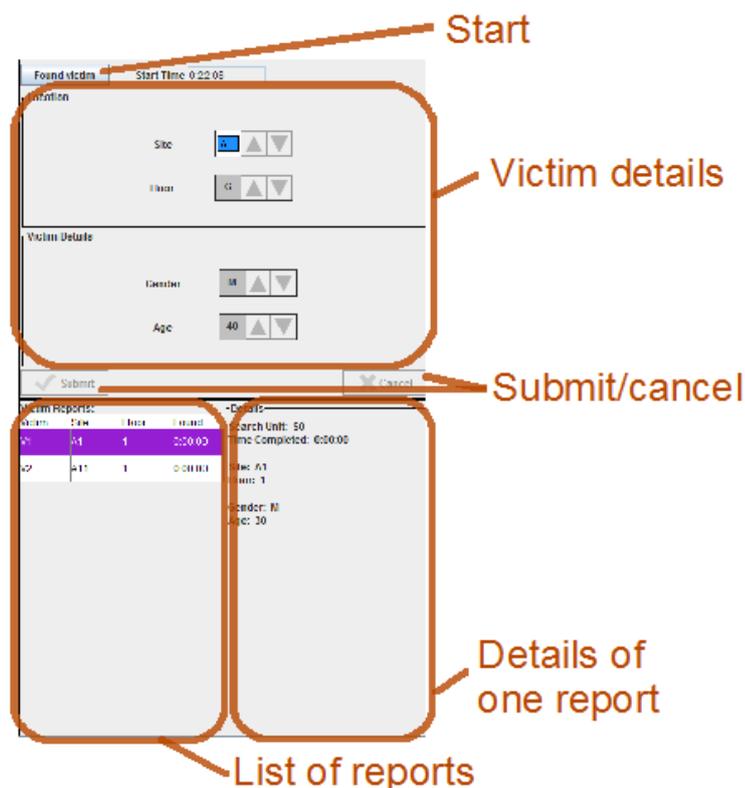
The details of a victim should be entered in the top half of the display, before selecting "submit". Previously entered reports will be listed in the bottom half.

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9. Workspace Awareness

The shared workspaces (map, timeline, and reports) have several 'workspace awareness' features to aid collaboration.

Telepointers
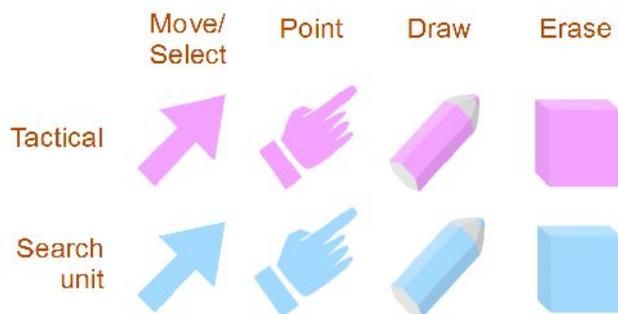
A pointer shows where each person is interacting with the shared workspace. The colour of the pointer indicates the persons role: purple for tactical, blue for search. The shape of the pointer indicates what function the user is performing. Each pointer is visible to all users.

Traces

Each pointer makes a trace behind it as it moves. This may be useful for gesturing to other users.

Visibility regions
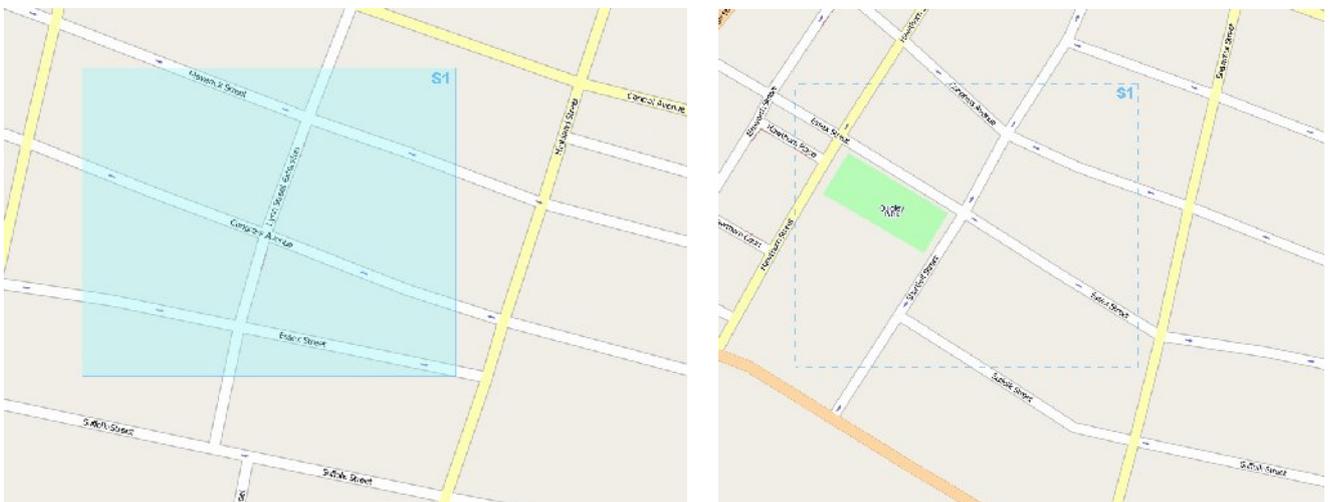
The tactical actor can see visibility regions (blue rectangles) on his workspaces, showing where the handheld view of the search unit is. In this way he can remain aware of what the search unit is looking at.

The regions are shaded (left) when the search unit can actually see that area on his display, and unshaded (right) when he is currently viewing a different workspace (the handheld display only shows one workspace at a time). The tactical actor can move the search unit's view to another position by dragging the 'S1' at the top right of the corresponding region.

Highlighting
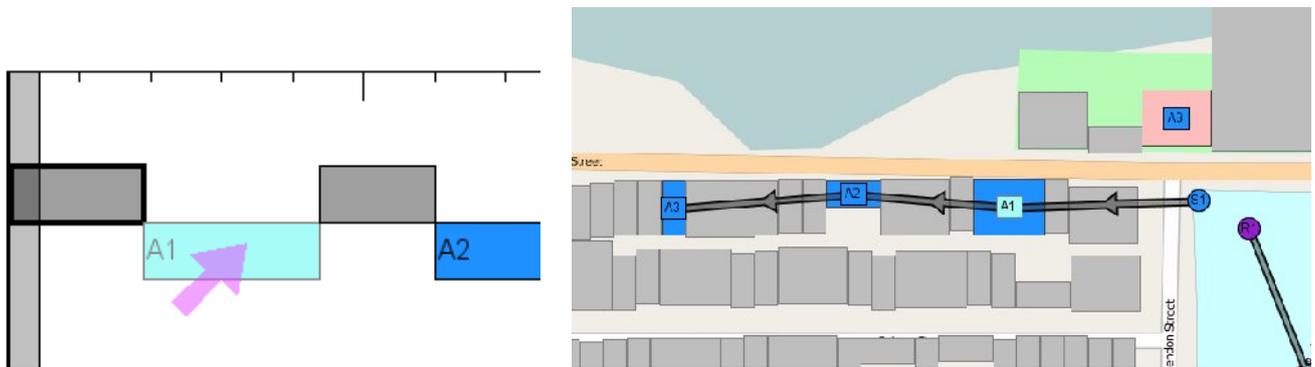
Various objects are linked by highlighting. For instance, when the user moves his pointer over a task in the timeline (left) the task is highlighted, and the corresponding site in the map is also highlighted (right)

Feedthrough
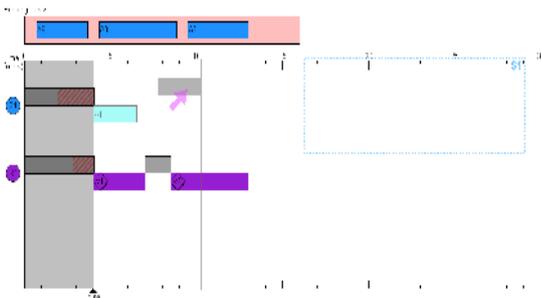
All actions in the shared workspaces are visible to all users that are looking at the corresponding part of the workspace. For instance, if a task is dragged in the timeline (see above) all users will be able to see that.

Annotations
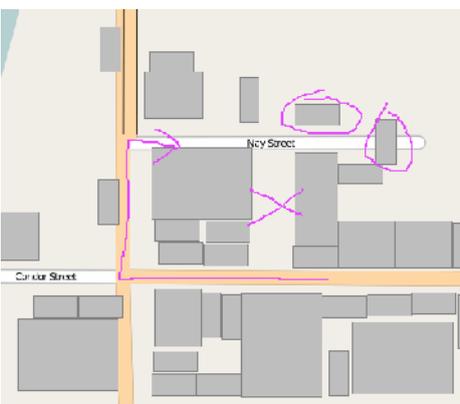
All users can annotate the map by writing on it. The colour of the annotations indicates the role of the person who made them.

Over-the-shoulder view

The tactical actor has a copy of the handheld display on the tabletop. This copy is known as an 'over-the-shoulder view'. It provides an easy way to check exactly what the search unit is seeing, and also to control his display remotely.

10. Tactical Information

The tactical actor will have an extra window on the tabletop display that is not available to the search unit.
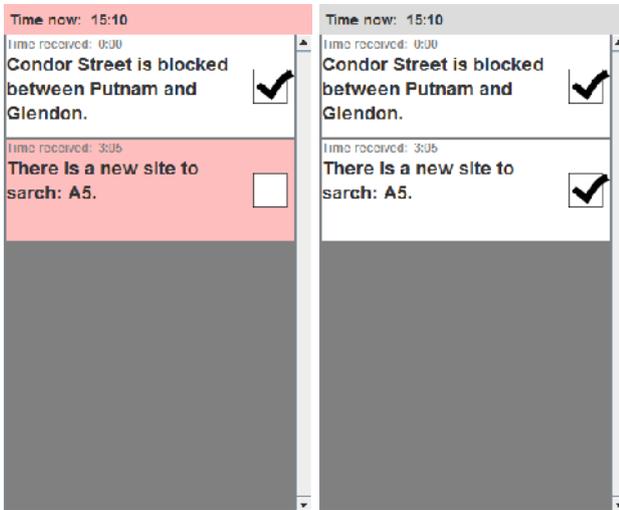
This window displays messages that will appear during the mission. The information in the messages may influence the mission. A new message appearing will be indicated by a sound effect – a ringing phone. New messages are displayed in red (left). The user can click the tick boxes to indicate the messages have been read (right).