Command and Control for Major Incidents
Critical Incident Management and the Information Gap

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1. Introduction

Incidents involving hazardous materials present particularly severe problems in operational command. The problem is primarily one of the availability and suitability of information on which to base an incident ground assessment of risk. It is this problem which can be seen as constituting the 'information gap' and which needs to be addressed if Fire Service and other Emergency Service command and control systems are to meet the expectations and demands of increasing public awareness, especially in the aftermath of the events in New York on 9 September 2001.

2. Command and Control Procedures

Major incidents are often characterised, at the review or enquiry stage in the months that follow, by a realisation that inter-agency communication difficulties contributed greatly to the operational problems experienced. Proper liaison between the various Emergency Services – Fire Department, Police, Ambulance and Emergency Medical Services, the Emergency Planners and regulatory agencies such as Environmental Protection – must be combined with a clear definition of primacy of authority. Without suitable and sufficient information, which must also be timely and operationally relevant, proper command and control cannot be exercised; critical incident management will fail in terms of having the 'authority' to allocate and control resources, to achieve co-ordination and direction, and to complete assigned activities and functions correctly.

2.1 What is the 'Information Gap'

The information gap can be defined as consisting of a failure to provide adequate, concise and up-to-date information to an Incident Commander, resulting from:

- lack of suitable and sufficient information
- failure in vision of what is foreseeable
- inadequate technical data resources
- failure to distil operationally relevant material
- poor database maintenance leading to out-of-date information

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- retrieval system not robust or fail-safe
- communications loss or breakdown
- poor line of authority and concept of primacy
- breakdown of inter-agency communication or liaison
- excessive 'institutional' secrecy between agencies, or even within the Emergency Services.

Information must be: (i) condensed and concise; (ii) accurate and up to date; (iii) easily understood; (iv) produced as hard-copy; and (v) sufficient for the incident commander, any specialist advisers and Agency officers. Information is required which is reliable (validated), accurate (verified), current (up to date), comprehensive, easily assimilated and operationally relevant, providing guidance in fire fighting and rescue procedures, handling hazardous materials incidents including CBNR attack, protective clothing, occupational exposure limits, shelter / evacuation policy, fire safety measures including fixed installations, building construction and legal trigger levels, and which is continuously capable of being updated on the incident ground.

3. Decision making

Decision making under highly stressful, real-life, real-time conditions, such as are found at any major incident, is characterised by an operational situation that may be fluid, dynamic in the sense of not being easily controlled, rapidly changing and such that decisions once taken cannot be reversed easily, if at all. This area of research has been termed Naturalistic Decision Making (NDM), as defined by Zsambok and Klein[i]. Traditional, normative decision making is more suited to taking those decisions required for strategic and emergency planning, especially when developing worst-case scenarios, and in which the possibility exists for testing decisions and modifying them, not for rapidly changing, fluid situations[ii]. As pointed out recently by Crichton and Flin[iii], "*...Situation assessment, a key feature of most NDM models, is considered paramount to effective decision making (Cannon-Bowers and Bell, 1997; Endsley and Garland, 2000), where the first step in the decision making task is to evaluate the characteristics of the event correctly...*". Obviously to evaluate the characteristics of the event correctly suitable, sufficient and comprehensive information must be available at the time.

Recognition Primed Decision (RPD) making, based on a model developed by Gary Klein[iv] as a descriptive lemma of NDM, is an intuitive form of decision making suited to situations requiring rapid decisions to be taken without reference to written rules or procedures. The RPD making model was developed originally as a result of work on decision making by fire ground commanders[v], so is directly relevant to the current discussion.

The acquisition of heuristic competence in dealing with complex, dynamic and opaque situations through training has been shown to lead to better performance in dynamic decision making. Conversely lack of heuristic competence can lead to certain types of characteristic primitive decision making behaviour, referred to as 'pathologies of decision making' by Dörner[vi] and considered predictive of failure by Jansson[vii]. Three of the most important disorders of decision making, which may apply not only to an individual, i.e., the Incident Commander, but also organisationally to whole staffs at large incidents or to those responsible for strategic planning, have been identified and discussed previously[viii], as follows:

- *thematic vagabonding* (or wandering), in which the decision maker first concentrates on achieving one goal, shifting to another and then another, and so on. In complex situations this leads to failure because many goals may need to be considered simultaneously and in parallel;
- *encystment* (or fixation), in which the decision maker concentrates on a single goal that he or she considers they have the competence to achieve, at the expense of other necessary goals. This also leads to failure, basically for the same reasons that apply to thematic vagabonding;
- *refusal* to make decisions (paralysis), arising from the inability of the decision maker to take decisions under stress. Again it may be the individual that is incapable of taking the necessary decisions, or a staff suffering from bureaucratic overload, or plant operators overwhelmed by too many alarms sounding simultaneously resulting in them being turned off (as happened recently in a large refinery fire), or an undefined command hierarchy.

All of these disorders represent effects of stress on decision making, individual or corporate, with reversion to primitive decision making behaviour.

Learning through experience can be helped considerably through structured post-incident debriefing, the use of formal regulatory bodies' reports on major incidents, reference to commercially available compiled accident databases[ix], or books where a wide range of incident management experience is discussed by practitioners expert in various fields[x].

Whatever the psychological theory behind human error propagation and decision making during critical incident management, it remains absolutely essential that suitable and sufficient information is provided, often of a highly technical nature, in a form that can be used efficiently by an operational incident commander to support the use of their cognitive skills in dynamic decision making. This requires thorough training and the acquisition of the relevant skills, i.e., heuristic competencies, to handle complex, inter-related information. Lack of such information or its effective transmission, especially critical in incidents involving hazardous materials or severe structural damage, is what constitutes the 'information gap'.

Latent errors brought about by organisational and system deficiencies, often over a long period of time, by producing fertile ground for the commission of active errors at the time of an incident represent a very serious source of concern in strategic planning for critical incident management. Lack of proper, comprehensive, current and accurate information is one of the most potentially serious organisational deficiencies for any major incident, either at the planning stage or on the incident ground itself. There are specific and separate needs for information intended either for strategic and emergency planning, or for operational use in a dynamic environment, which must be addressed before the need for critical incident management arises.

4. Inter-Services Liaison and Communication

It is clearly a truism to say that if the various agencies and services with responsibility for the incident site do not communicate with each other either before or during the event, then overall command and control will fail with potentially disastrous consequences. The failure to communicate may be institutional. Intelligence agencies and the Police are notoriously unwilling to pass on information to organisations that they consider insecure.

Procedural, technical and institutional problems with communication between the various agencies involved have been identified in the recent FDNY-McKinsey Report on the World Trade Centre (WTC) terrorist attack, as well as in the other major disasters such as the 1992 Boeing crash near Schiphol airport Amsterdam.

5. Emergency Planning

5.1 Accident, Human Error or Intent?

The likelihood that a major incident involving hazardous materials will occur, not by reason of any 'accident' of nature or through human error but because of malign intent, has increased significantly since 9/11. A terrorist attack employing hazardous materials as agents of mass effect has, as its raison d'être, a desire to cause as much havoc as possible with the widest possible dispersion and loss of containment of the agent as well as with the greatest possible contamination of people and property. This change of emphasis renders obsolete old ground rules for what is reasonably foreseeable or predictable on the basis of probability derived from the historical record or test procedures, such as the mean time before failure (MTBF). It requires, by contrast, a new way of thinking from strategic and emergency planners about how one might use hazardous materials to create maximum effect, whether this is actual physical damage to property or life, or the destruction of society's infrastructure by triggering mass panic and disruption of normal services. The second of these objectives may be achieved, without any specific crime being perpetrated and at very limited expense in resources, if the emergency and law enforcement agencies over-react to the perceived risk.

In order to meet this challenge satisfactorily the strategic planner must enter the distorted but not necessarily illogical, criminal mind – the 'poacher turned gamekeeper' syndrome – and the tactical planner or operational commander must assume that loss of control of a dynamic incident is not only likely but that such loss of control is intended. You must always ask yourself the question 'What would I do, with sufficient technical background knowledge, to cause the most damage?'. But you must then go one stage further as the potential Incident Commander and ask 'What could I then to do to limit the consequences of this action?' If this process is repeated a number of times, at each stage refining both the initial action and the response to it, then one is more likely to reach an approximation of what is meant by foreseeable.

It may not always be easy to distinguish clearly between accident and human error. Accidents can be considered as events that are unexpected and lead to undesirable consequences. Accidents are defined legally at national and international level[xi], and most often involve the element of severe damage to property or the severe injury or death of individuals. Incidents and near-misses which do not make the grade as accidents, tend to be grossly under-reported. Very rarely do accidents occur in which it is possible to say that human error did not play a part. Catastrophic natural events such as earth quakes, tsunamis, flooding or lightning strikes may belong to this category, although it can be argued that even here human error is involved in poor prediction based on long-term historical data or failure to finance and implement defence or protective measures.

Human behaviour is probably the single most important cause of accidents and the effects that these produce, compounded in many cases by ignorance and negligence. The performance of the individual, and with it the concepts of human error and decision making, has been studied extensively. There has always been a desire to blame someone, preferably an identifiable individual to whom can be ascribed the '*mens rea*' required under the legal system, when an accident occurs, often driven by moral or legal positions. Over the last few decades the move has been away from blaming individuals to apportioning blame to the ways in which individuals are organised , i.e., organisational failure, regarding a level of individual human error as unavoidable. One purpose of the organisation can be seen as minimising the consequences of both individual human errors and system failures, e.g., the failure of a single pipeline valve or gas detector. Modern work has discounted the concept of the accident-prone individual, based on Freud's ideas that error was the product of unconscious drives[xii], mainly because of the methodological deficiencies and difficulty in identifying with any certainty the accident-prone personality[xiii].

Perrow[xiv] has suggested that unexpected events in tightly coupled and highly complex systems lead inevitably to accidents. Based on Perrow's work, Reason[xv] has proposed that accidents arise in complex systems from the actions of the people involved – "individual accidents" – and also from actions of the organisation itself – "organisational accidents". The unexpected initiating event, not foreseen at the emergency planning stage, may seem obvious in retrospect. But, as pointed out recently by Reason[xvi] in his foreword to Strauch's book, hindsight is not foresight and hindsight bias or the use of the 'retrospectroscope' is unlikely to be helpful and may apportion blame unfairly. Various models of human error have been proposed, ranging from that of Rasmussen[xvii], based on Norman's cognitive model[xviii], which classifies error as: skill-based; knowledge-based; and rule-based; to that proposed by Reason[xix] who extended concepts of human error developed by others in the field to include "active errors", committed by operators at the so-called sharp-end and leading directly to accidents, distinguishing these from those attributable to designers, planners and managers – "latent errors" or system errors – which represent situations waiting for an accident to happen. Analysis of near-misses will often help to understand these system or organisational deficiencies without the attendant cost of a 'real' accident.

Senders and Moray[xx] have developed a useful nomenclature, including a model of error-in-depth, based predominantly on the precepts of Reason and Rasmussen, for understanding why individuals make errors. Important factors are considered to be: cognitive processes or the individual's personal "information processing system"; the work environment; stress factors producing biases; as well as mental and emotional factors and the ability to concentrate on the task in hand at the time of the incident. Errors are described at four different levels, which include manifestations of error; cognitive processes; goal-directed actions; and external influences such as the situation (the 'atmosphere') or the design of the equipment available.

Active or operator errors, in the sense meant by Reason, will affect what actually happens on the incident ground, whereas latent or organisational errors will determine more how the situation develops once the initial active error has been made.

5.2 Risk Assessment

Situation assessment can, in many respects, be considered synonymous with operational risk assessment. The basic principles of risk assessment remain the same whether risk assessment is used operationally and tactically, or for strategic and emergency planning. The major distinction is that one has many more options for controlling or reducing the risk at the strategic planning stage. Incidents that arise by accident or by intent do not change the general principles which include (i) hazard identification and hazard inventory, (ii) risk analysis of the danger posed and its likely consequences, (iii) elimination, reduction and control measures to mitigate consequences, (iv) risk assessment including societal impact and damage to infrastructure, and (v) training needs identified through feedback and debriefing mechanisms.

The weight given to individual components of the risk assessment process, or to particular hazards, depends, however, on the purpose for which the risk assessment is being used as well as the risk environment in its widest sense. Risk assessment as applied by the

Fire Service represents a sub-set of the modified failure-mode-event-analysis (FMEA) process, one of a number of risk assessment approaches used throughout the safety engineering industry[xxi]. Under certain circumstances it may be appropriate to carry out a model or generic risk assessment, rather than to commit considerable resources, both financial and human, to performing a site-specific assessment with all this implies[xxii].

Fire Services are currently poorly prepared to deal with the full range of hazardous materials that can be converted into weapons of mass effect, i.e., 'weaponised'. This is in contrast to their state of preparedness for dealing with those hazardous substances normally found on chemical process and petrochemical industry sites falling under national and international legislation, or being transported by road, rail, water or air.

Of particular concern are those chemicals or agents that are classified as 'dual use' under the Chemical Weapons Convention (CWC) and derived national legislation, for example, the UK Chemical Weapons Act 1996[xxiii]. These are substances that can be used as precursors for chemical weapons but also have a perfectly legitimate civilian use, such as in pesticide or pharmaceutical manufacturing processes. At large industrial sites holding CWC dual-use classified materials, for example, phosgene or phosphorus oxychloride, the phenomenon of 'inventory leakage', i.e., small losses attributed to poor book-keeping but in reality lost through theft, must be taken seriously. Although not realised by many senior fire officers in the UK, the Fire Service has an obligation to report the presence of dual-use compounds detected on site inspection if the quantity being stored exceeds limits specified under the CWC and the Chemical Weapons Act 1996.

Hazard identification and the establishment of a full hazard inventory has absolute primacy in any risk assessment process for strategic planning purposes. If one does not know what hazardous substances are likely to be involved in any incident, one can hardly plan for what may happen!

5.3 Authority and Primacy

It is crucial to have a clear line of command at any major incident. Not only must senior officers <u>formally</u> assume command, i.e., not by default, when taking over from subordinates, who may have arrived at the incident first and thus become *de facto* the Incident Commander, but it must also be clear which Service assumes primacy when ranks are equivalent. Is the senior police commander the Incident Commander *de jure*, or only when the incident ground counts as a scene of crime? If the incident is primarily a technical one involving hazardous materials, complex rescue operations or the fighting of fire, is the senior Fire Department officer in overall charge of resources and personnel? These are not trivial questions and need to be clarified at the strategic planning stage. In 1992 an El Al Boeing 747 cargo plane crashed into the Bijlemeer housing estate near Amsterdam Schiphol airport. The subsequent report identified as a major problem that the Emergency Services did not know for nearly 24 hours who had primacy of command, i.e., was it the Fire Chief, the Police Chief or the head of the disaster management team?

5.4 Joint Control Rooms

Although a political 'hot potato' in some countries, joint control rooms consisting of police, ambulance and fire department staff have major advantages in the handling of any major incident. In the recent series of fire fighter strikes in the United Kingdom, joint operations control rooms (JOCs) run by the military in conjunction with the police and fire service were found to perform well. The setting up of joint control rooms is part and parcel of breaking down inter-service and inter-agency secrecy and exclusivity in handling information, both of which can spell disaster for emergency responders on the incident ground itself.

5.5 Joint Communications

Harmonisation of communications equipment and frequency allocations seems, in retrospect, such an obvious means of improving the reliability and robustness of communication between the various emergency services and any agencies involved in dealing with a major incident, that it is surprising that difficulties still occur. This is probably due to problems of common funding and procurement procedures, apart from institutional bias, particularly if the political responsibility for the different organisations is not the same. Not only must equipment be fully compatible <u>and interchangeable</u> but so must communications frequencies with the establishment of common channel frequencies accessible to all those involved. Radio communication protocols and procedures must also be standardised, for otherwise the police, fire service and rescue services may not be able to understand the information format being transferred. Joint communications need to be tested in exercises in order to identify difficulties under circumstances in which these can be corrected, and not for the first time in a real incident. There are many examples available of communication between groups failing because of non-standardised equipment, frequencies or procedures. Famously during the battle of Arnhem in World War II the Allied ground and air forces could not communicate with one another because the wrong radio-frequency crystals had been issued!

6. Information Retrieval

6.1 Standardisation of Databases and Software

Database transparency, in terms of structure and information organisation, as well as standardisation of the software used, especially in terms of data input and output formats, represent essential stages in establishing an information retrieval system that is functional, robust in a safety critical sense, redundant, fail safe and organisation independent. Domestic or office operating systems, software and hardware are, in general, quite unsuited for safety critical use by the Emergency Services. Systems with enhanced reliability, thoroughly tested under field conditions, with measures in place to prevent loss or corruption of data, loss of service or the need for rebooting the computer, are technologically achievable. The main issue is one of cost and specification, i.e., political will. You get what you are prepared pay for; but you must have a clearly defined idea of what the system is supposed to deliver at a technical level and specify components and software accordingly. The procurement process is the key to a successful, reliable IT system for Emergency Service use.

6.2 Hazardous Materials

General considerations of physical and chemical behaviour broadly follow the classification of hazardous substances into the four categories most often encountered in national and international legislation. National legislation often determines how these materials are marked for storage and transport, what quantities can be stored on site, and how incidents are dealt with in terms of occupational exposure limits or contamination of the environment. Strategic planning must take account of these legal constraints and any obligations imposed for reporting incidents[xxiv].

Under normal circumstances, the Emergency Services can expect that hazardous cargoes will be correctly marked and placarded according to national regulations, with further, more detailed information as to the identity of the material available from manifests and bills of lading. Fixed installations, such as chemical process plant or refineries, will have specialist staff on-site and a well established inventory system. Malicious attacks using hazardous materials are, however, a very different matter. No accurate information, or worse misleading information on the hazard will be available. First responders will have to identify the hazard based on very little intelligence before being able to decide on correct operational procedures. This can take considerable time which may not be available, or actually make matters worse. In this sort of critical incident lack of information and an overriding need to identify the hazard assumes major importance.

6.2.1 Chemical substances

Chemical substances cover those hazardous materials not otherwise classified as explosives, as radioactive substances, or as biological agents. Toxicity, flammability, the ability to form explosive mixtures with air, corrosive and irritant properties, violent reactions with water or other chemicals, as well as damage to the environment, are all properties that must be considered in critical incident management and strategic planning. Although extensive physical properties such boiling points, freezing points, and flash points, as well as upper and lower explosive limits, are available within the scientific literature and have the advantage of being quantitative and internationally accepted, this does not mean that this information is readily available in an easily digested form for either strategic or operational planning.

6.2.2 Explosives

Most explosives are characterised by a chemical composition that is very high in nitrogen and contain sufficient oxygen to support self-oxidation and decomposition, leading to a very rapid build-up of pressure. These materials typically contain nitro-groups or strained nitrogen rings. Detection methods rely on this characteristic chemical composition. Apart from direct blast and the very high temperatures associated with the explosion itself, producing both traumatic and burn injuries, incident commanders should not forget that the decomposition products can be quite toxic in their own right. Clearance distances must be determined for blast and thermal radiation effects, especially important when considering, for example, a LPG storage facility from the point of view of it being an 'explosive' incident. An outer ring, in excess of blast and heat effects, must also be established to allow for flying debris, ranging from complete storage tanks to gravel-sized stones or metal splinters.

6.2.3 Radioactive materials

Radioactive isotopes and the chemical compounds containing them are classified according to whether these emit alpha, beta, gamma, X-rays or neutron radiation. Acceptable limits for exposure and intake are determined by national legislation derived primarily from the International Commission on Radiological Protection (ICRP) recommendations. The risks associated with the different types of isotope vary considerably and are important when considering operational and incident planning procedures

6.2.4 Biological agents

In order to plan effectively for incidents involving biological agents, the properties as well as the dispersal and epidemiological patterns of the agent need to be known, as do the possibilities for treatment, vaccination or neutralising the agent with antidote. Unlike a 'normal' chemical incident in which only a few first responders are involved, procedures will have to be in place for dealing with large numbers of the population. In general, however, protective clothing and respiratory protection at individual level is not a problem; it is the scale that presents most problems. There is a need to establish a suitable inventory of protective clothing together with an infrastructure capable of distributing it when the need arises. Nor is the removal of any infectious agent or toxin, with the exception of some of the viruses.

6.2.5 Detection on-site

Portable, hand-held detection equipment is now available for most hazardous materials, including toxic gases, chemical weapons and biological agents. Use of more sophisticated techniques such as photo-ionisation detection, infrared and ultraviolet spectroscopy, as well as gas chromatography alone or combined with mass spectrometry, remains outside the reach of all but the largest and best financed fire brigades, although portable equipment is available at a price.

6.2.6 Protective clothing and decontamination procedures

Provision of the equipment itself is not a problem. The problem is one of establishing a large enough inventory of protective equipment, located so that it can be deployed rapidly, especially for a major incident in which there are mass casualties expected. Decontamination procedures must be robust, simple to operate, reasonably agent non-specific, and address the issue of contaminated run-off water which may be present n considerable volume if large numbers of people need to be decontaminated.

6.3 Information Technology Needs

Computer hardware is not a problem and software need not be a problem. However good a system one has, it is no better than the primary information on which it based. The overriding need, therefore, is for reliable, well validated and verified data on which to base an information system suitable for strategic and tactical planning purposes. This information must be available at a variety of different levels and in a variety of different forms, digested so that it is meaningful to (i) the Fire Service operational commander, (ii) the specialist Hazmat fire officer, (iii) the scientific adviser, (iv) the senior Police officer present, and (v) any regulatory agency officers in attendance at the incident. Detailed considerations in setting up an IT solution for providing technical information before and during hazardous materials major incidents have been discussed in a series of articles which appeared in the Fire Engineers' Journal during 1997-1998[xxv].

7. Operational Procedures

7.1 Control of Incident Ground

Control of the incident ground is essential in any major incident involving hazardous materials. Even assuming that significant numbers of the public are not involved, tight control measures are required to ensure that the Incident Commander knows who is within the geographical boundaries of the incident – thought of as the totality of the hot (red), warm (orange) and cold (green) areas or zones –as is a 'pass' system for controlling movement between the various areas. Decisions will need to made as to an appropriate and graded level of protective clothing for each zone, based on the chemical, physical and biological properties of the contaminant., ranging from Type A gas-tight suits with self-contained compressed air breathing apparatus (CABA) for personnel in the hot zone to coveralls and respirators for ancillary support staff and law enforcement personnel.

Dispersal of finely divided material, for example, a toxin or radioactive material, as a powder or dust, especially if the particle size is in the micron (10^{-6} metre) range and the material is either sparingly water soluble or insoluble, poses particular problems. Wind and convection spread are likely. The use of water spray for decontamination may assist spread rather than hinder it. Inhalation of sub-micron particles as dusts or aerosols will result in efficient and effective internal contamination through the lung aveoli.

Involvement of a large number of members of the public, for example, in the hundreds to thousands, makes the need for strict movement control absolutely imperative if spread of the contaminant and cross-contamination of facilities, such as hospitals, morgues, and emergency service vehicles, is to be avoided. Law enforcement or military personnel will be required to assist the rescue and medical services. Decontamination procedures, although adequate on a small scale for 'normal' emergency service use, may break down in situations where hundreds of frightened civilians need to be de-contaminated. Is the inventory of protective clothing immediately available adequate to the task in hand? What arrangements have been made for collecting and treating large volumes of contaminated run-off from the DECON procedure? For many highly toxic chemicals (e.g., pesticides or CW agents), radiological contaminants, or biological agents (e.g., viruses such as Small Pox or spore-forming bacteria such as Anthrax), allowing the contaminated run-off to enter surface waters or groundwater is not an option, as this would result in widespread cross-contamination of water supplies and land areas.

Spread of the contaminant and cross-contamination of the environment and social infrastructure is a particular problem in a terrorist CBNR incident involving large numbers of people, as discussed below. Very rigorous control of the incident ground will be required if spread is to be minimised.

8. Differences between Normal Incidents and Terrorist CBNR Incidents

8.1 How does a CBNR Incident differ from a standard HAZMAT Incident?

No knowledge (necessarily) of the agent. Malign intent to cause

- casualties
- panic and fear
- maximum damage and disruption
- intentional loss of containment
- damage to societal infrastructure
- very high risk to first responders
- problems of scale

8.2 What is Reasonably Foreseeable? Do NOT think as a reasonable person!

Think how you would

- cause maximum damage
- engender panic and fear
- cause maximum spread and loss of containment
- maximise the numbers of casualties
- maximise the difficulties of decontamination
- put first responders at maximum risk
- make identifying the material used as difficult as possible
- cause normal Command and Control procedures to break down.

Why make life difficult for yourself (the terrorist)? Nerve gases, radioactive materials, biological agents and explosives are difficult to make or get hold of without being traced. Therefore use everyday materials such as chemical industry feedstocks or fuels.

8.3 What Agent is Being Used? Unusual use of normal materials

- Aviation spirit in aircraft fuel tanks (= 9/11)
- LPG, LNG or H_2 in large storage facility
- chemical feedstock in road or rail tanker
- phosgene
- vinyl chloride
- chlorine
- hydrogen chloride / fluoride
- ammonia
- sulphur dioxide, etc.
- ship or barge, e.g., ammonium nitrate
- chemical process plant or refinery attack.

8.4 Unusual Methods of Dispersal or Detonation

- Weaponised containers or tankers with internal bursting charge
- Stored energy of fuel gases or liquids
- Difficult to detect triggers, e.g., X-ray transparent, X-ray sensitive ionisation chamber
- 'Dirty' bombs.

8.5 Initial Risk Assessment?

- Risk assessment within minutes requiring
    - On-site immediate detection capabilities?
    - Mass spectrometry
    - Photo-ionisation detection (PID)
    - UV/IR Spectroscopy
    - Scientific infrastructure
    - Knowledge database and management systems
    - not restricted to known CW agents!
- Officer training
- Medical support

9. Training Implications

There are significant training implications if Emergency Service officers are to understand the broad range of hazardous materials to which they and the public may be exposed. This must include not only the traditional categories of chemical and explosive substances but also the full range of radiological hazards as well as biological agents. Protective equipment must be robust, suited to purpose and not particularly hazard-specific. Decontamination techniques need to be simple, reliable and again not absolutely agent-specific. Both table-top and real-life exercises involving members of the public as 'extras' (i.e. a caste of many thousands!) are necessary to develop the mindset needed to deal with possible terrorist attacks involving weapons of mass effect and to inform the emergency planning stage. The horizon of what is reasonably foreseeable must be expanded to include the malign intent of a warped and unreasonable mind. Anything that is technologically possible, especially if of relatively low cost, is possible and thus foreseeable.

10. Conclusions

Critical incident management and strategic planning for major incidents involving hazardous materials requires extremely reliable basic information on which to base an assessment of risk. This underlines the need for an integrated risk assessment database covering the four important classes of hazardous materials, chemical substances, explosives, radioactive materials and biological agents. The software to manage this database must be suitable for Emergency Services use in terms of reliability, stability, concurrency and redundancy, as well as in its capability to produce meaningful information for the different stakeholders using it. The requirements of such a database are somewhat different depending on whether it is being used for strategic or tactical planning. There are many advantages to having the data available on a laptop at the incident ground. A prototype solution to this problem – the Phoenix integrated risk assessment database – has been developed over the last fifteen years and experiences in doing this will be discussed, using various examples.

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