ICCARUS

"Intelligent" Command and Control: Acquisition Review Using Simulation

EMPLOYMENT DEPARTMENT GROUP

LEARNING TECHNOLOGIES PROJECT REPORT

"INTELLIGENT" COMMAND AND CONTROL: ACQUISITION REVIEW USING SIMULATION

Research and Development Team

James Powell

Chris Creed

Charlie Gunter

Stephen Hall

Brian Logan

Paul Newland

Theo Wright

Independent Evaluator

Valerie Hey

A report by Workhouse Ltd
in collaboration with
The Design Information Research Team, Portsmouth Polytechnic
and the West Midlands Fire Service
for the Learning Technologies Unit, Employment Department

1. BACKGROUND

At present in Britain there are 5000 fire officers, all of whom could find themselves having to take charge of a large fire incident (defined as one requiring the attendance of five or more pumps). In addition, within the ranks of the fire brigade there are 500 potential fire officers per year who require training before promotion and 200-300 per year who require refresher courses. The West Midland's Fire Brigade alone estimates that they spend approximately £1 million per annum on training and there are 62 brigades in the UK.

Efficient management of major fire incidents brings considerable cost benefits. The Fire Research Station estimated that the average cost per minute of a major fire during the time between the brigade's arrival and when the fire is brought under control, was about £800 in 1965. At current property and content prices this would probably be about £10,000/minute. Definition of what might be a major fire is problematic. However, two possible definitions providing an upper and lower limit are here offered. In 1987 some 220 fires led to damage in excess of £250,000 in each case. Total loss in these fires was about £219 million. In 1983 some 9% of fires in occupied buildings were large enough to spread beyond the room of fire origin (ie approximately 8000 fires). Fire statistics are generally reasonably stable year upon year and these figures are taken from the most recent available to us, (HO Fire Statistics UK 1983 and Fire Prevention June 1988). Thus we may assume that an average saving of one minute on each major fire would save the country somewhere between £2.2 and £80 million per annum. Either way training which effected time savings at a large incident will produce considerable financial benefits to the country.

Brigade approaches to training senior officers in the management of major fires at present occurs in two main ways:

(i) On the job
(ii) Large scale mock–ups

Major difficulties are experienced with both these training methods. 'On the job' training requires senior officers to gain their learning experiences of large incidents first hand while controlling a fire for themselves and while it is actually burning. In such situations any mistakes they make can be costly in terms of lost buildings and, more seriously, life. Furthermore, the infrequency of callouts to such incidents does not aid consolidation of the learning processes for command. 'Mock-ups', on the other hand, demand the marshalling of huge resources for the training of a single individual and the almost inevitable calling away of some of the training resources during the exercise to attend real incidents.

In recognition of these problems the Learning Technologies Unit of the Employment Department at Moorfoot made available funds for the development of an 'intelligent' simulator which would 'exercise' senior fire officers in command and control problems of large fire management.

Research and development funds were initially awarded (C2 Project) in October 1988 for a 12 month period. This study successfully demonstrated to all parties the usefulness of the approach taken and led to the creation of a prototype shell. On the basis of these investigations the present grant was awarded (the ICCARUS Project) to the same research consortium to further develop the ideas and incorporate them in a full working prototype. Indeed it is important to emphasise here that a substantial part of this report details work accomplished under the original C2 Project. Since the one project flowed naturally from the other it is convenient here to make no distinction between the two projects in this report.

The research consortium with regard to both projects is a collaboration between Workhouse Ltd, the Design Information Research Team (DIRT), School of Architecture, Portsmouth Polytechnic and West Midlands Fire Service (WMFS).

Workhouse Ltd – Provided the project management team.

DIRT – Provided expertise and personnel in the realms of knowledge elicitation, artificial intelligence software, interface design, interactive multimedia design and audio/visual production.

WMFS – Provided content expertise in officer management skills, fire variables, a video unit with expertise in the filming of fires and a large library of archive video material.

Overall Aim

The aim of the project was to produce an 'intelligent' interactive multimedia package to provide simulated experience for senior fire officers in the command and control of large fire incident management. A further aim was to investigate the feasibility of providing a debrief for the simulation user.

It was expected that this would be realised through the combination of artificial intelligence techniques and interactive media simulation whilst incorporating a realistic fire model running on a transputer.

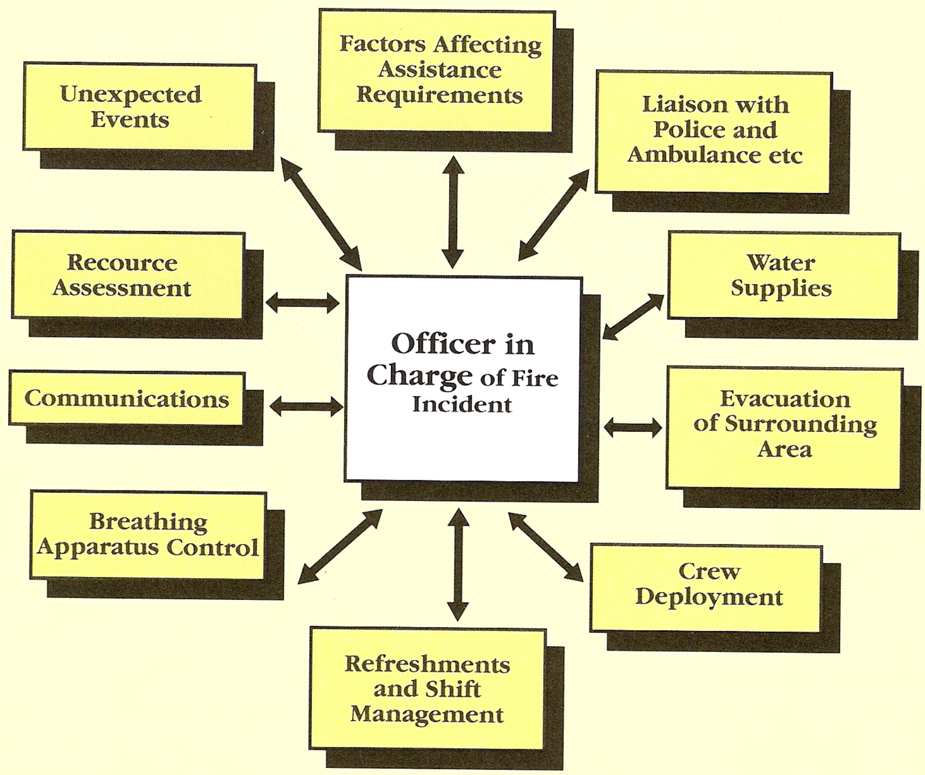
To ensure the validity of the simulation as a genuine training experience the brief for this project also required a thorough evaluation of the final prototype to be undertaken.

This report therefore documents the development and final implementation of these requirements as ICCARUS – Intelligent Command and Control: Acquisition and Review Using Simulation. All the above broad aims were achieved and in addition the debrief feasibility study was extended to the stage of a working debrief.

2. THE TRAINING NEED: PRESENT TRAINING AND PROBLEMS

Effective command and control by an Officer-in-Charge of a major fire involves overall co-ordination of a wide range and high complexity of human and other resources. To do this the officer has to maintain a large scale real time information communication network. Acquiring management skills to do this effectively and efficiently is vital for potential fire officers – to prepare them for command – and for existing officers, to keep them alert to situations they might only deal with very occasionally.

On arriving at an incident, officers are bombarded with a mass of visual and other information relating to the incident and its context. In a short time scale and under great pressure, they have to understand the problem and prioritise actions on the basis of a reasonable strategy. They have to decide what can be done with the personnel available, when to call for reinforcements, what these should be and how many are needed. This requires an overall capability for parallel control of the areas of responsibility summarised in the diagram below.



Senior Command Responsibilities

As fire service officers progress through the higher ranks, one of their duties is to take command of major incidents and strategically control the actions of many firefighting teams. Each officer is likely to attend only a few large incidents in a year, so they have little real 'on-the-job' training for such events. Therefore, training and practice for such a complex job are clearly needed and ideally not 'on-the-job' with possible costs to buildings and human lives.

Nevertheless, a primary problem in the effectiveness of Fire Officers' training lies in the realism of the training task when compared with 'real' life incidents. Much of present training consists of a 'blackboard and chalk' discussion in which a training officer describes a fire incident, followed by a question and answer session: the officers build up check lists of what to do and not do in such incidents. However, this does not help them understand how to work intelligently under stress. To cope with this some brigades mount role playing exercises. When they do, the situations they choose have to be contrived and cannot easily be given the sort of realism and variety that would truly tax the skills of strategic command and control.

Understanding the responsibilities and complexities of managing the large number of resources necessary to fight a fire efficiently and effectively is extremely difficult without concrete experience. Until now the only means of acquiring this concrete experience, short of actual job performance, has been through the creation of 'mock' incidents, involving real men and hardware. For those to be realistic the necessary scale of operation places huge demands on resources that far outweigh the benefits. Only one individual in such 'mock-ups' can participate as Officer-in-Charge – they are, therefore, rare and expensive occasions. Furthermore such 'mock-ups' are invariably destroyed when real incidents demand the removal of resources from the training exercise.

3. OBJECTIVES

The project reported here aims to provide a useful and usable solution to the fundamental training problems outlined above and represented now as a key question: how can an officer be prepared to deal with command and control at an event he may never have experienced? The research team and the Learning Technologies Unit believed a solution to gaining the required management skills could be provided by the development of an 'intelligent' simulation based upon the dynamic response of computer managed interactive media. Such a simulation would create and maintain a context for:

- varying the type and extent of a fire incident.
- developing the broad management skills of delegation, referral, allocation of resources and moment-to-moment decision making.
- requiring an overall capability for parallel control and command of the various areas of responsibility.
- maintaining a workable and efficient communications network with all parts of the fire incident.

The West Midlands Fire Service specified that an objective of such a simulation would be to develop and maintain officers' expertise by allowing them to exercise such skills under simulated conditions. At present it is not feasible to give this sort of training through the use of a tutor/trainer at a brigade, for the following reasons:

(i) Fire Service protocols require that a tutor is of equivalent or higher rank to the trainee. There are no tutors of appropriate rank available outside the Fire Services College.

(ii) Because of the nature of the duty system, training will have to be done on an opportunistic basis, ie when the officer has spare time. Obviously it would be impractical to employ tutors on this basis.

Furthermore, it is not desirable to present the trainee with a model answer to a situation, because there are no model situations. Each situation is novel and in a large incident is complex and often 'wicked', in that it changes obstructively as it progresses. Thus firefighting cannot be a purely objective process because it demands commanders imposing their intelligence on each problem to solve it. Therefore, because of the high degree of subjectivity inevitably resulting, we believe it is better for the trainee to be presented with a record of their actions and the consequent results. This allows them to draw their own conclusions on their own actions and behaviour. Nevertheless, such a saved record of their command and control actions is an ideal initiator for tutorial discussion.

Our preliminary survey of simulator requirements indicated that it should at least:

- stand alone
- operate in real time
- emulate as nearly as possible the 'feel' of the fireground
- present a realistic fire progress
- incorporate the vast majority of those resources which would be present at a real incident, each of which should be capable of operating on its own with either reasonable intelligence or verisimilitude
- subject the trainee to a great deal of decision making
- bombard the trainee with information from many sources
- provide as few system-prompts as possible
- provide learning through experience
- have the potential to present an interrogable visual debrief of a trainee's simulation run
- be available for a hardware and software environment costing not more than £12,000

  and of overriding importance

- **to emulate as nearly as possible the feelings and stresses of the command role.**

4. TARGET AUDIENCE, SOURCES OF KNOWLEDGE ACQUISITION AND FINAL SPECIFICATION

The intended users of ICCARUS are those who may now, or might soon, be in charge of a large fire incident. Potential users are thus all fire officers of the ranks Station Officer (SO), Assistant Divisional Officer (ADO), Divisional Officer (DO) and possibly Assistant Chief Officer (ACO).

Given the complexity and huge number of possible variables associated with the problem of command and control (for instance, the type of building, the type of fire, the fire crews' actions, the resources available, as well as the interactions between all these possible variables) it was extremely important to gain a thorough understanding of the domain and its terminology. In order to elicit fire brigade protocol for the role of Officer-in-Charge and initiate a basis for knowledge acquisition the following sources where investigated:

(i) Books 1-7 and 10-12 of the "Manual of Firemanship". HMSO. Issued under the authority of the Home Office (Fire Department).

(ii) The study of the detailed record and fire investigation report of one particular 20 pump fire that occurred at a plastics factory within the West Midlands Fire Service area.

(iii) Observation of a half day training exercise involving ten Station Officers, a Command Unit and radio communications, with a blackboard simulation of an incident which attempted to train one of the Station Officers in the problems of command and control.

From these sources and the knowledge provided by our team's fire training officer a rapid prototype was constructed as a visual talking point. This prototype interface (see section 6.4) acted as a visual anchor and summary demonstration of the team's understanding of the nature of the problem and facilitated conversation at a deeper level on the following occasions:

(i) A group discussion at the Fire Service College, Moreton-in-Marsh with a Brigade Command Course where the proposed simulator was described, interactive video demonstrated and the course participants discussed what should be included and the nature of an ideal simulator, both as individuals and in group discussions.

(ii) Individual tape-recorded, open ended interviews with nine Senior Divisional Officers from all over the UK. The Officers described fires they had managed (both 'successful' and 'unsuccessful') and specified those factors they felt to be most responsible for stress, confusion and difficulties experienced while in the Officer-in-Charge role. They were asked to elaborate on those factors which occurred most frequently. These interviews lasted from 30-45 minutes each.

(iii) On the basis of the knowledge gained from the above, a series of open ended questions was devised and was presented individually to six Divisional Officers

(vii) In the simulation, fire crews must behave 'intelligently'. For example, when a fire crew has been sent into the building to firefight a particular area, but then discovers some trapped occupants, it has to be capable of changing tasks and attempting to rescue the persons involved, without being ordered by the user to do so and without, initially, the user of the system being aware that they have changed actions.

(viii) The simulation should at times provide the user with the information that the presumed empty building is suddenly now believed to contain members of the public.

(ix) That at times (ie not on all simulation 'runs') fire crews should go missing and be unaccounted for as they would in real incidents.

(x) That the incident should commence at five pumps with a Command Unit, since our informants considered this to be the size at which command and control problems begin.

(xi) That the simulated incident need not progress beyond a 15 pump fire since our informants believe that qualitatively different command and,control problems do not occur as size increases beyond this number.

(xii) That the resources available should reflect those associated with a fire up to 15 pumps ie in terms of men and common equipment. Additionally, a turntable ladder, hydraulic platform and chemical unit should be available.

(xiii) That the simulation be capable of delegating areas of responsibility to 'actor-officers' who will 'intelligently' perform these roles and report back.

(xiv) That during the simulation there should be no down time in the audio-visual environment, ie there should always be at least an appropriate still frame on the video and background fireground noise to continually keep the Commander under 'thinking or emotional pressure' by way of realistic perceptual and cognitive interventions.

(xv) That the simulation should allow the user/learner to go anywhere on the fireground or remain in the Command Unit.

(xvi) That all orders, enquiries and information should sound as if they were coming from a radio when the user has decided to leave the Command Unit.

(xvii) That the user/learner should be exposed to information at a 'real – incident rate' and that they should feel pressured to take decisions at the 'real – incident rate'.

(xviii) That the user/learner should be interrupted from his task by members of the public (eg press, someone who believes a friend or relative is in the building) as they would be in reality.

(xix) That the user/learner should be able to call for a number of experts (eg keyholder, structural engineer).

(xx) That at the end of the simulation a user/learner should be able to access a fully interrogable visual presentation of their run on the simulation and that these debrief documents can be saved for later reference and comparison.

(xxi) That if the user cannot control the incident then the building shall be 'lost'.

(xxii) That if the user calls for resources beyond those maximally available within the simulation (ie 15 pumps) a more senior officer will arrive in the simulation and will ask to be briefed by the user.

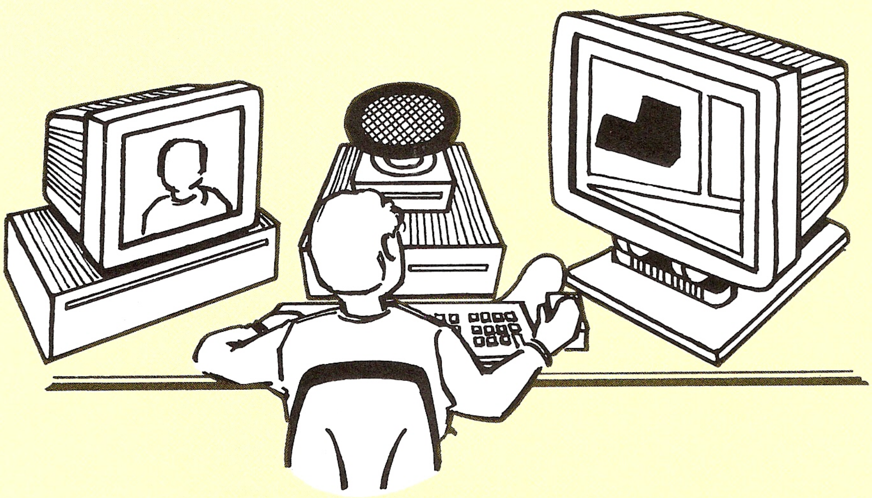
The order of the above specifications does not reflect any order of importance.

5. THE SOLUTION – AN OVERVIEW

The success of our ICCARUS Simulator depended on the effective integration of three major components; suitable delivery hardware and user interface, a unified AI/computing environment and a capacity to portray appropriate contextual audio/visual material.

5.1 The Simulation Environment

To create a suitable mechanism to deliver the ICCARUS Simulation we employed state-of-the-art technology. A Macintosh IIci hosts the central processor which is supported by a transputer and controls an array of peripherals – A3 high resolution screen, videodisc player and CD-ROM drive. Visual output is directed to a PAL standard TV monitor and audio is mixed and amplified by a stand alone stereo speaker. The diagram below details a typical set-up.



ICCARUS: Simulation Set-Up

The user-learner converses with the simulation via a mouse. This point and click input is facilitated by a Prolog enhanced WIMPS interface. This graphical interface, portrayed on the A3 screen, orientates and informs the user while providing the means to actuate his command and control strategy – the design process and full description of this interface is given in section 6.4

When integrated the above hardware gives the basis for projecting a **restricted but genuine** experience of a large fire incident. The software components required for achieving such a suitably realistic simulation capable of suspending disbelief in the trainee are summarised in the next two sections.

5.2 The Interlinked AI/Computing Programme Modules

Five major programme modules form the ICCARUS Simulation. In sequence of running operation they are: the tutor set-up, fire model, stage/actors/script factory, action/event recorder and debrief. Detailed descriptions of each module are provided in sections 6.2 and 6.3 – the outcome of their integral operation is outlined here.

The ICCARUS Simulation can best be compared to an improvised opera. To initiate different 'stress' factors the Tutor Set-Up allows both the creation and selection of scenario data files, each data file provides a particular set of props which will be present for that particular run of the simulation. The Fire Model can be viewed as an over enthusiastic orchestra which will either free run or be brought under control by appropriate direction of the actors. Such direction is the goal of the user-learner who has the Stage/Actors/Scripts factory at their disposal. However, each actor is a 'soloist' in their own right with the 'intelligence' to participate without requiring total direction – the interaction of up to 200 such semi-autonomous actors at any one incident provides the necessary complexity to engage and challenge the capabilities of any user-learner.

As the incident progresses the Action/Event Recorder ensures a transcript of this one-off operatic production is retained for posterity. The Debrief module then presents a graphical interpretation of the incident transcript using interrogable timelines, databases and animated diagrams. In this non-judgemental manner the Debrief allows both user-learner and trainer to review the strategic actions taken throughout the simulation run.

5.3 The Replication of an Audio/Visual Context

To provide the user-learner with a convincing experiential 'feeling' during the ICCARUS Simulation the portrayal of an appropriate audio/visual context was fundamental. We created such sensory orientation through obtaining live footage from the controlled torching of a disused cinema. This night time video was skillfully integrated with archive material so that the progress of conflagration of a real building from beginning through to 'car park' (Fire Brigade terminology for a lost building) could be seen from a variety of positions on the fireground. This video was then made readily accessible by pressing it onto a 37 minute videodisc.

Supporting the visual material is a two hour audio resource captured digitally on a CD: Through software synchronisation of videodisc and CD player, video stills can be overlayed with authentic fireground and command unit messages. Also available from the CD is a looped background sound track which provides a true-to-life aural environment. Full details of the audio/visual considerations and content are presented in section 6.1.

5.4 The Scenario for a Command and Control Learner

The following description gives an impression of how a typical user would initiate, run through and complete a session on our ICCARUS Simulator. User-learners make themselves comfortable in front of the two screen system and become accustomed to the mouse. With a double click on the stand alone application "ICCARUS", the request for a user identity is presented, this is the only time use of the keyboard is required. From this point on only mouse control is necessary. Activated behind the scenes is either the choice of a random set-up scenario or one that a tutor has previously selected for the user. Meanwhile the user is guided by a voice-over introduction which draws him into the simulation scenario. They are told that they are presently driving towards a 5 pump incident which is taking place on their 'patch'.

At this stage the video screen becomes active and a sequence of stills portrays a time–lapse point of view drive through an urban environment. Meanwhile on the car radio various messages can be overheard concerning the incident which are being relayed to Fire Control. On arrival at the incident the video, which remains point of view throughout the simulation, shows the user leaving his car and approaching the Command Unit. Through interaction with the interface the Officer-learner now has various options: they can be briefed asking SO Hall (the present Officer-in-Charge) for a summary of the present situation (based on the the three main questions used by all Officers; What have you got? What messages have you sent? What have you done?); they can enter the Command Unit; they can ask to be taken to the fireground. At some stage when the user feels acquainted with the situation they inform SO Hall, "I am taking charge", our typical user now becomes Officer-in-Charge.

In this role the user is given full access to the command and control structure of the interface, he is now at liberty to make pumps (ie ask for more appliances), create sub officers, send messages, move pumps and co-ordinate teams wearing breathing apparatus and firefighting crews. As he takes these actions, corresponding audio-visual material confirms and relays the consequences of these undertakings for men, equipment and the fire progress. As the number of active decisions required increases, this audio-visual environment also introduces strong 'stressor' agents such as distraught persons fearing someone is trapped in the building at the centre of the incident and officials of various professions wanting to know what is happening and how they should assist. By this time the simulation will normally have induced a suspension of disbelief and the user is wholly involved in a realistic and experiential command and control activity (see section 8 and Supplementary Report D**).

The simulation is completed in one of three ways: when the user sends a 'Stop' message (ie the fire has been extinguished); the user's actions lose the building; or a senior officer arrives to take charge if 15 or more pumps are requested by the user. In what ever way the user completes his interaction there is provision for a comprehensive debriefing session.

All the simulation events and user's actions are recorded throughout the simulation run. On exiting, the computer creates a personalised debrief based on the collected data and this is presented to the user as a four section intelligent visual display. Each interrogable section covers one of the four questions – Have I an overview? Am I using my resources appropriately? Are my communications centralised and reliable? Am I responding to the moment? These were felt to be the main areas of debrief concern as elicited from the questionnaire responses of 88 assistant divisional and divisional officers from a cross section of Britain's fire brigades (see Supplementary Report B). As the user peruses their debrief there are facilities for them to look at on screen notes made by their brigade trainer and for them to make their own notes for later review with a tutor. The debrief is a permanent record of the user's simulation run and they can refer to it at any time or compare it with other sessions they undertake with ICCARUS.

6. DETAILS OF THE ICCARUS SIMULATION

6.1 Scenarios and the Audio–Visual Environment

Many of the problems of commanding a real fire incident and many of the points made by our informants concerning the nature of an ideal simulator were seen to stem from the two major tasks of the commander role, ie firefighting and logistics. The fundamental problem is one of balancing between firefighting demands and maintaining a logistical overview of the whole incident. This underlying difficulty emerged from our informants' discussions of the way command changes as fire size increases.

Below five pumps the Officer-in-Charge is clearly predominantly concerned with firefighting. In such an incident the brigade's command and control resources have probably only recently arrived, the firefighting strategy has to be initiated, pumps and jets placed, the seat of the fire found, its likely spread assessed, etc. Above 15 pumps the Officer-in-Charge is almost totally concerned with command and control logistics. The fire incident is now of such a size that the fireground itself will have been zoned, with the firefighting in each zone under the command of a more junior officer. The Officer-in-Charge will now be involved in making sure adequate resources are available to zone commanders; coordinating back up; liaising with other agencies such as police and ambulance; arranging for water supplies, safety, salvage; and managing the complex communications that all of this implies.

** The detailed supplementary reports produced by the research team and listed at the end of this report. Any of these is available at a cost to cover photocopying and postage. Please contact either Chris Creed or Paul Newland, ICCARUS Project, Department of Design, Lion Gate Building, Lion Terrace, Portsmouth, Hants. PO1 3HF.

Thus below five pumps and above 15 pumps the role to be taken by the senior officer is usually clear. Below five it is most usually appropriate to 'get in there' quickly: effective control of the incident entails getting to the seat of the fire and tackling it directly. Above 15 the concern is with the fire's periphery – the boundaries of allowable spread.

The major problem for the Officer-in-Charge occurs at 5-15 pumps, when uncertainty arises from whether his role should be primarily controlling firefighting, setting up command logistics, or the difficult combination of both. There is no clear answer to this dilemma.

The overall aim of our audio-visual material was, therefore, to represent the fireground in a way that allows for good performance of command and control firefighting while giving 'temptations' and providing 'stressors' which might cause the user to lose the overview necessary for adequate performance. In an analogous way, the Command Unit environment should be represented by allowing for an adequate performance of the command and control logistical role while providing the chaos, interruptions and communication overload that might destroy good role performance – putting the Commander under the sort of pressure which would make them lose their idea of the relationship between the parts that need to be co-ordinated.

Simulation Setting

The attempt was made to create a video of a setting which was as non-specific as possible while maintaining user credibility. We decided to go for a night-time fire and to look for a building such as an old 2-3 storey factory where we could film.

A number of reasons determined this decision. There is some good archive footage of such fires. Daytime fires are so obviously of a particular and unique building that our video would all have to be of this one place and time. This would have denied us access to archive material which we could mix with our own video. However, we knew we would have to use such archive film since our own resources and budgets were not large enough for us to film everything necessary to provide a rich enough environment for the genuine but restricted user experience we were seeking to portray. And, of course, many continuity problems (the major problem for the credible 'look' in any interactive project) can be solved by portraying an incident at night. If you can't see much you can't complain that things aren't where they should be. Furthermore with limited time available on the videodisc (37 minutes), compared to the demand that the simulation should typically run from 2-4 hours, and with limited resources set by the project brief (such as the number of actors available), a night-time scenario makes it possible to repeat the same sections of video (with different audio) without it becoming boringly repetitive.

As noted above, we wished to allow our user-learners to adopt either a firefighting role or a logistical role or a mixed role. In each case we wanted the experience to be a rich one. In each case we wanted to use the video to tempt (and stress) the user away from a satisfactory implementation of their chosen role. Various stressor/tempters have been detailed by our informants.

1. For the firefighting role this generally related to the 'call of the fire'. This means making the fireground video as compelling as possible. Specific tempters are as follows:

    People in trouble in the building (public and firemen)
    Losing the building
    Inheriting the plan (ie taking over).
    There is still time to 'get in there', but serious implications for the men sent in
    Unknown content hazards

2. For the logistical element of command and control this generally relates to interruptions and information overload. This entails making the Command Unit video as rich in detail as possible. Specific temptations are as follows:

    People in trouble in the building
    Losing the building
    Chaos of details
    Partitioning the logistics into a limited but adequate number of deputy roles
    Number of messages
    Interruptions

A number of possible options were available to us for collecting the audio–visual material. We could have relied entirely upon archive material, but we knew that by taking this course we would never achieve a 'feel' of one time and one place. Another possibility was to film under the controlled conditions available at the Fire Service College at Moreton-in-Marsh. However, the buildings at Moreton are so familiar to fire officers, and so odd looking (they are designed to be 'burnt down' twice a day) that we wished to avoid this option. A further option might have been to wait at the ready with a film crew, to rush out and film a real incident. But the cost of film crews, together with our restricted budget, ruled this out. In addition everything would have had to be filmed in one take.

It seemed apparent, therefore, that we had to find a derelict building of our own which we could set alight and film in our own ways. Finding such a building adequate for our brief, derelict and not wanted, situated at a safe distance from the public and with permission to carry out a little legal 'arson', was not easy.

Luckily building control in the city of Birmingham found us a disused cinema that was due for demolition and one which they were prepared for us to 'torch' to a limited extent. It was not ideal since it was rather too near a lot of occupied houses on two of its sides. The implications of this were that the burning would have to be more limited than we would have liked because of the danger to residents. Furthermore, the filming had to be restricted to a mere two and half to three hours (from nightfall to midnight), on the three nights available to film, because of the nuisance factor. But it was REAL.

The Luxor Cinema can be seen in the photographs included here.

It was a fine old building and a pity to vandalise even parts of it. However, our guilt was assuaged by the benefits to our project and the fact of its imminent demolition anyway.

Access round the building was good, and its type and nature allowed us to meet major demands on the simulation ie that building use and context could be varied across simulation runs. Specifically this building could allow us to develop scenarios concerning a private cinema/club or a warehouse which could contain a variety of differently dangerous, noxious and unpleasant substances.

Audio–Visual Material Obtained

Filming took place on three nights in late May 1989. Filming and editing resulted in the following material being edited onto a videodisc. (The order given below corresponds to the order that material is laid onto the videodisc).

(i) Simulation endings: showing the arrival of a more senior officer to the fireground and to be used in the event of the building being 'lost' or if the user were to call for resources beyond 15 pumps. (Approximately 30 seconds videodisc time).

(ii) Pressure points: showing a series of arrivals at both the fireground and the Command Unit of a number of individuals (both relevant experts and members of the public) demanding the attention of the Officer-in-Charge. These persons were: the press, the police, an insurance man, an angry photographer who has been involved in a fracas with one of the fireman, a woman who believes her friends are in the building having been invited to an after hours party, the keyholder, a gasman, a British Rail engineer concerned about the adjacent rail line and tunnel, a structural engineer from building control and the wife of the cinema projectionist whose husband is missing. (Approximately 5 minutes videodisc time).

(iii) Command Unit: shots inside the Command Unit showing activities of the three personnel of the Command Unit: two radiomen sending and receiving messages and the officer in command of the Command Unit updating information on crewboards, site plans etc. (Approximately 5 minutes videodisc time).

(iv) Fireground Perspectives: views of the building from all sides from no smoke through light, medium and heavy smoke to smoke and flames. (Approximately 7 minutes of videodisc time).

(v) Fireground Incidents: fire crews fighting the fire, BA (breathing apparatus) teams entering and exiting the building, chemical crews kitting up and going in, all shown at various stages of the fire. (Approximately 13 minutes of videodisc time).

(vi) Close-ups of fireground activity: taking equipment from the pumps, connecting hoses, runners arriving, kitting up in BA, etc. (Approximately 2 minutes of videodisc time).

(vii) Arrival and Briefing: user sees a point of view of 'themselves' arriving at the incident and being greeted by the officer they are to relieve. Walks around the building and fireground and entry into the Command Unit while the officer briefs them. (Approximately 3 minutes videodisc time).

(viii) Archive material: showing hydraulic platform, turntable ladders and the final stages of a large warehouse fire showing the whole building alight and the roof collapse – this building had an almost identical shape as seen at night to our own cinema. (Approximately 2 minutes videodisc time).

(ix) Stills: approximately 500 photographs around the building showing various stages of burn from various perspectives. (Approximately 30 seconds videodisc time).

In addition to the videodisc material some two hours of audio material has been recorded and pressed onto a compact disc. This audio material will typically be accessed to be played while appropriate stills remain on the video screen of the simulation set-up. The audio includes various versions of the briefing – to set-up different scenarios at the start point (eg whether the building is a club or a warehouse); many specific messages to the fireground and to fire control at Brigade Headquarters as from the radio operators in the Command Unit; messages to be received on the radio of the user as from the Command Unit to the user on the fireground; much general fireground noise and speech from all of the 'characters' mentioned above in the 'pressure points' section, who can provide various stories and elaborations of what they know, to the user, if enquired of.

Typically appropriate audio-visual selections will be made by the computer when it examines the simulation state every 1/60 of a second. The questions it must ask itself in order to make a 'good' selection are as follows:

First, the simulation will enquire of itself where the Officer-in-Charge is presently located. Are they in the Command Unit or on the fireground and, if on the fireground, exactly where are they and what is in their field of view? Second, the simulation enquires of its fire model what is the present state of the fire in this location. Does this fire state imply no smoke, light, medium or heavy smoke, or smoke and flames? Now the simulation enquires of its location list what is in this field of view in terms of men, machines or both and then if, say, men are present, it asks whether they be BA teams, chemical teams, carrying a jet, making an entry etc. Having asked and answered all of these questions it has in fact identified a number of sections of the audio-visual material, any of which may be appropriately shown at that instant. From all of these possible options the simulation will choose at random.

6.2 Computing and Control Strategy for the Simulation Core

Background

This section clarifies the objectives and developments of the detailed software components of ICCARUS. The simulation has applied a number of novel 'AI' techniques throughout its development (see Supplementary Report A). Before describing them it is important to emphasise that the purpose of the package is to give the user experience of the kinds of decision-making situations which occur in managing large scale incidents. As a result it was felt more important that all the characteristic pressures of the command and control situation were reproduced (resource planning and allocation under uncertainty) rather than that the details of any particular situation or event be totally accurate. For instance, rather than choose to represent the spread of fire or the diffusion of smoke with total accuracy we chose a model which had a workable fidelity, but with computing demands compatible with the simulation's realism (ie able to be modelled on an integral transputer board rather than an external dedicated computer – note that should greater fire spread fidelity ever be desired it would be relatively trivial to include a more comprehensive model). In short, we chose to satisfy all computing events to enable a genuine but restricted experience to be developed within real time and a micro-computing environment.

The package can be broken down into two main components:

(i) a real-time, event-based qualitative simulation capable of realistically modelling the behaviour of both the fire and decision-making capabilities of the agents under the Officer-in-Charge's control, and

(ii) an interactive multimedia interface which allows the user to request and allocate resources, ask for information etc, through a protocol which mirrors normal brigade practice by 'delegating' the relevant tasks to 'intelligent' assistants, and which provides feedback on the state and progress of the fire by means of dynamically assembled audio/visual/textual sequences.

Our simulation model was based on ideas drawn from a number of sources, principally Cohen et al (1989) and Hewitt's (1977) work on modelling control structures as networks of 'actors' together with much of the more recent work on object-oriented programming and qualitative modelling (refer Supplementary Report A for a detailed developmental background to the theoretical aspects of this project). 'Qualitative' in this context means that the simulation is largely symbolic in character rather than being purely numerical, although clearly both numbers and equations are required to represent many of the processes of interest.

The simulation itself was composed of two main types of objects: actors and messages. The number and type of each is determined by the scenario or storyline of the simulation which specifies the number of each type of actor required, how they are interconnected and the types of messages with which they communicate. Clearly the flexibility of the package in use depends to a considerable extent on the ease with which scenarios are constructed to provide a range of practical experiences to support skills learning and practice, and the major aim of ICCARUS has been to allow the definition of scenarios in a flexible yet consistent way.

Actors are the basic building blocks of the simulation: individuals, teams, pumps and walls are all 'actors'. Each actor consists of a script together with a collection of local variables representing the actor's state. A script is basically a set of condition-action pairs which determine the actor's capabilities and behaviour in response to messages. When an actor receives a message, an attempt is made to match the message against one of the condition-action pairs forming the script. If this is successful the associated action is 'fired' which may result either in further messages being sent or modifications of the actor's internal state (or both). At one level therefore, the whole system can be seen as a straightforward production system. However, conceptualising the productions in terms of actors and events has considerable advantages in designing, constructing and maintaining large scale simulations.

From this brief description two points emerge; the differences between actors are entirely a result of differences in their scripts – the basic underlying framework is the same in each case, and, therefore, the degree of 'intelligence' exhibited by an actor is entirely dependent on the complexity or otherwise of the script. A complex script will allow an actor to be larger and more complex, increasing both the development time and the time required to 'run' the actor at each time step.

The complexity within the ICCARUS simulation develops as actors begin to interact and pass messages to each other. During this message passing the storyline of the simulation develops and is related back to the user-learner via the interface. The user-learner has complete strategic control over the simulation as he sends different problem solving actors to cope with different aspects of the incident he controls.

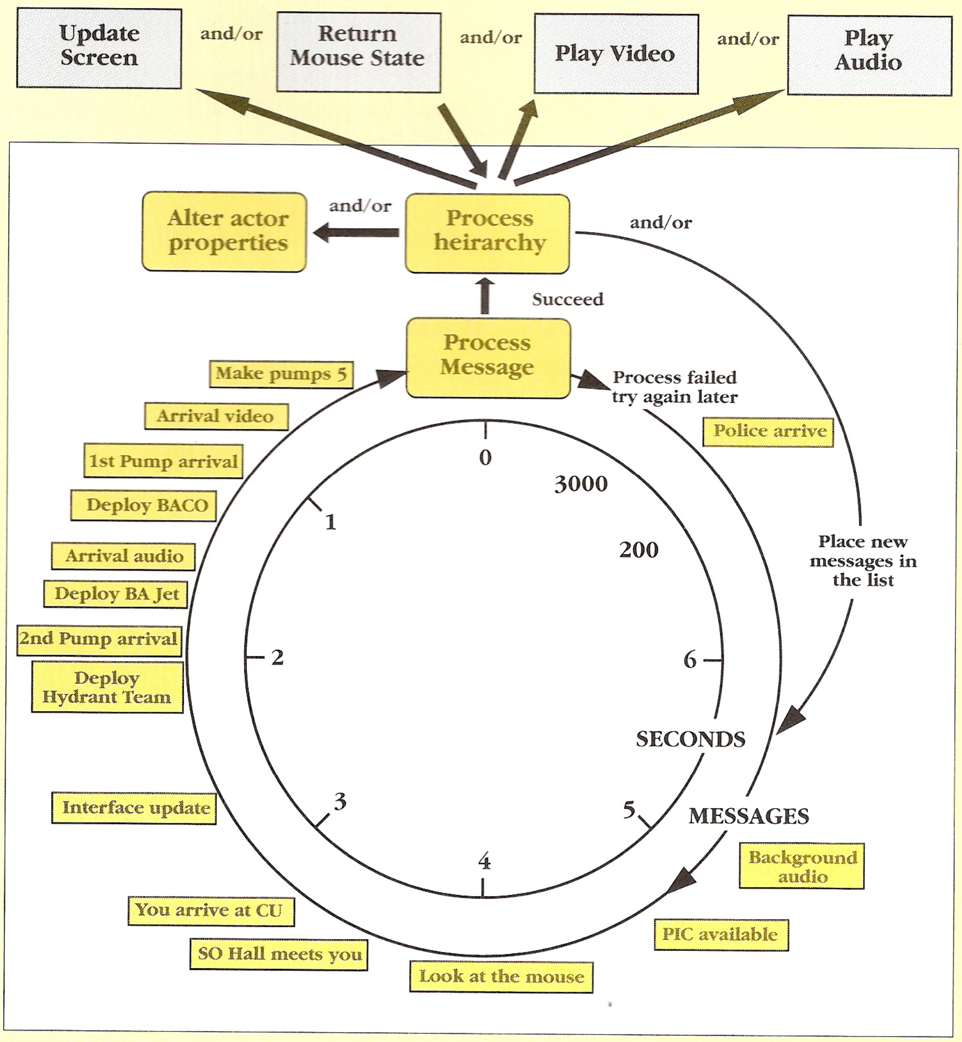
Clearly messages and message handling are the other important issues in the development of an effective and efficient simulation. Our original concept of message structures and their associated access procedures went through many stages of extensive revision in an attempt to provide access messages on both a 'message by message' and an 'actor by actor' basis, and to eliminate structure copying. In a 'structure copying' design the message structure is copied by replicating the binary tree of binary trees and adding the new message to the actor tree or, if a new time step is required, adding a new branch to the time step tree and placing the message under its actor name in this new branch. Further messages within the same time step will be added to this new branch forming eventually a sub tree of actors.

If 'structure copying' is to be avoided space has to be made for the new message by 'walking' existing messages out of the way. In the penultimate version of the software the message structure was a binary tree of binary trees of incomplete lists keyed by time step and actor. At the beginning of each time step (ie during sys : COPY), the system could elect to retrieve the messages for the next time step either as a list of individual messages (using the procedure messages) or as a list of messages grouped by actor (using the procedure actor-messages). As a result it was possible to process the messages either one at a time or as a list of all the messages for the next actor. This had the advantage of increasing flexibility, but at the cost of greater complexity.

During the final development stages it became apparent that the pending message list was all that needed to be processed at each time step, and that this could be optimised by time stamping the messages. A more theoretical explanation of this our final solution is shown in the next section.

Systems Architecture

All the actor scripts, interface and videodisc control have been implemented in LPA Prolog on a Macintosh IIci. As already indicated all processes within this environment are controlled by messages, the initial state of the simulation is obtained by placing messages in the message list eg 'Make Pumps 5', 'Deploy BA Jet'. ICCARUS, therefore, consists of a message list and a hierarchy of procedures that can respond to messages taken from the message list.



ICCARUS: Control Strategy Using Timed Messages

All messages are time-stamped in 1/60 of a second. This allows for advantageous control of the CD audio allowing combined sentences to be 1/60 of a second apart as opposed to one second (the initial prototype time step). It also allows complex tasks, that have to be performed in real time, to be broken down into a series of smaller messages which are processed at short intervals. This avoids the mouse becoming inactive for long time periods and allows other messages the opportunity to be processed at the 'same time', resulting in many messages being processed sequentially and creating the realistic illusion of parallel processing. For example a section of audio can be played, the video can be started and a text message displayed on the screen all within a second.

The diagram above shows messages arranged in order of their required processing time, with messages being taken off the front of the list and new messages added at any point in the list depending on the required time of processing. Any messages that fail to be processed at the correct time can be placed back in the list to be processed at a later time, the extra delay entailed can be set to reflect the priority of the message. The most frequent occurrence of this action concerns the video which can be delayed until the present video sequence has finished. The box 'process hierarchy' in the diagram contains not only the processes for controlling the video, audio, obtaining the state of the mouse and redrawing the graphics but also the hierarchy of actor scripts.

Placing all control in the message list means that actors can influence the way in which the screen is redrawn or the frequency with which the mouse position is looked at. When 'You' (the simulation's name for the user who has not taken charge) arrive at the fireground the actor 'You' can request that the screen display is updated, in the same way when the user starts to move an item on the interface a message can be sent to update the mouse position more frequently, giving enhanced feedback to the user.

The simulation core thus provides the structure for a dynamic, responsive actor/script/message factory. Around this basis various integral and peripheral modules facilitate the strong degree of fidelity conveyed by ICCARUS.

6.3 Computing and Control Strategy for the Integral and Peripheral Simulation Modules

This section takes in turn each of the four integral and the two peripheral computing modules which interact to support the core simulation computing strategy of ICCARUS. These modules, the building model, the fire model, transputer access, CD audio access, debrief and tutor set-up were written in 'C' or SuperCard, with specially authored routines to communicate with each other and the Prolog based simulation core (for full documentation see Supplementary Report C).

The Building Model

The building around which ICCARUS operates has been coded with two alternative internal room layouts: a cinema and warehouse. The building model as such was created from the following constraints to give a manageable but realistic structure to harbour a fire incident:

(i) Each room has one ceiling.

(ii) Each room is of a single uniform height.

(iii) Each room contains a single uniform type of fuel (which is evenly distributed and occupies a percentage of the volume of the room).

(iv) The percentage of each room occupied by fuel is constant throughout the building.

(v) Each room-room boundary includes no more than one wall.

(vi) Each room-room boundary includes no more than one ceiling.

(vii) Each room-room boundary includes no more than a specified number of doors.

(viii) Each room-room boundary includes no more than a specified number of windows.

Both the building encoding, and the fire model described below implement the concept of multi-storey buildings, though due to resource limitation this is not represented on the interface of either the simulation or the debrief at present.

The building model has been designed so that there are several factors that can be used to modify the behaviour of the fire without affecting the fire model itself. However, at the moment formally describing the structure of a building is currently done 'by hand'. This is a rather awkward process done by a programmer rather than a trainer. This setting up procedure would be made more open in the production phase and development.

The Fire Model

The over-riding principle behind the development of a fire model was that it should be believable when seen in the simulation. Our advisors believed it unnecessary to model fire behaviour with absolute accuracy, as this would be a major computing task and was not the purpose of the project.

The mathematics of the fire model were derived from relevant literature (FRS Fire Modelling Documentation) and discussions with fire experts. Most of the available literature was either too simplistic, not providing sufficient mathematical information from which to proceed, or too complex providing far too much detail to implement. To arrive at the current model, the tendency had been towards the parsimonious, supplementing this information with some basic physics, and emphasising particularly important aspects drawn from discussion with our fire experts.

The fire model was implemented as a single process written in C which cycles around on the transputer. Most of the time it is idle, but at intervals (currently every two minutes) it updates itself. A second process that also cycles, provides communication between the fire model and a C code resource on the Macintosh host. This communication is only ever instigated from the Macintosh side.

Calls are provided to the transputer from C code resources (called from Prolog) to access most of the parameters of the fire, as well as information related to the building itself (such as whether there is a wall joining two particular rooms; and if so, what its number is).

The fire model can be stored for later retrieval if, for example, the user pauses the simulation.

The behaviour of the fire model is summarised below:

(i) Each **room** has various attributes including its contents which may provide fuel for the fire, and its associated structures that link it to other rooms and the outside world (eg doors, walls).

(ii) Each **structure** is composed of a material that has attributes related to particular properties such as ignition temperature and heat transmission. Structures become 'notional' (ie they disappear) when they are destroyed. Additional 'notional' structures may be present in the building to artificially break up large rooms and rationalise the internal structure.

(iii) **Walls** are destroyed by high temperature difference between the two sides. **Windows** are destroyed when they reach a certain temperature. **Doors** and **ceilings** (which are equivalent to floors in rooms above) can survive for a specified number of minutes once a particular temperature has been reached. They are destroyed when that time runs out.

(iv) **Combustion** depends on the presence of sufficient oxygen, sufficient fuel and a high temperature. **Flame** intensity and **temperature** are modelled room by room. Temperature is artificially limited to 1000 ºC.

(v) Parameters such as temperature, flame and smoke are only modelled on a room by room basis. This leads to certain problems. Specifically, once the fire in a room has been extinguished, because the surrounding rooms may still be very hot, the room will reignite in the next time step. To avoid this unrealistic instant **re-ignition** an appropriate time delay has been built in.

(vi) The amount of **oxygen** in a room is modelled as the volume of the room not occupied by fuel. Oxygen can also enter a room by seepage through open boundaries. It is assumed that there is an inexhaustible supply of oxygen outside each room.

(vii) **Smoke** has particular qualities determined by the nature of the fuel in which it is present. Heat and smoke tend to equalise throughout the building by movement through open boundaries (such as open doors, destroyed walls). Smoke and heat tend to rise.

(viii) **Hazardous materials** exhibit different effects when they ignite. If an explosion occurs (eg with LPG cylinders) the temperature is instantaneously raised, and some of the structures 'in' the room may be destroyed.

(ix) **The seat of a fire** is modelled as an initially high temperature in that room. All heat in the model from then on is generated by combustion of fuel materials in the rooms.

(x) **Firefighting** is achieved by applying water, which tends to dissipate heat through conversion to steam; or foam, which tends to restrict the available oxygen.

The Role of the Transputer

The initial aim of the project was to place many of the processes performed by the Macintosh IIci onto a transputer board. To this end a message passing protocol was developed on a compatible non-Machintosh based transputer which would enable messages to be passed from actor to actor and from mouse to disc drives, screen, CD-ROM and videodisc.

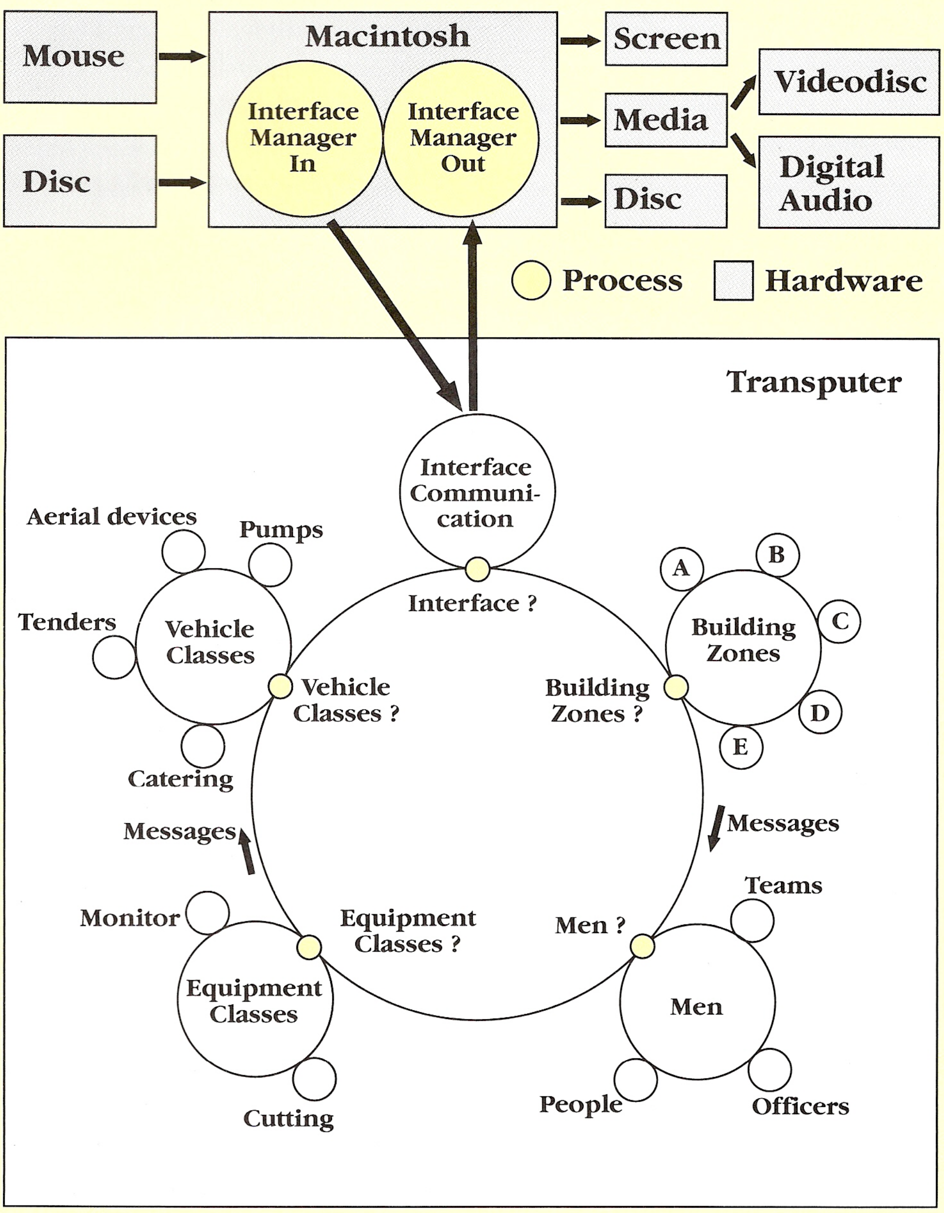
Messages in this system were transferred around a ring structure written in Occam, but able to call low level routines for CD-ROM access and videodisc control written in C. Provision was also made for sections of Prolog code to be transferred to the transputer and accessed from one of the nodes in the Occam ring structure. Time stamped messages destined for a particular actor or process could be sent around the ring until they reached a kernel capable of handling that particular message. These messages would be placed in this kernel message buffer ready to be sent around the first sub-ring (see diagram overleaf). As processor time became available messages could be taken from this first buffer and passed around the sub-ring to the kernel given the task of storing and distributing these messages.

When the kernel found its clock matched the required processing time of the first message in this buffer it would allocate a free processor to match a condition-action pair. This would result in a further message being sent to either videodisc, CD-ROM or an actor in the simulation. Given the parallel processing capability of transputers it was hoped that a truly non-deterministic simulation could be obtained.

Our problems started when we tried to move to the Macintosh environment. We soon found we were the first people in the country using transputers in this way and various communications with other Macintosh transputer users confirmed that there was no help available in Britain. However, we persevered and after initial problems and lengthy correspondence with Levco (the sole manufacturer of a transputer board for the Apple™ Macintosh) in California, success was achieved in C running on the transputer and communicating successfully with a C code resource on the Macintosh.

The Levco board has proved to be extremely reliable, although many further software revisions to the transputer PROM, a change of manufacturer and an upgrade to the

Macintosh system and Prolog itself have meant that much of our time was spent upgrading aspects of the software to maintain compatibility. This has resulted in the Fire and Building Model, along with the simulation set-up being located on the transputer. The C code for determining which audio sequence should be played has been left on the Macintosh although it is ready to be transferred to the transputer. However, a Prolog compiler for the transputer board on the Macintosh was not available. So all actors scripts have been left at present on the Macintosh.



ICCARUS: Transputer Feasibility Study

CD Audio Access

Although CD ROM XA was considered for the audio, the equipment necessary was not available for the Macintosh. It was decided that a limit of 148 minutes of audio would be acceptable, and therefore using a conventional audio CD on a CD-ROM drive would be the best route to take.

After an initial false start, caused by attempting to use CD-Assist software from PDO (which proved to be ineffective for our project), appropriate specifications were obtained from the Apple developer's group.

Various routines have been developed for accessing the audio; including routines to play from point to point, pause the CD, resume play, check the status of the CD drive, initialise the CD drive (including disc identification), and check the status and location of the disc. C code resources have been built to allow access from Prolog and an XCMD to allow access from SuperCard.

The current software only supports the Apple CD SC CD-ROM drive although conversion to another drive would be a relatively small task.

Debrief

The debrief was developed by first identifying four areas of concern into which the information could be partitioned. The knowledge elicited by a questionnaire (see Supplementary Report B) based around these areas was then matched with the simulation, eliminating aspects that the simulation simply didn't include. The debrief was then designed with the intention that the display formats used should be flexible and appropriate to the data being presented. It was important that the debrief should be extremely rich in information and that it should be easier to operate than the simulation (due to its subsidiary role). By writing it in SuperCard both these goals were met.

It was also decided that the debrief should only represent the period after the user had taken charge and should allow for a simulation of up to four hours from that point.

A C code resource was developed that could be called from the Prolog simulation to store data to disk. The data stored can be classified in three types:

(i) Regular Data – Some data needs to be stored at regular intervals throughout a simulation run. For instance, information on the number of men and appliances currently deployed is stored every ten minutes after the user takes charge. This is 'time-stamped' and stored in specific files designated for 'resource' and 'fire' information.

(ii) Event Data – This data needs to be stored on the user's actions during the simulation. When the user calls for pumps, for example, that information needs to be stored. Similarly there is a need to record events that are generated by the simulation but which the user perceives (such as the gas official giving some information or a BA crew reporting that they have found fire). Each action or event is 'time-stamped' and appended to a file that maintains a running log of events in the simulation.

(iii) Summary Data – There is a need for summary information on whether certain things occurred during the simulation at all (eg did the user ever go and look at the front of the building; did they create a water officer). There may also be a need for some simple statistical information on the events that occurred during the simulation as a whole. This information is derived from the log of events described above at the point when the user chooses to quit the simulation. At this point, two other things occur: (a) the data collected in the log is converted from a format that can be read easily from C to a simple text format that is accessible from SuperCard; (b) a copy of the debrief template (described below) is made and recorded according to the name chosen by the user at the start of the simulation.

The SuperCard side of the debrief is in two main parts, an amendment program, and a template. The **template** consists of a complete SuperCard program containing the structure of the debrief that will be presented to the user, but it contains no data drawn from the simulation. The **amendment** program takes the data obtained from the simulation and blends it with a copy of the template, forming a debrief that represents that specific simulation, which can then be presented to the user.

The amendment program can be run any time after the data has been collected, but would typically be run immediately after a simulation. The resulting debrief is immediately presented to the user and on exit is stored (in a folder 'Debriefs') for future reference or deletion as required.

The structure of the debrief tries to achieve a compromise between a clear presentation and the desire to be able to compare every data element with any other in a way that is not predetermined.

Much of the debrief uses the convention of displaying events and actions within the simulation as icons that will be familiar from use during the simulation. When clicked on, a text message shows what the icon represents (eg 'You talked to the policeman', 'You deployed a BA Jet Team with communications to the rear of the building', 'Zone Officer 1 reported . . .') and, where appropriate, additional buttons are available to allow the user to replay audio heard during the simulation.

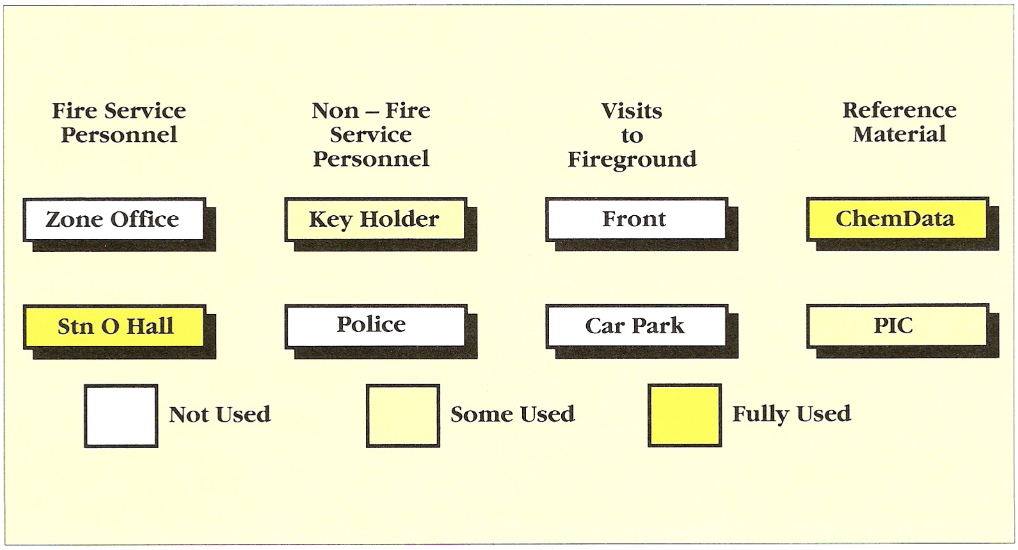
The decision was taken that the debrief should include audio, but not video as this would add too much complexity and take too long to implement. The structure of the debrief is best understood by looking at the software itself, but is summarised overleaf (the information on which the debrief format is based is further elaborated in Supplementary Report B):

Strategy

In this area the prime consideration of the Officer-in-Charge is whether they have had an appropriate overview. This section of the debrief is broken down into the three sections detailed here.

Information Sources

A summary screen showing information sources that were accessed or ignored *during the simulation.*



The First 15 Minutes

A timeline showing the information sources that were accessed during the first 15 minutes.

Location

A timeline showing the user's location (eg Command Unit, Rear of the building) during the simulation.

Structure

This area of the debrief is concerned with demonstrating the Officer-in-Charge's ability to delegate and receive information. In particular summary information on the referral of members of the public to other officers is presented here.

Function

Consideration is given in this section to the Officer-in-Charge's approach to requesting, deploying and relieving resources and a review of the fire development is also provided here.

Use of Resources

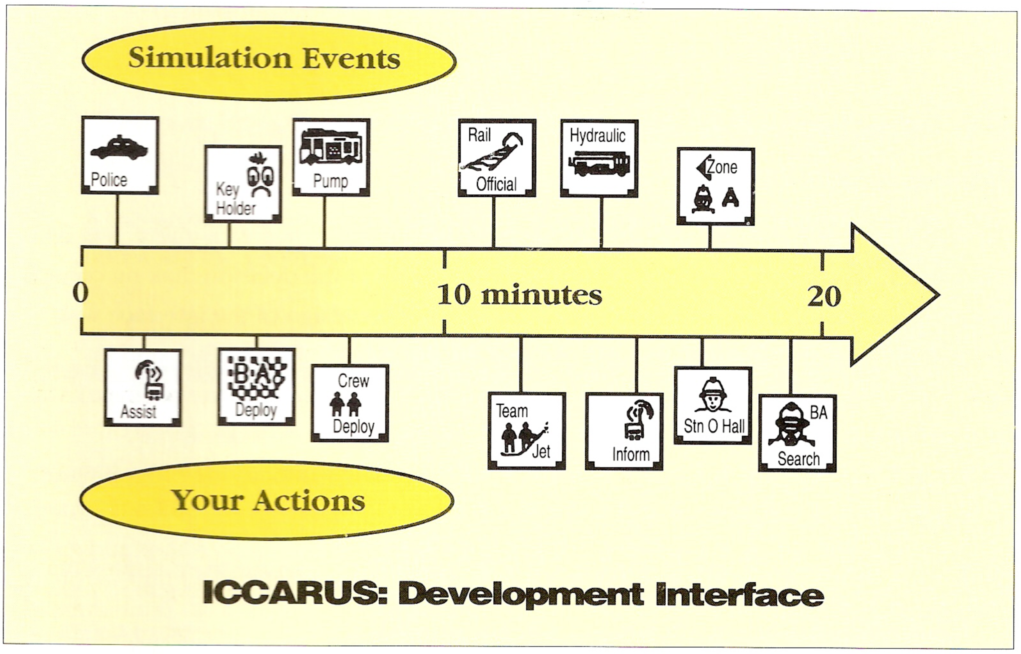
A series of 30 minute timelines showing the use of personnel and appliances during the simulation

Fire Spread

An animated map of the building showing the state of the fire during the simulation

Action

The prime concern for this section is reviewing the moment by moment response of the Officer-in-Charge as the incident progresses. In particular a series of 30 minute timelines showing the events of the simulation against the Officer-in-Charge's actions.



Tutor Set-Up

The tutor set-up program allows a tutor to produce any number of fire scenarios which can each be used in future runs of the simulation. An existing scenario is read in from disk, and the variable aspects of the building, as described below, can be amended by the user before storage again to disk.

(i) Fire Seats – Between one and three seats of fire can be selected. These can be placed in any of the ground floor rooms using a map of the building.

(ii) Suspect – A choice is available between 'people suspected of being in the building' and 'people not suspected of being in the building'.

(iii) People – The following people are available to be selected: an individual or a group of between 2 and 9 people. These can be placed in any of the ground floor rooms using a map of the building.

(iv) Hazards – The following hazards are available to be selected: either of two fertilizers: Nitram and Malathion and up to four stores of LPG (each one consisting of up to four cylinders). These can be placed in any of the ground floor rooms using a map of the building.

(v) Doors – Each of the internal doors in the building can be switched between the open, closed and locked states.

The tutor set-up program does not however allow the tutor to change the layout of the building. This is currently a programming job.

Unfortunately, there has only been time to implement the warehouse scenario in the tutor set-up program. The additional cinema scenario is largely a matter of adapting the user interface, since a C implementation of the tutor set-up for the cinema has already been written for programmers' use.

6.4 Interface and User Manipulation Requirements

The role of a user interface is to provide a simple and intuitive means of interacting with a simulation which at the same time maintains the reality of the decision making context by giving the user the appropriate level of assistance. The design of the interface was determined by a number of factors: the desired appearance of the interface and in particular its integration with the video material (the 'look and feel' of the package), the form of the user's interaction with the system (in particular the level of support considered appropriate) and the facilities available within the underlying programming environment.

At the very least there was the need for this interface to make explicit the complexity of activities and information sources that an Officer-in-Charge is required to command and control at a large fire incident. However, the major challenge for the interface was the requirement to facilitate simultaneously both the natural structuring of commands and reception of messages by the user whilst providing an adequate coding and decoding of such events to inform the simulator's program. The options for enabling such interaction divided into three categories; written, aural or iconic.

Direct written input as a means to structure commands was deemed inappropriate since the level of keyboard skill demanded from the user with such an interface would be too intrusive to make written commands effective or realistic. Any keystroke error would give rise to interpretation consequences which could easily become confused with genuine errors of judgment made by the user.

Voice input, although available on the Macintosh remains at a research and development stage. An aural interface would have been the ideal choice as this would duplicate the prime means of communication of an Officer-in-Charge. However, we felt the required accuracy of speech recognition has not been obtained and such an interface would at present be as restrictive as a keyboard based interface.

Nevertheless, the limited vocabulary used to formulate commands in the fire service did enable the possibility of a sophisticated icon based interface, controlled by 'mouse' alone. Icons act as visual summaries and in many contexts they have the disadvantage of limiting the subtlety of what can be defined, but for this simulation, this restriction was in our favour. The limited vocabulary of fire officers during an incident enabled a 'point and click' iconic representation of commands to both naturally match the user's usual structuring and, adequately cover the range required to induce a realistic simulation.

The decision to proceed with an iconic interface can be summarised on the basis of the following:

(i) Direct written input demanded unrealistic levels of keyboard skill.

(ii) Voice recognition had not reached the required level of fidelity.

(iii) The limited operational vocabulary used by fire officers alleviates the problem of creating a restrictive iconic interface.

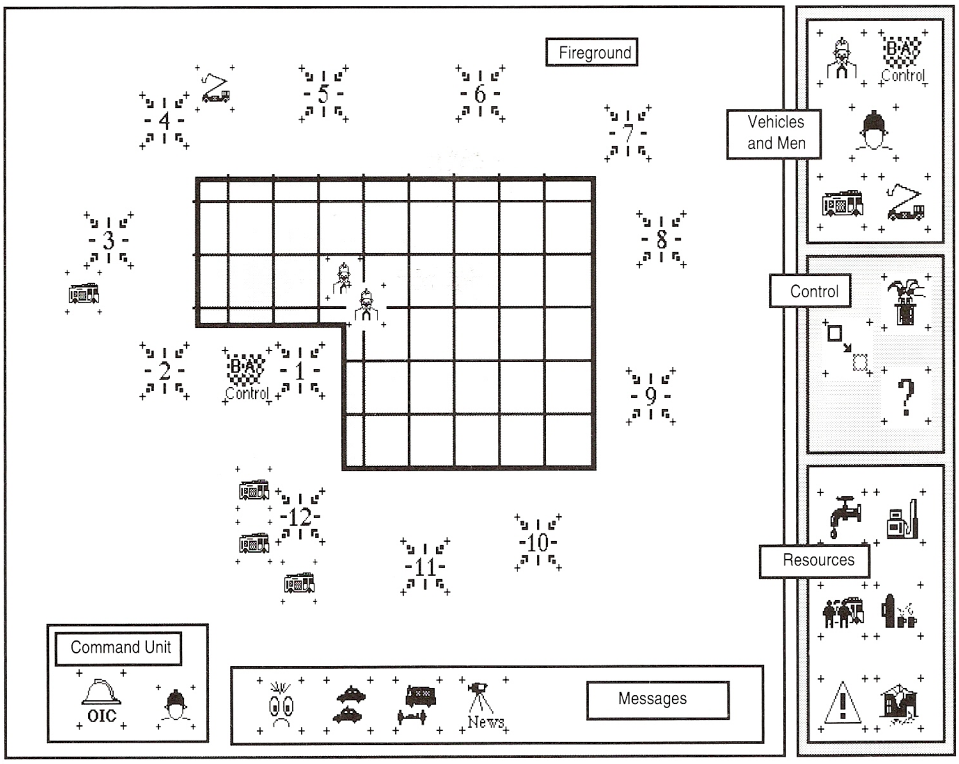
(iv) Icons provide an appropriate level of visual abstraction and operable control necessary for a restricted but genuine simulation of the task of an Officer-in-Charge.

Development and Assessment of Initial Interface

In order to create an initial design for the required iconic interface, use was made of the Manual of Firemanship, in particular Book 11, which details the recommended action for "Control at a Fire". Knowledge drawn from this official documentation was supported and elaborated by transcripts of conversations with instructors from the Moreton Fire Services College. Further to this textual and verbal knowledge elicitation, all members of the project experienced simulations of fire incidents conducted at Moreton and by the West Midlands Fire Service Training School. The outcome of these preliminary enquiries led to the interface presented in the figure overleaf.

Equipped with this hard copy of a suggested interface our team proceeded to interview 13 fire officers of Divisional Officer status. These extensive and recorded interviews were in retrospect crucial to the final development of an appropriate interface. The initial interface provoked conversations of a depth unforeseen by the interviewers and gave rise to a detailed specification for a far more appropriate interface. This in our view demonstrates an important point to consider in projects that to a great extent rely on the quality of knowledge elicitation.

Our first attempt at such elicitation led to a rather superficial understanding and consequently an inappropriate interface design, however, the result of this preliminary knowledge elicitation facilitated a far deeper penetration of what was acceptable and worthwhile to our targeted profession. To assess the implicit knowledge of a domain requires a high degree of understanding by the researchers involved. We found our initial attempt at an interface acted as a mediator which gave our interviewees the confidence that we could comprehend their deep felt concerns.

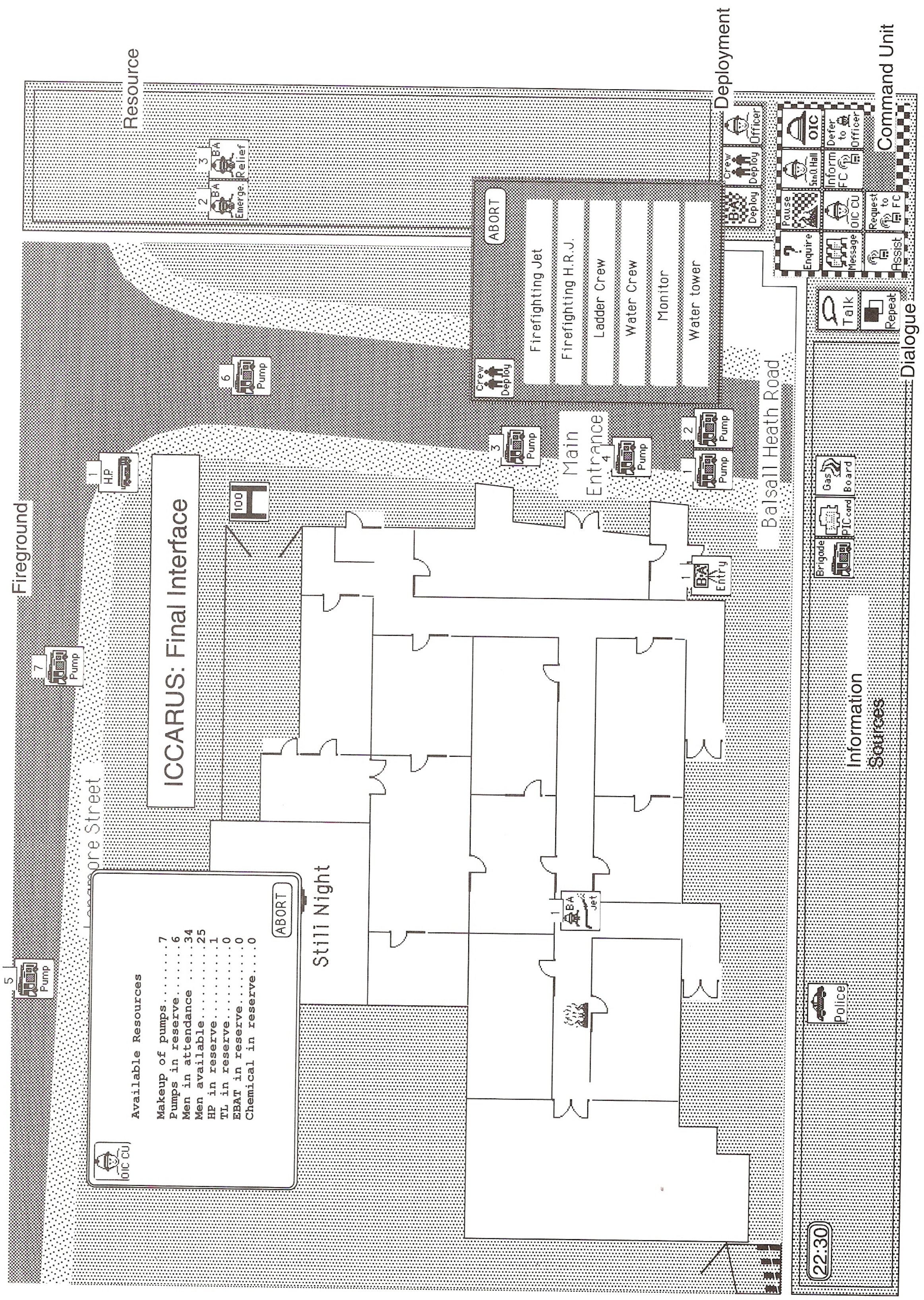


ICCARUS: Development Interface

From Prototype to Present Solution

Our present interface is presented in the figure overleaf and represents the culmination of 15 months intensive collaboration between all the parties to this project. The interface echoes the initial design, but now facilitates the user's structuring of commands in a way that parallels the natural procedures of an Officer-in-Charge.

The detailed honing of this interface was achieved by using a pool of ADOs and DOs from Hampshire Fire Brigade. Each week a member of the six strong pool would use the simulator and talk through their difficulties with its use. Particular attention was given to eliciting their views on the implied protocol of the iconic interface and whether it matched their intuitive approach or hindered such interaction with ICCARUS. In short effort was placed on ensuring the interface was as transparent as possible and avoided concern with its operation detracting from the real issue of command and control (see overleaf for the final interface design).

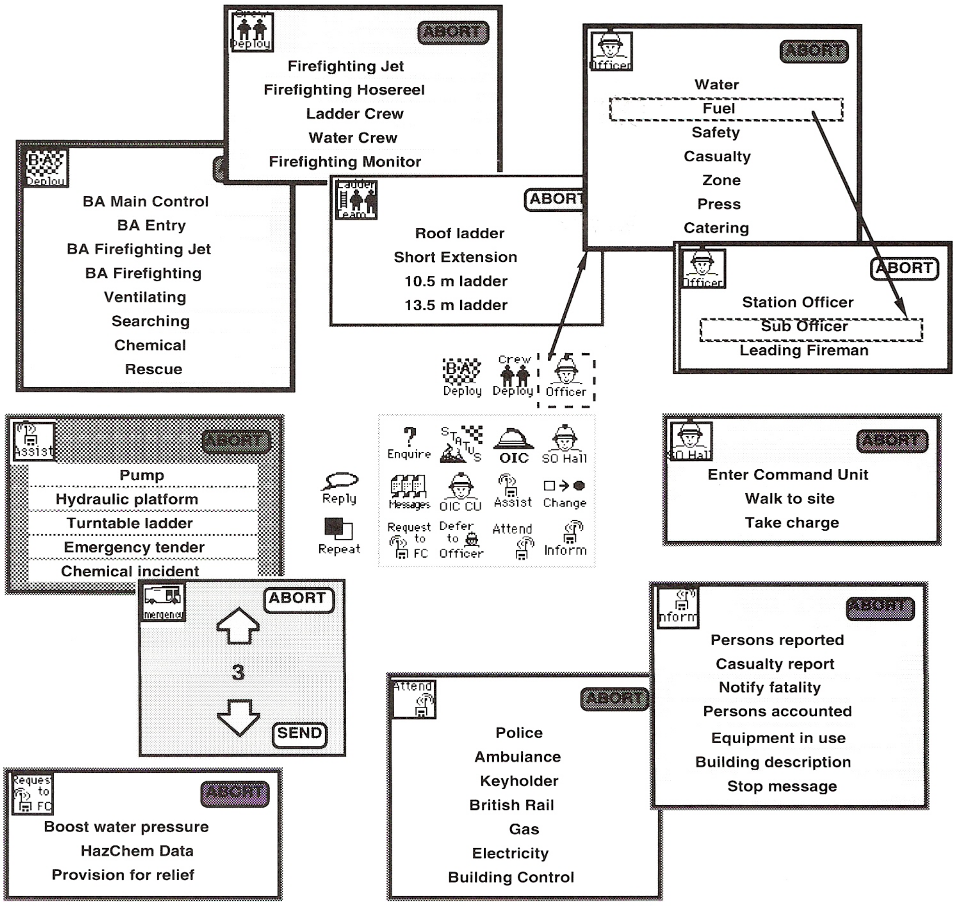

ICCARUS: Final Interface
Fireground
Resource
Deployment
Command Unit
Dialogue
Information Sources
Available Resources
Makeup of pumps.........7
Pumps in reserve........6
Men in attendance.......34
Men available...........25
HP in reserve...........1
TL in reserve...........0
EBAT in reserve.........0
Chemical in reserve.....0
ABORT
Still Night
Main Entrance
Balsall Heath Road
Firefighting Jet
Firefighting H.R.J.
Ladder Crew
Water Crew
Monitor
Water tower
Pump
Police
Brigade
Gas Board
Talk
Repeat
Enquire
Pause
OIC CU
Message
Assist
22:30

A short description of the interface and a follow through example of using one of the icons is intended here to give a flavour of how interaction takes place. The authors would recommend any interested party to request a fully fledged demonstration to best understand the nature of the ICCARUS interface.

Six defined rectangular areas emphasise particular functions within the interface presented to an ICCARUS user (refer to full page diagram above). A red and white chequer board area in the bottom right corner indicates the Command Unit. The icons contained within this area give access to the command and control structure normally found at such a location ie the ability to inform Fire Control, ask for assistance (request pumps etc), defer messages/people to other officers, look at the message board and inquirer of all other actors. Above the Command Unit area are three icons which sit in the deployment area, these icons allow the user to create Breathing Apparatus (BA) Teams and Entry Points, firefighting crews and Officers. As such teams and officers are created, they appear, along with arriving pumps and special appliances, in the large right hand area called resources. Any icons appearing in the resource area can be picked up by the user and positioned on the fireground to the left.

The fireground represents the building plan which is usually drawn on a wall of the Command Unit. In ICCARUS as at a real incident the diagrammatic representation of the fireground mediates the user's knowledge of his resource movements, development of the fire and location of BA Teams within the building. The final two areas running along the bottom of the Macintosh display are used for accessing information sources and conversing with them. The larger of the two provides a location for icons which represent actors which can appear in the simulation eg the Keyholder and the Electricity Board, and fire personnel who are not located in any specific area of the fireground. Here also the user can interrogate the Premises Inspection Card. The dialogue area gives a pseudo conversational ability to the user and through the repeat and talk icons they can review messages and put a series of questions to particular actors.

In order to show the operation of the interface for a particular task let us take the example of how the Officer-in-Charge chooses a sub officer to act as a person responsible for fuel (refer to the flow diagram overleaf). Firstly he points at the officer icon in the deployment area of the template and clicks the mouse button. The officer deployment menu appears on the screen and the Officer-in-Charge chooses 'Fuel' on this menu. The 'Officer Rank' menu now comes on the screen. Once the Officer-in-Charge clicks on the 'Sub Officer' an icon representing the 'Sub Officer–Fuel Responsibility' then appears in the 'Messages' area of the template. When there is any information on the state of fuel resources this Fuel Officer icon will change to 'red', which informs the Officer-in-Charge that the Fuel Officer has a message.



ICCARUS: Creating a 'Fuel' Sub-Officer

Behind the overt aspects of the interface are three other components that are important to the functioning of the package.

(i) The Interface Manager: this defines the user's interface to the simulation and is responsible for translating user commands into a sequence of messages to the appropriate actors and receiving and displaying the resulting replies on the screen.

(ii) Implementation of the menus controlling the various user or instructor set parameters (tutor or random set-up).

(iii) Videodisc, transputer, CD-ROM control and integration.

ICCARUS integrates all these aspects together into a working interface that is user friendly and can undertake all major computing control functions. Its effectiveness at achieving this result is reported on in sections 7 and 8.

6.5 Hardware and Software Choices

The delivery mechanism for ICCARUS is based on a Macintosh IIci, Apple computer, with various peripherals to support the necessary audio-visual environment. An Apple rather than IBM environment was chosen primarily because of the high screen resolution required for a sophisticated screen graphical interface. The Macintosh IIci also had the necessary speed and open architecture to enable the control of videodisc player, CD-ROM etc, while supporting an A3, 72 dpi monitor.

For the laserdisc player, we opted for the Sony Laservision LDP–1600P player because of its speed in frame finding and its ability to jump up to 200 frames without displaying black.

We determined upon Prolog for our software language. In this language, difference structures can be copied with a single line of code. Further, in Prolog there is no need for memory management. FORTRAN was rejected since a common block would require memory management, while C was not ideal since it requires a structure using pointers to be copied section by section. PASCAL on the other hand does not have the necessary routines for producing different structures. MacPROLOG not only has Prolog's advantages, but also has all the graphics routines which we required and, therefore gave us the best head start.

7. TESTING AND EVALUATION

Constant formative feedback from our Senior Fire Officer informants played a large part in shaping the objectives, specifications, interface design, icons and menus, the presentational form and type of information given in the debrief. All of these aspects of the simulation are detailed earlier in this report. When these various system parts had been fully elaborated and the fire model on the transputer was operational and interacting with the actor scripts, particularly with the amount of water put upon it, a period of intensive testing commenced.

The trialling was conducted over a period of two months. At the beginning of each week two fire officers (of ADO and DO rank) from Hampshire Fire Brigade would work through the simulation up to that point where they felt that they were out of control due to **problems with the simulation** rather than due to the intractable nature of the fire incident. At this point the simulation run was terminated and in discussion with the two fire officers a note made of all simulation problems. The task during the remainder of that week was then to rectify all of these 'bugs' and to make the various script and message changes that were indicated. The same procedure was repeated each week. At the beginning of the testing period simulation breakdown was occurring after approximately 20-30 minutes: by the end of it, however, the simulation ran reliably for one and a half to two hours.

The major changes made during this period were a vast increase in messages from fireground personnel from whom the Officer-in-Charge wished to obtain progress reports. This feedback was mainly concerned with having access to reports from the BA

Teams. In addition several items were added to the menus eg in 'Request to Fire Control' a Fire Investigation Team was added. Several icons were slightly modified (eg the 'status' icon was renamed 'pause') and much of the simulation was speeded up, especially the response time of the 'mouse' which had previously been so slow that users were unsure as to whether or not it was working.

At the end of this testing period it was felt that the simulation was now in a state where serious evaluation could take place. We felt that it was inappropriate for members of the ICCARUS development team to undertake such an evaluation. Thus on the advice of Portsmouth Polytechnic's educational evaluation expert (Dr Angela Brew), Dr Valerie Hey from the Social Science Research Unit, Institute of Education, London University was hired for this purpose. Dr Hey was asked to set-up an evaluation procedure which would provide information to answer the fundamental question **"To what extent does the using of ICCARUS feel like being involved in a real command and control situation?"**

Dr Hey and team member Stephen Hall spent two weeks with the simulation at the Fire Services College at Moreton-in-Marsh. During this time 15 Senior Fire Officers, themselves all with considerable experience in the training field, were taken through an intensive session (approximately 3 hours) of simulation use, followed by an in depth interview. Stephen Hall operated ICCARUS during the simulation session driving the interface in response to the user's commands. This was thought to be necessary since we were not primarily interested in problems associated with learning how to use the interface. An additional initial period devoted to familiarising these users with the interface would have made too great a demand on the professional time schedule of these officers.

Giving a précis here would compromise the independent nature of this exercise. The report is full of a wealth of useful information highlighting many improvements that could still be made and a number of problems that remain to be overcome. Nevertheless, it is considered that it is correct to state that **the ICCARUS simulation succeeds in its fundamental aim of involving users in a set of stresses and problems that are congruent with those experienced during the command and control of an actual incident.**

We quote here from a brief summary of the evaluation exercise that was written by Dr Hey:

> *"The principle research question posed ... was 'Does ICCARUS meet its principle design objective of providing a sufficiently challenging experience to fully engage the officer-user?' ... If the Officers couldn't take the simulation 'seriously', treated it as a mere 'game', then their responses would be superficial, targeted to 'beating the machine' and relegating the experience to the domain of 'games of chance' rather than viewing it as a high order training opportunity.*

"What I will say is that all the users bar none, got 'stuck into' ICCARUS and this is true even for those users who claimed that it had (remedial) design and script faults (indeed it is particularly true of those users). Several of the users for example were drawn into the narrative of the fire scenario despite their own declared (and self-evident) commentary that technology couldn't replicate the smell and feel of a fireground, and that it lacked other aspects of the affective realm – that of the interpersonal hustle and bustle of decision making under stress ...

"... forms of [their] *speech certainly indicated a sense of urgency, a level of concentration, and a strong commitment to resolving the 'fire' expressed in the personal and professional discourses which I imagine as contiguous with a real incident ...*

"... [that they were] *literally / metaphorically in the 'hot seat' – reacting to the escalating demands of making and managing complex decisions, suggests that the design team have created a training experience of substantial credibility."*

Dr Hey's evaluation report now follows and it is important to emphasise this report is reproduced here as an unedited document written by Dr Valerie Hey.

8. INDEPENDENT EVALUATOR'S REPORT

by Dr Valerie Hey

8.1 Introduction

This evaluation will take the form of a critical interpretation of 15 transcripts of officers who took part in the ICCARUS testing at Moreton-in-Marsh Fire Services College in April 1991. The main research and evaluation question addressed is that of **assessing the quality of the simulation in terms of its ability to generate experiential dimensions of stress and challenge consonant with the real experience of fireground situations.**

The structure of this evaluation report will describe in abbreviated form, the contexts of the simulation trialling and will take the following form:

1. THE METHODOLOGY OF DATA COLLECTION – An account of the ICCARUS session.
2. PRESENTATION OF THE DATA – A look at some patterns of appropriation.
3. RECOMMENDATIONS AND REVISIONS – A summary of some of the design alterations recommended by the users.
4. CONCLUSIONS AND CONTEXT OF USE – A consideration of the training location of ICCARUS.

8.2 The Methodology of Data Collection

This is best summed up in the sequence – 'asking, listening, observing, asking, listening' which reflects the following practices:

a. the ambition of the evaluator to establish for the user a 'comfortable' social context in which to experience the new demands of familiarising themselves with ICCARUS – hence 'asking' describes a pre-simulation interview featuring my inquiring of the officer about his/her background within the fire service.

b. 'listening' – self-evidently refers to the social courtesies and qualitative sociological skills of establishing rapport.

c. 'Observing' – describes the processes of my recording the user's interaction with the demonstration of ICCARUS – undertaken by Stephen Hall, the programmer.

d. 'Asking' – refers to the post-simulation interview conducted immediately after the user had been 'hands on' with the simulation.

e. 'Listening' – repeats the intention of the earlier session – this time incorporating my 'observations' on how I experienced the participants using the interface.

The general intention of the ICCARUS session was to situate the officer as positively as possible in relation to the exposed situation of having to 'perform' before a 'strange' machine and 'strangers'. The session team – myself, Stephen Hall and Montse Chapero tried to 'routinise' the session to cut down the opportunity for the introduction of 'wild' variables. We therefore established a common practice after the first four sessions of conducting the simulation, with Stephen operating the 'mouse', with a refreshment break, with warm up introductory interview, prior to both the demonstration and the user-simulation and with a close down to the session featuring a personal debrief supplied by a one to one encounter between myself and the officer.

The interview guideline is included as Appendix A, but it needs to be borne in mind that an intention to standardise the sessions does not eliminate the variable social interpretations which the fire officers placed upon the 'invitation' to try the ICCARUS 'hot seat' (as one of them tellingly called it). This is not the place to rehearse all the arguments about the mediating social factors which 'interfere' with the process of data collection – it is my intention to try and hint at these contextual elements in the following pages. However, as my main argument is that these dynamics are indivisible from the business of the social event called an 'interview' and a 'simulation' – indeed they constitute the actual business itself – then the scope of the appropriations of the event – ie who took it in what direction and why, are the primary sources for description and analysis. The early decision to tape all elements in the session was thus predicated upon this recognition (of the indivisibility of task and context), and proved a vital resource in reconstituting the sequence, the 'flavour', the 'texture' and the ostensible content of the events. The taping was supplemented by brief 'first impression' notes made by me as the session began, augmented during the course of the event, and brief 'post-impressions' notes made to highlight particular key moments, or phrases, or stylistic characteristics to enable me to evoke a quick sociological 'pen portrait' to momentarily 'place' each of the 15 people who were to form the subjects of the testing.

The tapes were processed through a technique which I have called 'selective transcription' which functions to make accessible the data by reference to the context of its production. A short rationale for this methodology appears as Appendix B. The transcripts of all the sessions are available for consultation and cross referencing. The key points embedded within the transcripts are coded with respect to their (approximate) location on the tapes, by numerical notation. Thus interested parties can trace observations back to their original generating context and hear the tones of voice deployed – experiential dimensions which fail to transmit straight from the page. In order to try and compensate for the 'sensory deprivations' of reading transcripts, I have occasionally inserted into the transcript my own narrative on the occurring sequences – to convey something of my initial reading of the data. The following analysis draws significantly from these notes.

This supplementary critique also functions to remind me of the differences between users on their interpretations of ICCARUS and of the prevalence of contradictions within individuals, between their stated versions of their session, and their experiential reactions to the problems which ICCARUS presented them with.

8.3 Presentation and Analysis of the Data

My interpretation of the data is drawn from a recognition of the impact of the wider fire service culture upon how the officers situated themselves in relation to the demands of performing on ICCARUS. It is therefore necessary to offer some characterisation of the working culture of the British Fire Service as it is represented within the officers' discourse. I have sought to show how this wider working culture interacts with how the officers interpret the invitation to take part in the ICCARUS simulation, and I have paid particular attention to their accounts as expressing a complex set of articulations between the individual, the simulation and the fire service. My analysis seeks to describe the 'interactive' nature of these practices.

Throughout my argument I will substantiate the comments through reference to the appropriate transcripts.

Context and Culture

It is commonly acknowledged that the service is overwhelmingly masculine in ethos and style, (F13, F7 refers to a 'macho culture', F2 and F3 indicate that the college itself is aware of the problem and taking steps to address equal opportunities issues). However, the tradition of physical prowess is strongly woven into the history of the service, even if some of the more enlightened senior staff view its continuing relevance critically, but they too have an emotional investment in this celebration of masculine accomplishment

– F13 called his generation of fire fighters – 'men of iron' who worked in fireground without BA and rest periods – castigating today's officers as 'soft puddings'. He was also ironically, one of the most outspoken against the privileging of the competitive masculine style. (The 'coiled springs' of F4's laconic description). Commenting upon his own performance with ICCARUS – he noted 'that if you put younger officers in front of it and they lost it as I did, it's almost a suicide note on the mat – (F13).

Strongly expressive of this ethos is the prevalence of proceduralism within the operational and administrative functions of the service. Several officers, especially those in the more senior ranks, (F5, F8, F13) were highly critical of this aspect of their profession – claiming that officers were looking for certainties in what after all is, in their case, literally an uncertain and dangerous world. These officers characterised their men as too code orientated – (F8), or as demanding 'lists' when they viewed management as much more 'discretionary', (F3, F13). Equally other officers recalled situations when they had been victimised themselves for failing some aspect of procedure – one noted that the only thing his supervisory officer said to him at one fire, where he had been the officer-in-charge, was that he had been using the wrong sort of torches! As many officers remarked, fire is a dynamic entity noting that 'procedure goes out of the window when the situation demands it', (see F13's account of incidents).

Cutting across this quasi-militaristic set of expectations, and taking the edge off its harsher, more individualistic aspects is the recognition of the role of team work, especially as operationalised on the fireground. Like all service enterprises, this aspect expresses a particularly masculine mode of group work combining as it does strong egalitarian notions of mutual respect and interdependence within a wider culture which is hierarchical in nature. Interestingly several of the officers related to the session primarily through constructing Stephen as part of the team actively 'fighting the fire' and in terms of managing the interface – these were the officers I think, who found their way around the system much more effectively than those who took up a much more private relationship to the simulation, (cf. F5 and F8 with F9 and F2).

This coalition of the values of competitiveness, conformity and interdependence represents the predominant social context in which the fire service operates and it necessarily infuses the learning and training at Moreton. Brevity of space compels me to reduce the description of the complexities of the wider culture but it needs evoking, especially as a major part of the training culture is individual assessment and ICCARUS inevitably got pulled within this immediate locating frame, regardless of how often I tried to mediate it to the users as our 'testing' the system, **not** their operating of it. Several users either explicitly or implicitly described their experience of doing ICCARUS within these terms – 'the hot seat' (F1) or 'against the wall' (F7), or as a 'pigeon' (F2), like an exam test (F2, F7), whilst another officer directly asked if 'the assessment was purely on that side' (F14).

In a sense the last comment hits directly at the ambiguities around conducting a qualitative evaluation – namely that as an evaluator it was important to try and describe evidence of stress – (viz the principal research question) but as a social researcher conducting an encounter which was self evidently threatening to fellow human beings by virtue of witnessing their interaction within a non-neutral learning experience, you were also part of the genesis of the stress you were describing. I will return to this point later.

To further complicate the interpretation of the sessions, it is important to note that all the officers who did ICCARUS were themselves positioned as trainers. This impacted upon how they related to the experience and meant that for many of them they operated a double axis (at least!) to the task in hand, with the simulation making demands of them and they equally and simultaneously making demands of the simulation. The more senior the officer and the more secure they felt, the more 'critical' they were in terms of having the confidence to detach from the interactive nature of ICCARUS, (see F7, F3, F8, F12). However, it also needs underlining that no matter how frequently users switched modes within a session from 'examinee' to 'examiner' all of them offered evidence that ICCARUS was functioning to engage them in significant challenges of an intellectual, professional and emotional nature. One of the most interesting observations from my point of view was noting the circumstances in which users flicked 'channels', and the sense in which some operators managed these switches quite effortlessly, (F8, F2, F3, F11, F12). What is of particular relevance to this evaluation is **not** that operators felt able to disengage to become the professional trainers, they were not able to exit into this more distanced stance more consistently and comprehensively – something about the way ICCARUS functioned to invite them into its own agenda prevented any substantive defensive resistance.

Some users, it has to be said, never adopted this 'evaluator' role during their own simulation and only proffered criticism during the specific feedback interview, (F1, F5, F6, F9). Another broad category of user which overlaps with the last group to some extent, contains people who interpreted the session as an opportunity to test their own predetermined theory that simulations could **never** function to replicate the demands of a real fireground.

Now obviously, this is incontestable – a simulation by its very nature cannot reproduce the full modalities of a fireground – 'the sights, sounds and smells' as one experienced officer remarked – but the point is not to place this set of criteria on ICCARUS, but to seek to offer the learner officer a quality simulation of these dimensions which nevertheless presents a form of command and control experience consonant with the sort of decisions applicable on the fireground. The contextual elements to a fireground as a physical experience – the sensory aspects can be addressed through refining the audio and visual components, (see section 3). However, the point I am making is that some users were already negatively positioned with regards to the opportunities of ICCARUS and this has consequences as it impacts upon how they then subsequently interacted with the package.

This antagonism stems from several sources; from disappointing experiences with less sophisticated computer packages – officers were openly sceptical of 'fighting fires on computers' (F1); another remarked that just handing over the computer to the brigades would mean that they would just learn to 'beat the machine' (F2) and indeed a couple of officers operated their sessions just like that – (F14, 'I was fighting what was in the computer' or F2 who described his own performance on the interface as the 'technology beating him').

I understand these particular orientations to ICCARUS as attributable, less to how ICCARUS functions, as to how some users perceive the idea of a computer simulation. I have mentioned before the style of the service – an ethos revealed in the key concepts of the fire officers I interviewed. The most compelling descriptive category which seems to function as an organising principle of this culture is the use of the word 'professional' – the key term of which **practical**.

The discourse of professionalism as expressed within the fire service tries to pull together all the contradictory values I have identified earlier. It is a term which kept recurring in nearly all my interviews as a depository of many positive meanings about how officers described their work – it referenced the correct expression of responsibilities on the fireground, (F7, F11) and especially the abilities of practical firefighters with good fire fighting techniques, (F1, F2, F14). It celebrated the reliance of fireground staff on each other. It was a word which contained all the sedimented history of meanings to do with a collective sense of pride in doing a dangerous and physical job.

Set against this affirmation of positive work values, officers explicitly counterpoised another discourse – which I will call the 'theoretic' in which all sorts of negative meanings found a place – officers who couldn't deliver on the fireground were accused of 'spoofing' (F7), (the practice of disguising ignorance), whilst others noted the existence of 'poseurs'/'desk types' who were very 'hyper' but who basically lacked practical command and control fireground experience. After all, the fireground is an 'organised chaos' or 'absolute bedlam' (F3) as officers testified, and it was conceded for example, that officers do panic but that their macho style prevented their own admission of the fact, even if their pose of super-confidence was exposed by their incompetence as 'bullshit' by everyone else, (F7). One officer graphically summed up this last type as 'high profile/ low output'. In a sense this scenario expresses the continuing valence of the macho ethos in the way that men are literally trapped by their own adoption of a style they cannot live up to – which paradoxically makes them overact the part (the hyper) only to be found out on the test ground!

This opposition was also expressed as institutionalised within two of the college's schools, with the Command school as being the more 'theoretical and more to do with senior management' set against the Operations school which was more concerned with the 'nuts and bolts' of the technical aspects of practical fire fighting, (F11). Yet others located this opposition as between the practical brigades and the 'theoretical' college or as existing between the practical fire service and the civil service mentality (F5) – whatever the provenance of this opposition, it is sufficient to note the persistence of its application – to suggest that it works as one of the principal structuring ideologies of the fire service culture.

For men who had all come through to seniority from being in their words 'hairy arsed fireman' – to positions of exercising a range of managerial responsibilities – there is, I would aver, a strong sense of uncertainty about how to occupy the 'professional' status sought by the fire service. It is quite unique amongst other 'professions' in having no graduate entry requirements – hence the emphasis on practical fire fighting skills. More immediately, the fire service like all the emergency and military services inevitably implicates its officers in the constant stress of having to 'do the business'. Hence the cultural power of these informal identifiers of 'spoofers'. Authenticity as a good fire fighter, is in the final analysis, the only acceptable and verifiable mark of a true professional.

Given this principal structuring opposition, it is unsurprising that some users elected to 'prove' that the 'theoretic' ICCARUS would not be able to deliver the equivalent of actually doing the practical job provided by 'real fire fighting' – this found expression in two basic styles – the 'beating it at its own game' approach and the 'hands off' approach – the former relying upon playing ICCARUS as a 'game' – decoding the scenario as having 'red herrings' (F1) or 'traps' (F5) or as having an inbuilt 'solution' (F14) – whilst the latter orientation, evidenced in only one session (F9), was instanced by the officer concerned comprehensively refusing to accept responsibility for decisions undertaken during the course of the simulation, seeking refuge in comprehensively 'blaming the machine' – a strategy partially applied in other sessions, though in a much more fragmented way.

I want to underline at this point – that categorising the styles of appropriation is not meant to suggest that all officers operated with just one particular style in their session, as I hope I have suggested earlier this was far from being the case. I am simply indicating the range of ways in which officers took up the invitation and claiming that these orientations are predicated upon how they took up their role within the general culture of the fire service and the particular college culture. Most users moved in and out of these positions with respect to ICCARUS, not only prompted by their interactions with the unfolding fire scenario, but also in response to the explicit questioning of other session organisers – myself or Stephen Hall. I should now like to flesh out in more detail the way users responded at the experiential level to the actual demands of the interface.

'JUST ANOTHER CAR PARK?' – How officers interpreted ICCARUS

Of necessity this sub section will simply skim the surface of what was an extremely rich and revealing set of data. I have already abstracted out issues to do with the user's general orientation to the session, now I would like to concentrate on other aspects of their detailed use of the programme and these will feature considerations of the extent to which ICCARUS challenged the officers. What needs to be borne in mind right from the outset is that the users, despite what some of them might have **said** about the interface, revealed through various involuntary mannerisms a comprehensive range of close engagements with the interface. These included both verbal and non-verbal makers of them being actively involved in problem solving: degrees of concentration expressed through leaning forward in chairs (eg F3, F7), intensively scrutinising the graphic screen (eg F6), asking for message repeats (eg F13), interrogating Stephen for further information when the feedback from the icons was not forthcoming (most officers) and still persisting in monitoring the fire spread after they had 'finished' using the simulation, (F13, F12). There were officers who bit their fingernails, took their ties off, forgot to drink their tea, tapped their feet and made all sorts of accompanying utterances to the on-screen action!

Equally and significantly, other tell tale signs of engagement and stress, suggested that the mode of address of the simulation pulled people into its dynamics despite their resistance, and professional detachment. F13, for example, spoke the language of the 'old hand experienced fire fighter' but he also produced frequent spontaneous outbursts of annoyance that the fire was not being 'knocked down' – 'is there a scenario where you can put this damn thing out anyway?' as well as the more detached and cooler 'professional' discourse of critiquing the programme in terms of its lack of the 'feel of the fireground'. At one point he actually makes the point himself that he 'lost concentration and I think that's part of discussing the model'. Even the user who I christened 'Mr. Cool, Calm and Collected', failed to suppress his emotional engagement with the simulation, it reappeared as persistent mouth clicking, irritation in his voice when resourcing problems occurred, as well as a compunction to whistle whilst awaiting the resources to arrive! The transcripts are peppered with expletives, signs of impatience and frustration, (one officer told 'the woman' to 'bugger off!').

And although it is impossible to simply equate each utterance to any one simple casual factor – ie was it the stress of being watched by non-civilians? (actively discussed by F2), or by University people? (F1), or being sent by superiors into a room full of new equipment and new people? (F1 and to a large extent all the users), or were the stress reactions indicative of mild technophobia? – as (F2 suggests) or as F1 and F3 proposed caused by failures in decoding the graphic format? Was the whole immediate context of assessment, as being the primary function of training at Moreton 'contaminating' of the whole enterprise (as it must have been to an immeasurable and unavoidable extent – see my arguments earlier). In a sense all these factors cannot be quantified, because in the final analysis they cannot be separated out. However, given that **any** user of ICCARUS in **any** context will come to the experience through many other and different mediating circumstances – the precise identification of the generator of these stresses remains a redundant activity. What the evaluator/researcher is concerned with is describing these mediating circumstances, and tracing patterns within and across the simulations to show something of the working of the interactions as complex social negotiations. Of necessity

I have concentrated on aspects of these negotiations which centre upon the questions of realism, stress and challenge.

To try and elicit the users own views on their session, I elected to try and get the users to critique their own relationship to the simulation by reference to these terms as my implicit or explicit agenda – this augmented the qualitative data already on tape, which was signalling their continuous and sequential reactions to each part of the evaluation session.

Within my debrief interview with the participants I posed back to the officers, how I had experienced them using the simulation, enabling officers to contradict or confirmed my own perspectives. Most of them explicitly confirmed what their own continuous narrative of interaction had revealed, namely that the session had proven challenging: 'if it's to test stress, it's doing a good job' (F1), another user said that his adrenalin was going 'as on an on-site situation', 'I got carried away' (F6), whilst (F7) sees it as a 'good generator of stresses', and another user said 'The model's a really good model – it does put you in a stressful situation' (F8), another said 'It does make you think' (F10), and yet another said in summary 'Well, interactive it certainly was!' (F11).

If these comments reveal that 'stress' was generated by the programme, it is important to register the extent to which these comments are themselves reflective of the criteria of 'reality' being applied to ICCARUS and deployed by the fire officers through their invocation of the categories of their own experience and professionalism.

My argument is that a failure to generate a challenge indicates a failure on the simulation's part to sufficiently replicate the approximate context within which the fire officer feels he can draw upon his past professional experience. The fact that officer-users felt able to directly try and apply their experience of 'real' fires to the ICCARUS incident says more about its effectiveness than anything else. For example, several officers spoke about thinking from their past experience of 'old cinema' fires, and anticipating the likely scenario, many others expressed irritation that the fire refused to be 'knocked down' when they had 'piled on the water', some argued that this was not consonant with 'reality', whilst for others it was exactly this 'unpredictable' nature of fire which replicated proper fires (F13), another conceded that the fire spread was realistic, 'You're going to get fire spread unless you're very careful as to where you put those jets' (F11). Several officers also saw that the purpose of the simulation was not that of simply demanding more resources and pouring on water anyway, since in reality this was irresponsible, depleting brigade area cover (F15), others applied the criteria of 'good fire fighting skills' in their attempts to manage the simulation, consistent with how they described their pride in doing a professional job on the 'real' fireground, (F11, F15 and others). Other indicators of the seriousness with which the participants treated the simulation are coded *in their narrative, through their applying* the language of the 'real' fireground to the simulated fire – and this was done quite unconsciously as officers worked through their interaction on the machine. It is not, of course, the case that

ICCARUS functioned to displace the notion of the 'real' – clearly, we all knew it was a simulation, (F2, F11), but nevertheless there was substantial and incontrovertible evidence that it had the power to interpolate the users as managing a command and control scenario on a fireground. Early on in one session, an officer called the fire 'a hell of a job that', and wondered if it was going to become 'just another car park' – the fire service parlance for lost jobs. This phrase echoed throughout the sessions – or other similar utterances 'I'm going to loose this' (F6), 'Can we have jets, things are getting a little out of hand?' (F1), another commented 'this is a burn out job now' (F7). Some officers also volunteered the information in more considered form, several supplying auto-commentaries – 'I did get a sense of having lots of balls in the air, which is quite ... which is exactly what it should do' (F15), whilst another remarked, 'And real things happen. The things that happen on there are things that happen to you' (F7), whilst another user comments '... it was certainly realistic ... you are trying to picture what's happening especially with the messages coming back as well ...' (F10).

I now want to briefly summarise in the last section the various points which officers expressed, concerning the technical functioning of ICCARUS. I would strongly advise that the design team consider the technical points in detail as they are represented on the tapes (especially F3, F5, F8 and F13) and through the helpful commentary taken by Montse Chapero during the sessions. My comments will be restricted to considerations of the technical points as they impact upon how the user's experienced the simulation as an affective interactive event. Therefore, I will not refer to the points about the 'reality' of the fire model, in part because Stephen Hall is aware of the problem and has sought to rectify it within the sessions. Fuller details of these more technical modifications can be reconstituted through the transcripts where I have highlighted the relevant commentary, (see especially references to the representation of the fire spread and the requests that qualitative aspects of the fire intensity/size etc need to be coded).

8.4 'Sight, Sound, Smell' – Suggested Areas for Improvement

I have elected to pull these observations into one major theme viz the need for the simulation to incorporate through its technical facilities of vision, audio and graphics, the sense of the fireground having incessant interpersonal and affective dimensions. One remarked that it lacked any 'real personalities' or as another commented, when he went on the simulation 'walkabout', 'I didn't meet anyone' (F3). F1 put the point most forcefully – 'That's where I felt lost on the simulation. I felt I had no support on the ... 'er simulation – I felt as if I had no support available where as that is not always the case when you are in charge of a fire. It's normal to have at least one person with you all the time.' He goes on to argue that he felt as if he had to 'think of every little 'em snippet and there wasn't much prompting going on'. Another user noted that people on the fireground 'jog your memory' – pre-empting events, (F6).

Many other users substantiated this feeling of, in a sense, shouldering the whole weight of the incident on their own. Another senior officer remarked, 'It seems like I've always got to keep asking for it – (ie information), there's nothing coming to me, yes you do get that on a fireground, but you don't get it as often as it seems to be in the computer', (F8). F6 described the experience of doing ICCARUS as 'isolating'. One noted that the simulation wasn't 'noisy enough'. many more represented this case through a demonstration of how it would be on the fireground – for eg 'Look Guv, in twenty minutes time, we're going to need three relief teams, and you know it's going to take 15 minutes to get another pump here, you'd better order some more now', (F13 and cf F8).

It is important to bear in mind two qualifications at this juncture – one that users may be expecting too much from the technology. One crucial and interesting point which several of the users mentioned, was the importance on the fireground of delegation and that the management of this hinged around the officer knowing the calibre of personnel available – now self evidently this qualitative aspect of real people is impossible to reproduce through the specifying of icons. The second consideration to note, is that officers' views might also contain in another form a residual resistance to having to take on this simulation task. However, from my reading of the data I want to argue that even the most enthusiastic participants (ie those who did self evidently enjoy themselves on ICCARUS and said so (F3, F5, F6, for example), all felt that the simulation would benefit from having more feedback facilities – most expressed a preference that this information should be made available through an increased audio output capacity. As one user put it 'It seemed to be two dimensional' – adding also that the video screen needed enlargement, (a point also made by F6). Several remarked that the audio output required substantial additional sound bites – so that it is 'making noises and things that are distracting you', (F3).

Criticism of the package was predicated upon a majority view supportive of the ambitions of ICCARUS – indeed this was explicitly stated – 'the basis is there it is brilliant' (F3), whilst another who had reservations about the fire model and who admitted that he didn't look at the video once, said 'It's superb, the concept is superb, it really is'. One other aspect of this desire to recreate something of the dramatic tension of the fireground was expressed in the way that officers spoke about their experiencing of the video footage – several were critical that the graphic message of 'heavy smoke' was not then confirmed by a picture showing heavy smoke, several noted the jet left outside one of the doors which they then took up within their interpretation of the fire decisions taken by SO Hall – an image which subsequently was found not to have had that significance.

However, in general terms, officers admitted to relegating its significance to well below that of the graphic screen, as one rather unkindly put it 'The information I got from the TV screen was 3/4 blank walls and a roof vent!', (F3).

8.5 Concluding Remarks

I am reluctant to reduce over 45 hours of taped transactions to some definitive statements on ICCARUS as a product. In part this stems from my recognition that tools and context are mutually interdependent, and that although my research brief was to examine the value of ICCARUS within its own terms, I have to claim to having strong opinions as to what I see as the ideal learning context in which I think ICCARUS should be embedded – viz what another officer describes in the following terms – 'What I have to say is that we can not be in a situation and say "This is the right way to do it." There is no right way ...' proposing the style of a developmental debrief – 'Okay, you've fought this fire. Let's go back and see what we can learn from this.' Therefore I will argue that the full potential of ICCARUS will best be expressed as a 'stand together' piece of training – in which trainers deconstruct the narrative of the session in a way which allows for the user(s) to learn from the encounter, not so much what they have 'done wrong' as soliciting accounts of their decision making and providing supplementary feedback on the experiential aspect of their performance.

In the final analysis, I am compelled to offer an evaluation of the strengths and weaknesses of the programme. As I hope to have convinced the reader, I consider ICCARUS to have the capacity to offer a quality training and learning experience of a command and control nature. The 'fine tuning' of the programme is not outside the technical competencies of the design team and with a refined fire model, improved fire status information, audio feedback and more mobile and relevant video footage. With such changes the final version of ICCARUS should prove a valuable asset to any training context. If operationalised within a context sensitive to the developmental needs of the officer-users, I have absolute confidence in its ability to provide a credible supplement to the range of training opportunities available within the British Fire Service. I would, however like the final words to go to the officers who said of their experience of using ICCARUS:

'I think it depends on your attitude, when you're sitting here, if in fact you want to play at 'er a game or whatever then you go along with the game – if in fact you sit here and think "Well, it's only a game you know" ... I'll just sort of sit here and ... I think at one point when I was sitting there I thought, ...Well, wait a minute ... if that jet's ...? I felt myself ... going forward, you know ... and so if it's happening ... you know then obviously ... then you are actually (engaged)'. Whilst another inadvertently described the way ICCARUS pulled him into a dilemma, 'I was thinking about what I was doing in the building, not about resources' (F5), which as every senior fire commander recognises is precisely the tension enacted upon the fireground between the role of a commander as a 'standing back job' (F2) and the 'heat of the moment temptation to get pulled in' (F2). If ICCARUS has succeeded in implicating its users in this level of behaviour then it has successfully performed to its own criteria.

8.6 Evaluation Report: Appendix A

ICCARUS Evaluation Interview Guide
Moreton-in-Marsh Fire Services Training College
April 15th – 24th 1991

1 **Opening Protocol**

Introduce myself

Introduce the activity

Establish the context

Place the interview in context

Negotiate permission for taping

Stress confidentiality through non-attributable nature of comments

2 **Personal Information**

Could you tell me just a few things about yourself?

Rank, Brigade and Brief Job Description

Length of time in service

What is the purpose of the course?

3 **Job Experiences**

Prior to this activity, have you ever been the officer in charge of a five pump plus fire incident?

How many?

Can you describe the most memorable fire?

Premises, type of fire?

Can you describe what happened?

Supplementaries:

What action did you take in Command and Control on arrival?

What action plan did you set in motion after the initial stage?

What problems did you encounter?

How did you manage these?

What was the outcome?

How did you feel that you had handled the Command and Control situation?

4 **Simulation Experience**

What sort of experience/incident was the latest, ie the ICCARUS fire?

What sort of premises, type of fire?

Can you describe what happened?

Supplementaries:

What action did you take in Command and Control on arrival?

What action plan did you set in motion after the initial stage?

What problems did you encounter? ie if an action was thwarted by failed communication, etc

How did you manage these?

What was the outcome when you left?

How did you feel that you handled the Command and Control situation?

5 **Training Context**

What experience of Command and Control training have you had previously?

Was it challenging / enjoyable / practical / developmental?

What did you think of ICCARUS?

How could ICCARUS be improved?

6 **Interview Context**

What do you think of being involved in an evaluation of ICCARUS?

What other factors should we consider in evaluating the ICCARUS training activity?

- computer familiarity
- experiences of fire officers
- any others?

7 **Signing Off**

Thanks and reminder about confidentiality

Mention group conversation – an ICCARUS USERS GROUP?

8.7 Evaluation Report: Appendix B

ICCARUS Transcripts Rationale
The Methodology of Selective Transcription
(see Supplementary Report D)

I decided on reflection to get 'stuck into' the tapes myself and to eliminate the need for another transcriber. This was a result of my having literally to hand, and also my thinking about the process of familiarisation with the data, of reminding myself of the 'texture' of the different sessions, which is best done through the time consuming labour intensive business of transcription. Given that my analysis is not a discourse critically to substantiate my arguments, I elected to develop a form of abbreviated transcription – a compromise between notes and the 'full works'. Key exchanges and utterances are fully transcribed.

As working documents, they are pretty true to the 'spirit' of the sessions and they are fully annotated enabling further follow up transcription to take place if considered necessary.

What I've tried to reflect is the sequencing of action, the narrative of the event, the sort of 'personal' style the user brought into the session, and the actual record of the command and control decisions made as transactions between – the user, the screen 'actors' and 'events' – the simulation demonstrator and others in the room. For most of the sessions the tape recorder was kept running throughout all aspects of the session – this gives us some insights into the processes of context, adaption, usage and officers' self-reflection on those processes.

I also tried to signal in my transcripts the key terms deployed by the user in all elements of the session – interesting phrases or ways of expressing a position in relation to their work, the experience of real fires and the experiences of managing the scenario ICCARUS.

9. CONCLUSIONS

The ICCARUS team believe they have fulfilled their major objective to deliver a low cost interactive and intelligent simulation capable of supporting the learning of command and control in the context of large fire incidents. A reliable and robust package has been developed that is already being used by the Fire Services College (FSC) in Morton-in-Marsh. *FSC has already ear-marked further funds to tailor the system to its needs and to extend the debrief* to put over *its own training feedback conforming to their high* standards. They will be using the 'shell' we have produced and have asked us as a team to be involved with them in the next phase of the ICCARUS development. When we started this project only the LTU had sufficient faith in our notions that relatively cheap interactive media could be used to simulate this domain. Clearly higher cost simulators are being developed (one in Germany at a cost of £2 million and another by the Swedish Rescue Services at a development cost of £2 million with a per system cost of half a million) that can do a similar job to ICCARUS.

However, while they are computationally richer they do not appear to portray a better learning environment for the purposes of command and control. Indeed the Swedish Rescue Services are now thinking of purchasing ICCARUS for testing against the more sophisticated high cost equivalent. We look forward to the result.

The other successful aspect of our studies in the second phase of ICCARUS development has been the production of the debrief. Backed firmly by our steering committee we determined not to provide instantaneous feedback as the exercise proceeded, but to bring important performance data in a summary form at the end of each simulation run. This has proved to be the correct choice and seems to provide an appropriate non-judgemental framework for satisfying the learners' wants and needs.

The simulator requirements were listed in section 3 above. It is worth repeating them here:

- stand alone
- operate in real time
- emulate as nearly as possible the 'feel' of the fireground
- present a realistic fire progress
- incorporate the vast majority of those resources which would be present at a real incident, each of which should be capable of operating on its own with either reasonable intelligence or verisimilitude
- subject the trainee to a great deal of decision making

- bombard the trainee with information from many sources
- provide as few system-prompts as possible
- provide learning through experience
- have the potential to present an interrogable visual debrief of a trainee's simulation run
- be available for a hardware and software environment costing not more than £12,000

and of overriding importance:

- **to emulate as nearly as possible the feelings and stresses of the command role.**

At present the simulator does not **stand alone** since it requires a front end tutorial in order that the user may learn its operating procedures. With this addition the simulation will stand alone. However, we have now (since the completion of the evaluation) reached a point where we must seriously question whether ICCARUS is best used in a completely **stand alone** mode. We refer to the evaluator's report which argued strongly that the simulation would provide its most effective training in a **stand together** mode.

> *"Therefore I will argue that the full potential of ICCARUS will best be expressed as a 'stand together' piece of training – in which trainers deconstruct the narrative of the session in a way which allows for the user(s) to learn from the encounter, not so much what they have 'done wrong' as soliciting accounts of their decision making and providing supplementary feedback on the experiential aspect of their performance."*

The simulation does **operate in real time.** The simulation at present needs improved fireground video and more audio feedback if it is to truly provide a **'feel of the fireground.'**

The fire model did not at the start of the evaluation exercise **present a realistic fire progress**, although changes made during the evaluation exercise itself appear to have overcome the problem of the fire model realism. However, clearly further evaluation of this aspect of ICCARUS is needed.

ICCARUS does incorporate the **vast majority of resources present at a real incident.**

ICCARUS appears to provide an intellectual/professional challenge by forcing the user to make **a great many decisions.** However, perhaps the user is being asked to make too many decisions at a low level. It is not apparent enough to the users at present just how much decision making is being done by the 'actors' since, although the trainee is **bombarded with information from many sources,** there is a requirement for much more audio feedback and reporting from 'actors' to whom referral has been made.

ICCARUS **provides few system prompts** and learning through experience. Additionally ICCARUS has more than just the **potential for** but stands at present with an **actual interrogable visual debrief of a trainee's simulation run.**

The team has managed to produce a **hardware and software environment of less than £12,000.**

And most importantly it is evident that the simulation does 'pull' the user into its world, inducing stresses and challenges that **emulate the stresses of the command role.**

Finally, our constant emphasis upon formative evaluation seems to have reaped rewards, as the ICCARUS simulation now appears to be approaching the demands of discerning expert trainers. Clearly in any such low cost development one can always see room for improvements. Indeed the independent summative evaluation suggests where improvements can be made. However, particularly pleasing to the present R & D team is the evaluator's major finding that our simulator does actually put Fire Officers under the sort of stress they would experience in the **'real event'.**

We conclude that ICCARUS offers a credible supplement to the range of available fire fighting training.

10. LISTING OF SUPPLEMENTARY REPORTS

These are available from either Chris Creed or Paul Newland, ICCARUS Project, Department of Design, Lion Gate Building, Lion Terrace, Portsmouth, Hants. PO1 3HF.

Theoretical Underpinning: Simulating the Command and Control Environment
Supplementary Report A, ICCARUS, Ports. Poly, 1989

Debrief Questionnaire, Knowledge Elicitation and Summary Report
Supplementary Report B, ICCARUS, Ports. Poly ,1990

System Documentation
Supplementary Report C, ICCARUS, Ports. Poly, 1991

Evaluation Transcripts and ICCARUS Evaluation Interview Guide
Supplementary Report D, ICCARUS, Dr. Valerie Hey, 1991