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TRANSPORTATION OF NUCLEAR WEAPONS THROUGH URBAN AREAS IN THE UNITED KINGDOM

CHAPTER 1

ABSTRACT & SUMMARY

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This work was first published with limited circulation in 1990. Since that time there have been some changes in the nuclear warhead design with the Trident weapons system replacing Chevaline; new transportation vehicle have replaced the Mammoth Majors; the response in the public domain has been subject to new regulations; and, although not strictly mandatory for this radioactive transport mode, more immediate involvement of the local authorities would be expected. All of that said and accounted for, I doubt that the risks, outcome and consequences of a severe accident involving a nuclear weapons convoy will have changed that much.

Of course, not at all considered for the original study was the dimension of international terrorism which, now in the wake of the terrorist events of 9/11 (2001) in New York and Washington and in London at 7/7 (2005) occurred must surely be considered a realistic threat to the nuclear convoys operating in the public domain.

The fully detailed 6 Chapters of the entire study are available upon request.

Included in this edition are footnotes that identify the salient changes that have occurred since the original 1989 version, although these footnotes are not intended to be entirely comprehensive.

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ABSTRACT & EXECUTIVE SUMMARY

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TRANSPORTATION OF NUCLEAR WEAPONS THROUGH URBAN AREAS IN THE UNITED KINGDOM

ABSTRACT

The study commences with a brief outline of the overall activities of the nuclear weapon industry in the United Kingdom. This includes description of the transportation of nuclear warhead components destined for final assembly at the Aldermaston-Burghfield complex, although the risks and consequences of accident associated with this phase of the United Kingdom's nuclear weapon programme are not considered in detail. Similarly, the storage and service deployment (at sea and in the air) of nuclear weapons within the United Kingdom are not included in the study and, by this omission, only limited reference is made to air and sea transit to and from the UK of the nuclear weapons deployed by US visiting forces stationed in the United Kingdom.

The study concentrates on the road carriage of assembled nuclear warheads to and from the Atomic Weapons Establishment complexes at Aldermaston and Burghfield, Berkshire - a task that is necessary to deliver new warheads to the sites of storage and deployment,[1] and which also entails movement of existing stocks of warheads being returned to Burghfield for maintenance, refurbishing and or replacement. During these movements there is risk of accident and damage to the warhead assemblies in transit and, therefore, consequences that could result in harm to people and property in the locality of the accident.

Accident probabilities are discussed but no attempt is made to define the range or frequency of accidents that could result in such harm. It is assumed, quite reasonably, that such an accident could conceivably occur and result in consequences in the public domain. Similarly, the study does not consider the possible ways in which malicious actions, such as sabotage and acts of terrorism, could promote damage to and failure of nuclear warheads when in transit.

The nuclear weapons programme overall is an extremely sensitive subject so it is necessary to consider how secrecy, applied centrally by the Ministry of Defence (MoD) in this topic may have impaired the study. There is, however, sufficient information and data available from other sources to assess the hazard, risks and consequences of a nuclear weapon accident. The sufficiency of this information is, essentially, that nuclear warheads in transit in the United Kingdom include at least two extremely hazardous materials. These materials are the large quantity of conventional high explosive built into the warhead and, at the heart of the warhead, the fissile mass of plutonium. The first of these materials, the high explosive, is extremely destructive and the second, the plutonium, extremely toxic even in minute quantities.

The performance of each of these materials at the onset, immediate and post-accident phases of an accident involving a nuclear warhead is considered. First, it is concluded that the warhead containment, including its transporting vehicle cover, would be totally violated upon inadvertent detonation of the high explosive charge and, secondly, that this loss of containment surety would permit the release of the warhead's plutonium core to the atmosphere.

The consequences arising from the release of the plutonium, when aerosolised and dispersed into the atmosphere, are assessed. Two phases of the plutonium hazard are evaluated: The first and immediate phase arises from inhalation of airborne plutonium over an area that could extend 40km or more from the scene of the accident. During this phase, commencing at the onset of the accident and lasting, perhaps, up to two, three to seven hours or more, immediate countermeasures would be required to mitigate health harm to the population caught in its path. The second phase, commencing when the plutonium had settled (deposited) from the overhead plume, would be long-lasting requiring population movement controls and extensive decontamination, if not complete recovery of all plutonium from ground, building and other surfaces.

The nature of the harm to people, particularly from inhalation of airborne plutonium is such that prevention of inhalation is the only effective countermeasure. Thus during the critical inhalation phase it is absolutely vital that people be protected and isolated from the airborne contaminant and, for this, emergency measures have to be implemented efficiently and without undue delay.

The emergency plans that would be implemented should such an accident occur are reviewed and comparisons are drawn between the approaches of the US and UK authorities. It is concluded the UK planning is wanting and deficient in several important respects, particularly in that there is no significant prior consultation with or involvement of the local authorities.

The congenital element of the MoD's emergency planning fabric is the central application of widespread and all embracing secrecy. It is noted that this secrecy extends far beyond safeguarding the detailed make-up of the weapons and nuclear warheads: there is no official information available on the nuclear weapon convoy routes; on how much plutonium would be available for release; the likely form and dispersion of any release; and how the MoD would manage and co-ordinate the emergency response. This secrecy denies national, county and local civil authorities crucial information and the means of preparing for such an accident: the characteristics and toxicity of plutonium are not readily available; monitoring and protective equipment, clothing and decontamination procedures are not specified; fire, ambulance, police and other emergency personnel

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[1] Now it is acknowledged that the UK nuclear deterrent comprises solely the submarine-launched weapons system operating from Faslane with the warheads being stored at nearby Coulport.

have no experience of operating in a plutonium contaminated environment, and the regional health authorities do not have the resources to deal with short and longer term civilian casualties simply because they do not know what resources are required.[2]

In short, MoD secrecy endeavours to deny the very existence of nuclear warhead transit operations, so much so that the corollary of not involving civil authorities in advance prevails. This somewhat absurd outcome of secrecy extends to the central organisation, the NRPB, responsible for implementing the national emergency arrangements for incidents involving radioactive release (NAIR), which has no data for or experience in assessing the possible consequences of a nuclear weapon accident.

In effect, there is no local authority preparation possible for an emergency arising from a nuclear weapon accident, either independently or co-ordinated from within the NAIR scheme. In the absence of prior knowledge, experience and guidance the local authorities may have great difficulty in fulfilling their generally accepted responsibilities of safeguarding people and property.

The MoD claims itself to be the competent authority, capable of monitoring and determining the extent and levels of radioactivity likely to be widespread in the air and on the ground following such an accident. The MoD also claims that its planning for such an accident includes provision for countermeasures necessary to safeguard people and property in the extended aftermath of an accident.

However, in the aftermath of a serious accident where plutonium has dispersed, countermeasures would have to be implemented immediately and then modified and progressively extended as time passed and the airborne dispersion developed. These countermeasures are likely to require evacuation and sheltering of many people, perhaps thousands, located nearby and at extended distances from the accident site. On one hand, considerable effort, organisation and manpower would be required to ensure that the consequences were minimised. On the other hand, there might be only twenty to thirty MOD and military personnel accompanying the convoy at the scene of the accident; the majority of these would be involved in security, accident control and warhead safing operations, some may be injured and incapacitated and not all would be trained in the countermeasures required.

Clearly, a serious deficit would quickly arise between the manpower and resource demands of the accident and the facilities available to the MoD at the scene. Thus it is an absolute certainty that the MoD would require to enlist the skills and resources of local authorities during the early part of an accident aftermath. Yet the MOD is not willing to inform local authorities of its requirements for assistance in advance, nor will it acknowledge the likely nature and severity of such an accident so that local authorities may prepare independently for such an accident.

There is, understandably, concern that in the event of a nuclear weapon accident the MoD simply could not cope. There are also doubts about the soundness of the MoD's strategy, so far as this can be ascertained since nothing is published, for the management of the emergency response following an accident. One doubt arises because of the known MoD policy to either deny or, at least, suppress information to the public domain relating to the release of radioactivity yet, at the same time, the MoD would be required to direct operations and countermeasures to minimise the harm to the public from the release of radioactivity. For both members of the public and local authorities such could result in confusion serving to impede the implementation of countermeasures. Other doubts relate to the extent of the MoD's responsibilities in controlling and directing the overall emergency response, none of which are clearly defined; clarification is required on what facilities are to be made available to and what is required from the local authorities; nothing is published on the levels of plutonium, both airborne and on the ground, at which the MoD would initiate countermeasures; and there is ambiguity on many detailed aspects of accident management, including the primacy of local authority officers such as the Chief Constable and Chief Fire Officer at the scene of the accident.

The assumption by the MOD that it has the right to supervise such arrangements and impose upon local authorities without prior consultation and agreement is considered to be particularly illustrative of the MoD's brash and, so far as the study is able to ascertain, grossly inadequate approach to emergency planning.

The study concludes by expressing reservations on the MoD's ability to fully manage the aftermath of a nuclear weapon accident in the United Kingdom. It is concluded that although the MoD may well be able to muster the resources necessary to secure and recover the remains of nuclear warheads in the immediate locality of such an accident, it would be hard-pressed if not incapable of implementing effective countermeasures beyond the immediate area. For this the MOD would have to utilise the resources and skills of the local authorities but, and to this end, the MoD does not advise, involve or exercise these local authorities in advance. Thus, the success of the local authorities in protecting people and property in the event of a real nuclear weapon accident must remain subject of considerable speculation. Accordingly, the severity of consequence in immediate, short and longer terms of a nuclear weapon accident aftermath arising because of these inadequacies is also speculative.

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[2] Even though the *Radiation (Emergency Preparedness & Public Information) Regulations* were introduced in 2000, these regulations do not strictly apply to the road transportation of nuclear weapons. Even so, the local authority experience of other nuclear emergency (via preparation of off-site plans and exercises) is not sufficiently extensive to apply fully to a nuclear warhead incident. Also, many of the local authorities along the nuclear convoy route have no civil nuclear facilities within their jurisdiction and, hence, these LAs would have no experience of REPPIR.

TRANSPORTATION OF NUCLEAR WEAPONS THROUGH URBAN AREAS IN THE UNITED KINGDOM

1.1 UNITED KINGDOM NUCLEAR WEAPONS

In the United Kingdom the nuclear weapons which provide the so-called independent deterrent have formed the mainstay of the nation's defence policy for the past three decades. To continue this defence commitment it is necessary for the nation to undertake the broader-based activities of maintaining the nuclear warhead arsenals, to progressively develop more advanced nuclear weapons together with delivery systems, and to extract and manufacture the materials and components that finally assemble into a nuclear weapon system overall.

These broader-based activities are completed at a number of localities throughout the United Kingdom.

The weapons and warheads are based at relatively isolated sites with the principal deterrent, Chevaline and its Polaris submarine delivery system,[3] attracting little public attention when at sea or berthed at ports such as Faslane in Scotland. The warhead manufacturing plants at Aldermaston and Burghfield carry on with the manufacture and assembly of the warheads in the absence of undue public concern and, although often the focus of considerable public attention, particularly in respect of radioactive discharges to the marine environment, the nuclear plants producing, extracting and refining the warhead fissile and other nuclear materials at Chapelcross, Capenhurst and Sellafield are all too often associated only with the civil nuclear power programme. Other ordnance and manufacturing plants where components of the warheads are fabricated, such as Llanishen near Cardiff and Foulness, rarely attract public attention.[4]

Public awareness of the UK nuclear weapons programme stops at recognition that the 'bomb' exists, failing to grasp, so it seems, the complexity of the UK nuclear weapons industry that manufactures not just one bomb, but a variety of nuclear weapons and arranges all of the supporting activities that are necessary to secure the nuclear deterrent system overall. Indeed, there is the public's general confusion on the number and different types of nuclear weapons maintained by the United Kingdom, how and where these weapons are deployed and that an overseas nation, the United States, is seemingly free to operate its own nuclear weapons arsenal within the United Kingdom.

Thus public awareness is extremely limited and some would say uninformed. First and on the public's part it is, perhaps, too difficult for lay individuals to assimilate the technical complexity of the nuclear weapons industry overall and, of course, the principle of nuclear deterrence is often an emotive issue which itself may forestall the inquiring mind. Secondly, the nuclear deterrent is subject to much State secrecy for it is, after all, the very system that arguably secures the defence of the Realm.

Nevertheless, all of the nuclear weapon activities have to knit together in order to produce a nuclear weapon or, as is the case, several different types of nuclear weapon at one locality. This central locality is the atomic weapons factory complex at Aldermaston and Burghfield in Berkshire.

Like the centre of a spider's web, Burghfield receives a variety of components, processed and prepared materials from various manufacturing plants throughout the United Kingdom. From Aldermaston, about 10km west of Burghfield, the cast fissile materials are delivered; conventional high explosives most probably derive from a munitions plant at Foulness and Fort Halstead; the precision machined beryllium reflector shells from Llanishen; and the radioactive tritium from the nuclear reactors at Chapelcross in Scotland. Some these plants also receive materials and components from other places of manufacture with Aldermaston, for example, accepting plutonium and enriched uranium feed stock from the British Nuclear Fuel plants at Sellafield and Capenhurst respectively. In fact the chain of manufacture and supply extends further afield: To extract the plutonium the reprocessing plant at Sellafield requires nuclear reactor irradiated fuel from, it is claimed, the reactors

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[3] Now the Trident weapons system based on the *Vanguard* class of SSBN ballistic missile submarine.

[4] The warhead facilities at Foulness and Llanishen are now closed as are the reactors at Chapelcross.

dedicated to military plutonium breeding at Chapelcross and Calder Hall.[5] In turn, these reactors have to be fuelled with uranium refined and smelted at a plant at Springfields near Preston, and this plant requires uranium yellowcake feed stock gained from overseas mines. And so on and so forth.

In this way and even before the nuclear weapon assumes its final assembly, hazardous radioactive materials such as plutonium, uranium and tritium, the extremely toxic metal beryllium and high explosives are regularly in transit throughout the United Kingdom.

Once an individual nuclear warhead has been assembled at Burghfield it has to be transferred to either a storage or operational deployment site. These sites are scattered around the United Kingdom with the principal nuclear deterrent (Polaris) arming facility at Faslane in Scotland which, itself, is served by the nearby nuclear weapons store at Coulport where the Chevaline warheads are held in preparation. Two other nuclear weapons are known to be deployed by the UK armed services in the form of a free fall nuclear bomb for the RAF and a nuclear depth charge for the Royal Navy[6] - both these weapons are likely to utilise the same type of thermonuclear warhead, the WE177. For its secondary nuclear weapon, the Royal Navy major store is most likely at Ernestettle or, perhaps, at Bull Point within the Devonport Dockyard. The Royal Air Force maintains a number of nuclear weapons storage facilities such as Scampton, Waddington and Cottishall.

Of course, each nuclear warhead and its complex safety, arming and fusing systems require periodic maintenance and, because of natural radioactive decay, the fissile and radioactive materials that form the heart of the warhead, the so-called nuclear physics package, require refurbishing and/or replacement from time to time. The precision and sealed nature of the warhead, together with the stringent radiological measures required for safe handling of warhead components, necessitates that each warhead complete is returned to the specialised factory at Burghfield for overhaul on a regular basis.

The number of individual nuclear warheads held within the UK arsenal is not published, estimates of this vary from a total of 225 to 1,000; the shelf life of each warhead varies with the type of warhead, its service operation and its required nuclear yield; and the rate of new warhead production is unknown. Thus the frequency and numbers of transport operations moving nuclear warheads to and from Burghfield cannot be predicted with any great certainty.

However, nuclear warheads are transported on the public highways by convoys comprising very distinctive vehicles, so distinctive in fact that enthusiastic, civilian nuclear weapons spotters seem able to keep a reasonably accurate log and tally of all movements throughout the United Kingdom. This somewhat macabre variant of train spotting suggests that a nuclear weapons convoy takes to the roads on a reasonably regular frequency of about once every four to five weeks.

Each of the weapons carriers, drawn from a small fleet of specially adapted large lorries known as Mammoth Majors,[7] has an assumed capacity to carry a cargo four to six warheads and there are usually four to six Mammoth Majors in each convoy. Thus and by necessarily crude reckoning, there might be a total number of 16-20 warheads on the roads somewhere in the United Kingdom every four to five weeks.

The obvious questions arise: What are the hazards involved in transporting nuclear weapons in this way ? What if one of the Mammoth Majors was involved in a serious road traffic accident, caught fire or if its cargo was subject to sabotage ?

Posing such questions prompts further questions:

If subject to severe shock, fire or malicious damage would a nuclear warhead detonate and release its devastating nuclear power ? Could the warhead spill its radioactive and highly to toxic contents to the

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[5] In the mid-1990s the UK government announce that it would not longer dedicate facilities for the production of ‘weapons grade’ plutonium – the current stockpile of WG plutonium is believed to be in excess of 5 tonnes compared to the 100+tonnes of reactor grade plutonium extracted from the reprocessing of civil nuclear reactor fuel.

[6] The Royal Air Force no longer deploys free fall nuclear weapons and the Royal Navy no longer has nuclear armed depth charges and all of the WE177 warheads are now believed to have been dismantled.

[7] Mammoth Major vehicles have been withdrawn from service being replaced with a Foden articulated tractor unit and covered trailer.

atmosphere and thus subject the populace of the area to risk of health injury ? And, if so, how large would the area be and how many members of the public would be involved ?

And further questions still: Are the safeguards taken and countermeasures held in contingency by the operators of these convoys, the Ministry of Defence, adequate in all respects ? In the event of an accident or, indeed, for the contingency planning for such accidents, will it be necessary to involve the local authorities and, if so, how prepared are these local authorities for such an emergency ?

Such questions form the basis of this study into the transportation of nuclear warheads in the United Kingdom.

1.2 MANNER OF REPORTING

When we, at Large & Associates, undertook this study I and my colleagues firmly believed that we could objectively assess, without too much difficulty, the risks and consequences of accident associated with the transportation of nuclear weapons in the UK. Our instructing brief was to examine the road transportation of the assembled weapons which are regularly moved to and fro between the various weapons stores and the refurbishing and assembly ordnance works at Burghfield. This activity is open and cannot be concealed from the public, with the weapon transporters passing along the motorway and major road network both through and nearby centres of population in well ordered and easily recognised convoys. Thus, we proceeded to collect and collate the information and data necessary for our evaluation.

Our project management approach to this study was straightforward, comprising three distinctive objectives: First, we needed to identify the actual nuclear weapons involved, secondly and from this determine the hazard arising should such weapons being involved in a severe accident, and thirdly assess the consequences in the public domain of a severe accident.

Our sources of information to meet these objectives also seemed straightforward. Obviously, our instructing Clients (the National Steering Committee of Nuclear Free Local Authorities) could provide a reasonably well collated assemblage of past studies into this topic and, particularly, copy correspondence with the Ministry of Defence. We assumed that the Ministry of Defence itself would wish to co-operate in our study, providing or at least confirming such information that would demonstrate the procedures and contingency plans were maintained and well rehearsed to absolutely secure the safety and welfare of members of the public along the convoy routes. Also, we were drawn to overseas sources of information, particularly the United States, where weapons accident exercises have been conducted and openly reported. And, finally, we somewhat cautiously referred to several of the ‘peace’ groups who had in the past and continue to show a particular interest in the movement of nuclear weapons in the United Kingdom.

Obviously, the Ministry of Defence featured much in this information gathering exercise. Previously, individual local authorities, compiling overall our Clients, had approached the MOD as had the peace groups and we, during the course of our study, communicated to the MoD on many occasions. We also referred to a number of past Parliamentary Questions and Answers that related to the transportation of nuclear weapons in the UK.

The striking feature of the MOD response to all of these inquiries was not that of secrecy (for this was obvious throughout) but that of careful management and release of information that it, the MOD, considered to be appropriate for and commensurate to this topic. I believe our work to be the first study in which opportunity has arisen to make comparisons of the detailed response of the MoD, comparing the MoD’s management approach to the dissemination of information to Members of Parliament, responsible local authorities, local and national interest groups, individuals and technicians such as ourselves.

In studying the numerous documents that we have assembled during the past months, particularly in drawing comparisons between matters of physical or scientific fact and statements from MoD, I consider certain of these statements to be unreliable. Furthermore, I have studied the response of Cabinet Ministers to Parliamentary Questions and enquiries from local authorities, finding similar contradiction of fact in certain statements - since I assume these Ministers are advised by the MoD, I conclude that the information they receive is also subject to careful management by the MOD.

In openly stating this opinion I am aware that I and my colleagues are likely to be rebuked by the MoD. This draws me to explain the manner of our reporting of this study.

In organisation, the following chapters consider the matters relating to the risks and hazards of the transportation of nuclear warheads. We have endeavoured to ensure that the content of each of these chapters is objective and as matter of fact as possible, referring to publicly available references and source documents to endorse this information. We have also endeavoured to seek clarification and/or endorsement of certain core elements our findings directly from the MoD but, disappointingly, our requests have been fobbed off by long delays and, when eventually received, what are best described as blatantly evasive answers.

The following chapters are as comprehensive as our instruction and time scales permit. There are gaps in our information and knowledge, no doubt some of which are at our fault and, of course, there are instances likely to have arisen from misunderstandings on our part. Nevertheless, my colleagues have reported on but drawn conclusion from the vast amount of information studied during this project. My role is somewhat detached in that I have to present an opinion and to draw an overall conclusion in this executive summary chapter.

The opinion and conclusion that follow are my own and in this way I choose to shield my colleagues, although I lean heavily on their work which is represented only in part by the voluminous chapters that form the bulk of this report.

Earlier I touched upon the secrecy that envelops the nation’s nuclear deterrent and so it would be expected that sound information would be scarce on this subject. Indeed, the Ministry of Defence make much of this for early in our correspondence with the MoD we received an oddly phrased reply which I consider illustrates the isolated attitude of the Ministry. The Ministry said, in effect, that since it would *not* provide information then we, as engineers, would not be in a position to report to our Clients. This reasoning is quite absurd for two reasons.

First, nuclear weapons and the warheads are engineered fabrications, being matter of fact these devices that utilise contemporary technology and which are designed and manufactured with quite commonplace engineering and scientific knowledge. It is only the *detailed* design and specification of these fabrications that is not available.

Secondly, on secrecy the impression is that the MoD employs a battalion of mandarins to safeguard the information but, equally, there is another battalion of well informed individuals and organisations eager to disgorge the information that they have collected by resolute effort over the years. Similarly, turn to libraries in the United States where its *Freedom of Information Act* overturns the efforts of the MoD ‘weeders’ who, in the UK and for this topic, render the Public Records Office a museum of scarce fact - in this way, official US documents quite often and openly refer to the very same information that the MoD will neither confirm or deny in the United Kingdom.

Other than prompting what I assume to be a feigned disinterest from the MoD, our involvement in this study attracted considerable interest from number of other parties. During the course of study we received many offers of assistance, regular updates of the weapon convoy movements, even more bundles of further information. In other words, we at Large & Associates have be swamped by information, so much that our report on this topic can only be a shadow of what available for other researchers in this field.

Now, I give my opinion:

1.3 COMPONENTS OF A NUCLEAR WEAPON

Essentially, a nuclear weapon comprises two components.

There is the nuclear warhead which provides blast, fire storm, radiation emissions fall-out when detonated and, to carry the warhead to a prescribed target, it is necessary to employ some form of delivery system.

Nuclear Warheads

The warhead may assume the form of either atomic fission device, the atomic or A Bomb, hydrogen fusion device, the thermonuclear or H Bomb.

The fission warhead may achieve nuclear detonation by either firing together (a gun type) or uniformly compressing (implosion type) a mass of fissile material. This fissile material comprises either highly enriched uranium, or, for the UK warhead design, a core or fissile pit of plutonium metal. Until moment of detonation the fissile core of warhead is held in a sub-critical spatial arrangement. To initiate nuclear detonation conventional explosive charges are fired to violently compress the fissile mass to a super-critical arrangement at which neutrons are internally generated within the fissile core. In turn, these neutrons interact and generate more neutrons and a very rapid nuclear chain reaction occurs, with each link of the chain liberating energy.

A number of tricks involving engineering and physics are required to ensure that this process occurs sequentially, very rapidly and successfully. In the implosion warhead, the conventional explosive charges are arranged as a series of lenses, faceted around the fissile core, all of which are simultaneously fired to produce an even, inward push or coalescing squeeze on the core. The fissile core itself is encased within shells of depleted uranium and a zirconium alloy pusher and an inner shell of beryllium which serves to reflect successive generations of neutrons back into the core or pit of the warhead. Within the assembly is an initiator that at the moment of the detonation sequence provides an abundance of neutrons to commence the process overall.

The whole sequence of initiating, firing, compressing, reflecting and finally nuclear detonating a fission warhead will occupy no more than a few millionths of a second.

A fusion warhead includes and centres on a fission device. Essentially, the inner primary stage (the atomic bomb) is surrounded by a secondary stage of fusion fuel of deuterium, tritium and lithium wrapped in a blanket of uranium. The nuclear process commences when the conventional high explosive is detonated, prompting fission of the atomic bomb within. The fissioning atoms vaporise the interior of the warhead casing forming a very hot and dense gas which in turn compresses the fusion fuel charge the secondary stage. This in turn sparks fusion the secondary stage by transforming lithium into tritium. The tritium fuses with deuterium producing a great abundance of neutrons which irradiate and ignite the uranium blanket. The uranium begins to explode, trapping the expanding fusion fuel between two blankets of exploding uranium in a fission-fusion-fission process which liberates enormous fusion/fission energy.

The entire thermonuclear process fission-fusion-fission in these two stages, other repetitive stages if present, occupies a few microseconds.

Thus the innards or nuclear physics package either a fission or fission-fusion warhead is a relatively simple but highly integrated assemblage of precision components. Some of these components are naturally radioactive (the fission core blankets) and other components are in concentrated radioactive form (the tritium) and within the nuclear physics packages are materials that are highly corrosive (lithium) and very toxic (beryllium), and others that are unstable chemical (high explosives) and radioactive (plutonium) senses.

Considered individually or in interaction with each other, the materials within a nuclear warhead are very hazardous. If the warhead progresses nuclear detonation these components and materials interact to form radioactive fission products other activated radio-isotopes which, even if the devastating blast and fire storm of the nuclear detonation are somehow ignored, present considerable health hazard to surviving members the public in the short, medium and longer terms.

If the warhead is involved in a severe accident but does not undergo nuclear detonation, the release and dispersion to atmosphere of the basic building block materials within the warhead will also present a considerable health hazard to members of the public in the medium and longer terms.

Weapons Delivery System

Corresponding to its complexity of service role the delivery system will also include hazardous materials.

In its simplest form the delivery system might comprise just the external casing and stabilising fins of a free-fall bomb or be extremely complex such as the Polaris system, including a submarine launcher, multiple stage missile and individual re-entry vehicles each carrying one or more independent targeting warheads.

For example, a ballistic missile will include highly flammable, perhaps unstable and corrosive chemical reagents for its propulsion fuel. It is likely that a staged missile system will also carry explosive charges for the separation of the propulsion stages and, separately, a high explosive charge dedicated to self-destruction of the weapon should the mission require aborting.

The warhead or individual warheads carried by a large ballistic missile, such as Polaris or Trident, might each include a propulsive system, either in the form of propellant fuel or as a gas generator, with which to target the individual warhead. Moreover, these warheads might be in close proximity to other on-board vehicles that utilise explosives to deploy chaff or other means to deter detection when in flight. In some weapons, such as Trident, the warheads are packed around the mid-section of the final propulsive stage and thus in close proximity to the missile fuel.

In another form the delivery system might simply comprise a charge to propel the nuclear round to its target, such as the explosive charge used to fire a nuclear tipped artillery shell.

Weapon Overall

Whereas the service specifications for the various delivery systems cover a wide range of requirements, the role specification of the warhead is quite specific, being simply that of providing the required nuclear yield at target.

The trend in weapon development has therefore been towards a standardised warhead (or nuclear physics package) which will adapt or fit to a number of delivery systems. Example of this standardisation is the now ageing WE177 warhead which provides for both the UK free fall bomb and nuclear depth charge weaponry.

Of course, standardisation to a single warhead cannot be achieved totally, but generally the approach facilitates the ease of separation of the warhead from its delivery system which is advantageous for transportation. To disadvantage, standardisation requires that the fissile material content of any one warhead of a standardised series is set by the largest nuclear yield requirement of the series which, in the event of an accidental release of radioactive materials, sets an upper and higher limit of consequence.

1.4 NUCLEAR WEAPONS AND SAFETY SYSTEMS

The overall safety of a nuclear weapon may be broadly separated into a number of regimes.

Interaction of Warhead and Delivery System Regimes

Both warhead and delivery system have their own safety regimes as separate entities. For example, malfunction of the delivery system might be confined to the delivery system alone, eg spilling propellant fuel which if ignited would endanger of the safety of nearby personnel. Of course, an adverse event occurring in the delivery system could cause interaction with the warhead, here the burning or exploding missile fuel might cause failure of the warhead containment releasing some been proportion of the radioactive and toxic materials contained within the warhead.

As I have previously noted, the nuclear weapon is formed when the warhead is coupled to the delivery system so, and obviously, the first safety feature of a nuclear weapon is that the warhead is uncoupled and separated from its delivery system at all times other than when it is deployed in a the state of readiness.

For some nuclear weapons this essential safety prerequisite is readily achieved by separating the weapon at what are called ‘field breaks’. For example, a nuclear tipped artillery round and its charge (incidentally, it is unlikely that this particular nuclear weapon is manufactured or deployed in the United Kingdom) can be kept separate until loaded into the artillery piece.

In the broader sense and for a free-fall bomb, the delivery system also includes the aircraft carrying the weapon. There are two known and recorded nuclear weapon accidents where failure of the aircraft component of the delivery system adversely affected the warhead. These incidents, involving United States Strategic Bomber Command aircraft, occurred at Thule in Greenland and Palomares, Spain. In the aftermath of both of these accidents a number of warheads broke up on impact with the ground, exploded and or caught fire and dispersed plutonium over a wide area of land.

In the narrower sense certain warheads include parts of the final delivery system. As I have noted previously, it is most probable that the United Kingdom Chevaline warhead (which sub-divides into a number of individual, independent targeting warheads) includes propulsive means, either propellant fuel or more likely a gas generating device, to guide the individual warhead to target. With this type of final stage weapon system it may not be practicable to field break the individual warhead from its propellant charge.

Interaction of the Warhead Safety Regimes

As I have previously explained the warhead achieves its intended nuclear detonation by organisation of a sequence of separate events in very rapid succession. For a fission warhead the two most important events in this sequence are the compression of the fissile material by the high explosive charges and, then, attainment of super-criticality in the fissile mass. In a fusion warhead, there are two subsequent events involving the creation of plasma and fusion of the fusion fuel charge, although both of these are dependent on the successful sequencing of the fission device at the heart of a thermonuclear warhead. I also noted that the warhead includes a number of other devices (tricks) that serve to guarantee the rapidity of the sequence and improve the nuclear yield of the warhead.

With regard to accidental detonation of a warhead these devices and, in a thermonuclear warhead, subsequent fusion sequencing does not assume primacy. This is because even partial success of the fission process is sufficient to generate enormous forces and liberate radioactive material and, particularly, fission products. Thus absolute and fail-proof safety against accidental nuclear detonation may be only be absolutely guaranteed if the high explosive charges are separated and distanced from the fissile core of the warhead.

Current warhead design and construction does not facilitate the separation of the high explosive charges and fissile material until the warhead is dismantled at a specialised plant such as Burghfield. Thus, safeguarding a nuclear warhead against accidental nuclear detonation, at least in part, cannot be absolutely guaranteed.

In fact, the United States acknowledges the risk of inadvertent nuclear detonation of a warhead, albeit with the caveat such an event is considered to be of extremely low probability, and there is a substantial research programme underway to develop warhead designs that facilitate insertable nuclear components. Put simply, an insertable nuclear warhead design is where the two primary components, the high explosive charge and the fissile core, are kept separate until the warhead is deployed in anger. For example, the high explosive might be kept separate in the form of a paste that is extruded into the warhead pit immediately prior to or following dispatch of the weapon. In the United States this research has not developed much beyond the concept stage and I doubt very much that warhead development in United Kingdom is in advance of the United States in this specialised and high technology field.

High Explosive Charge Stability and Safety

Thus current nuclear warheads are deployed, stored and, importantly, transported with the two prim components in-situ.

Of these two components, the fissile material sensibly, with respect to triggering an accident the passive component whereas the high explosive charge, at risk of accidental detonation, is the active component. Necessarily, therefore, safing of a nuclear warhead centres on rendering conventional (chemical) high explosive as safe practicably possible.

The role of the high explosive charge within warhead is extremely demanding. As I have previously outlined, the exploding charge required to uniformly compress the fissile core down to a supercritical mass. The forces required to achieve this compression are extremely high and the means by which these forces generated complex.

In the firing sequence of a warhead, each individual high explosive lens has to generate a progressively strengthening and inward propagating shock or detonation pressure wave which, together with the other lenses, eventually coalesces on and exactly matches the shape of the surfaces of the fissile core. This is achieved compiling the inner and outer layers of each with slightly different formulations of high explosive which, in detonation, are characterised by different shock front or wave propagation speeds - thus, I final detonation pressure wave front shape may matched to the surface of the fissile core over the projecting area of each lens and, overall, for all lenses surrounding the core. For a successful nuclear detonation compression of the fissile core has to be achieved before failure of the outer warhead casing and this, essentially, relates to the timing and paths assumed by the explosive waves generated within the lenses.

Military explosives are generally characterised by ‘brisance’ or the ability of the explosive to shatter and fragment steel, concrete and other very hard structures. Essentially, this capability relates to the magnitude of the detonation pressure so, and since the warhead high explosive lenses are required to compress the hard plutonium (and uranium and other metal shells wrapping the) core, the warhead charge is likely to exhibit a very high brisance. Brisance is determined by both the chemical formulation and density of the high explosive with the denser cast explosives exhibiting a higher brisance than moulded or pressed explosives. I understand that both cast and moulded high explosive lenses are utilised in nuclear warheads and that, generally, the moulded derivatives are somewhat more sensitive or unstable than cast forms.

If the high explosive charge of a warhead should inadvertently detonate then the brisance or the bursting/fragmentation capability of the charge will result in destruction of the entire warhead and its containment. In its service role this self-capability of the high explosive to destroy the warhead is of no importance since the few micro-seconds of delays involved permit the nuclear processes to complete. If, however, the nuclear processes do not complete then the energy of the high explosive detonation will dissipate in destruction of the warhead assembly. Thus the requirement for high brisance in the warhead service role is extremely undesirable in the inadvertent detonation or accident case. I doubt if a satisfactory compromise has been achieved between these two, quite different service and safety requirements.

To initiate detonation of high explosive first it is necessary provide input of sufficient energy to the main charge or, for a warhead, to each of the lenses or clusters of lenses via a small explosive device known as a detonator. Essentially, a detonator provides a heat source to a small high explosive charge by either spark, flame, impact, hot wire or the exothermic liberation of heat via chemical reagents.

The detonators utilised in a nuclear warhead high explosive charge are, most probably, hot-wire triggered and include a booster stage. The detonator booster stage, comprising a small coupon of highly sensitive explosive, serves to shape and reinforce the detonation wave firing each of the lenses. In fact, the booster stage may require a second detonator and include a number features serving to interrupt, delay and sequence the firing overall - in certain ordnance designs the booster stage establishes a second wave front to direct the main charge inwards.

Thus the safety regime of the warhead high explosive encompasses both the main charge and the individual detonators. The main charge will be susceptible to, as are all explosives, inadvertent explosion via undue shock, excessive temperature and chemical instability. The detonators are also prone to these conditions but, in addition, protection is required to ensure that spurious electrical signals do not enter the firing circuits leading to the detonators.

Safeguarding the conventional high explosive charge and detonators of a warhead against inadvertent detonation is achieved, essentially, by three means.

Safing, Fusing and Arming

First, the safing, arming and fusing circuits and devices which are used to prepare the high explosive charge towards the ultimate and intentional nuclear detonation of the warhead are likely to be complex and multi-layered.

There is considerable speculation on just how these systems work, and on their reliability and effectiveness in isolating the high explosive and detonator circuits. Modern warheads also incorporate permissive action links and sealed authentication systems, and much is made of the so-called weak-strong link safety systems which, it is claimed, place priority with maintaining the warhead safe in all conditions. The implication here is that the warhead safety systems are the strong, positive links capable of overriding and negating any spurious signals that would progress the warhead arming and fusing systems.

However, for its intentional role the warhead (and its arming and fusing systems) has to survive what may be very strenuous launch and delivery phases and, as it home towards its target, the warhead has to be sufficiently durable to withstand any enemy countermeasures. These phases might involve forces, stresses and strains on the warhead hardware that are at least comparable in many respects to the abuse conditions arising from a severe accident involving the warhead. This suggests that when intentionally deployed in a service role the arming and fusing systems are likely to have priority over any safing system - in other words, when deployed in anger the arming and fusing signals of a warhead are the strong, positive links capable of overriding and negating any signals that would stand down the state of preparedness of the warhead. Put another way, the logical design approach to implementing a safety system is to arrange simply to disconnect the arming and fusing systems, that is to have no actual safety hardware incorporated within the warhead that could interfere with or jeopardise fulfilment of its primary function.

This reasoning leads me to the conclusion that when a nuclear warhead is in transportation the primary safety or safeguard of the warhead is that the active arming and fusing systems are disconnected - I doubt if safety of the warhead is achieved by any much more complicated or sophisticated way.

High Explosive Detonating Circuits

The second means of safeguarding the conventional high explosives against inadvertent detonation is to arrange for the charge overall to comprise many, independently-fired charge cells or lenses. Since the compression of the fissile material has to be uniform and virtually instantaneous, any delays or non-firing of individual lens would lessen the probability of a nuclear detonation.

In fact, in an implosion type warhead man lenses of high explosive have to be distributed around the fissile material pit in order to achieve a uniform explosive compression or squeezing over the outer surface of the pit during the first stage of converting the sub-critical fissile material to a super-critical mass - these lenses are shaped and arranged in a pattern not dissimilar to the individual segments that make-up the outer skin of a modern football. Each lens is complete with some form of detonator cap that, when linked to the firing circuit, results in the desired simultaneous detonation of all lenses.

Thus linking each individual lens, or groups of lenses, to separate detonator firing circuits ensures that even with the occurrence a spurious firing signal in one detonator circuit this would not fire all lenses simultaneously. The United States warhead designs incorporate this type of safety feature, with the detonation sequence somehow arranged to provide a warhead considered to be intrinsically *‘one-point safe’*.

The Ministry of Defence have refused to confirm or deny that United Kingdom warhead designs utilise a similar safeguard.

One-Point Safe means that in all probability (put at a probability of one in a million) inadvertent firing of the warhead high explosives charge would not result in a partial nuclear yield or fizzle greater than the equivalent explosive power of four pounds (~2 kg) of conventional TNT explosive. However, this does not mean that the remainder of the warhead charge would not explode, but that the explosion of the remaining charge would be sufficiently delayed or corrupted so as not to promote a full nuclear yield. In a one-point safe accident, the fission products irradiated by the fizzle and the remaining plutonium core material (and other radioactive and toxic materials within the warhead) would be dispersed as the warhead containment disintegrated.

Insensitive High Explosives

The third means of improving stability and safety of warhead high explosives is to use the so-called insensitive high explosive for the warhead charge and/or individual detonator devices. Although there is much reference to insensitive high explosive in US documents, it is not absolutely clear whether insensitive high explosive is applied universally through the warhead or confined to the detonators and their boosters.

The United States first introduced insensitive high explosive in 1979 and has subsequently developed new warheads with this explosives formulation. However, not all warhead designs may be adapted to insensitive high explosive (for example, the current development programme for the US W88/Trident II and W82/2 155mm artillery projectile do not incorporate insensitive high explosive). Similarly, the United States has experienced difficulty with retro-fitting certain of its existing stockpile of warheads with insensitive high explosive. It is implied that warheads utilising a highly enriched uranium fissile material (and not plutonium) are unsuited to insensitive high explosive, as are warhead re-entry vehicles that detach from their parent missile in the outer atmosphere.

The first of these restraints suggest that the brisance of insensitive high explosive is insufficient to guarantee adequate compression of an enriched uranium core, and hence implies that insensitive high explosive is not used for the main explosive charge. The second restraint relating to warhead re-entry vehicles, implies that heating of the weapon overall (during the re-entry phase) may impair operation of detonators utilising insensitive high explosives.

No information is available from the Ministry of Defence on the use of insensitive high explosives in its warheads. Currently, other than the warheads deployed in the Chevaline-Polaris weapon system, the main British warhead seems to be the WE177 which is deployed in both air-launched and depth bomb weapons and originates from about 1967. Little is known about the re-entry performance specification of the Chevaline warheads and if this (if similar to the US Navy W88/Trident II) renders the warhead unsuited to insensitive high explosive. The WE177 is an ageing warhead design and this design may also be unsuited to insensitive high explosive.

Interaction with External Interference

For the high explosive to inadvertently detonate the warhead, or its internal systems, must be subject to some form of abuse. Normally, this abuse is assumed to arise from intense impact or fire, but there is another form of interference that could, it seems, result in inadvertent detonation. This form of abuse is commonly referred to as electromagnetic pulse (EMP) or interference (EMI), sometimes electrostatic discharge (ESI) or more specifically as hazard of electromagnetic radiation to ordnance (HERO) - the acronym EM is sufficient to cover all of these definitions and interpretations.

The radioactive releases from the two previously considered nuclear warhead accidents of Palomares and Thule, are both most likely to have resulted from detonation of the high explosive charges at impact with the ground. A third incident, acknowledged but not reported in meaningful detail, resulted in the explosion of a US Army Pershing missile on its launch pad deployed in the European Theatre. This missile may or may not have been fitted with a nuclear warhead. The US military concluded that this accident arose because of EM interference.

The protection of nuclear warheads from EM is a sensitive topic, although it is quite clear that this has attracted considerable attention in the United States. For example, US Army standing orders require nuclear weapon storage facilities to undertake EM surveys on a regular basis and in such detail that extends beyond the requirements of conventional munitions facilities. Similarly, in their nuclear weapon accident exercises, the US allocates a specific prohibited zone for radio transmitters and other EM generating equipment. This restriction, applied when the warheads involved in the accident scenario are quite separate from their delivery systems, implies that warheads in a condition prepared for transport are also at risk of electromagnetic interference. This risk from EM undoubtedly applies to the detonators and the contingent circuits of some nuclear warheads.

The UK Ministry of Defence has stated that all UK nuclear warheads are protected against EM, but is not prepared to demonstrate how this is achieved. The restrictions adopted by the United States suggest that the warhead alone cannot provide total EM shielding and that additional precautions have to be employed at the scene of a nuclear weapon accident.

Imagine, therefore, a serious road traffic accident involving a weapons transporter on a motorway. If the US prohibited zone for radio transmitters (a source of EM) were to apply (and there is no reason to believe that similar prohibition should not apply in the United Kingdom), then the convoy security personnel would need to assess and control the total radio transmitter power bands (wattage and frequency) of emergency and other vehicles attending the scene. Since to my knowledge, the MoD has not informed the emergency services of such a restriction, police, firefighters, ambulance personnel and others could unknowingly use their radio equipment and thus, conceivably, jeopardise safety at the scene of the accident.

1.5 HAZARDS OF THE WARHEAD HIGH EXPLOSIVE CHARGE

Instability of the warhead high explosive may result in one of two outcomes.

First and as previously considered, the high explosive can inadvertently detonate. Depending on the timing, sequencing and completeness of the detonation, the warhead might undergo full or partial nuclear yield or break up and disintegrate with no significant nuclear yield.

Secondly, the high explosive might only partially explode with the remainder or some proportion thereof igniting and burning fiercely.

Detonation of the High Explosive

A gauge of the power of the conventional high explosive within a typical nuclear warhead is illustrated by the US Army field manual requirement for evacuation of a fragmentation zone of 610 to l,000m radius around a warhead at risk of high explosive detonation.

The worst, conceivable nuclear weapon accident nuclear detonation of the warhead which would result in similar damage and consequences though the warhead had been intentionally deployed in anger. If such catastrophe is to be scaled the second ranking would be accorded to accident where the warhead underwent a part nuclear detonation or fizzle, where a proportion of the consequences would result from blast, fire storm and contamination of the populace by fission product and the remaining portion of the plutonium charge. Further down the scale catastrophe is where the high explosive charge necessary for the nuclear detonation, accidentally exploded producing *no* nuclear yield but which was of sufficient force to release and disperse radioactive and toxic materials within the warhead (ie a ‘dirty’ bomb).

The general consensus of scientific and technical opinion is that although an inadvertent **nuclear** detonation is theoretically possible (as openly acknowledged by US authorities) the probability such an occurrence is virtually non-existent. Similarly, the probability of a partial nuclear yield arising from inadvertent detonation of high explosive charge is very remote and, even this event occurred, the fission products generated by a fizzle would be unlikely represent a health risk greater than if all of plutonium core of the warhead dispersed without fission product component.

I concur that the risks of both full and part nuclear detonation arising from a nuclear weapon accident are very remote, although not entirely inconceivable.

If this is accepted, the most serious hazard associated with a nuclear weapon accident is that of asymmetric detonation of the warhead’s high explosive charges resulting in disintegration of the warhead release of the plutonium core and other materials. In its severity, this accident could result in the entire plutonium core being dispersed to atmosphere in aerosolised form of which approximately 20% would be at or below the respirable particulate size of 10 microns.

Fire of the High Explosive

If the accident involved severe fire with the warhead engulfed in the flames, then the high explosives could detonate, burn or melt and/or flow out of the warhead casing.

Fierce burning of the high explosive, which I consider to be the most likely of these outcomes, could serve to aerosolise the plutonium and other materials within the warhead. Plutonium, in the base metal (slightly alloyed) form used for the fissile core of a warhead, is itself combustible in the presence of air with spontaneous ignition commencing in temperature conditions of, most probably since little is published, about 200 - 250°C. In other words, once ignited the plutonium will, if conditions remain favourable, continue to burn and aerosolise.

In its severity this accident could result in approximately 1 to 2%, or thereabouts, of the plutonium core being dispersed to atmosphere in respirable particulate form of about 1 or less equivalent diameter micron size.

Knock-On Consequences

In the United Kingdom nuclear warheads are transported in road vehicles, the Mammoth Majors, each capable of carrying four to six warhead assemblies. At the same time, the vehicle cargo may also include the so-called limited life components (initiators and other devices containing radioactive materials), so these devices would also be at risk.

Details of the Mammoth Majors are not published although the observation of the vehicles under movement on the public roads is possible. Other than a number of features which mark the specialised military adaptation of a commercial lorry chassis (together with other features that improve security of crew and cargo, but which it would not be prudent to discuss in detail here), there is nothing extraordinary about the containment provided by these vehicles. My own observation of these vehicles leads me to the conclusion that in the event of a serious road traffic accident there is risk of the outer body shell (the slide back cargo hold cover) failing and that, very certainly, detonation of one or more warhead high explosive charges within would be sufficient to breach if not totally destroy the body shell.

Similarly, details of the transit packaging of the individual warheads carried within the vehicles are not available. However, if I refer to US documentation relating the packaging adopted for road and rail transportation (where some weapons are shipped completed without outer packaging), again I conclude that there is nothing extraordinary about the packaging that would protect the vehicle or warheads against fire, elevated temperature, explosion and severe impact.

My overall impression is that there is no apparent design feature of the transporting vehicles (nor of the warhead packaging and routines adopted for the convoys), that absolutely guarantee safeguarding the warhead cargo in the event of a road traffic accident. I conclude that the warhead cargo is therefore at some risk during transport from external events and that, if the warhead or warheads were to inadvertently HE detonate, then the transporting vehicle would be of insufficient integrity and overall strength to contain the explosion.

As I have previously noted, the United States adopts a fragmentation zone of 610 to l,000m radius around a warhead stricken or disabled by accident. This zone is adopted to safeguard personnel in the event of high explosive detonation. It is assumed that large fragments or shrapnel of the warhead casing and undetonated high explosives would be projected over this area. It is also acknowledged that fragmented high explosive remains at risk of detonation when in the air on when settled on the ground. Hence, the detonation of one warhead provides mechanisms, impacting shrapnel and or impacting and exploding high explosive, in the immediate aftermath of an accident whereby the damage may proliferate.

Obviously, all of the warheads and other devices contained within one vehicle would be at risk of damage should one warhead of the vehicle cargo be subject of malfunction or damage during an accident. Similarly and since up to six Mammoth Majors travel in closely spaced convoy, other warhead cargoes within the convoy would be subject to the risk of a knock-on accident proliferating from another vehicle.

The probability of events proliferating in this way cannot be reckoned with any great reliability. However, I am of the opinion that inadvertent high explosive charge detonation of a single warhead within one vehicle would, in all probability, adversely affect the containment surety of the other warheads and devices within that vehicle. In the extreme, all warheads within the vehicle cargo hold could detonate or ignite the high explosive charge in a knock-on way. Providing vehicle spacing in the convoy was maintained, I doubt that an explosive or fire event in one vehicle could propagate to the other vehicles. I would expect, however, that several of the convoy vehicles would be damaged and disabled, a number of escort personnel would be injured and incapacitated, and that control and safe recovery of the remaining warheads would be rendered difficult.

Other circumstances of accident would also impede safe recovery of surviving warheads. For example, if such an accident occurred on a busy motorway, then detonation of the high explosive of one or more warheads, would also result in personal injury and, most likely, fatality of civilians, together with damage and disablement of vehicles caught within the fragmentation zone. Emergency services access to the scene of the accident would be impaired if the motorway was completely closed (which is more than likely), traffic tail-backs would form, and confrontation occur between confused and bewildered members of the public and the convoy security personnel. Even if detonation of a warhead did not occur in the immediate aftermath of such an accident, I doubt very much if the convoy security personnel could clear and maintain an adequate fragmentation/blast zone of 600m radius, or thereabouts, until all of the warheads had been rendered safe.

United States accident experience and training exercise preparations provide a rough and ready gauge of the risk of knock-on proliferation.

At Palomares the weapon carrying aircraft broke up in mid air with the individual weapons falling to the ground (and sea) over a wide area. In this accident there was no knock-on proliferation and two of the weapons exploded or ignited quite independently at impact with the ground. At Thule it seems that the greater part of the weapons carrying aircraft remained intact when it crashed into the ice covered ground and there resulted detonation and or ignition of all four weapons on board. In this accident it is likely that knock-on proliferation occurred between the individual weapons, although it should be recognised that the high impact forces of an aircraft crash and the fierce burning of aviation fuel could have contributed significantly to the onset of detonation and or burning of the individual weapons.

US training exercise accident scenarios typically involve three or four weapons and, sometimes, a number of limited life devices. The exercise scenarios generally centre around accidents involving aircraft crash, of both fixed wing and helicopter type which seem to be the predominant means employed by the military to move nuclear warheads. Although, the US warhead manufacturing plant in Texas, Pantex, is known to ship warheads by both rail and road these modes of transport have not featured in US nuclear weapon accident scenarios to date. All of the US exercises have provided for the detonation or fire of at least one warhead at the moment of impact but none have included the delayed detonation of a warhead in the post-accident phase. However, all of the exercises provide for a period during which the warheads are considered to be a risk of high explosive detonation, with this risk remaining until the individual warheads have been inspected and, where necessary, rendered safe.

An interesting feature of US accident scenarios is that aircraft crash predominates so it is generally assumed the warheads will scatter from each other in falling to the ground. Thus and by this simple default, US accident scenarios do not consider knock-on proliferation of a number of individual warheads confined to a single locality. In contrast, road transportation in the United Kingdom guarantees that two, three or more warheads will be in close proximity to each other in any accident scenario involving either one or more Mammoth Major vehicles of a warhead convoy.

1.6 HAZARDS OF DISPERSION OF THE NUCLEAR WARHEAD MATERIAL

Nature of the Hazard

I have previously outlined the radioactive and toxic natures of certain of the materials included within the nuclear warhead assembly.

The release and subsequent dispersion of the plutonium core of the warhead by far predominates in the composition of the possible severity of consequences arising from a nuclear weapon accident. A few types of nuclear warheads do not contain plutonium, utilising a highly enriched uranium fissile mass instead, so extreme accidents involving such weapons would result in a lower consequence. However, I understand that all UK warheads contain a plutonium core and do not utilise enriched uranium for the fissile mass function, although uranium will be present in the fusion stages of a thermonuclear warhead.

Other hazards that may arise from a nuclear weapon accident include the release of radioactive tritium in a dense gaseous form that will require time and distance to dilute to relatively innocuous levels. The heavy metal beryllium, used as the neutron reflector, is extremely chemio-toxic and dispersion of aerosolised beryllium poses a hazard in both inhalation and, in the longer term, ingestion uptake modes. Lithium, used as a fusion fuel, will burn explosively when exposed to water and during this process liberate highly corrosive by-products.

The blast and fragmentation of a high explosive detonation is injurious; if burning, high explosive liberates toxic gases and residues which may harm those endeavouring to control such fires; and undetonated fragments of high explosive remain a hazard underfoot until all such pieces are accounted for and recovered. In addition and in the presence of airborne plutonium, shrapnel injuries arising from a high explosive detonation will provide open wounds for ingress of plutonium into the bloodstream, which will worsen the consequence for those individuals caught within the fragmentation zone.

Dispersion and Uptake

Subject to detonation or fire, plutonium will aerosolise into small particles (down to below 10 to 1 micron, or smaller, in equivalent diameter) that are readily borne aloft and dispersed in the atmosphere. Warhead plutonium (the radio-isotope Pu is an alpha radiation emitter of very persistence half-life (about 24,400 years). Alpha particles are difficult to detect and when released into the environment relatively immobile in the insoluble plutonium form.

In the immediate aftermath of a nuclear weapon accident, where the high explosive has detonated or burnt, the plutonium particles are available for direct inhalation and/or absorption into the bloodstream through an open wound. In the short, medium and longer terms, plutonium particles deposited on the ground, on building and other surfaces could enter the human metabolism by ingestion and other routes or, if resuspended by disturbance, inhaled. It is generally agreed that inhalation is the most efficient route of plutonium uptake into the human metabolism.

Thus, and particularly because of the persistence of plutonium-239, the risk of inhalation, ingestion and, to a limited extent, ingress via wounds remains so long as the plutonium is present in the environment. The UK Minor Trials experiments at Maralinga demonstrated that plutonium dispersed from inadvertent (contrived) detonation of replica warheads, remained on the top surface of the ground, migrating less than a few millimetres into the top soil over three or more years. Because of the persistence and continuing hazard presented by plutonium, all of the released plutonium must be recovered.

Particles of plutonium are a primary hazard to all forms of life when absorbed in these ways. Once in the body, plutonium particles are distributed in a manner similar to that of calcium, being carried to the bones, liver, kidneys and being deposited in the skeletal frame - plutonium is a systemic toxin commonly referred to as a *‘bone-seeker’*. The action of plutonium particles once deposited in the body is that the ionising alpha emissions bombard the surrounding tissue and cellular matter causing malignancy. It is generally agreed that once absorbed within the human metabolism, there is very little than can be done to reduce the risk of malignancy and thus the risk of implicit health injury is effectively set at and remains sensibly constant from occurrence of uptake.

The size of the aerosolised particles of plutonium is important, particularly during the initial dispersion phase when the inhalation hazard is greatest. Generally, it is accepted that plutonium of particulate size at or smaller than 10 microns readily enter the bloodstream via inhalation. The quantity and particulate size of the plutonium release arising from a nuclear weapon accident depends on the nature and severity of the accident. Nuclear weapon accidents involving detonation and or fire will involve the release of some proportion of the plutonium. In a high explosive detonation where the warhead totally disintegrates all of the plutonium is likely to be released in aerosolised form and, as previously noted, of this about 20% will be of respirable size.

The United Kingdom conducted a number of test burnings of plutonium and non-nuclear detonations of replica warheads that aerosolised and dispersed the fissile core plutonium in the early 1960s at the Maralinga range in Australia - these tests simulated the accidental detonation of a nuclear warhead. Although detailed results of the subsequent monitoring of the Maralinga range have never been published, it is known that the inhalation hazard extended some 17 to 35 miles during the two to three hours following the test firings and that actual ground contamination was at unacceptable levels for several miles from the test firing site. In the series of tests where the high explosive charge of replica warheads were detonated, three separate campaigns to decontaminate the land were undertaken, although no plutonium was recovered.

Following the weapon accidents at Thule and Palomares, the US authorities scraped and removed several thousand tonnes of plutonium contaminated top soil for dispatch to and final disposal in the United States. The Maralinga Vixen B tests, with fully assembled, replica warheads, clearly demonstrate that a large tract of land would be heavily contaminated following a severe nuclear weapon accident - the accidents at Palomares and Thule have also demonstrated this to be the case.

The US authorities adopt simulated hazard areas for their nuclear weapon accident exercises that endorse the Maralinga inhalation and ground contamination zones. For example, the airborne plutonium dispersal assumed for high explosive detonation of a warhead comprises three zones of countermeasures, each triggered by the maximum whole body radiation dose recommended by the International Commission on Radiological Protection (ICRP).

The first of these inhalation hazard zones is defined by the shadow of an overhead plume of about 1.5km length and 1km width from which evacuation of members of the public is necessary. Emergency services and other personnel engaged within this area of land require respirator protection. The second zone requires consideration of immediate evacuation of members of the public, certainly sheltering and respirator protection within a plume of about 8km length by 1km width. Members of the public remaining unprotected within the third zone, of about 130km total area defined by a plume of 40km length by 5km width, would exceed the recommended whole body radiation dose equivalent of 5mSv and in which sheltering is recommended.

These inhalation hazard zones apply so long as plutonium contaminants remain airborne, usually assumed to be for the first two, three to seven hours, or longer following the onset of detonation. Thereafter and in account of land contamination from deposition of plutonium, other zones are applied to minimise resuspension and inhalation, ingestion and control of foodstuffs, water supplies, and spread of the contaminants beyond the immediate area. The land contamination zones are similar in shape and size to the inhalation hazard zones.

Recently, a UK accident exercise organised by the MOD - Exercise *Pantograph*, based on a crashed aircraft laden with nuclear weapons - adopted evacuation and sheltering zones of 3.5km and 10km respectively, included a nearby town of 24,500 population and required rigid population movement controls to be in effect for 36 hours. Of course, the actual exercise play of *Pantograph* did not extend beyond the air base and off-site action was notional, although post-exercise analysis expressed considerable doubt on the availability of resources to implement controls and countermeasures over such a large area and numbers of population.

Thus, it is generally acknowledged that the hazard of plutonium uptake, first by inhalation and subsequently, in the longer term, by inhalation and other paths, would extend considerable distances from the site of the accident. Obviously, the hazard distances are determined by the severity and nature of the accident and by the prevailing meteorological conditions, although a generalised worst case involves countermeasures and controls applied tens of kilometres from the accident site. If such an accident occurred in the United Kingdom then it is most probable that a large number of population would be involved and at risk.

Applicability to a UK Road Convoy Accident

At this point I should draw comparisons between the nature of the Maralinga experiments and the US accidents to possible accidents that could arise under the road transport mode adopted for movement of warheads to and from the Royal Ordnance Factory at Burghfield in the United Kingdom.

First, consider the condition of the warheads. In the Palomares and Thule accidents the warheads were assembled into complete free-fall bomb weapons on board aircraft, being most probably in service deployment condition, complete with arming and fusing systems. For the Maralinga Vixen A experiments rods of plutonium were burnt in petroleum-fuelled fires and for Vixen B the devices detonated are believed to have been completely assembled replica warheads. As I have previously noted, nuclear warheads under road transportation in the UK are moved with the high explosive charge and plutonium core in situ, so in terms of self-destruction capability and potential to aerosolise and disperse plutonium these UK warheads provide much the same hazard as any other nuclear warhead, irrespective of whether the warhead is deployed, in storage or, as studied here, in transit.

Secondly, consider the possible severity of the accident. The Maralinga Vixen A experiments simply burnt exposed rods of plutonium and this resulted in considerable dispersion of about 1 to 2% of the plutonium in an aerosol of respirable size several thousand metres downwind. The Palomares weapons dropped from a great height as the parent aircraft broke up in mid air, the ground impact was sufficient to break-up, detonate and/or ignite the high explosive charge of at least two of the warheads, with dispersal of the plutonium - these weapons, falling freely through the air might have impacted with the ground at a terminal velocity of about 120 to 160 mph. At Thule the complete aircraft crashed into the ground, there was an immediate aviation fuel fire which most probably prompted high explosive detonation of all of the warheads on board - the maximum temperature achieved by the fire, but not necessarily the warheads, was most probably in the region of 1,000 to 1,300°C.

The two US accidents provide example of conditions of impact shock and temperature at which the high explosive charge is known to have detonated and or ignited. This does not mean, however, that these extreme conditions have to be attained to trigger instability of the warhead high explosive charge. Two other accidents provide example of possibly much lower thresholds of instability. The explosion at Aldermaston in 1959, which killed two workers and injured a third, occurred when a consignment of high explosive was accidentally dropped from a trolley, that is falling no more than a few feet. Although little is known of the condition or purpose of this explosive consignment, this accident suggests that the explosives then in use were very susceptible to relatively low level impact shock. More recently, the Wiltshire road accident in which a warhead transporter, a Mammoth Major, overturned prompted what I can best describe as a dramatic response from the MoD emergency teams, involving procedures that intimated the warheads allegedly inside the stricken transporter remained at continuing risk.

The vulnerability of high explosive at moderately low temperature is well understood, illustrated by field instructions issued by the US Army to firefighters tackling a nuclear weapon accident fire. These instructions require all personnel to withdraw should the exposed warhead casing become hot to the touch with the bare hand, even after the fire has been doused, and recommends the use of foam to blanket warhead casings to protect against heat radiated from the fire and nearby structures.

Although road accidents are generally not as severe as aircraft crashes, I note that some road accidents are very severe and highly damaging to the vehicles involved - for this I just need to recall the newspaper and television pictures of any one of those multiple vehicle pile-ups that seemingly occur every year on the motorways. These pile-ups are characterised by cars and heavy goods vehicles ploughing into each other, the damage is extreme and quite often accompanied by outbreak of fire in one or more vehicles - I recall one recent accident in which a fuel tanker ploughed into the tail end of a motorway jam, spilled its load which caught fire wreaking havoc amid nearby vehicles.

I suggest that it not preposterous to consider such a pile-up possibly involving the vehicles of a nuclear weapon convoy. In such an accident, a warhead transporter might be crushed by another heavy goods vehicle, indeed the following Mammoth Major might be that second vehicle, telescoping into the relatively unreinforced rear section of the cargo hold and crushing the warheads held within - the crushing and impact forces generated directly on the warhead casings by this scenario could be as great, if not greater, than the impact forces sustained by the Palomares weapons. The pile-up of vehicles could also be accompanied by fire. If a petroleum or flammable chemical tanker was involved then there might be sufficient fuel present to generate temperatures similar to or greater than the temperatures assumed for the Thule accident.

Thus I am of the opinion that there is little distinction between the condition or state of the warhead (be it deployed, in store or in transit) in its potential to self-destruct; and that the nature of the accident that befalls the warhead (be it an air crash or severely damaging road traffic accident) is not particularly important in terms of creating conditions that would prompt the warhead to self-destruct. In other words, a severely damaging road accident involving a nuclear weapon convoy could give rise to much the same result as the crash of an aircraft carrying nuclear weapons - the only distinction is that aircraft crashes have occurred in which warheads have broken up, whereas and fortunately a nuclear weapon convoy has not been involved in a severely damaging road traffic accident.

1.7 EMERGENCY PLANNING FOR A NUCLEAR WEAPON ACCIDENT

Procedures adopted in the United States

In the event of a real accident involving one or more nuclear warheads in the United States, the US commander at the accident scene will be provided with an updated version of the inhalation hazard zones. This is achieved by an on-line system which enables the US Atmospheric Release Advisory Capability (ARAC) to model the accident situation, local topography and prevalent meteorological conditions necessary for an accident/site-specific forecast. The result of this analysis, together with site-specific advice, is transmitted to the site commander within an hour or so from the onset of the accident. In addition, the site commander will, as standing orders dictate, establish two prohibited zones relating to electromagnetic interference (EM) and fragmentation area, the latter of which effectively requires immediate evacuation of all members of the public and non-essential personnel from an area prescribed by a 610 to l,000m radius from the point of the accident. Thereafter and during the developing aftermath of the accident, specialist teams are deployed by the military and federal authorities, with the management planning of both these authorities including for the use of local county and state resources available on the ground at the time.

The resources dedicated by the US authorities in contingency for a nuclear weapon accident are impressive. These measures do not, however, guarantee that the aftermath of such an accident would be inconsequential. Very certainly, some time would be required for the site commander to arrive and establish the necessary infrastructure at the accident site; there would be delays in modelling and transmitting the inhalation zone forecasts by the ARAC and these forecasts may not be absolutely reliable, particularly where urban areas are involved; and when the forecasts are received, time is required to implement countermeasures, particularly evacuation if large numbers of general public are involved. Nevertheless, during the early phases of a real accident such preparation aids the site commander and emergency response teams when deciding courses of action to protect people and property - I have reproduced a typical ARAC forecast for the inhalation hazard zones of a nuclear weapon accident as FIGURE 1.

Procedures adopted in the United Kingdom

I imagine, since no information is available, that the MOD also exercise and maintain similar contingency planning for nuclear weapon accidents in the United Kingdom. However and other than the somewhat guarded assurances issued by the MoD, there is little visible evidence of these contingency plans.

Consider for example the forecasting of the inhalation hazard zones necessary to evacuate or shelter members of the public. In the aftermath of an accident these zones might extend 40km (see FIGURE 1) or so downwind of the accident site and, by virtue of this, involve many thousands of individuals. If countermeasures are to be effective, then the appropriate actions have to implemented quickly as the plutonium contaminated plume progressively develops downwind of the accident site - the time scales during which the inhalation is at its greatest might vary between one, two to seven hours. The UK accident site commander could not simply rely on knowledge wind direction for this is but an extremely crude measure of the dispersion, nor would there be sufficient time to locate the airborne contaminant solely by monitoring in the field. Furthermore and to implement optimal countermeasures, it may be necessary to undertake actions that will involve degrees of compromise between different groups of population, or those necessitated by matching available resources to the gravity of the situation.

In other words first, the site commander must rapidly assimilate a complex array of information which relates to the nature and severity of the accident. This aspect of the emergency response might be laid down in advance for a number of prescribed accident scenarios. Then and to implement appropriate countermeasures, the site commander has to account for conditions prevalent at the time and in the locality of the accident. These conditions will determine the consequences of the accident but, and since these are largely site-specific, the appropriate countermeasures cannot be prepared in advance. The arrangements whereby US site commanders have immediate access to the ARAC facility enables the site commander to apply one of a number of prepared plans to the locality conditions which, as I have previously explained, might extend a distance of 40km or more from the scene of the accident.

In the United Kingdom the organisation responsible for advising on radiological matters is the National Radiological Protection Board (NRPB),[8] with this responsibility being set down by central Government Health Ministers in 1977. The NRPB has considerable experience in forecasting the dispersion of radioactive release (although it has yet to be involved, first hand, in a real radioactive release of any magnitude) and it acts as the central co-ordinating body to National Arrangements for dealing with Incidents involving Radioactivity (NAIR). So and in contingency for the event of nuclear weapon accident (and following the US practice), it would be expected for the MoD to have set up and practised arrangements with the NRPB to act in a similar role to the US ARAC.

This is not so for the NRPB has stated that it has no data, and has performed no radiological accident analyses, for nuclear weapon accidents. Thus it may be assumed that the MoD site commander will not have the benefit of direct and immediate communication with the NRPB and, unless some other internal MOD facility is available, the site commander will have to implement countermeasures in the absence of a reliable hazard inhalation zone forecast specific to the accident locality. Although the MOD maintains a group of personnel, known as the *Nuclear Accident Response Organisation* (NARO), nothing is published on this group’s planned activities so it is not known if the MoD has the in-house facility (via NARO or similar) to rapidly analyse and predict the atmospheric release forecast in the manner provided by the US ARAC.

Of course, countermeasures have to be implemented in good time to avert a specific radiation dose uptake and this requires reliable prediction, so far as it is possible, of the radioactive dispersion and deposition. Thus in the event of a plutonium release it is not at all clear who (either the MOD or NRPB) would advise local authorities of the ‘tolerable’ limits of airborne plutonium on which countermeasures would be based. If advised by the NRPB (as their statutory duty requires) then, as I have explained, their lack of data and preparation is likely to result in some element of ad hoc decision-making, particularly in forecasting the dispersion of the aerosolised plutonium which is necessary to define the inhalation hazard zone in advance. If set by the MOD (via NARO), then the limits of acceptable airborne plutonium concentrations (that is acceptable to the military and which may relate to battlefield requirements) are neither published nor known in advance. Also, it is not known if the MoD has the facilities to provide a reliable prediction of the inhalation hazard zone within the very short time scale required.

The problem here is that the inhalation hazard zone for a severe nuclear weapon accident (say, an accident involving detonation of the high explosive) is most likely to progressively extend several if not tens of kilometres from the accident site. Countermeasures would need to be effected in this zone from the onset of the accident, that is decisive action taken in the immediate accident aftermath and during the few hours following. I doubt that MoD personnel, who will be heavily engaged at the scene of the accident in warhead safing, recovery and security operations, could extend to manage such a large area. So it is a certainty that during the very early phase of a nuclear weapon accident local authority emergency services and resources will have to be deployed to safeguard public health.

Hence the critical early phase involvement of local authorities would be at the direction of the MOD, but local authorities have no knowledge of the MoD emergency planning procedures, of the equipment and personnel requirements, or how these resources are to be deployed in the field. Thus and although it is a virtual certainty that local authorities will be required to assist in the immediate

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[8] Now the Health Protection Agency (HPA).

aftermath of a nuclear weapon accident, no information or sound guidance is provided to them in advance.

Even if the MoD (via NARO) could adequately direct local authorities of when and what countermeasures should be implemented, I very much doubt if the delivery and receipt of this direction would match the rapidity of a worsening accident aftermath - this is a serious gap in the emergency response procedure, particularly during a period when it is critical to act decisively in implementing countermeasures.

1.8 CONCLUDING OBSERVATIONS

My opinions and conclusions are as follows:

Mode of Transport Adopted

In the United Kingdom nuclear warheads are moved to and from the warhead manufacturing factory at Burghfield by convoys of specially adapted road vehicles known as Mammoth Majors.

All modes of transportation include risk of accident, but it is generally acknowledged that road transport incurs the highest risk of accident. For the transportation of radioactive materials the US authorities reckon that road transport is about 100 times riskier than any other form of commercial transport.

Road transport may incur greater risk of accident but, and again generally, it is accepted that realistic road traffic accident scenarios are not so demanding on the vehicles or cargoes involved as, for example, an aircraft accident. The Department of Transport does not publish data that directly relates the failure of radioactive material packages involved in transportation accidents in the United Kingdom. The equivalent US data is somewhat sketchy, although this provides a rough and ready measure of the comparative risks of packaging failure with mode of transport:

TABLE 1.1 (see CHAPTER 5)

RADIOACTIVE MATERIAL TRANSPORTATION ACCIDENTS BY MODE

TRANSPORT MODE	NO OF ACCIDENTS	PACKAGE FAILURE ACCIDENTS		TOTAL N° OF PACKAGE FAILURES IN ACCIDENTS
		Nº	%	
Air	12	4	33%	6
Rail	12	2	16%	7
Road	143	18	12%	77

Notes:
1) data for the period 1971 to 1984
2) data for United States land mass
3) data includes all radioactive transit shipments, civil and military

The collated data of **TABLE** 1.1 indicates that radioactive material packages are no exception. The general rule is that whilst it is riskier to transport by road than by air or rail, the probability of a package being severely damaged in a road accident is less than if the same package were to be involved in an air or rail accident. This is not to dismiss the fact that certain types of road accident can be extremely damaging to the vehicles and cargoes involved and, previously, I have identified the multiple collision or pile-up accident, accompanied by fire, to be the worst case accident scenario.

Also, it should be noted that nuclear weapons are quite exceptional packages. This is simply because certain of the contents of the package, notably the high explosive charge of the warhead, is capable of totally disintegrating the warhead and all subsequent layers containment - I do not know of any other nuclear or radioactive transport consignment that shares this unique feature.

In this important respect, the MoD's safeguards and packaging arrangements for the transportation of nuclear warheads cannot satisfy the *International Atomic Energy Agency* (IAEA) regulations that are applied in the United Kingdom for consignments of civil radioactive and nuclear materials. MoD assurances that the transportation of nuclear warheads comply with the IAEA regulations so far as is practicably possible, can only relate to the radioactivity emission shielding and leakage surety afforded by the packaging during normal transport. In the event of a serious accident involving detonation of the high explosive or fire, the MoD cannot satisfy any part of the surety of containment aspects of the IAEA regulations which are, not surprisingly, the substantive requirements.

Involvement and Preparation of Local Authorities

In previous sections I have noted that the nuclear warheads deployed by the US and UK are not dissimilar, although I indicated my reservations that the age and likely service performance requirements of the two principal UK warheads would not facilitate modification with insensitive high explosive. I also noted that transportation by road in the UK introduced the additional risk of knock-on proliferation of high explosive detonation between a number of warheads. I made comparisons of the overall approach of the US and UK to nuclear weapon contingency planning and exercises, how these involved local authorities and drew upon central resources.

My general conclusion is that UK nuclear weapons are at much the same order of risk (perhaps at slightly greater risk) as US nuclear weapons in transit. Since the design, construction and materials content of both US and UK weapons is about the same, I conclude that the consequences of accidents involving nuclear weapons here or in the United States would be about the same if no effective countermeasures were implemented. I note, however, that because of greater population density and, particularly, the mode of transport adopted in the United Kingdom then, by chance, it is likely that a greater number of general public would be involved in the aftermath of a nuclear weapon accident.

In other words, the risk of accident and potential consequences in the UK are, all things being taken into consideration, probably greater in the United Kingdom than in the United States.

I find that the approach of the US and UK authorities in nuclear weapon accident planning and training to be quite different.

In the United States the reporting of nuclear weapon training exercises is quite open and there is progression towards greater involvement by the local County and State authorities. This involvement includes access to literature describing not only the arrangements and safeguards implemented for the movement of nuclear weapons, but also insight into the organisation and structure of the military who would initially respond to any accident.

There are obvious advantages accruing from this open and frank exchange: The local authorities not only have details of how the warheads are moved, and what safeguards exist, but there is an understanding of how the military command structure would work during the course of an accident; there is familiarity with and comprehension of the jargon used; and a clearer definition of the roles and responsibilities of both parties. On its part the military benefits by being able to identify how the local authority is able to extend its equipment and manpower resources in the field and, importantly, the vexing issue of controlling the general public during an emergency is eased by efficient deployment of knowledgeable local authority personnel, including the civil constabulary and emergency services. The general public benefits since emergency arrangements and plans are established in contingency by the local authority prior to the onset of an accident and, importantly, these plans may be reconciled to site and local area specific requirements.

The United States has yet to reach the degree of co-operation with local and state authorities from which all of these benefits would accrue. Nevertheless, the nature of emergency exercises and the increasing involvement of local authorities in the United States is moving, albeit slowly, towards this end. The most recent US nuclear weapon accident exercise *Sagebrush*, which incidentally was organised and co-ordinated by a civil federal authority and not the military, involved local County and State authorities. The post-exercise analysis commended the actions of the County and State authorities but was critical of certain actions and decision-making procedures adopted by the military participants.

Things are very much different in the United Kingdom.

Here and although the MoD undertakes regular exercising and training for the response to nuclear weapon accidents, so far these exercises have not significantly involved local authority personnel to any great extent. Similarly, the MoD participates in exercises on the UK mainland with US personnel in contingency of a US weapon accident in the United Kingdom but, again, these exercises do not involve local authority personnel.

The MoD attitude towards greater involvement and participation of local authority personnel is baffling. Exercising the response to a nuclear weapon accident would not incur the need to publish sensitive information on the design or construction of the warheads since local authority personnel involvement would be concentrated in the aftermath of the accident. Furthermore, primary activities of the local authority personnel would be in zones relatively remote from the centre of the accident so the replica warhead, transportation arrangements, safing and recovery aspects of the exercise would be beyond their observation and, I suggest, interest. Senior local authority personnel, for example the Chief Fire Officer and Chief Constable, who would be involved at the exercise operation support centre could or have the necessary security clearances.

Yet, it seems as though the MoD approach is to remain entrenched in this somewhat archaic attitude, keeping local authorities at ‘arms length’ and informing only those individuals that it deems fit to receive such information on a ‘need-to-know’ basis.

Fallibility of the MoD Approach

Accidents are by their very nature accidental. There is considerable evidence to demonstrate, as common sense suggests, that major disasters in complex, well defended systems are rarely caused by any one factor. Rather, accidents arise from the unforeseen and usually unforeseeable concatenation of several diverse events, each one necessary but singly insufficient to promote the accident alone. Nuclear weapon accidents are no exception to this.

A nuclear weapon accident would give rise to complex technical, logistical and management challenges for which there are no ideal solutions, no nostrums or ready made prescriptions. The implication of the MoD’s refusal to inform local authorities of and to involve them in its response arrangements for nuclear weapon accidents is, I suggest, illustrative of its fallibility.

The MoD attitude and planning is fallible in several important respects.

First, the assumption that road carriage of nuclear warheads can be undertaken with an acceptable level of risk of accident is fallacious, particularly if this is demonstrated by reliance upon the past record of carriage. In transporting nuclear warheads by road the MoD are only able to maintain control over one small element of the overall safety composite - this element comprises the design and maintenance of their own vehicles and with training of their own personnel. Yet passing alongside the nuclear warhead convoys are numerous and untrained individuals, in control of vehicles of varying states of repair and road worthiness, any of which could be carrying an extremely hazardous cargo, and so on and so forth. The risk and probability of a road accident involving a nuclear weapon convoy is incalculable in these circumstances.

The fallibility here is that the MoD relies upon its past safety record as an indicator of its future performance, whereas the actual safety is predominantly determined by people, factors and future events over which the MoD has no effective control.

Secondly, a real nuclear weapon accident is not a paper exercise that takes place in an ideal world. In the immediate aftermath of a real accident, there would not be time to call a halt to assess the situation, consult with and train local authority personnel in the specialised means necessary to mitigate the consequences of the accident so far as is possible. On their part, local authority personnel would not have time to acquire specialised equipment, to organise and plan the health care facilities likely to be required, or to fully prepare the local population for speedy evacuation or sheltering. Similarly, the co-ordinating body of NAIR, the NRPB, would not have time to practise its analysis and forecast of the plutonium dispersion and deposition and, as a result, hundreds or thousands of individuals could be placed at risk of medium and longer term health injury.

The fallibility here is that the MoD assumes that it is able to define not only the nature of accidents and their aftermaths by referring to a series of prescribed accident scenarios, but also that the response of its personnel and, particularly, the response of inexperienced local authorities will proceed in accord with its prescribed plans. In this way, the MoD gives no cognizance to the sometimes inexplicable behaviour of human beings and organisations when acting under duress.

There is one other point of MoD fallibility that I find very disturbing. This arises from the MoD's intention to carefully manage and limit information release into the public domain - this cannot be denied by the MOD for there are a number of what I assume to be 'leaked' documents in circulation. These documents serve to provide the MOD press or public relations officers at the time of an accident with a series of prepared answers to questions that are likely to arise. More to the point is that the answers, which are effectively holding (or delaying) statements, are clearly intended to portray a very limited severity of accident and, particularly disturbing, underplay the health hazard. In detail, certain of these statements are quite contrary to fad stating, for example, that there is no danger to the public beyond control area *"distances of several hundred yards"* from the centre of the accident and that *"exposure of less than 2 days"* to plutonium at the immediate scene of the accident would result in *"little if no radiological danger"*, that *"outside any control area the levels would not constitute radiological danger"* and, similarly, that *"outside any controlled area it [radioactivity] would rapidly become so dispersed as not to constitute radiological danger to human or animal life"*.

Obviously, such statements issued during the aftermath of severe accident would be factually incorrect.

Other than the patent ethical quandary, there are two points of issue here: The first is that to my knowledge the MoD have no prepared statements that would portray the most likely aftermath of severe accident - even though the MoD undertakes exercises, such as *Pantograph*, each based or severe accident scenarios - so I assume it is the MoD's intent to play or scale down the actual severity of any accident. The second point is that if the general public and, perhaps, local authorities accept the MoD's scaled down version of the accident severity then this false impression, in itself, may result in higher consequences because any countermeasures are likely to be ignored or, at least, not taken seriously. On the other hand, the misleading nature of such statements might be, and I suggest would be, recognised by the general public and this could result in hostility and lack of co-operation which, in turn, could counterpoise and compromise local authority effort in implementing the necessary countermeasures.

1.9 SUMMARY

I began this executive summary chapter by outlining the nuclear weapon industry's activities in the United Kingdom, including reference the transportation of the nuclear warhead components destined for assembly at Burghfield. Our study has not included the risks associated with this phase of the United Kingdom's nuclear weapon programme. Nor have we considered the storage and deployment of nuclear weapons within the United Kingdom and, by this omission, only limited reference has been made in the following chapters to the air transportation of the nuclear weapons deployed by US visiting forces stationed in the United Kingdom.

Then I touched upon the secrecy of the MoD in all matters relating to nuclear weapons, extending in its absurd way to seemingly trivial information that is published openly in the United States. I expressed my lack of concern over this secrecy, considering our study had not been unduly impaired since sufficient information was available for us to assess the hazard, risks and consequences of a nuclear weapon accident. The sufficiency of this information is simply that nuclear warheads in transportation in the United Kingdom include at least two extremely hazardous materials. The first of these materials, the high explosives, is extremely destructive and the second, the plutonium, is both very toxic and dispersive.

This led me evaluate whether or not the containment of a nuclear warhead could be breached in an accident situation. Of the two hazardous materials contained within the warhead, I concluded that inadvertent detonation of the high explosive charge would be sufficient to completely disintegrate the warhead and thus permit the release of the other hazardous material to the atmosphere. I then reasoned that the force generated by the high explosive charge of a single warhead would be sufficient to breach the vehicle containment and that, moreover, the severity of the accident proliferate by knock-on detonation of any other warheads contained within that vehicle.

I then considered the hazard represented by the second material, the fissile plutonium mass, when aerosolised and dispersed into the atmosphere. I identified two phases of this hazard: The first and immediate phase arises from inhalation of airborne plutonium over an area that could extend 40km or more from the scene of the accident. During this phase, commencing at the onset of the accident and lasting, perhaps, up to two, three to seven hours or longer, immediate countermeasures would be required to mitigate the health harm to the population caught in its path. The second phase, commencing when the plutonium had settled from the overhead plume, would be long-lasting and require extensive decontamination, if not removal of all plutonium from ground, building and other surfaces.

I then reviewed the emergency plans that would be implemented should such an accident occur, drawing comparisons between the approaches of the US and UK authorities. I concluded the UK planning to be wanting and deficient in several important respects, particularly in that there was no effective liaison with or involvement of the local authorities. I also noted the fact that the national organisation responsible for implementing emergency arrangements for incidents involving radioactive release, and which is charged with statutory responsibility for advising on tolerable radiation limits, the NRPB, has no data for or experience of predicting the consequences a nuclear weapon accident - this I considered to be particularly illustrative of the MoD’s brash and, so far as I am able to ascertain, grossly inadequate approach to emergency planning.

Also and throughout my summary I referred to the blanket secrecy applied by the MOD to this topic. As I discovered in the course of our study this secrecy is not totally effective since sufficiently reliable information is available from other sources. Although I admit that this secrecy, as well as the general attitude of the MoD and its response to our enquiries, served to frustrate our research it certainly does not, as suggested by the MOD, invalidate the findings of this study.

Of more fundamental importance, are the ways in which secrecy shapes and, indeed, limits the MoD emergency planning approach.

This secrecy extends far beyond safeguarding the detailed make-up of the weapons and nuclear warheads: there is no official information available on the nuclear weapon convoy routes; on how much plutonium is available for release; the likely form and dispersion of any release; and how the MOD would manage and co-ordinate the emergency response. This secrecy also denies national, county and local civil authorities crucial information and the means of preparing for such an accident: the characteristics and toxicity of plutonium are not readily available; monitoring and protective equipment, clothing and decontamination procedures are not specified; the fire, ambulance, police and other emergency personnel have no experience of operating in a plutonium contaminated environment, and the regional health authorities do not have the resources to deal with short and longer term civilian casualties simply because they do not know what resources would be required.

In short, MoD secrecy endeavours to deny the very existence of nuclear warhead transit operations, so much so that the corollary of not involving civil authorities in advance prevails. This somewhat absurd outcome of secrecy even extends to the central organisation, the NRPB, responsible for maintaining, advising and co-ordinating the national emergency arrangements for incidents involving radioactive release.

Thus arising as a direct result of secrecy it is not practicable for local authorities to prepare in advance for an emergency arising from a nuclear weapon accident, either independently or co-ordinated from within the NAIR scheme. In the absence of prior knowledge, experience and guidance the local authorities could not, realistically, fulfil their generally assumed responsibility of safeguarding people and property.

I conclude by expressing my concern about the MoD’s ability to fully manage the aftermath of a nuclear weapon accident in the United Kingdom. In my view, the MoD may well be able to muster the resources necessary to secure and recover the remains of nuclear warheads in the immediate locality of such an accident, but it would be hard-pressed if not incapable of implementing effective countermeasures beyond the immediate area. For this the MoD would have to utilise the resources and skills of the local authorities but, and to this end, the MoD will not advise or significantly involve these local authorities in advance. Thus, the success of the local authorities in protecting people and property in the event of a real nuclear weapon accident must remain the subject of considerable speculation.

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