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EMERGENCY RESPONSE TRAINING USING NEW TECHNOLOGIES

Dr Panos Topalis, panos.topalis@dnv.com
Det Norske Veritas, Palace House, 3 Cathedral Street, London SE1 9DE

Emergency response management in the chemical industry is an important area which has the potential to benefit from recent technical progress in accident scenario modelling, artificial intelligence and other computing and education technologies. Emergency response training, in particular, is thought to be an area which is particularly suited to the use of new educational and software technologies. There has been some research and development work in this subject during the last few years with variable success. A review of relevant approaches and tools is presented with emphasis on emergency training. Is the current technology mature enough to provide useful help to the chemical industry? The industry is currently experimenting to find out more.

This paper introduces a international research project, aiming at improving training in serious technological emergencies resulting from chemical production and transportation. The new training approach makes use of a real-time expert system, dynamic consequence simulation, Geographical Display Systems and Multi-media within a client-server architecture. The integration of these features to create realistic interactive emergency scenarios is summarised.

The training methodology relies on a wide participation of users from the chemical industry. A user-requirement analysis was conducted with detailed questionnaires and interviews. The results of the analysis are presented, including functional requirements and the legal and institutional context. The emergency training methodology will be tested with customised training cases in five countries. An example of a training case is presented to illustrate the possible tool contents and the associated design process.

Emergency training, software, user requirements, artificial intelligence, distributed development, multi-media

INTRODUCTION

The use of simulation tools to assist emergency management and emergency training in the chemical industry started in the 1980s when some progress had been achieved in the area of consequence modelling and when graphical user interfaces and visualisation technology started being noticed. However, the first applications were not as interactive and user-friendly as we expect them to be today and it took some time before we could see applications which benefit from the advancements in the computing technology. Many software packages claim to be emergency management tools but this is a general term that may have different meanings and interpretations.

EMERGENCY PLANNING TOOLS

There are a number of consequence effect models, available publicly or commercially, which can assist with the development of an emergency plan. The commercial consequence analysis package PHAST (DNV, 2000) performs a wide range of effect calculations such as dispersion (Witlox and Holt, 1999)[29], fire and explosion. It also has the capability of graphically overlaying the effect zones on map images. Publicly available models such as HGSYSTEM (Witlox, 1993)[27] and SLAB (Ermac, 1989)[12] can also be used for dispersion calculation. All these tools are useful for the design of emergency plans in the chemical industry.

CAMEO (EPA, 2001)[12] is a publicly available software tool (through the Environmental Protection Agency) which is referred to as an emergency management tool but its main functionality is a consequence modelling. DISCOVER is a program developed by ICI in the early 1990s (Preston, 1994)[23]. This has been used mostly for dispersion calculations but it also has facilities for overlaying dispersion concentration contours over maps.

Development of emergency planning models was also reported recently. The SEVEX tool described by Dutrieux and Van Malder (2000)[11] emphasises compliance with the SEVESO II directive and appears to be an integrated consequence package. An interactive web-based planning and decision support system (HEVAN) has been described by Cameron (2000)[5].

EMERGENCY MANAGEMENT TOOLS

Some real time emergency management tools are described on the Internet or in the proceedings of specialist conferences:

The Riskware system (Fedra and Winkelbauer, 1999)[16] is a decision support software system which was progressively developed as part of European funded projects, especially the HITERM project (ESS, 2000)[15] and has been the starting point for the A-Team emergency training system. The Riskware system combines databases (hazardous installations, safety reports, hazardous substances, etc.) with an environmental Geographical Information System (GIS). All tools are embedded in a real-time expert system framework, which provides operational guidance and assists the emergency command and control tasks.

SAFER (SAFER Systems, 2001)[26] is known to provide a live link between consequence models and real time weather data to assist real time emergency management. CICERO is a program for Communication, Co-ordination and Control by α-COM and it is described by Ledger (1999)[18] and on the Internet (Cicero, 2000)[7]. Atlas OPS is distributed by Atkins and Partners Ltd and is presented by Atkins (1999)[2]. Another system is the Command Planning System (CPS) which is distributed by Fortek Computers and is described by Godliman (1999)[17].

Most of the above systems are described as Emergency Management systems but generally they could probably be used for Emergency Training.

EMERGENCY TRAINING TOOLS

Moeller-Holst (1988)[22] reports one of the earliest applications for emergency response training and planning based on expert system techniques. There are currently a number of computer systems which are referred to in the literature as emergency training systems:

The program TUTOR (Adamson, 2000)[1] was developed by the Defence Evaluation and Research Agency (DERA) in the UK and it has emergency training capabilities. The Minerva multi-media simulator training system was developed by the Metropolitan Police (Crego, 1999)[9]. The Emergency Simulation Program (ESP,2000)[14] is a Windows-based *authoring* system specially designed to create and present multi-media simulations for the training of emergency personnel. Bruhn Newtech's NBC-Analysis software (Bruhn Newtech, 2000)[4] takes hazardous input either manually from the user or directly from detectors.

Recently some multi-media and web-based training applications started appearing in the chemical industry literature. Goh et al (1998)[18] reported a safety improvement by a multi-media operator training system. Lee et al (2000)[19] developed evaluation algorithms for their operator training system.

EXISTING TOOLS AND THE A-TEAM PROJECT

The literature search indicated that there are a few computerised emergency management and emergency training tools, some of which are commercially available. We have not generally

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tested these tools, so we cannot make any judgement on their robustness or fitness for purpose. Some of these tools have been sold commercially and this is an indication that the industry and/or the emergency services are interested in and are prepared to experiment with these tools.

Some observations from our literature search:

- *Current practice*. The chemical industry still uses mostly conventional non-computerised systems for emergency training despite the growing interest in software tools
- *Consequence analysis packages*. Conventional consequence analysis programs are suitable for emergency planning (usually done by engineers or personnel with strong technical skills) but they need substantial customisation and a different graphical user interface if they are going to be used for emergency training
- *Control and command versus accident simulation*. Many emergency training packages are essentially 'control and command' training tools and they do not include any mathematical models of the accident. Sometimes the tools are used as one component of the emergency exercise while the rest of the exercise is done conventionally outside the software. Training in 'control and command' is obviously very important but it is thought that integration with simulation models would be a significant enhancement to the systems
- *Graphical user interface and model accuracy*. Most of the recent emergency training programs have focused on improving graphical users interfaces. Addition of multimedia capabilities is also given high priority. There appears to be little emphasis on improving the accuracy or realism of any attached consequence effect models.
- *Specialisation*. There are a number of tools that have focused on training of specific public services such as fire brigades or the police but they are probably less well adapted to the needs of the chemical industry. For example programs specialised to fire brigade training may not be very well suited to dealing with training for toxic gas dispersion incidents in the chemical industry.
- *Geographical Information Systems* (GIS) and electronic map systems are used to some extent for emergency response *planning* but these systems (GIS) are usually not integrated with emergency *training* systems. In general, it is not so common that emergency training systems make use of GIS.
- *Evaluation*. Evaluation in adult learning, especially in a work environment, is often a sensitive issue and sometimes it is not done properly to avoid emotional clashes. However since emergency response is a critical activity, evaluation of the trainees and the effectiveness of training are important. We are not aware of the evaluation included in the existing software systems and it seems that it is generally done outside the system. There is scope for research to improve evaluation within the software tools.

Our conclusion from the literature review is that modern computing technologies have provided significant potential for building useful emergency training software tools and there has been rapid progress during the last few years. There are some tools, which have interesting and useful features. On the other hand we have not found many systems which have all the important components necessary so that they would be accepted by the chemical industry. In this respect, the current computerised emergency training technology cannot yet be considered mature and there is scope for further research and development.

The A-Team project was defined with the aim of improving learning in the area of technological emergency response training. This aim would be achieved with the integration of artificial intelligence technologies and realistic consequence simulations. This would result in a system serving interactive multi-media content within a real time knowledge based system. The system would employ client-server architecture and would support easy access/

connection through Intranet/ Internet distributed systems. A-Team is a multi-partner European project and includes testing of the training approach and the tool by five partners in different countries. DNV will be testing the system with emergency training in the chemical industry. Our tasks include:

- A user requirement analysis, which has focused mostly on UK chemical companies
- Contribution to the tool architecture and development, especially by providing well established consequence analysis models
- Developing a training case and testing the approach with chemical industry users

Further exploitation and industrial use of the results of this work, including methodology and tools, is strongly encouraged by the sponsors, as this will motivate production of tools, practical and useful to industry.

EMERGENCY RESPONSE TRAINING IN THE CHEMICAL INDUSTRY

INDUSTRY SURVEY

Selected companies and public organisations have been contacted in several European countries. DNV started the user requirement analysis with 8 companies, mostly in the UK, who expressed an interest in the emergency training tool. A very detailed questionnaire was sent to all participants and then interviews were conducted with almost all companies in order to clarify and finalise the questionnaires and to collect additional information. Exhibit 1 shows a sample page from the questionnaire filled partly during an interview, containing information on the current emergency organisation and practices. The questionnaires and interviews covered the following areas:

- General information on the company, the site, the chemical processes, the area and the environment
- Legal framework and interaction of the company with the competent authorities, the public agencies and the other stakeholders
- Current emergency organisation and training
- Definition of potential emergency training cases and trainee profiles
- Functional requirements i.e. what the software tool should do, contents of the training
- Non-functional requirements – constraints e.g. hardware and software constraints, educational requirements/ constraints.

Some of the results are summarised below.

LEGAL FRAMEWORK AND INTERACTIONS WITH OTHER STAKEHOLDERS

The COMAH regulations in the UK (COMAH, 1999)[8] is the implementation of the Seveso II Directive (Seveso II, 1996)[27] and this is the most important piece of legislation governing emergency planning and training in major hazardous installations in Europe. The main Seveso II requirement is that there should be an emergency plan and it should be tested at least every 3 years with the participation of external agencies, generally the fire brigade.

In England there are two relevant competent authorities: the Health and Safety Executive for safety issues and the Environment Agency for environmental issues. Emergencies have to be reported to these two authorities. The chemical company usually interacts with other stakeholders as follows:

- Fire Brigade
- Police
- Regional or local Emergency Planning Unit (EPU)
- Ambulance

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- Regional Health Authority and Ambulance Trust
- Armed Forces (Terrorism, special branch etc)
- Neighbouring operating companies, which often participate in mutual aid schemes

EMERGENCY ORGANISATION AND CURRENT TRAINING METHODS

Most of the chemical companies in the UK (as well as in other European countries) have a similar organisational structure during emergency. This is shown in figure 1. The incident would first be notified to the incident controller (typically the shift supervisor) and his team. They would first attempt to control the incident at source at an operational level and then mitigate its immediate consequences. If the incident appears to be significant, the tactical team will be called so that they can direct and control the medium and longer-term effects. It can be seen that there can be a third level of emergency team (the crisis team) composed of the most senior people and having as objective to protect the company's reputation and take care of the longer term business interests of the company. If an external fire brigade is called, the fire commander needs to put his efforts together with the main controller to co-ordinate the response. It is usual that the fire brigade commander usually takes the initiative when there is a fire. However if there is a toxic gas dispersion, the fire brigade would leave the initiative to the plant manager/ main controller.

The survey also indicated that the following emergency training methods are commonly used:

1) Live exercises. These are major exercises, which try to mimic a major accident and its development in real time in the field. They typically require mobilisation of a large number of people to participate in the exercise on the same day. They involve the tactical management team, the at-the-scene incident control team, fire fighters etc. They can last from half a day to two days. They require prior preparation and organisation, sometimes several months in advance. They take place infrequently, at best every six months. They often involve external agencies. The fire brigade is the most common external agency. The exercise often involves the police, the ambulance service and the local or regional authority. Good descriptions of live exercises can be found in Ramsay et al (1995)[24] and Ramsay (1999)[25].
2) Regular drills. These field involve an accident scenario, typically a fire and the development of this scenario is followed to some extent but not to the same details as a major live exercise. Regular drills are organised by the safety manager or the shift supervisor or the emergency trainer and they involve a small number of people particularly the fire teams. Under the best circumstances they take place every week. They have a limited duration, say one hour. They don't involve external agencies.
3) Tabletop exercises. During a tabletop exercise, a major accident scenario is assumed and people sit around the table and play the roles they would have during an emergency. This is essentially a discussion of the participants' roles, responsibilities, and their actions under the circumstances of the accident. Tabletop exercises last about one to two hours. They are more frequent than the live exercises and they can take place a few times a year. They can involve external agencies but most of the time they do not.
4) Seminar training. This is normally lecture-based and typically: It includes basic knowledge on fires, hazardous chemicals, risks, case histories, emergency organisation and procedures. The emphasis is on problem identification and solution finding rather decision taking. Seminars are often introductory to other types of exercises such as live exercises.

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5) Control post exercises. These exercises start again with a scenario while people (mostly team leaders and communications responsibles) are seated in their respective separate positions. People consider the various hazardous outcomes and practice communications.

REQUIREMENTS SPECIFICATION FOR A COMPUTERISED TRAINING SYSTEM

Table 1 shows the main observations of those who participated in the survey about weaknesses of the existing emergency training systems. The table has been used to compile some of the user requirements for the new computerised tool. A large number of user requirements came from the user's responses to the functionality questions and they are documented in a special report (McCracken et al, to be finalised, 2001)[21]. The most important requirements are summarised here:

System Architecture

The system will have a distributed architecture, at least during the development and testing phase to facilitate deployment and access. The main A-Team server (the real time expert system RTXPS) will run on its native Linux/ Unix while other components (the DNV models) will be running on Windows and communication will be through HTTP. User access will be primarily through web browsers.

Consequence Models

A-Team will run "live" all consequence models that can run reasonably fast i.e. all DNV models and most of the other models. The case-based reasoning technique will be used to display results from the slower models (CFD). For given model input data, this artificial intelligence technique allows selection of the best-matching results from a large database of pre-calculated results.

GIS

The system will use the existing RXTPS Graphics Display System to display and use maps.

Contours

The program will calculate concentration, radiation and explosion contours so that they can be overlaid over maps or site plans. It will be possible to plot contours at different time intervals in advance.

Communication

There will be some provision for allowing people to train in communications. This is likely to be through a system simulating communications.

Multimedia

The system will make use of multi-media elements such as photos, graphics, animations, symbolic objects and interactive links and text. It will be possible to play these elements as far as this information had been fed into the system. Access to the PC will be through the keyboard and mouse.

Links

The system will provide links to contact lists, site plans and operational posts and asset descriptions.

Table 1: Issues with Current Emergency Training and Possibilities of Improvement

Category	Issues identified by the Chemical Industry	Possible requirements for tool
General emergency training issues	• Training is not frequent enough. We cannot easily get all the relevant people together • There is a lack of real understanding of roles in a major emergency team	• Use tool to practice roles and responsibilities in emergencies
Live exercises	• They are inconvenient and costly. Result: They are not frequent enough. • Public emergency services are busy. They are not easily available for joint exercises	• Use software to practice more frequently. Simulate agencies
Regular fire drills	• Regular drills. As they cannot mimic actual emergency well, they cannot impose the same stress levels as a real emergency • The fire drills are repetitive and predictable and the trainees often lose interest	• Use tool for realistic mimicking of emergencies • Include multi-media in tool
Tabletop exercises	• They are not so realistic and not in real time	• Self-paced (seminar type) multimedia courses should be combined with emergency scenario practising
Seminar exercises	• They do not provide any real experience by themselves	
Some computerised exercises	• Lose effectiveness when computer tools are not customised to the company's scenarios	• Allow customisation of scenarios to company's processes
Main Controller (tactical team) issues	• Ineffective Communications with the other parties: incident control team, external agencies • Debriefing Documentation is not usually good enough to be used for improvement of emergency response	• Tool should allow main controller to practice communications • Tool should produce full debriefing documentation
Incident Controller (at--the-scene team) issues	• He cannot easily visualise development of unusual major accidents because he has not been sufficiently exposed to a realistic accident representation. • He has little experience in assessing a complex incident i.e. diagnosing what went wrong from the signs and symptoms and predicting what could happen next. He has difficulty in weighing up pros and cons of decisions and answering urgent questions such as: Should a major emergency be declared? Is it safe to go into the building? This is partly due to limited understanding of the escalation potential of the initial incident and little familiarity with risks and risk assessment • There are problems of interaction between the company fire teams and the production operators/ technicians	• Interface tool with realistic consequence models to allow visualisation of accident consequences • Tool should teach Incident controller elements of risk assessment. It should also allow practising decision taking under pressure • Practice communications

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A-TEAM EMERGENCY TRAINING TOOL

Figure 2 shows the system architecture in more detail. The top boxes show the user access options. The primary access method is through a browser, which serves HTML, Java and possibly XML content. The main A-Team server is running under its native operating system UNIX/ Linux and is accessing the GIS and the real time expert system RTXPS. The use of HTTP and a browser, on the client side, has the big advantage of easy installation and easy updating. Figure 2 also shows that development of the other services (e.g. the DNV model service) can be initially running in different locations (e.g. London) far from the main server and under a different operating system i.e. Windows. When development is complete a decision will be taken if, for the purposes of the final distribution version, it is better to keep all components in the same box. Apart from the DNV model server there are two more servers:

- The DocCentre Multi-media and Course server. This manages an Oracle database which contains the multimedia material and the course management system
- The Case-based reasoning server, which accesses a database of CFD run results and selects the most appropriate results for user's input parameters.

TRAINEE PROFILES

The following groups of people were initially identified as candidate users of the emergency training tool:

1. *Operational* emergency response personnel who are employees of a chemical company. This may include: The incident controller (leader of the Incident Control Team) who is typically the plant shift supervisor, the fire team leader, a production technician or operator who assists with the initial control/ mitigation of incident, a fire fighter, other members of the emergency response team e.g. first aiders, security guards
2. Members of the *tactical* emergency response team, who are employees of a chemical company. This team includes a variety of roles but some of these roles could be assumed by the same person: Main Controller-leader of the team, assistant to the Main Controller, Technical Advisor-Engineer, SHE (Safety, Health and Environment) specialist, Communications responsible, Secretary-Record Keeper, Public Relations (PR) responsible, Human Relations (HR) responsible
3. *Public fire brigade* team leaders in chemical industry areas
4. *Police* officers dealing with emergencies in chemical industry areas
5. *Local/Regional authority* emergency response co-ordinators in chemical industry areas
6. *Ambulance* personnel in chemical industry areas

So far DNV has contacted mainly chemical industry potential users in categories (1.) and (2.) who have provided contributions to our user requirement analysis. However it is a possibility that people from the other categories will be considered, at a later stage, for using the training software tool. Public fire brigade officers (3.), police officers (4.) and regional authority emergency response co-ordinators (5.) are known to be users of similar software and are considered likely candidate users of A-Team.

Two trainee profiles have been selected for this initial phase of the A-Team tool are shown in Table 2. Both are team leader roles and there is some common knowledge that is included in both training cases. However there are some important differences:

- The Main controller is likely to have a good background education and knowledge and would think of both short term and long term issues and offsite consequences. The main controller represents the tactical team and would assume the most demanding role in his team.
- The Incident Controller is likely to have a very good practical knowledge and experience and would focus on short term and operational problems. The Incident Controller represents the people "at the scene" and has clearly the most demanding operational role.

Table 2: Trainee Profiles for a Test Case

Trainee Category	Primary job responsibilities	Roles in emergency situations	Relationship of role to other roles in emergency situations	Work practice
Main Controller (tactical)	Manager-Engineer	Emergency response control at a tactical level. Minimise consequence effects and offsite risk, including –short term and long term effects	Give advice/ recommendations to Incident Controller. Co-ordinates with external agencies	Management and /or technical experience
Incident Controller (operational)	Shift supervisor	Responsible for Incident Control at the scene. Mitigate consequences Address immediate hazards	Takes recommendations from tactical team (main controller) but maintains operational responsibility and control	Long practical experience. Some emergency response experience but only as a part time activity

TRAINING CASES AND POSSIBLE CONTENTS

The A-Team project considers 3 types of computerised emergency training:

1) *Single-user, self-paced* (style similar to distance learning) for background information; this may include:

- basic safety knowledge such as hazardous materials, hazards, scenarios, consequences etc
- simple model simulations for illustration purposes only
- emergency response knowledge such as emergency response organisation and emergency procedures
- a briefing for the 2nd part of the training which is the real time scenario-driven exercise
- a simple evaluation test of the trainee's knowledge before and after the exercise. This is based mostly on automated multiple-choice questions.

The trainee can go through the first part in his own time and in his own way. The idea of this first part is to prepare the trainee for the second and most important scenario driven exercise. This first part allows the user to go back as he wishes or to request additional information if he finds it necessary. This type of training parallels the currently provided seminar training but it will be much more visual and interactive.

2) *Single user,* scenario-driven emergency response exercise in real time. This is started with a hazardous initiating event, which is typically a release of a hazardous material. This includes a continuous dialogue between the system and the trainee, which is normally time-constrained i.e. the exercise runs generally in real time and the trainee has a limited time to respond or to take decisions. Under normal scenario-driven mode the user will not able to request additional information. On the other hand, the system avoids giving additional feedback or information so that the trainee does not deviate from his real time realistic scenario development.

The scenario-driven exercise initially takes place under trainer supervision, possibly within a small team of people. It logs the full scenario history in a file. The history is available for the debriefing session and is also used for the evaluation of the trainees. The evaluation is not initially completely automated and involves a discussion between the trainer and the trainee. The scenario driven exercise is intended to replace or to assist the conventional fire drills, tabletop exercises and live exercises.

3) *Multi-user* (multiple actor input, one or several actor-specific views) *externally driven* real-time scenarios, primarily for simulated emergencies.

Our training is initially implementing training of types 1 and 2. Training of type 3 is considered particularly suitable for integrated multi-agency training and it is considered an important and useful enhancement of the tool.

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CONCLUSION
This paper has provided a detailed review of recent advances of computer-based training in the technologically difficult domain of emergency response and it has also presented a new development in this area. Thanks to rapid progress in computing technology, including artificial intelligence, Geographical Information Systems, multimedia and visualisation techniques and advances in the area of consequence effect modelling, the components are now available to allow building of a useful emergency training simulator. The Chemical Industry needs to experiment a little more since this technology has the potential not only to cut training costs but also to bring an improvement in emergency training and ultimately an improvement in safety.

ACKNOWLEDGEMENTS
This work is partly funded by the European Commission, Information Society Technologies Programme IST-1999-10176, 5th Framework Research Programme. The author is solely responsible for the contents of this paper. This paper does not represent the opinion of the Commission or the opinion of Det Norske Veritas.

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Exhibit 1: Extract from a user questionnaire, with answers

4 Emergency Organisation and Training

4.1 Do you have your own onsite emergency plan? Or do you share a plan with other companies in the area?

- [x] Company onsite emergency plan
- [ ] Onsite emergency plan shared with other companies/organisations
- [ ] Other, specify:

4.2 What is the composition of your emergency response team? Please specify responsibilities of each team member.

Incident Control Team
The purpose of the team is to provide the first response to the incident at the scene
The team is led by the Incident Controller who is typically the shift manager
It also includes 3 other members. There are 5 shifts of this team. The responsibilities of the team are:
- quick initial assessment of the incident and decision if a site emergency will be declared or not
- first response to the incident e.g. shutting isolation valves
- initial first aid
- initial security functions
- initial fire fighting

Major Emergency Control Team
The purpose of the Major Emergency Control Team is to provide tactical management of the emergency if a site emergency is declared.
The team is led by the Main Controller. This is typically a senior manager or director.
There are 7 shifts and each shift has 4 members, who are typically plant managers. The members of a shift must be accessible by telephone or pager and should be able to reach the site within 30 minutes. The team members have the following roles:
- SHE Advisor. He advises on technical matters of Safety, Health and the Environment (SHE)
- Communications Responsible. He deals with communications mainly with external agencies and other organisations. He speaks to silver-level (middle-rank) managers of the Police, fire brigade and ambulance He also communicates with the Incident Controller and provides information to the record keeper
- Record keeper

Crisis Control Team
This is a strategic crisis management team at a very senior level. It manages impacts on business image, operations and liabilities. It also liases with the Communications responsible of Major Emergency Control Team. It normally includes the following members:
- Site Director
- Human Relations (HR) Director
- Manager of the Regional SHE Group
- Public Relations (PR) responsible

4.3 Does the Organisation conduct training on emergency issues? Yes [x] No [ ]

4.4 Is that training carried out internally or is it conducted by an external organisation?

There are both:
- Internal courses
- External courses (we used DNV for advice and Link Associates International)

4.5 What are the topics and skills actually taught in the current training?

A course typically includes 3 sections:
1) Lecture: The topics depend on the level. It may include case history, stress management principles, incident control principles, principles of command, dealing with the media and actions to take for the different types of incident
2) Pre-exercise briefing
3) Incident Exercise
Skills: It depends on the level. Can be fire fighting skills, decision making skills, and communication skills

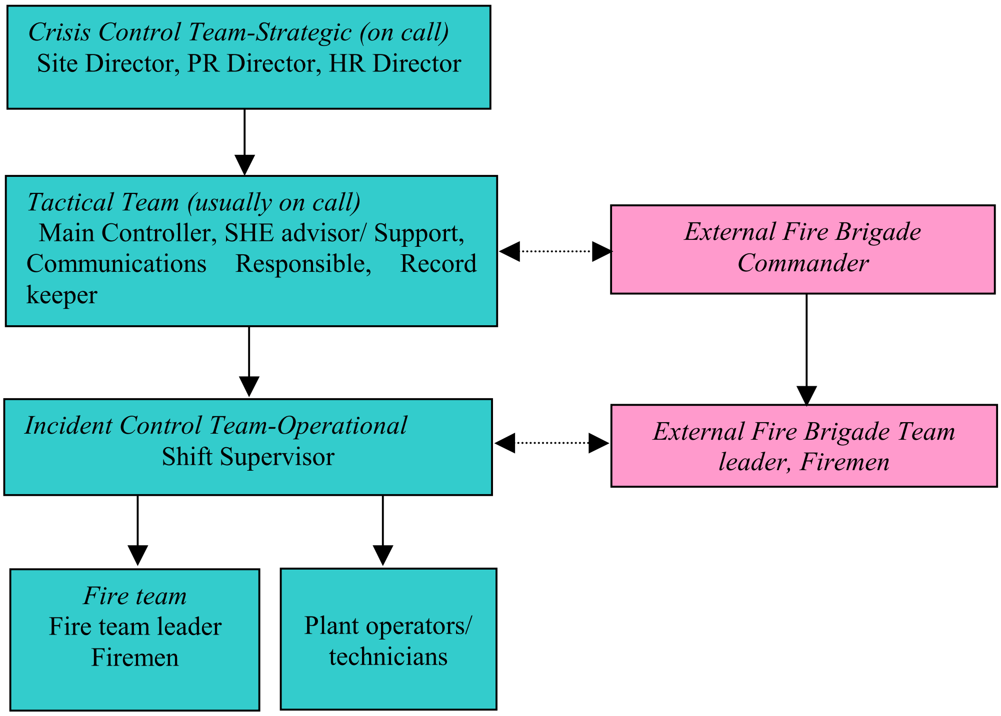

Figure 1: Emergency organisation of a typical british chemical company

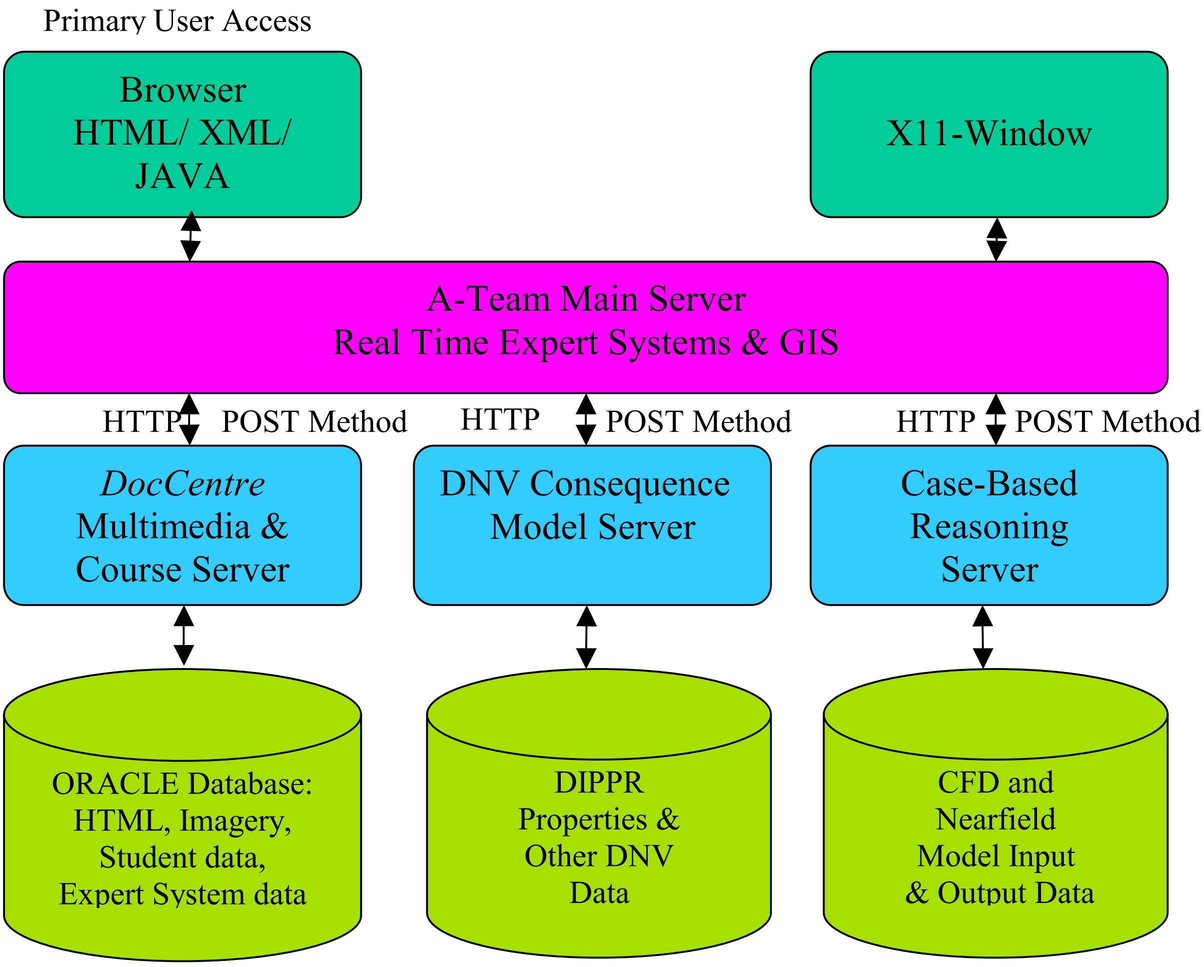

Figure 2: A-Team Emergency Training Tool Architecture