PLAYING WITH FIRE:

NUCLEAR WEAPONS INCIDENTS AND ACCIDENTS IN THE UNITED KINGDOM

#PLAYINGWITHFIRE | NUCLEAR INFORMATION SERVICE | FEBRUARY 2017

This report is dedicated to the memory of John Ainslie, whose persistent and meticulous research exposed many of the accidents described here

CONTENTS

REPORT AUTHOR: PETER BURT

REPORT HEADLINES

Why we did this study:

This report presents the accident record of the UK's nuclear weapons programme over its 65 year history. Our aim in doing this is simple: to remind the public of the risks posed by nuclear weapons, and to alert politicians and decision makers to the need to eliminate these risks.

What we found:

- The Ministry of Defence has only once, in 2003, published an official list of accidents which have occurred to British nuclear weapons. The 27 incidents recorded are far from a full record of all the accidents which have happened involving British nuclear weapons.
- This report describes 110 accidents, near misses, and dangerous occurrences that have occurred over the 65 year history of the UK's nuclear weapons programme, comprising of:
  - 14 serious accidents related to the production and manufacturing of nuclear weapons.
  - 22 incidents that have taken place during the road transport of nuclear weapons.
  - 8 incidents which occurred during the storage and handling of nuclear weapons.
  - 45 accidents that have happened to nuclear capable submarines, ships, and aircraft.
  - 21 security-related incidents.

  This is not a comprehensive list and we believe it represents merely the tip of the iceberg. There have been a further 17 incidents involving US visiting forces and nuclear weapons.
- Government sources have invariably underplayed the seriousness of accidents involving nuclear weapons and refrained from telling the whole story. There is a consistent gap between the Ministry of Defence's commentary on an accident and the assessment of independent outsiders, and between public statements and the picture revealed by confidential internal reports.
- The following factors have all contributed to accidents involving British nuclear weapons:
  - Failures caused as equipment reaches the end of its operating life.
  - Equipment in short supply or overused.
  - Operations hurried or conducted under pressure.
  - Workers failing to follow even the strictest instructions and procedures.

  Currently resources in the Ministry of Defence are stretched, exacerbating these hazards.
- Experience also shows it is impossible to guard against unpredicted and unforeseeable chance accidents. Nuclear weapons are complex technical systems, themselves part of wider systems of even greater complexity. Accidents occur because our understanding of the technology and systems involved is inadequate to contain the dangers they may pose.
- Throughout the history of the UK's nuclear weapons programme there have been numerous instances when operational needs have been placed ahead of safety needs. There are relentless pressures on managers, military commanders, and politicians to maintain nuclear operations at all costs as a national imperative.

Our recommendations to the government:

- Introduce procedures for publicly reporting accidents involving nuclear weapons.
- Place Ministry of Defence nuclear programmes under external regulation.
- Support an international ban on nuclear weapons to permanently eliminate the risks posed by an accident involving a nuclear weapon.

A nuclear armed Trident submarine, HMS Vigilant, returning to Faslane after deployment

FOREWORD

Rob Edwards

A government nuclear regulator once told me something that has stuck with me over the years. Imagine, he said – off the record – that the Ministry of Defence (MoD) had come to us asking for permission for a shiny new project it was keen to pursue. Let's call it Triton.

Triton, it turned out, involved taking some toxic and radioactive heavy metals, encircling them with high explosives, and packing the resulting bombs around a powerful rocket motor driven by a highly flammable and potentially explosive fuel.

> ***The MoD nuclear bomb project was conceived in secrecy and haste, carried out for decades behind closed doors and was never run past a safety regulator actually representing the public interest***

Triton tubes containing all these hazards would then be squeezed into cramped submarines that would disappear under the oceans for months at a time to carry out top-secret close-quarter manoeuvres that might occasionally cause crashes.

And, said the MoD, we'd also have to load and unload Triton tubes near population centres, regularly transport them by road the length of the country and occasionally test fire them across the Atlantic.

Faced with such a proposition, said the regulator, the response would have been rapid, firm and unambiguous: no way. No-one with even a basic grasp of health and environmental safety would countenance such a stupid and dangerous idea.

But that of course is not how it happened. The MoD nuclear bomb project was conceived in secrecy and haste, carried out for decades behind closed doors and was never run past a safety regulator actually representing the public interest.

Even now, as this report highlights, the MoD avoids transparent and independent regulation by relying on its very own, entirely internal and chronically shy Defence Nuclear Safety Regulator. It's essentially MoD chaps watching over MoD chaps and assuring each other that it's all OK.

But it's not OK. As the Nuclear Information Service (NIS) graphically and authoritatively documents, there have been countless accidents, incidents and blunders. They have been kept secret, played down and spun to try and ensure public reassurance. We can never be sure we've learnt the whole truth about any of them.

The account of how mohawk-haired rainbow-jumpered protestors scaled fences, tiptoed past guards and walked into the control room of a Polaris nuclear submarine docked at Faslane on the Clyde is in turn riveting, alarming and comical. "We're from the Peace Camp," one of the protestors ended up saying. "We're hijacking this submarine. Take us to Cuba."

We now know that this incident infuriated the then Prime Minister, Margaret Thatcher, and led to a series of security clampdowns. But we only know that because of official papers released nearly 30 years after the event – and there are presumably still things that we don't know.

The painstaking work of piecing together what has actually happened with UK nuclear weapons could hardly be more important. In an increasingly uncertain world, the task of prising open the MoD's baroque and secretive citadel is crucial.

We need to know all the things that have gone wrong, and we need to understand all the risks that are being taken in our name, and with our money. That means, as NIS argues, that we need a new system for honestly reporting and rating nuclear weapons accidents.

It means that we must subject the MoD to truly transparent and independent regulation. We need, in other words, a fundamental shift – a sea change – in the relationship between the MoD and the taxpayers that fund it.

Perhaps then we could see for the first time the full scale of the hazard in our midst, and understand how dangerous it really is to play with fire. And then we could decide whether we want to live with it, or get rid of it.

Rob Edwards is a founder member of the investigative journalism co-operative, The Ferret, the environment editor of the Sunday Herald, and writes for The Guardian. He is a nuclear muckraker.

EXECUTIVE SUMMARY

This report from Nuclear Information Service discusses the accident record of the UK's nuclear weapons programme over its 65 year history, looking across the full scope of the programme and describing the most significant incidents in detail.

The report describes 110 accidents, near misses, and dangerous occurrences that have occurred over the 65 year history of the UK's nuclear weapons programme, comprising of:

- 14 serious accidents related to the production and manufacturing of nuclear weapons, including fires, fatal explosions, and floods.
- 22 incidents that have taken place during the road transport of nuclear weapons, including vehicles overturning, road traffic accidents, and breakdowns.
- 8 incidents which occurred during the storage and handling of nuclear weapons, including instances when nuclear weapons have been dropped.
- 45 accidents that have happened to nuclear capable submarines, ships, and aircraft, including collisions, fires at sea, and lightning strikes. 24 of these accidents involved nuclear-armed submarines.
- 21 security-related incidents, including cases of unauthorised access to secure areas and unauthorised release of sensitive information.

In addition, there have been 17 incidents involving US visiting forces and nuclear weapons in the UK and its coastal waters.

These figures include 27 fires and eight explosions. Seven workers have died in industrial accidents at the Aldermaston nuclear weapons factory, and at least nine have died as a result of suspected radiation contamination. A further 100 are estimated to have died from cancers caused by the 1957 fire at the Windscale reactor which was producing fissile materials for nuclear weapons.

We are certain that this represents the tip of the iceberg. The MoD has acknowledged 180 engineering and operational incidents that occurred during the road transport of nuclear weapons over the period 2000 – 2016 alone. Hundreds of accidents have been recorded as taking place at the Atomic Weapons Establishment, where the UK's nuclear weapons are designed and built. Thousands of cyber attacks are launched against the Ministry of Defence and its contractors every day. The majority of these incidents are insignificant, but had events played out differently their impact may in some cases have been much greater.

Perhaps understandably, the Ministry of Defence has never been keen to talk about the accidents and mishaps that have afflicted its nuclear operations. But we believe it should have been more forthright than it has been – and more frank too. It was not until 1992 that the MoD acknowledged that "some twenty" accidents and incidents involving nuclear weapons had occurred since 1960 following a review of the safety of nuclear weapons undertaken by Sir Ronald Oxburgh, its Chief Scientific Adviser. Only in 2003 did MoD publish a list giving more details – and then only because it was forced to as the result of a six year campaign by the Guardian newspaper.

The 27 incidents identified in the 2003 list are far from a full list of all the accidents which have happened involving British nuclear weapons. This report has been prepared from official records of accidents involving nuclear weapons, including the Oxburgh report and the 2003 list, supplemented by information from Parliamentary questions and more detailed accident investigation reports, in many cases obtained using the provisions of the Freedom of Information Act. Where available we have also drawn on contemporary news reports and the work of other researchers, and accounts from witnesses and whistleblowers.

Given the nature of nuclear weapons, the risks that they pose to public safety are substantially greater than those posed by conventional weapons. Nuclear weapons contain not only radioactive materials, but also high explosives and toxic chemicals. The principal radiological hazard arising in an accident where a nuclear weapon is damaged would arise from the combustion of plutonium and uranium and their subsequent release into the environment

as airborne particles. The impacts of such an accident are difficult to quantify, but they would be severe socially, economically, and politically.

This report aims to take a holistic approach to nuclear weapons accidents and examines all the stages in the operational life cycle of a nuclear weapon, documenting mishaps that have occurred during the manufacture of nuclear weapons, their transport between locations, storage and handling, and their deployment on submarines, ships, or aircraft. We also look at incidents where the security of nuclear weapons has been compromised, and briefly examine the nuclear accident record of United States visiting forces based in Britain. Seven detailed case studies are given to illustrate each section of the report:

> ***...it is impossible to guard against completely unpredicted and unforeseeable chance accidents***

- The 1957 Windscale fire - the UK's most serious nuclear accident to date, which happened because of short-cuts taken as Britain raced to produce military nuclear materials for its hydrogen bomb programme.
- An accident in 1987 when a truck carrying two nuclear weapons skidded and overturned on an icy road in Wiltshire.
- An incident which took place at RAF Bruggen in Germany in 1984 when a container containing a nuclear bomb slid off a trailer because personnel had ignored procedures for securing the container to the trailer.
- The story of why nuclear weapons were taken to the Falklands Islands, despite the risks involved, by the Task Force which set out to recapture the Islands from Argentina in 1982.
- Details of the underwater collision which took place in the Atlantic Ocean between a British and a French submarine, each nuclear armed, in 2009.
- One of the most serious security breaches in the history of the UK's nuclear weapons programme, when three peace campaigners managed to break into the control room of a Polaris submarine in 1988.
- A Cold War air crash which took place at RAF Lakenheath in 1956 when a US Air Force bomber collided with a storage igloo containing three nuclear bombs.

Although this report is not a rigorous quantitative analysis of the accidents which have befallen the UK's nuclear weapons, it is possible to draw some general conclusions from the study. They may seem obvious to many, but they nevertheless deserve to be clearly stated and presented.

- The risk of failures and accidents increases when equipment reaches the end of its operating life – be it a submarine, truck, nuclear processing facility, or merely a length of pipework.
- Risks also increase when equipment is in short supply and is overused.
- Accidents are more likely to occur when operations are hurried or are conducted under pressure.
- Workers sometimes may not follow even the strictest instructions and procedures.

Accidents involving British nuclear weapons have happened for all these reasons. Some broader themes also emerge. The first of these is that it is impossible to guard against completely unpredicted and unforeseeable chance accidents. Nuclear weapons are complex technical systems, which themselves are part of wider systems of even greater complexity. 'Normal accident theory', developed by Charles Perrow, postulates that accidents are inevitable in complex and tightly linked systems. With nuclear weapons we are dealing with extremely complex systems, and the potential consequences if things go wrong are grave.

A second theme is that when operational needs come up against the demands of safety, operational imperatives consistently trump safety. Under these circumstances, when operational essentials confront safety needs the balance will always fall in favour of keeping the operation going.

The third theme to surface relates to the honesty with which the authorities will report on nuclear accidents. Government sources have invariably underplayed the seriousness of accidents involving nuclear weapons and refrained from telling the whole story.

To address these concerns we make three recommendations to the government:

1. **Introduce procedures for publicly reporting accidents involving nuclear weapons.**

   In order to remove the cloak of official secrecy which surrounds nuclear safety in the Ministry of Defence, safety regulators should prepare a quarterly report describing and evaluating all accidents with an International Nuclear and Radiological Event Scale (INES) rating of one or more which have occurred within the MoD's nuclear programmes.

2. **Place Ministry of Defence nuclear programmes under external regulation.**

   We propose that regulation of the military nuclear programme should become the responsibility of an expanded Office for Nuclear Regulation, and visibly subject to the same regulatory standards as the civil nuclear sector. Such a step would help reduce the conflict of interest that the Secretary of State for Defence faces in managing nuclear programmes and redress the balance between meeting operational requirements and maintaining safety standards.

3. **Support an international ban on nuclear weapons.**

   NIS believes that the only way of eliminating the risks posed by an accident involving one of Britain's nuclear weapons is to eliminate nuclear weapons themselves. This year negotiations will commence at the United Nations on a nuclear ban treaty which will prohibit the use, deployment, and manufacture of nuclear weapons. The ban treaty gives us an opportunity to get rid of nuclear weapons for once and for all, and Britain should embrace this opportunity.

INTRODUCTION

"As long as nuclear weapons exist fully assembled there will be a risk of catastrophic accident. And every single country that possesses nuclear weapons endangers its own citizens by having them"

- Eric Schlosser
Author of 'Command and Control', August 2014[1]

"The greatest risk to my force is an accident. The greatest risk to my force is doing something stupid"

- Lieutenant General James Kowalski
Officer in command of all US Air Force nuclear weapons, July 2013[2]

This is a report about what happens when things go wrong. It presents the accident record of the UK's nuclear weapons programme over its 65 year history, looking across the full scope of the programme (for example accidents at production sites, during transport, on board submarines, and at other stages in the life cycle of nuclear weapons) and describing the most significant incidents in detail. As far as we are aware this is a story which has never before been told in full – even within the walls of the Ministry of Defence's headquarters. Our aim in telling the story is simple: to remind the public of the risks and dangers posed by nuclear weapons, and to alert politicians and decision makers to the need to eliminate these risks.

The MoD's standard reply when questioned about the safety record of its nuclear weapons is that "there has never been an accident involving Defence Nuclear Material in the UK that has led to, or come anywhere near leading to, the release of radioactive material to the environment".[3] We fully expect the Ministry to use precisely these words in any comments it may make responding to our report. But this constant mantra is only part of the story. There have been plenty of serious accidents and near misses involving British nuclear weapons. A Trident nuclear submarine was nearly lost when it went into an uncontrolled dive. A fully armed torpedo has fallen onto a rack of nuclear depth charges. A Vulcan bomber loaded with nuclear weapons was stuck by lightning. At the sites involved in producing nuclear weapons and materials there have been fatalities in industrial accidents and deaths caused by radioactive contamination.[4] The UK's most serious nuclear accident, the Windscale fire in 1957 which contaminated substantial areas in the North of England with radioactivity, took place expressly because the reactor involved was producing special nuclear materials urgently needed for Britain's hydrogen bomb programme (see case study 1).

Perhaps understandably, the MoD has never been keen to talk about the accidents and mishaps that have afflicted its nuclear operations over the years. But we believe it should have been more forthright than it has been – and more frank too. It was not until 1992 that the MoD acknowledged that "some twenty" accidents and incidents involving nuclear weapons had occurred since 1960 following a

1 Eric Schlosser: 'The Most Dangerous Machines'. Speech at the Vienna Conference on the Humanitarian Impact of Nuclear Weapons, Vienna, 8-9 2014. https://ratical.org/radiation/NuclearExtinction/EricSchlosser120814.html
2 Quoted in Elliott Negin: 'A simple step towards a safer world'. Union of Concerned Scientists, Catalyst Spring 2015. http://www.ucsusa.org/publications/catalyst/sp15-simple-step-towards-safer-world
3 This form of words is taken from the following document and is regularly repeated in MoD press statements on nuclear incidents: Ministry of Defence: 'Local Authority and Emergency Services Information'. August 2014. P4. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/361976/LAESI_10.pdf
4 Readers who are unfamiliar with the history of the UK's nuclear weapons arsenal and the nuclear facilities at which material and components were manufactured are directed to Carey Sublette: 'Britain's nuclear weapons'. Nuclear Weapons Archive. http://nuclearweaponarchive.org/Uk/index.html

review of the safety of nuclear weapons undertaken by Sir Ronald Oxburgh, its Chief Scientific Adviser.[5] However, precise details of these accidents were not published (and indeed, only brief summaries were given in Oxburgh's report). Only in 2003 did MoD publish a list giving more details – and then only because it was forced to as the result of a six year campaign by the Guardian newspaper. A request from the Guardian for information about these accidents was initially blocked by the Ministry, prompting the newspaper to lodge a complaint of maladministration with the Parliamentary Ombudsman. The Ombudsman ordered that the details should be released, ruling that disclosure of the information would not endanger national security as many of the weapons involved in the accidents had by then been withdrawn from service. She concluded: "It is therefore difficult to envisage the release of information about events that happened some time ago to weapons that no longer exist could cause harm if made more widely available".[6] The only official list of British nuclear weapons accidents ever published was placed in the libraries of the House of Commons and House of Lords in October 2003 and has long since disappeared from official publications, although it can be found on the website of the 'Nukewatch' network.[7]

This episode was illustrative of a broader lack of openness on nuclear accidents from the MoD. One of the conclusions of this study is that the Ministry of Defence has consistently attempted to hush up and downplay the risks from accidents involving nuclear weapons, perhaps because of fears of a backlash from the media and public that would raise awkward questions and could undermine the nuclear weapons programme. Some of the accidents which have happened have taken place overseas – for example, in Germany, Cyprus and Singapore – and it is evident that the governments of these countries were not notified of the accident, and in some cases had not even been informed that nuclear weapons were present on their territory. We were surprised and disturbed at the bland descriptions of accidents given on the 2003 list, which made no mention of the sometimes serious - and avoidable - failures that had led to the accidents. These failures were often outlined in graphic detail in the inquiry reports which were prepared following investigations into the accidents. We have drawn extensively on such documents, where they are available, in preparing this report.

The 27 incidents identified in the 2003 list are far from a full list of all the accidents which have happened involving British nuclear weapons. This report describes 110 accidents, near misses, and dangerous occurrences that have occurred over the 65 year history of the UK's nuclear weapons programme, comprising of:

- 14 serious accidents related to the production and manufacturing of nuclear weapons, including fires, fatal explosions, and floods.
- 22 incidents that have taken place during the road transport of nuclear weapons, including vehicles overturning, road traffic accidents, and breakdowns.
- 8 incidents which occurred during the storage and handling of nuclear weapons, including instances when nuclear weapons have been dropped.
- 45 accidents that have happened to nuclear capable submarines, ships, and aircraft, including collisions, fires at sea, and lightning strikes. 24 of these accidents involved nuclear-armed submarines.
- 21 security-related incidents, including cases of unauthorised access to secure areas and unauthorised release of sensitive information.
- In addition, there have been 17 incidents involving US visiting forces and nuclear weapons in the UK and its coastal waters.

This is not a comprehensive list and we believe it represents merely the tip of the iceberg. The

5 Chief Scientific Adviser: 'Report on the Safety of Nuclear Weapons' (the 'Oxburgh Report'). Ministry of Defence report CSA 42/5/1/1 (46/62), 12 February 1992.
6 Rob Evans: 'MoD catalogues its nuclear blunders' Guardian, 13 October 2003. https://www.theguardian.com/environment/2003/oct/13/energy.nuclearindustry
7 Nukewatch UK: 'UK Nuclear Weapon Safety'. Undated. http://www.nukewatch.org.uk/?page_id=178

figures include 27 fires and eight explosions. Seven workers have died in industrial accidents at the Aldermaston nuclear weapons factory, and at least nine have died as a result of suspected radiation contamination. A further 100 are estimated to have died from cancers caused by the 1957 fire at the Windscale reactor which was producing fissile materials for nuclear weapons.

Oxburgh himself acknowledged that his list may have been incomplete as there was no central MoD repository of incidents involving nuclear weapon systems.[8] Although Oxburgh briefly discussed accidents involving nuclear armed submarines in his report, these accidents were not included on the 2003 list and details have been redacted from published versions of Oxburgh's report. Information on incidents which took place prior to the early 1960s is particularly hard to locate in official records, partly because it may not have been routinely recorded and partly because, if it was, the record may not have been retained, or was retained only in local logbooks for the unit where it happened. Details of accidents which took place since 2003 have never been published in a single official source, and it is not clear whether they are even logged centrally by the MoD.

This lack of openness and transparency, and the 'nothing happened so there's nothing to worry about' approach from the MoD has contributed to the growth of a number of 'myths' and false accounts of nuclear accidents, which have sometimes been repeated in otherwise authoritative literature. Among these are persistent but erroneous rumours, for example, that nuclear weapons were on board HMS Coventry when the ship was sunk during the Falklands war, and that a nuclear weapon was destroyed when a US B-47 bomber caught fire at Greenham Common in 1958. One of our aims in publishing this report was to puncture such myths, and provide accurate information about these and other accidents using new information which is now available, as well as exposing less well known but potentially serious accidents.

This report has been prepared from official records of accidents involving nuclear weapons, including the Oxburgh report and the 2003 list, supplemented by information from Parliamentary questions and more detailed accident investigation reports, in many cases obtained using the provisions of the Freedom of Information Act. Where available we have also drawn on contemporary news reports and the work of other researchers. In some cases people who witnessed an accident or were involved in the response have published accounts or spoken to journalists about their experiences, and these too have been a useful source of information, especially in relation to the early days of the UK's nuclear weapons programme. More recently 'whistleblowers' have occasionally spoken out over nuclear safety concerns, and we can sometimes glean valuable details from their stories. Despite our research, the report does not claim to be a comprehensive study of accidents involving British nuclear weapons: almost certainly accidents have happened which have never been publicly disclosed.

WHAT DO WE MEAN BY A NUCLEAR WEAPONS ACCIDENT:

An important issue in the recording and reporting of accidents involving nuclear weapons is the matter of how to define an 'accident'. How should accidents be defined so as to ensure that situations with potentially significant consequences are captured, but at the same time avoid devoting undue attention to trivial incidents? This is a key point, as the language used can set the terms of debate on the seriousness and frequency of accidents: too strict a definition can give the impression that accidents are rare and may result in complacency, whereas too broad a definition may lead to undue alarm.

Within the MoD definitions of the term 'accident' have evolved over time. The nearest current equivalent is 'a Safety Alert', which is defined as "an abnormal event which poses a potential threat to, or causes serious concern for reactor plant,

8 Chief Scientific Adviser op cit. Para F1.1, page 11, Annex F.

nuclear weapon, or special nuclear material safety".[9] Although this definition may appear reasonably robust, the fact that terminology and definitions have changed over time poses difficulties when documenting the MoD's nuclear accident history. The current definition, for example, excludes some of the criteria which Oxburgh used for capturing information about nuclear weapons accidents.[10] It also seems to exclude conventional, non-nuclear incidents, which may be serious, security incidents, and environmental incidents.

Incidents in the civil nuclear sector are recorded using the International Nuclear and Radiological Event Scale (INES),[11] which is used by the government's nuclear safety regulator, the Office for Nuclear Regulation, to record and rate the seriousness of nuclear accidents. The INES scale ranks nuclear accidents on an eight point 'ladder' of seriousness, ranging from 0 (deviation with no safety significance) to 7 (major accident corresponding to major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures). This allows all incidents to be captured and at the same time can discriminate between them on the basis of their severity.

For the purposes of this study we have reported on all incidents recorded by government agencies which we feel are of interest, regardless of the reporting method used or the agency involved. In cases where information has been drawn from independent sources, we have included incidents which may not have been recorded as accidents using the current MoD definition, but would in our judgment have posed a potential threat to safety or security.

CONSEQUENCES OF AN ACCIDENT INVOLVING NUCLEAR WEAPONS

The Oxburgh report on nuclear weapons safety recognised that "all weapon systems are potentially dangerous; their design and the ultimate certification as suitable for service must represent some kind of judgmental balance between capability, risk, and cost".[12] Given the nature of nuclear weapons, the risks that they pose to public safety are substantially greater than those posed by conventional weapons. Nuclear weapons contain not only radioactive materials, but also high explosives and toxic chemicals. More detail is given about radioactive materials and the hazards they pose in the Appendix to this report.

According to the MoD's guidelines for responding to an emergency during the transport of nuclear weapons, the principal radiological hazard arising in an accident where a nuclear weapon is damaged would arise from the combustion of plutonium and uranium and their subsequent release into the environment as airborne particles.[13] The Royal Navy's procedures for the safety and security of the Trident II D5 strategic weapon system give a little more detail, reportedly saying that a fire can lead to the detonation of explosives in a nuclear warhead[14] and spread radioactivity: "If the HE [High Explosive] charge is exposed to excessive heat without burning, it may become more sensitive and could cook to (non-nuclear) detonation, releasing radioactive materials and aerosols over a wide area".[15] The MoD has conceded that there is also a remote theoretical possibility that, in an extreme situation, multiple failures could result in an "inadvertent yield" - the release of large quantities of

9 Ministry of Defence: 'Defence Nuclear Emergency Response'. Joint Services Publication 471. Page 1-A-1.
10 The criteria used by Oxburgh can be found at Chief Scientific Adviser op cit. Para F2.1, page 11, Annex F.
11 'INES. The International Nuclear and Radiological Event Scale'. International Atomic Energy Authority. http://www-ns.iaea.org/tech-areas/emergency/ines.asp
12 Chief Scientific Adviser op cit. Para 1.3, p9.
13 Ministry of Defence: 'Local Authority and Emergency Services Information'. August 2014. Para 4.9, p10. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/361976/LAESI_10.pdf
14 Readers who are unfamiliar with the components of nuclear weapons and the principles on which nuclear weapons work are referred to the web page 'How do nuclear weapons work?' by the Union of Concerned Scientists: http://www.ucsusa.org/nuclear-weapons/how-do-nuclear-weapons-work

radiation and energy (although short of a full nuclear explosion) if detonation of explosives in the warhead resulted in the plutonium core becoming compressed and causing the mass to become critical.[16]

A fire or explosion would carry contaminants into the air, resulting in the spread of radioactive plutonium, uranium and tritium from the warhead. The location of the accident and the weather and wind conditions would determine how large an area and how many people were contaminated. MoD emergency guidelines state that in the event of a radiation release following an accident involving a nuclear warhead convoy, a downwind shelter zone covering a 45 degree sector out to a distance of five kilometres should be set up, in which people would be advised to take cover indoors to reduce the risk of radioactive contamination.[17] Other sources have recommended sheltering and possibly evacuation within a radius of 16 kilometres.[18]

> *"The consequences of such an incident are likely to be considerable loss of life and severe disruption both to the British people's way of life and to the UK's ability to function effectively as a sovereign state"*

The impacts of such an accident are difficult to quantify, but they would be severe. Long term health impacts could be expected to result from the spread of radioactive material and the disruption caused by any evacuation required. The economic impacts resulting from the disruption caused by an accident and the clean up of any contamination would also be likely to be substantial. The political consequences would be enormous, and would place acute pressure on the UK's nuclear weapons programme, possibly leading to its termination. Should a serious accident involving a nuclear weapon occur in Scotland it would dramatically increase the political vulnerability of the Union of the United Kingdom. The severe consequences of a nuclear weapons accident are accepted by the MoD. In April 2006 David Wray, Director of Information at the MoD, turned down an appeal requesting information about nuclear weapons convoy routes which had been made under the Freedom of Information Act on the grounds that such information could help terrorists plan an attack on a convoy. "This is an issue of national security given that such an attack has the potential to lead to damage or destruction of a nuclear weapon within the UK ", wrote Wray. "The consequences of such an incident are likely to be considerable loss of life and severe disruption both to the British people's way of life and to the UK's ability to function effectively as a sovereign state".[19]

This report aims to take a holistic approach to nuclear weapons accidents and examines all the stages in the operational life cycle of a nuclear weapon, documenting mishaps that have occurred during their manufacture, transport between locations, storage and handling, and their deployment on board submarines, ships, or aircraft. We also look at incidents where the security of nuclear weapons has been compromised, and briefly examine the nuclear accident record of United States visiting forces based in Britain. Detailed case studies are given to illustrate each section of the report.

We accept that the UK's armed forces have been operating nuclear weapons successfully, and for most of the time safely, for many years. Modern nuclear weapons also have safety features to prevent an accidental detonation (although this was

15 Ministry of Defence: 'CB8890: Safety and security of the Trident II D5 strategic weapon system'. Cited in William McNeilly: 'The Secret Nuclear Threat. 18 May 2016. P9. https://www.scribd.com/document/265769050/The-Secret-Nuclear-Threat-Trident-Whistleblower-William-Mcneilly

16 Defence Logistics Organisation: 'Operational Safety Case for Transport of Nuclear Weapons. Executive Summary, Issue 2'. Nuclear Movements and Nuclear Accidents Response Group Ref. EEUK/200426.03/R3.ES. January 2005. Para 56, p 17. http://www.robedwards.com/files/trident_convoy_safety_case.pdf

17 Ministry of Defence: 'Local Authority and Emergency Services Information'. August 2014. Annex E pE1. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/361976/LAESI_10.pdf

18 Large and Associates: 'The Lay-Person's Alternative Guide to REPPIR Relating to the Atomic Weapons Establishment (AWE) Aldermaston and Burghfield'. Report number R3149-A1, 22 April 2012. P11. nuclearinfo.org/sites/default/files/Large%20%26%20Associates%20Report.pdf

19 Rob Edwards: 'Road crash could set off nuclear blast'. New Scientist, 5 July 2006. https://www.newscientist.com/article/mg19125594.300-road-crash-could-set-off-nuclear-blast

not the case in the early days of the UK's nuclear weapons programme when warhead designs were less sophisticated). As the UK's experience of operating nuclear weapons grows and the number of warheads in service decreases, so logic suggests that the frequency of accidents should decrease. However, these factors may be counter-balanced by opposing pressures, such as risks arising from ageing equipment and facilities and shortages of personnel and resources. Unfortunately it only requires a single accident involving a nuclear weapon to bring about a tragedy. Few of the accidents described in this report were unavoidable. They were caused by human errors, bad design, and inadequate resourcing – in most cases by a complex combination of these and other factors. They must be seen as warnings, from which we must learn important lessons if we are to prevent calamity from striking in the future. The intention of this report is to press the alarm button.

A nuclear weapon convoy travelling on the M74 in Scotland, 2016

Image credit: John Toher

THE PRODUCTION AND MANUFACTURE OF NUCLEAR WEAPONS

"AWE is a serious site, doing serious things, with serious substances and materials, with serious implications if we get it wrong".[20] These words greet contractors working at the Atomic Weapons Establishment as part of the mandatory safety induction presentation which everyone employed at Britain's nuclear weapons factory must attend. Nuclear weapons include components manufactured from radioactive materials, high explosives, and hazardous chemicals. The handling of such materials clearly poses significant risks – for example, explosive substances would not under other circumstances be permitted to be held in close proximity to nuclear materials. The production of fissile materials and the assembly of nuclear warheads are the first phases in the life cycle of these weapons, and, like other stages in the cycle, are prone to accidents and mishaps.

The first section of this study will focus mainly on the manufacture of nuclear weapons at the Atomic Weapons Establishment (AWE). The main production sites for the UK's nuclear weapons programme are at the Atomic Weapons Establishment's two sites at Aldermaston and Burghfield in Berkshire, where nuclear weapons are designed, manufactured, and maintained. Other sites have also been involved in the production of the fissile materials used in nuclear weapons, particularly in the earliest days of the programme. Although the UK and the USA, as allies during World War II, had co-operated in development of the atom bomb during the wartime 'Manhattan Project', soon after the end of the war the US government passed the 'McMahon Act' which effectively cut off all support for the UK's own atomic programme. This resulted in a frantic effort by the post-war government to develop the knowledge and technology required to build a 'British bomb'. Alongside a sustained diplomatic effort to coax the Americans into sharing nuclear expertise (which bore fruit in 1958 when the US-UK Mutual Defence Agreement was signed, and again in 1962 when the Polaris Sales Agreement was negotiated), the British launched an immense economic and scientific programme to develop an atomic bomb and produce the special nuclear materials needed to build it. Natural uranium was converted to uranium hexafluoride gas at Springfields in Lancashire and then enriched at Capenhurst in Cheshire. The enriched uranium fuel was used to produce plutonium for military uses at the Windscale nuclear site at Sellafield in Cumbria. After the 1957 Windscale fire (see case study 1) plutonium was produced in Magnox nuclear reactors at Calder Hall and at other Magnox sites around the UK, and more recently special nuclear materials have been acquired from the USA under the terms of the 1958 Mutual Defence Agreement.

In addition to the sites which play a role in the manufacture of nuclear weapons, other industrial sites play crucial roles in the UK's military nuclear programme. The BAE Systems shipyard at Barrow-

14 INCIDENTS, INCLUDING:

- 5 Fires
- 5 Explosions
- 3 Incidents involving radioactive contamination
- 1 Incidents involving failure or degradation of infrastructure or equipment
- 1 Incidents where nuclear reactors malfunctioned or went wrong

20 Atomic Weapons Establishment: 'Welcome to …. AWE Assurance Orientation'. Safety induction presentation Issue 6 January 2011.

in-Furness builds the Royal Navy's nuclear powered submarines, and nuclear reactors for the submarines are built at Raynesway in Derby by Rolls-Royce Marine Power plc. The Naval bases at Rosyth and Devonport also play a part in the submarine programme, as does the 'Vulcan' Naval Reactor Test Establishment at Dounreay in Scotland. Although there is a story to be told about the nuclear safety record at each of these locations, their accident histories will not be discussed in any detail in this report.

EARLY DAYS AT ALDERMASTON

For the first three years after Clement Attlee's post-war government decided to build a British atomic bomb the scientists working on this top secret programme – many of whom had worked on the Manhattan Project during World War II - were based at the Armament Research Department at Fort Halstead in Kent and at the Woolwich Arsenal in London. It soon became apparent, however, that they would need their own purpose-built facilities and equipment and so in 1950 the Atomic Weapons Research Establishment (AWRE) was established on the site of a disused airfield at Aldermaston in Berkshire. In an astonishing feat of management, engineering, and science the UK's first atomic weapon was detonated at the Montebello Islands off the coast of Australia on 3 October 1952, less than six years after the decision to build it was made. The atom bomb test was followed by a race to develop a British hydrogen bomb – exploded in 1958 – before an international ban on nuclear testing was agreed. But the speed with which Britain's nuclear weapons programme was proceeding had a price which was to be paid in safety standards. The early days at Aldermaston were plagued by a series of explosions and accidents which were documented in detail for the first time in a report published by Greenpeace in 1992.[21]

On 21 March 1955 a serious fire broke out in the high security nuclear production area at Aldermaston. The fire blazed out of the control of AWRE's own firefighters, and fire engines from Reading, Newbury, Pangbourne, and Mortimer were called in to tackle the incident.[22] Another fire broke out in December 1957 – this time fatal. The fire started in a laboratory furnace where scientists were melting lithium metal – a highly reactive component of nuclear warheads. Douglas Whittaker, a 30 year old Senior Experimental Officer was operating the furnace controls when the equipment exploded, showering him with molten metal. His colleague Maurice Pound fled from the building, returning seconds later to find Whittaker staggering from the building, horribly burned. He was rushed to Basingstoke hospital but died two days later from severe burns over 70% of his body. Pound and four others working in the laboratory were injured in the fire. The UK Atomic Energy Authority, at the time responsible for managing AWRE, described the incident as "minor", saying no radioactive materials had been involved and there was no question of any part of the Establishment being closed or having its work restricted as a result of the accident. At an inquest into Whittaker's death in Basingstoke on 17 December a request by the coroner for more information on the process he was working on at the time of the explosion was blocked on security grounds. The inquest recorded a verdict of accidental death.[23]

Two more workers were killed in another explosion at Aldermaston on 26 February 1959. Laboratory assistants Terence Bishop and Walter Mallin were unloading high explosive from a trolley when it ignited and blew up. The explosion set fire to the building they were working in and could be heard twelve miles away. Another worker was injured in the blast and twelve more were treated for shock. An inquest was unable to explain the cause of the explosion, and recorded a verdict of accidental

21 Greenpeace: 'Inside the Citadel: An Investigation into Britain's Nuclear Bomb Factory'. 1992. P17.
22 Greenpeace op cit, p17.
23 Greenpeace op cit, p17.

death.[24] Three months later, in May 1959, a construction worker, Norman Adams, was fatally injured in an explosion on the construction site for AWRE's HERALD nuclear research reactor. He died from multiple skull fractures and shock at the Battle Hospital in Reading on the same day.[25] Yet another explosion on 17 August 1960 wrecked a building where high explosives for warhead triggers were being processed by remote control. Fortunately, no injuries or release of radioactivity occurred.[26]

In one of a number of incidents where workers at Aldermaston were contaminated with radioactive material, Norman Davey, a 43 year old radiochemical analyst, was injured while he was handling plutonium in a glove box in a nuclear processing building in January 1965.[27] The glove split, and Davey cut his hand. He was checked for contamination and no traces of plutonium were found on his skin, but a splinter of plutonium had become lodged in the flesh of his hand and was not detected by the tests. Two months later Davey was involved in another radiation incident – this time whilst he was working at the Atomic Energy Research Establishment at Harwell – and was again checked for contamination. On this occasion a urine sample revealed high levels of systemic plutonium inside his body. The source of the contamination was traced back to the glove-box accident, and an operation was conducted on Davey's hand to remove the plutonium particle, which by now had been inside his body for 50 days. After the operation he became worried and depressed about the contamination and the likely consequences for his health. "I shall never live to retirement", he told his wife after returning home from hospital after the operation. By 1982 monitoring revealed that plutonium had accumulated in his lymph nodes, and later that year he was found to have developed cancer. He died from the cancer on 15 August 1983. Astoundingly, Davey was not invited to attend AWRE's internal Board of Inquiry into the accident, and nor was he told of its conclusions.

Another fatal explosion occurred at Aldermaston on 23 July 1979.[28] Peter Allen was a 39 year old Higher Scientific Officer who had worked at AWRE for 20 years, specialising in warhead electronic detonator mechanisms. He was working alone in a laboratory in the explosives technology area when a detonator exploded in his face, throwing him across the room. Colleagues who rushed to the rescue found his body wreathed in clouds of smoke. He suffered severe head injuries and died as a result of brain damage. There is an element of intrigue about Allen's death, as the fire report for the accident stated that it was the result of a "deliberate act". An inquest heard that the blast was caused by explosives and detonators that Allen did not normally use in his work, and that laboratory equipment had been modified to override normal safety systems. The inquest jury considered two possibilities: that Allen was working on an unauthorised private experiment, or that he had committed suicide, but concluded that there was not enough evidence to prove or disprove either theory and returned an open verdict.

Information compiled in the 1992 Greenpeace report from responses to Parliamentary Questions and accident reports revealed the grim statistic that between 1955 and 1986 seven workers had died in accidents at Aldermaston. At least nine more AWRE workers had died as a result of suspected radiation contamination. Greenpeace identified 14 cases of workers who had been exposed to plutonium overdoses, and up to 30 more who had detectable amounts of plutonium in their lungs. There had been numerous fires, explosions, and radioactive contamination incidents at the site over the years.[29]

24 Greenpeace op cit, p18.
25 Greenpeace op cit, p18
26 Greenpeace op cit, p18.
27 Greenpeace op cit, p18.
28 Greenpeace op cit, p21.
29 Greenpeace op cit, p2-3.

AWE Aldermaston seen from the air in 2009

Image credit: Ivaneol/Wikipedia

WORKER CONTAMINATION AND THE POCHIN REPORT

In 1978 radiation safety issues at Aldermaston came to a head when staff refused to work in certain parts of the Establishment. The shut down lasted for over a year and was triggered by concerns that up to 40 workers had been contaminated by radioactivity, resulting in a claim by trades unions for a 'danger money' allowance for working in radiation areas. It also forced the government to conduct the Pochin Inquiry – an investigation into radiological safety at Aldermaston conducted by Sir Edward Pochin, a radiation expert from the government's National Radiological Protection Board. Pochin's report concluded that Aldermaston's record of radiation protection was generally good,[30] but that there had been problems with "minor and unexpected releases" which had occurred "with moderate frequency" and which could result in "an increased risk of larger discharges".[31] Methods for monitoring plutonium contamination were outdated and the level of health protection against inhaled plutonium was of only "borderline adequacy".[32] More importantly, Pochin was scathing about staff cutbacks and shortages at Aldermaston, which he said posed significant safety risks. The number of Health Physics staff was "too few for the complex work of the establishment" and they were often inadequately trained,[33] and there had been a "progressive reduction" in maintenance staff numbers which was "erroneous".[34] These "serious deficiencies in staffing" seemed likely to have contributed "not only to an undue frequency of minor contaminations but also to a potential risk of larger discharges".[35] The report was also highly critical of waste management arrangements, finding that buildings and ground in the site's Waste Management Complex had been contaminated by radioactivity and that the complex was badly designed and badly run. The sludge processing facility within the complex was considered "unsuitable for use in a radiation process".[36] Pochin recommended that staff shortages at Aldermaston should be addressed and that new waste management buildings should be built.

> ***... Pochin was scathing about staff cutbacks and shortages at Aldermaston, which he said posed significant safety risks***

The 1992 Greenpeace study – prepared fifteen years after Pochin's investigation - concluded that little action had been taken to address the concerns he had raised. Recruitment and retention of staff was difficult, despite pay increases, to the extent that the production schedule for Trident warheads was under threat.[37] A programme to build new radioactive material processing buildings and waste management facilities had run into trouble, and the construction of new solid waste storage and processing facilities had not yet commenced. A new radioactive effluent treatment plant – the A91 building – experienced such intractable problems that the project was eventually cancelled and written off at a cost to the taxpayer of £147 million.[38] Housekeeping arrangements remained poor: even Aldermaston's own in-house magazine was critical of waste management standards, saying that "the site looks like a scene from war-torn France in the 1940s, with holes and mounds of soil everywhere: piles of twisted metal on every grass verge, and heaps of scrap timber". The dumped waste included "piles of scrap metal, timber, scientific apparatus, and gas bottles" - apparently discarded on any available piece of land as the result of poor planning and communication between different teams within the Establishment.[39]

30 Edward Pochin: 'An Investigation into Radiation Health and Safety at the Ministry of Defence (Procurement Executive) Atomic Weapons Research Establishment, Aldermaston'. The National Archives, file ES14/26. Para 50 p 11.
31 Edward Pochin op cit. Para 60c p12.
32 Edward Pochin op cit. Para 106 p 21.
33 Edward Pochin op cit. Para 62 p 12.
34 Edward Pochin op cit. Para 81 p17.
35 Edward Pochin op cit. Para 108 p22.
36 Edward Pochin op cit. Para 16i pH18.
37 Greenpeace op cit, p31.
38 'AWE'. Parliamentary written answer. Hansard, 21 January 2014 column 112W. http://www.publications.parliament.uk/pa/cm201314/cmhansrd/cm140121/text/140121w0001.htm#140121w0001.htm_wqn43
39 Greenpeace op cit, p32.

FLOODS

A freak storm which hit West Berkshire on 6 July 1989 was to prove disastrous for the Atomic Weapons Establishment, as it had by now been renamed. The heavy rain flooded ponds on the AWE Aldermaston site causing them to overflow into marshland and a lake on the neighbouring Aldermaston Court Estate – 137 acres of woods and parkland owned by Blue Circle Industries plc containing a Victorian country house and an award-winning office block. The flood water contained radioactive material and contaminated the marshland on the estate. AWE discovered the contamination later that month, but did not inform Blue Circle about the spill until January 1993 – three and a half years later. The news could not have come at a worse time for Blue Circle, which was about to close negotiations to sell Aldermaston Court to Sun Microsystems Ltd for £10 million. On learning of the contamination Sun backed out of the deal - just as the property market entered a slump.[40]

> ***Managers at AWE had decided it would be "prudent" not to reveal the impact of the flooding to the public and clumsily attempted to cover up the fiasco***

AWE was forced to spend £350,000 clearing up the spill. Sampling of marsh and lake sediments revealed hot spots containing plutonium at four times the permitted level, and 1,000 cubic metres of soil contaminated with plutonium were excavated from the estate. Blue Circle took the MoD to court over the incident, seeking damages for being unable to sell the Aldermaston Court Estate. Following a hearing in November 1996 the High Court found that the MoD had breached its statutory duties and ordered the Ministry to pay £6 million in compensation to Blue Circle, together with costs of £140,000 for additional clean-up and consultancy costs and legal fees estimated at £500,000. In his ruling Mr Justice Carnwath said it was "clearly foreseeable" that the radioactive contamination would have an adverse effect on the marketing of the estate, and that AWE was aware of this.

The story did not end there. The MoD took the case to the Appeal Court, asking for the award of damages to be reduced. The Court not only dismissed the appeal and upheld the original compensation, but increased it by a further £600,000 to account for the "stigma" which hung over the Aldermaston Court Estate. Lord Justice Simon Brown said there was "nothing in the least unfair or inappropriate in the MoD being found liable to pay the sums awarded".[41]

Another serious flood caused chaos at the Atomic Weapons Establishment's Burghfield site in July 2007. Live warhead work at Burghfield was suspended for nine months after the Burghfield Brook, which flows through the site, burst its banks following a sudden severe storm. Water came close to overwhelming the factory, causing long-term disruption to nuclear weapons manufacture. The flood rose to a height of two feet, lifting drain covers and completely cutting off one facility on the site. 84 buildings were affected and virtually every facility within the factory's nuclear warhead processing area experienced water ingress, causing widespread damage. The flooding only came to light a year later after documents were released following a request made under the Freedom of Information Act, revealing the full extent of the incident and highlighting a series of shortfalls in emergency arrangements. Managers at AWE had decided it would be "prudent" not to reveal the impact of the flooding to the public and clumsily attempted to cover up the fiasco.[42]

The documents showed that despite the scale of the crisis, a site emergency was not declared during the flooding and the government regulators responsible for the Burghfield site were not told about the incident until two days afterwards. Radioactive material was still being recovered

40 Blue Circle Industries plc v Ministry of Defence: Court of Appeal Judgment 10 June 1998. http://court-appeal.vlex.co.uk/vid/chanf-52585000; 'MoD must pay £6m damages to Blue Circle'. Newbury Weekly News, 28 November 1996.

41 'Judges boost MoD's £6m. Bill for leak of nuclear waste'. Newbury Weekly News, 11 June 1998.

42 Nuclear Information Service: 'Swamped! The devastating impact of the July 2007 floods on Britain's nuclear weapon's factories'. 9 October 2008. http://www.nuclearinfo.org/article/awe-burghfield-accidents-safety-media/swamped

An earlier flooding incident at Burghfield, 2000

from buildings at AWE Burghfield nearly three weeks after the floods and live nuclear work had to be suspended for nine months until buildings and emergency systems had been repaired. Even though the Burghfield site had a well-known history of flooding, a programme of remediation works had been neglected and emergency plans had overlooked many of the risks associated with flooding. Negotiations between AWE, the MoD, and insurers over liability for the costs of repairing extensive damage at Burghfield took two years to complete, and ended up with taxpayer footing the £5 million bill for repairs. Although the costs were incurred by the site operators, AWE Management Ltd and its associate AWE plc, the two companies reclaimed the money from the Ministry of Defence under non-nuclear indemnity arrangements.[43]

IN THE DOCK

In 1987, as the Trident warhead programme built up momentum, AWRE was grouped together with Royal Ordnance Factories involved in the production of nuclear weapons at Burghfield and Cardiff[44] to form the Atomic Weapons Establishment (AWE). Shortly afterwards the management and operation of AWE was privatised and from 1997 onwards AWE was for the first time required to operate under the same nuclear licensing arrangements and standards as the civil nuclear industry. The move to site licensing and independent regulation was a painful process for AWE, but it undoubtedly led to a huge improvement in safety at AWE sites. Under the new regime the Establishment was now subject to external regulation by the Health and Safety Executive's Nuclear Installations Inspectorate[45] and no longer had 'Crown Immunity' from prosecution over breaches of safety and environmental laws. It wasn't long before the regulators showed their teeth.

43 'Atomic Weapons Establishment'. Parliamentary written answer. Hansard, 16 June 2010 column 465W. http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm100616/text/100616w0009.htm#100616103000738

The first prosecution of AWE took place soon after Crown Immunity was lifted. The Health and Safety Executive (HSE) brought a case against AWE plc and its parent company, Hunting BRAE Ltd, following an accident on 15 December 1997 when two workers became contaminated with plutonium. The accident took place as a section of contaminated pipework was being dismantled during the decommissioning of a redundant glove box. As a worker removed a filter from the apparatus a piece of plutonium weighing between one and four grams "rolled out of it over his hand and disappeared." Radiation alarms sounded and the building was evacuated. The worker who was dismantling the pipework was wearing protective clothing and was unharmed following the accident but two others who were close by inhaled plutonium and received internal doses of radiation. Contamination of the area surrounding the glove box was so severe that it took two months to clean up.[46]

Following the accident AWE plc and Hunting BRAE Ltd pleaded guilty to breaches of the Nuclear Installations Act 1965, the Ionising Radiation Regulations 1985, and the Health and Safety at Work Act 1974. The two companies were fined a total of £22,000 and ordered to pay £7,500 in court costs. Prosecutors told the court that AWE had been guilty of "alarming widespread mismanagement and complacency" and that there had been "complete confusion" as to who was responsible for establishing an exclusion zone around the work area. Workers were not properly briefed and the root cause of the accident was "a specific lack of detail, planning, and supervision". Controls for the job were "inadequate and the risk assessment was "not good". The incident could have been avoided if lessons from a similar incident in February 1997, when five workers received radiation doses as a glove box filter was being changed, had been learnt.[47]

Soon afterwards it was the Environment Agency's turn to put AWE in the dock. In January 1999 the Agency received a tip-off from a worker at Aldermaston that groundwater contaminated with radioactive tritium was being unlawfully discharged into the Aldermaston Stream via the site's surface water drainage system. AWE managers were interviewed over the matter and admitted that the discharges were taking place and had not been authorised. Although AWE had been authorised to discharge groundwater contaminated with tritium via a pipeline into the River Thames at Pangbourne, permission had not been given for any discharge into the stream. The discharges had commenced in April 1997 and accounted for 70% of all tritium emissions from the Aldermaston site. "It started as a minor thing but it soon became a major source of discharge of tritium liquid waste – and the company knew it was unlawful", said Garrett Burne, prosecuting for the Environment Agency at the subsequent trial. Mr Burne told the court that natural levels of tritium were between five and 20 Becquerels per litre of water but the company had been discharging effluent with a content of around 100 Bqs per litre. "The company seems to have set itself a maximum figure of 100 Bqs - which has no scientific basis as far as the Environment Agency is concerned", he said. "But it even breached its own guidelines by 67% on occasions by pumping in waste that was over 100 Bqs". He said that the company had repeatedly been asked about its waste disposal routes but had failed to disclose the illegal discharges. In court Hunting BRAE pleaded guilty to charges of unlawfully discharging tritium contrary to the Radioactive Substances Act 1993, failing to report the discharge to the Environment Agency, and making false or misleading statements about tritium discharges. Magistrates fined the company £17,500 and ordered it to pay £4,220 in court costs.[48]

AWE was in court again following a fire at an explosives manufacturing facility at Aldermaston on the night of 3 August 2010. The incident resulted in damage to the building and one worker, Ashley Emery, suffered burns injuries to his face and arm. A number of local residents were evacuated and roads around the site were closed as safety precautions until the fire had burnt out.

44 The AWE Cardiff site was closed in 1997.
45 The Health and Safety Executive's Nuclear Installations Inspectorate has now become the Office for Nuclear Regulation.
46 BBC News. 'Aldermaston fined over plutonium leak'. 17 August 1998. http://news.bbc.co.uk/1/hi/uk/152536.stm
Campaign for Nuclear Disarmament: 'Aldermaston: Behind Closed Doors'. 1999. P12-13.
47 Health and Safety Executive: 'Prosecution of Hunting BRAE Ltd and AWE plc'. Press release, 14 July 1998; Nuclear Awareness Group: 'Atomic Weapons Establishment (AWE) Aldermaston in the dock'. Press release, 17 August 1998.

The accident happened as AWE employees were manufacturing a batch of nitrocellulose lacquer, which is used in the manufacture of explosives. The fire was suspected to have been started by a static discharge as nitrocellulose was being added to the solvent methyl ethyl ketone. The solvent ignited and the fire developed rapidly as flammable materials and explosives in the building burned, engulfing the front face of the building and blazing for five hours.[49] At its peak the incident was attended by more than 68 fire-fighters from four brigades. AWE's Chief Executive, Robin McGill, told members of the AWE Local Liaison Committee that a building had suffered "minor damage in what was a relatively small fire". "There have been some inaccurate reports about the scale of the incident and it is important that LLC members are in a position to reassure local people", he said.[50]

It soon became apparent that the accident had been far more serious than AWE was admitting. An internal report from the Royal Berkshire Fire and Rescue Service, which had spearheaded the emergency response, revealed that there had been "numerous difficulties" in fighting the fire.[51] AWE's own on-site responders were ill-prepared to deal with the blaze and there was only one control operator at AWE's on-site fire station, who was "overwhelmed by the demands of the incident and unable to effectively provide the information required". Liaison and communications with MoD police and on-site private security was "poor", leading to delays of up to an hour in allowing fire-fighting equipment access to the site. Fire hydrants were found to be "inefficient" as a result of "a mistake with the opening and closing of sluice valves by a maintenance contractor", and a special high volume pump had to be brought in from London to provide water to fight the fire.

An investigation into the fire by the HSE painted a damning picture of explosives safety standards at AWE and exposed a wide range of "comprehensive and basic" failings.[52] The investigation report concluded that it was fortunate that the incident did not lead to "numerous fatalities" and baldly stated that an internal report into the fire which had been published by AWE "played down" the seriousness of the incident. Explosives were being held in the building in contravention of an explosives safety order and the consequences of the fire "could have been far more severe" if they had ignited. Firefighters at the incident "were put at risk because they attended the building without knowing that explosives were present".

The report found that AWE's actions leading up to and on the night of the incident "fell far below the standard expected in an explosives manufacturing company". The investigation discovered that personnel working in the building where the fire broke out had not been adequately trained to undertake their duties. At the time of the accident all those present had worked their normal shift and were into their fifth hour of overtime. A health and safety assessor working in the explosives area had raised "numerous concerns" about shortfalls in risk assessments for the explosives area in November 2009, but these concerns had not been addressed by AWE and there was "little evidence of management acting on the issues brought to their attention".

AWE's actions leading up to and on the night of the incident "fell far below the standard expected in an explosives manufacturing company"

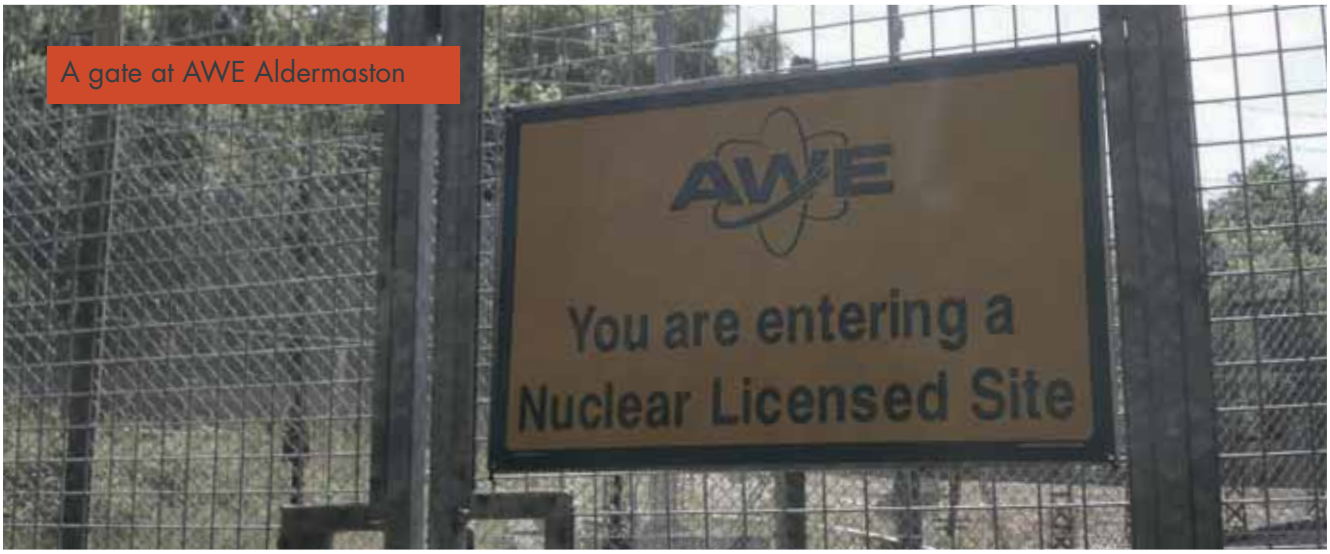
Ashley Emery, who was injured during the fire, was interviewed during the investigation. Mr Emery felt "upset that he was not made aware of all the risks

48 Vikram Dodd: 'Aldermaston fined for N-waste discharge'. Guardian, 14 December 1999. http://www.guardian.co.uk/uk/1999/dec/14/vikramdodd
Charles Arthur: 'Nuclear waste fed into Thames stream'. Independent, 14 December 1999.

49 Nuclear Information Service: 'Atomic Weapons Establishment fire: independent report highlights failure to comply with safety arrangements'. 9 June 2011. http://nuclearinfo.org/article/awe-aldermaston-accidents/atomic-weapons-establishment-fire-independent-report-highlights

50 Lucie Richards: 'AWE chiefs look to dampen fire fears'. Southern Daily Echo, 10 October 2010. http://www.dailyecho.co.uk/news/8443250.AWE_chiefs_look_to_dampen_fire_fears/

51 Nuclear Information Service: 'Nuclear factory fire report highlights AWE safety failings'. 31 May 2011. http://nuclearinfo.org/article/awe-aldermaston/nuclear-factory-fire-report-highlights-awe-safety-failings



A gate at AWE Aldermaston

when handling explosives" and "cannot understand why he did not have the same rigorous training and protection as he did for his normal day job". After Mr Emery had escaped from the building a locked gate prevented first aiders from reaching him and had to pass a burns pack over the fence to him, and he had to wait for the key to the gate to be found before paramedics could treat him professionally for his injuries.

Following the investigation HSE concluded that "there were so many management failings on the night of the incident" that prosecution was the "only realistic course of action." The fire was "entirely preventable" and could have been avoided if the company had heeded safety guidance. AWE plc pleaded guilty at Reading Crown Court to breaching the Health and Safety at Work Act 1974 by failing to ensure the health, safety and welfare of its employees. The company was fined £200,000 and ordered to pay £80,258 in legal costs and £2,500 in compensation to Mr Emery. Passing sentence, Judge Richard Parkes said that the failings which led to the fire "give rise to serious concern" and were "attributable at least in part" to AWE's management. He concluded that a fire could have occurred during the preparation of any previous lacquer batch, and "no credit attaches to AWE for the fact that it had not happened before".[53]

More recent cases of enforcement action against AWE have not involved prosecution. In August 2012 a routine inspection discovered corrosion at the base of a steel column supporting the structure of one of Aldermaston's main nuclear processing buildings. The A45 facility undertakes uranium processing operations at Aldermaston and played a major role in the production of Trident warheads in the 1990s. It was built in 1956 and therefore falls short of modern nuclear safety standards despite being categorised as a 'Class 1 structure – the "highest and most important classification for a nuclear structure" - by the Office for Nuclear Regulation (ONR). ONR was notified of the problem and concluded that "although the building remains safe to enter, corrosion has affected both the seismic and weathering withstand of this class 1 structure, rendering it unsafe for nuclear operations". Work in A45 involving fissile material was suspended.[54]

52 Nuclear Information Service: 'Investigation by safety watchdog concluded that AWE fire could have resulted "in many fatalities". 1 December 2013. http://nuclearinfo.org/article/awe-aldermaston/investigation-safety-watchdog-concluded-awe-fire-could-have-resulted-%E2%80%9C-many Article includes downloadable copy of the HSE investigation report.

53 HHJ Richard Parkes QC: 'R (Health and Safety Executive) v AWE PLC. Sentencing Remarks'. Reading Crown Court, 28 May 2013.

54 Nuclear Information Service: 'Fears over structural safety of buildings halts work at Atomic Weapons Establishment'. 24 January 2013. http://nuclearinfo.org/article/safety-awe-aldermaston/fears-over-structural-safety-buildings-halts-work-atomic-weapons

55 Nuclear Information Service: 'Safety watchdog: Atomic Weapons Establishment 'exposed people to risk''. 8 February 2013. http://nuclearinfo.org/article/safety-awe-aldermaston/safety-watchdog-atomic-weapons-establishment-exposed-people-risk

56 Nuclear Information Service: 'A45 corrosion of 'major' significance, reveal FOI papers'. 31 March 2013. http://nuclearinfo.org/article/awe-aldermaston/a45-corrosion-major-significance-reveal-foi-papers Article includes downloadable copies of ONR investigation reports.

Further inspections revealed that a "significant number" of other steel structural columns had also corroded as a result of rainwater accumulation and were in a "poor" or "bad" condition. An investigation by ONR concluded that "people were exposed to risk by AWE's failure to adequately maintain the class 1 structure" and found "clear evidence" that AWE had failed to comply with the conditions of its nuclear site operating licence because arrangements for the inspection and maintenance of a nuclear structure were not adequate to prevent its degradation.[55] Notes of a meeting between ONR and AWE observed that "This is not the first time ONR have found an AWE structure in need of repair".[56]

AWE escaped prosecution because ONR decided that it had not acted recklessly or ignored safety standards. Instead a formal Improvement Notice was issued requiring the company to complete a programme of remedial actions to tackle the problems. The significance of the incident was acknowledged as "major" by AWE staff and the incident was rated as a scale 2 incident on the International Nuclear and Radiological Event Scale (INES), corresponding to an "incident" where "significant failures" in safety provisions occurred, but with no actual consequences.[57] At the time of writing it remains the most serious safety problem recorded at any UK nuclear site since 2009.[58]

The most recent case of enforcement action against AWE involves a failure to deal with Aldermaston's legacy of radioactive waste. In March 2007 the nuclear safety regulator issued a Licence Instrument formally requiring AWE to reduce in volume and encapsulate at least 1000 205 litre drums of intermediate level radioactive waste held on site by 20 February 2014. The Licence Instrument aimed to ensure that hazardous untreated waste - known as 'higher activity waste' - which is too highly contaminated with radioactive material for disposal in existing facilities could be stored safely in a passive form over the long term. A previous instruction issued in March 2000, requiring AWE to have reduced and packaged 670 drums by the end of December 2006, had passed without the deadline being met.[59]

In June 2010 ONR wrote to AWE expressing concern about slow progress in dealing with the waste and in August 2011 the company told ONR that it would not be able to comply with the instruction by the February 2014 deadline. Initial proposals to compact the waste drums had been rejected by AWE as being too expensive. Searches for an alternative solution based around collaboration with other nuclear site operators floundered and the Licence Instrument expired on 20 February 2014 with AWE in breach of its legally binding requirements. ONR concluded that "AWE has contravened the Health and Safety at Work Act 1974" by failing to manage its wastes in a manner that reduced future risks, but decided not to prosecute the company for breaking the law.[60] Instead, "a more proportionate and effective response" would be to issue an Improvement Notice requiring AWE to demonstrate how it will manage its higher activity wastes "in a way that closes this compliance gap". In October 2016 ONR announced that AWE had developed options for the management of higher active wastes and had made sufficient progress to meet the requirements of the Improvement Notice - although the Aldermaston site continues to require "enhanced regulatory attention" from ONR.[61]

57 'INES. The International Nuclear and Radiological Event Scale'. International Atomic Energy Authority. http://www-ns.iaea.org/tech-areas/emergency/ines.asp

58 Office for Nuclear Regulation: 'Events reported to Nuclear Safety Regulator 2001-2015'. 4 February 2016. http://news.onr.org.uk/2016/02/events-reported-to-nuclear-safety-regulator-2001-15/

59 Nuclear Information Service: 'Atomic Weapons Establishment under investigation by safety watchdog for failing to comply with radioactive waste management orders'. 24 February 2014. http://nuclearinfo.org/article/awe-aldermaston/atomic-weapons-establishment-under-investigation-safety-watchdog-failing

60 Nuclear Information Service: 'Improvement Notice served on AWE after radioactive waste failure'. 2 August 2015. http://nuclearinfo.org/article/awe-aldermaston/improvement-notice-served-awe-after-radioactive-waste-failure

61 Office for Nuclear Regulation: 'AWE complies with Improvement Notice'. 12 October 2016. http://news.onr.org.uk/2016/10/awe-complies-with-waste-management-improvement-notice/

CASE STUDY 1

Date: 7-12 October 1957

Location: Windscale, Cumbria

Weapons involved: Graphite-moderated reactor containing 180 tons of uranium

The Sellafield site in 2010, with the two Windscale Pile chimneys in the foreground. Image credit: Beechwood Photography/Flickr

'AN ACCIDENT WAITING TO HAPPEN': FIRE AT WINDSCALE

"I've heard of Dante's Inferno, but it couldn't have been any worse than what I saw there."

Stan Ritson's description of the 1957 reactor fire at Windscale is a stark comment on the peril and danger he faced as one of the Windscale workers who put his life on the line fighting the blaze. Stan was a process worker at Windscale and, like many others, his bravery during the crisis exposed him to a high dose of radiation – earning him the title of 'the most radioactive man in Britain' according to the newspapers.[62]

The Windscale fire was Britain's most serious nuclear accident, rating a score of 5 on the INES scale for ranking nuclear accidents.[63] It is often forgotten that the accident occurred as a direct result of the production of nuclear weapons. Although the Windscale site (now known as the Sellafield nuclear complex) is usually associated with civil nuclear reprocessing, the site was originally set up as a nuclear plant to produce fissile materials - principally plutonium, polonium, and tritium - for the UK's emerging nuclear weapons programme. As the Cold War intensified following the end of World War II the need for nuclear weapons seemed greater than ever, and pressures on the men and women charged with delivering the programme were intense. Lorna Arnold, the UK Atomic Energy Authority's official historian, wrote in her account of the Windscale fire that the workers "responded as they and others had responded in wartime: the demands of national defence would be met at all costs".[64]

The speed with which the Windscale plant was built was truly remarkable: the decision to develop a British atom bomb was made in 1946 and the first of the Windscale Piles – the reactors which would produce the plutonium for the bomb – was operational in October 1950, followed by a second

in June 1951. The first reprocessing run at Windscale took place in 1952 and the extracted plutonium fuelled the UK's first nuclear weapons test on 3 October 1952.[65] However, this speed was achieved at a price. The safety arrangements for operating the plant were trimmed back as the pressure to produce nuclear materials increased - particularly for tritium, urgently needed for the forthcoming test of the UK's first nuclear fusion weapon. Some of the scientists working on the programme had warned about the dangers of an accident. "There's no doubt that using the knowledge that we have today those plants should not have operated at all - that there were various features about them which were really inherently unsafe - but the needs for the materials that we were producing were paramount at the time", said Ronald Gausden, former manager of the Pile Group at Windscale speaking on the fiftieth anniversary of the accident in 2007.[66]

> *"There's no doubt that using the knowledge that we have today those plants should not have operated at all ..."*

The engineers and scientists operating the Windscale piles had noticed a mysterious rise in the temperature of their graphite cores.[67] Unbeknown to them, this was caused by a build-up of potential energy in the core resulting from neutron bombardment of the graphite. If allowed to accumulate, the energy could escape spontaneously in a dangerous burst of heat. The plant operators had improvised an 'annealing process' to address the problem by letting the reactor heat up to allow a more gradual uniform release of heat. However, the reactor had not been designed to allow annealing to take place, and over time the process became progressively more difficult and unpredictable, requiring the reactor to be taken to higher and higher temperatures to release the energy.

On Monday 7 October 1957 the cooling for Pile 1 was shut down to allow a release of the stored energy. However, the next day it became apparent that the release had not succeeded – the reactor was behaving unpredictably and the temperature was falling when it was expected to be rising. A second attempt to heat the reactor was made, and this time the temperature rose. Fans controlling the air cooling system for the reactor were switched on to dissipate the heat.

By the morning of Thursday 10 October the reactor was again behaving unpredictably. Areas of the core were increasing in temperature and high levels of radioactivity were detected coming out of the chimney above it. Tom Hughes, the assistant works manager, decided to inspect the reactor to investigate what was happening. "To our complete horror we could see four channels of fuel glowing a bright cherry red", he recalled.[68] The reactor was on fire. An isotope cartridge for the production of tritium – specially redesigned to retain heat and increase the speed of tritium production – had caught fire, and by switching the fans on, the reactor personnel had inadvertently caused the fire to spread.

By 8 pm blue flames of burning gas were visible and the reactor temperature had reached an estimated 1300C as the graphite and uranium burnt. "This was a blazing inferno and we knew it was pushing radioactive fission product waste up the chimney all the time, and we didn't know what we could do to stop it", recalled Tom Tuohy, deputy general manager at Windscale, who led attempts to put the fire out. "Mankind had not faced anything like this before. There was no-one to give you any advice. You played by ear".[69]

A decision was taken to try to remove burning fuel and cartridges from the reactor core by pushing them with scaffolding poles through channels out of the back of the reactor into a duct of water. Workers and firefighters were conscripted and volunteer members of the public were press-ganged from a local cinema by the police. "We were working like fury," said Vic Goodwin, a graduate physicist working at Windscale, "but we were too busy to panic".[70]

The attempts to remove the red-hot cartridges failed

62 BBC Television: 'Our reactor is on fire', 1990. https://www.youtube.com/watch?v=vcsyMvQtlKs

63 The INES scale has eight levels, of which 0 is the least serious and 7 the most serious. A Level 5 incident represents "an accident with wider consequences". 'INES. The International Nuclear and Radiological Event Scale'. International Atomic Energy Authority. http://www-ns.iaea.org/tech-areas/emergency/ines.asp

64 Lorna Arnold: 'Windscale 1957: Anatomy of a Nuclear Accident'. Second edition 1995. Palgrove Macmillan.

One of the Windscale Piles shortly after construction
© Sellafield Ltd

65 Richard Wakeford: 'The Windscale reactor accident – 50 years on'. Editorial, Journal of Radiological Protection, Vol 27, pp211-215, 2007. http://iopscience.iop.org/0952-4746/27/3/E02
66 BBC Television: 'Windscale: Britain's biggest nuclear disaster'. 8 October 2007. https://www.youtube.com/watch?v=bC76mcgki9A
67 Paul Dwyer: 'Windscale: a nuclear disaster'. BBC News, 5 October 2007. http://news.bbc.co.uk/1/hi/7030281.stm
68 BBC Television 2007, op cit.

because they had been deformed by the heat and had stuck in the core. An attempt to quench the fire using carbon dioxide failed, and as a last resort Touhy suggested using water to cool eleven tons of uranium which were now ablaze – a risky approach, as there were fears that the intense heat would cause the water to react and generate explosive hydrogen gas. "I wanted to run, I felt really scared", remembered Jack Coyle, a maintenance fitter at Windscale who had been called in to help fight the fire. As the water was pumped into the reactor core all the scientists present were "looking really worried, not their usual cocky selves".[71]

Luckily the water did not cause a hydrogen explosion – but it did not put out the fire, either. However, an order was then given to switch off the fans which had been blowing air into the blaze in an attempt to cool the pile. Starved of air, the flames died down and by midday on Friday 11 October the fire was out. Water was pumped into the pile for a further 24 hours until it was cold, flooding the surrounding area with radioactive contaminants.

> *"Mankind had not faced anything like this before. There was no-one to give you any advice. You played by ear"*

The Atomic Energy Authority's initial public response to the fire was to issue a statement saying that "some uranium cartridges in the centre of the atomic pile at Windscale became overheated yesterday".[72] Local people were not warned about the emergency by the authorities, although many of those working at Windscale had contacted their families to warn them to take cover indoors or leave the area. The public were told that any radioactive contamination had been blown out to sea, although it had in fact travelled eastwards inland. Surrounding areas of Cumbria were contaminated and the government was forced to place a ban on the distribution of milk in a coastal strip running from 10 km north of Windscale to 20 km to the south. Warnings were issued that locally produced vegetables and crops should not be consumed.

An inquiry into the fire was led by Sir William Penney, head of the UK's nuclear weapons programme, and Penney's report was submitted to the government on 26 October, a "remarkably short time after the accident".[73] The report found that the primary cause of the accident had been the second nuclear heating on 8 October, applied too soon and too rapidly, and was highly critical of the technical and organisational deficiencies at Windscale. Penney concluded that measures to deal with the accident were "prompt and efficient and displayed considerable devotion to duty on the part of all concerned".

Penney's report caused considerable embarrassment for the government, which at the time was hoping to persuade the American government to share the secrets of their nuclear weapons technology with Britain. The Windscale fire had occurred just before Prime Minister Harold Macmillan was due to travel to Washington to meet President Eisenhower to reach agreement on a nuclear deal. Macmillan was worried that the Americans would refuse to co-operate with Britain if they knew the extent of the recklessness and short-cuts which had characterised the British nuclear weapons programme. "How are we to deal with Sir William Penney's report?", he wrote in his diary. "To publish it to the world, especially the Americans, might put in jeopardy our chance of getting Congress to agree to the President's proposal". Macmillan ordered the recall of all copies of Penney's report and instead published a White Paper to 'spin' presentation of the inquiry's findings. The White Paper made no mention of the safety shortfalls at Windscale and maintained that the fire had been caused by "an error of judgment" by the plant operators – the very same workers who had risked their lives in tackling the fire.[74]

Following the fire the two Windscale piles were permanently closed. Efforts were made to recover

69 BBC Television 1990, op cit,
70 Roger Highfield: Windscale fire: 'We were too busy to panic'. Daily Telegraph, 9 October 2007. http://www.telegraph.co.uk/news/science/science-news/3309842/Windscale-fire-We-were-too-busy-to-panic.html
71 Jean McSorley: 'Fighting the Fire'. 9 October 2007. www.no2nuclearpower.org.uk/articles/windscale_fire.pdf
72 BBC Television 2007, op cit.
73 Richard Wakeford, op cit.

the maximum quantity of nuclear material from the core and other parts of Pile 1 before the air inlet ducts and the outlet chimney were permanently sealed and the reactor was enclosed in a concrete tomb. Around 15 tons of uranium reactor fuel remain in the damaged core, which to this day is still awaiting decommissioning.[75] It has been estimated that the radioactive polonium, iodine, and tritium released by the fire would cause around 100 fatal cancers and around 90 non-fatal cancers.[76]

"The Windscale accident of 1957 is the equivalent of a wartime battle," wrote Sir Alan Cottrell in a foreword to Lorna Arnold's account of the fire. "All the same basic elements are there: misjudgments, professional rivalries, brilliant improvisation, desperate decisions and heroic actions, all wrapped in a cloud of uncertainty as dense as any fog of war".[77] Whatever the analysis, few would disagree with Arnold's conclusion that ultimately the operation of the Windscale Piles was "an accident waiting to happen" - or with Tom Tuohy's comment that the officials who had let the world think that his staff had been responsible for the fire were "a shower of bastards".[78]

74 BBC Television 2007, op cit.
75 A.E. Shiel, W Botzem, and C.K.Johnston: 'Decommissioning of Windscale Pile 1'. WM99 conference paper, 4 March 1999. www.wmsym.org/archives/1999/02/2-1.pdf
76 Richard Wakeford op cit.
77 Lorna Arnold 1995, op cit.
78 BBC Television 2007, op cit.

ON THE ROAD: ACCIDENTS DURING THE TRANSPORT OF NUCLEAR WEAPONS

A car is parked in a lane overlooking one of Britain's many motorway junctions on a cold wintry night. Despite the late hour, traffic is still hurtling past on the busy road. Blue flashing lights eventually roll into view among the headlights, and reveal themselves to be a group of police cars. Then a convoy of larger vehicles thunders past – four huge articulated military trucks with armoured escort vehicles followed by a breakdown truck, a fire engine, and more police cars. There are blue lights everywhere now, and traffic behind the convoy is being held back by police cars forming a rolling blockade. The woman in the parked car jots down some notes on a slip of paper and gets out her mobile phone. She's one of a nationwide web of volunteer activists who track the movements of nuclear weapons as part of the Nukewatch network, and she knows exactly what this high security convoy is and where it is going.

Thanks to the work of Nukewatch and other campaign networks a great deal is known about the movement of nuclear weapons on the UK's roads. Convoys of Trident nuclear warheads travel several times each year between the Atomic Weapons Establishment (AWE) in Berkshire, where they are manufactured and maintained, and the Royal Naval Armaments Depot (RNAD) at Coulport on Loch Long in the west of Scotland, where they are stored and loaded onto Trident submarines. Special nuclear materials – plutonium, tritium, and highly enriched uranium and components fabricated from these materials for use in the UK's nuclear weapons and submarine programmes - are also transported less frequently to and from the Atomic Weapons Establishment and other nuclear sites around the country.

During their transport across the country nuclear weapons are out in the open and are easily apparent to members of the public. Since the 1980s warhead convoys have been tracked by members of the Nukewatch network and its predecessor organisations. But as well as being at their most visible, the weapons are also at their most vulnerable. Eight of the seventeen nuclear accidents referred to in the Oxburgh Report occurred when nuclear weapons were being transported on the roads. On a number of occasions Nukewatchers have witnessed accidents involving nuclear warhead convoys and have promptly informed media outlets, resulting in widespread news coverage – as occurred in the case of a warhead convoy accident at West Dean in Wiltshire in 1987, when a warhead carrier overturned after skidding on an icy road (see case study 2).

22 INCIDENTS, INCLUDING:

- 1 Fires
- 8 Vehicle accidents
- 12 Other incidents involving vehicles
- 1 Incident involving a lightning strike

EARLY YEARS

Transportation of the earliest British thermonuclear weapons was evidently a hazardous business. Safety concerns about the RAF's first interim megaton weapon (the 'Green Grass' warhead in the 'Violet Club' weapon), which did not contain all the safety arrangements necessary to meet its operational requirements, were so great that AWRE insisted that any movements or transport of the weapon must only be done in agreement and after consultation with AWRE. The Green Grass warhead was not to be moved in an assembled condition by road.[79]

Official records on movements of nuclear weapons in the early days of the UK's nuclear programme are sparse, but some of the personnel involved in operating nuclear weapons convoys in the 1950s and 1960s have recollected incidents which took place involving the weapons in their charge. Air Commodore M.J. Allisstone, a former RAF convoy commander responsible for the movement of nuclear weapons, has described an incident which took place when he was posted at RAF Barnham, near Thetford in Norfolk, in the early 1960s. A Leyland Hippo lorry loaded with a nuclear weapon experienced a runaway engine - "this was not an uncommon occurrence" - at the top of a hill on the outskirts of Reading, Berkshire. An attempt by the crew to stall the engine by putting it into gear and letting in the clutch failed, and the clutch burnt out amid clouds of white smoke. "With the engine screaming, and apparently about to explode, the occupants evacuated the cab and the driver then bravely attempted to turn off the external fuel cock". Unfortunately, before he could complete the task the vibration released the hand-brake. "The driverless Hippo set off down the hill and, at the first bend it encountered, embedded itself in the front room of a terraced house". The elderly resident "emerged dusty but unhurt, to offer everyone a cup of tea!" The convoy's RAF police escort "did a good job of keeping the local press, etc at a safe distance" and the only national publicity was a small headline in a tabloid newspaper the following day. Allisstone was responsible for notifying No. 10 Downing Street of the incident.[80]

On another occasion when a convoy was moving during a thunder storm one "exceptionally vivid" flash of lightning struck a lamp-post alongside a Hippo lorry. The lorry "swerved into the middle of the road and stopped almost dead in its tracks" and the RAF police escort closed the carriageway in both directions. The driver "was sitting transfixed and completely dumb-struck", convinced that the load that he was carrying had blown up.[81] Another retired convoy crewman, John Wedlake, recalled two instances when convoys breached airfield movement rules when driving inside airbases. On one occasion a police escort motorcyclist ignored a red stop light indicating that an aircraft was landing and was hit by a flare intended to warn the aircraft. On another occasion confusion arose as a convoy was travelling around the perimeter taxiway of an airfield, and the convoy found itself facing a taxiing V-bomber, which was forced to give way to the convoy.[82]

The driver "was sitting transfixed and completely dumb-struck", convinced that the load that he was carrying had blown up

The earliest officially recorded accident known to have taken place involving a warhead convoy took place in Lincolnshire sometime in 1960 when an RAF low loader carrying a nuclear warhead had a brake failure on an incline and overturned. No information is available today about the extent of any damage or any inquiry into the incident.[83] Another early accident which was recorded happened in 1963

79 John R. Walker: 'British Nuclear Weapons and the Test Ban 1954 – 1973'. Ashgate Publishing, 2010. P58.
80 M.J. Allisstone: 'Recollections of Nuclear Weapons and No 94 MU, RAF Barnham'. Proceedings of the RAFHS Seminar on the RAF and Nuclear Weapons, 1960 – 1998. Royal Air Force Historical Society Journal No. 26, 2001. P28-29. http://www.raf.mod.uk/rafcms/mediafiles/F0B8FBE8_5056_A318_A85757EE24B2B010.pdf
81 M.J. Allisstone, op cit, p119-20.
82 'Nuclear Convoys & X-Flight'. RAF Barnham Nuclear Weapon Storage Site webpage. http://rafbarnham-nss.weebly.com/nuclear-convoys--x-flight.html

when a load carrier's brakes locked and caught fire when a nuclear weapon was being transported through Lincolnshire and South Yorkshire from RAF Coningsby to RAF Finningley. Traffic on the A1 was held up by a temporary cordon. The Oxburgh Report mentions that no damage to the warhead was known to have happened, but expresses concerns that "the incident was clearly observed by the public".[84] The Ministry of Defence has also published information about an accident which took place in April 1973 near RNAD Coulport when a Scottish Electricity Board Land Rover reversed into an RAF truck transporting nuclear warheads for Polaris missiles, and an August 1983 incident when an RAF nuclear weapons load carrier with two Polaris warheads collided with a private car on the M8 motorway near Glasgow. In both cases minor damage was caused to the warhead carrier vehicles but there was no damage to the weapons they carried.[85]

INTO THE EIGHTIES

From the mid 1980s until the mid 1990s nuclear warhead convoys were on the roads far more frequently than they are nowadays as WE177 tactical nuclear weapons were driven around for maintenance and refurbishment and newly manufactured UK Trident warheads were transported from AWE to the Clyde for deployment on the Vanguard class submarines which were replacing the Resolution class Polaris boats. The Nukewatch network had by now been established and was monitoring and tracking warhead convoys. As a result of observations made by Nukewatchers, supplemented by details from official publications and Freedom of Information requests, we have a reasonably comprehensive set of data about accidents during the road transport of UK nuclear weapons over the last three decades.

On the afternoon of Thursday 20 June 1985 a nuclear weapons convoy was passing through Helensburgh in Dunbartonshire as it approached the end of its journey to RNAD Coulport. As the convoy travelled down Sinclair Street in the town centre the brakes of one of the warhead carriers failed and it ran in to the back of another carrier.[86] According to local accounts, a public relations officer at the Faslane submarine base, John Chambers, was shopping in the Clarks shoe shop in Helensburgh as the accident happened and took charge of the situation, advising passers-by to take cover in local shops while the convoy was stopped and the damage was assessed in case the accident had caused a radiation release.[87] The rearmost warhead carrier was slightly damaged in the incident, with its front dented and windscreen starred, and following the accident it was towed to the Clyde Submarine Base at Faslane. Despite Mr Chambers' concerns, the Oxburgh Report states that "there was no damage to weapons and no hazard to the public", although the incident was "widely reported".[88] Even more widely reported was an accident in January 1987 when two warhead carriers in a convoy travelling between Portsmouth Naval Base at RNAD Dean Hill slid on an icy road in Wiltshire, causing one of them to topple off the road and overturn (see case study 2). The story led weekend radio and television news reports[89] and dominated the front pages of the newspapers for the first part of the following week.

Tragedy struck on 17 September 1988 when a warhead convoy was involved in a fatal collision. The convoy – which had already been delayed following a vehicle breakdown on the A36 near Wylye in Wiltshire earlier in its journey - was

83 Chief Scientific Adviser: 'Report on the Safety of Nuclear Weapons' (the 'Oxburgh Report'). Ministry of Defence report CSA 42/5/1/1 (46/62), 12 February 1992. Para F2.1, p11, Appendix F.
84 Chief Scientific Adviser, op cit, p12, Appendix F.
85 Ministry of Defence: 'Nuclear Weapon Accidents'. Response to Freedom of Information Act Request 03-02-2005-145211-024, 16 February 2005.
86 William Peden: 'Safety of British Nuclear Weapon Designs'. British American Security Information Council report 91.2, 1991. P32
87 Interview with Jane Tallents, 27 December 2016.
88 Chief Scientific Adviser, op cit, p12, Appendix F.
89 West Dean warhead convoy accident television news footage, 10 January 1987. https://www.youtube.com/watch?v=luvknRCyD-o

One of the Mammoth Major trucks that were used to transport warheads until the early 1990s

Image credit: Nukewatch

travelling empty to RNAD Bull Point in Plymouth to pick up a cargo of Naval WE177 weapons. It was travelling along a single carriageway section of the A303 Ilminster Bypass in Somerset when an MG sports car crossed the road and collided head on with one of the warhead transporters, forcing it to a halt within inches of a steep embankment. The car wedged underneath the warhead carrier and petrol spilled around the two vehicles, but did not ignite. The car driver was taken to hospital but died before arriving there. The warhead carrier received no visible damage and after checks and a short stopover at a nearby military base, the convoy continued on to its destination in Plymouth.[90]

A warhead convoy carrying WE177 nuclear weapons to RAF Honington broke down in another "widely reported" incident on 1 December 1991.[91] The convoy ground to a halt in busy traffic on the M25 motorway near Kings Langley in Hertfordshire when the rear suspension of one of the warhead carriers collapsed. The convoy was stationary for five hours on the motorway hard shoulder whilst the crew obtained permission from the Armed Forces Minister to close the motorway and transfer warheads from the broken down carrier to a spare vehicle. Another hour passed as the motorway was closed in both directions "for reasons of safety and security" whilst warheads were transferred between vehicles using a crane from RAF Northolt.[92] The convoy returned unceremoniously to ROF Burghfield later that evening with the broken down truck in tow. Closure of the motorway caused huge traffic disruption, with traffic at a standstill for ten miles in either direction, and the convoy once again hit the headlines. The MoD adopted the usual media tactic of refusing to comment on whether the convoy was carrying nuclear weapons but with limited success: the MoD incident commander's log noted that: "Police force on site made the point that they were happy to close as much of the M25 as we wanted, but that it was not a step they would take for a normal lorry accident: one direction was usually enough. Would this not draw additional attention to our supposedly safe load?".[93]

A similar mishap occurred twenty years later on the M6 near Knutsford in Cheshire when a convoy command vehicle broke down near Junction 20 of the motorway during the late afternoon on 25 July 2011.[94] According to the convoy commander's report, released following a request under the Freedom of Information Act, the vehicle "suffered a sudden and dramatic loss of power and was forced to pull onto the hard shoulder of the motorway together with the rest of the convoy assets". The convoy pulled onto the hard shoulder of the motorway for repairs "causing a minor obstruction of the near-side lane". Although the FOI papers state that the fault took just twenty minutes to repair, a post on the 'Trucknet' chat forum by a driver who witnessed the breakdown observes that two lanes of the motorway were coned off while the repairs were underway, which "caused about 10 miles of queues".[95] The cause of the incident "proved to be somewhat of a mystery" because, although a fuel system failure was suspected as having caused the problem, "the vehicle had been filled prior to the operation and there was no sign of leakage". Following the incident fuel systems across the convoy vehicle fleet were checked and rectified.[96]

The car wedged underneath the warhead carrier and petrol spilled around the two vehicles, but did not ignite

90 Chief Scientific Adviser, op cit.
William Peden, op cit.
91 Chief Scientific Adviser, op cit.
William Peden, op cit.
92 D Nuc Pol Sy: 'Incident involving an RAF nuclear weapon convoy'. Loose minute to PS/Minister(AF). D/ACDS(Pol&Nuc)/211/2/19, 2 December 1991.
93 Ministry of Defence: 'Report on convoy incident – Sunday 1 December 1991 – by NAR1B' D/ACDS (Pol&Nuc) 211/2/19, 2 December 1991.
94 Nuclear Information Service: 'FOI records reveal nuclear warhead convoy safety faults'. 3 August 2014. http://www.nuclearinfo.org/article/transport/foi-records-reveal-nuclear-warhead-convoy-safety-faults The article includes downloadable copy of MoD incident reports describing the breakdown.
95 Trucknet UK: 'Atomic Weapons Establishment Aldermaston'. http://www.trucknetuk.com/phpBB/viewtopic.php?f=2&t=74256
96 Nuclear Information Service, 2014, op cit.

A nuclear convoy in the Trident Special Area at RNAD Coulport

Image credit: Nukewatch

BREAKDOWNS, BUGS, AND BAD WEATHER

The highly public warhead convoy breakdowns which took place in the late 1980s and early 1990s occurred as the 'Mammoth Major' trucks then used to transport warheads reached end of their life and became less reliable. The frequency of breakdowns dropped when new Foden warhead carriers entered service in 1992-3, although the new Fodens were involved in an embarrassing breakdown incident on the M62 in July 1992 when a convoy was forced to stop for an hour off Junction 24 of the motorway.[97] A similar pattern of breakdowns and defects was observed during the transport of military special nuclear materials in the period between 2010 and 2015, when the ageing High Security Vehicles used to transport these materials (a separate design of truck to the warhead carrier vehicles) reached the end of their service lives.[98] An assessment undertaken by MoD in 2006 indicated that the vehicles would reach the end of their operating life in 2009 - itself an extension of an out of service date previously estimated as 2003. The assessment stated that the vehicles would become "increasingly unsupportable" if operated beyond 2009. However, the trucks - by then twenty years old - were kept in service for an extended period because of delays in arranging for new vehicles to take over their duties, and consequently suffered from a series of faults and problems in their final years. On 10 November 2010 a special nuclear materials convoy was forced to return to AWE Aldermaston after setting out because the clutch of the High Security Vehicle in the convoy kept slipping as a result of "wear and tear". The convoy set out again later the same day with a replacement truck substituting for the defective vehicle. On another convoy run in November 2012 the alternator on one of the vehicles failed. The convoy was diverted to a nearby MoD establishment for repairs, resulting in a 50 minute delay to the journey. Other faults were experienced in December 2010 when a tail lift failed to operate, in November 2011 when a vehicle suffered a minor fuel leak while on the road, and in June 2012 when a flat battery required a vehicle to be slave started. Each of the faults resulted in a "minor delay" to convoy journeys.

As well as admitting to various high profile, highly visible incidents which have occurred over the years, the MoD has released information about a further 180 incidents that have plagued its nuclear convoy operations between 2000 and 2016. The information, provided in response to requests made under the Freedom of Information Act, classes the incidents as either 'engineering' or 'operational' incidents. Collisions, map-reading errors, computer software bugs, bad weather, and protest actions are among the problems which have afflicted convoys over the years.[99]

In May 2013 a convoy was involved in two minor collisions: firstly when two convoy vehicles collided with each other and again when a convoy escort vehicle collided with a parked civilian vehicle. Another collision occurred in January 2014, when an escort vehicle collided with a car at a MoD base during a rest stop. In September 2015 one of the warhead carriers lost power and broke down soon after leaving a military site, and convoy escort vehicles twice broke down and were declared unserviceable during convoy journeys in November 2013 and July 2015. Adverse weather affected convoy journeys in November 2013, forcing a route change, and in January 2014, when a rolling police blockade was set up to safeguard the convoy during snowy conditions.[100]

In July 2010 a convoy strayed "unintentionally off route" as the result of an error by the escort commander. Stopping the convoy and rejoining the correct route resulted in a delay of 45 minutes to the journey time. Convoys were regularly re-

97 Daniel Plesch, Sandra J. Ionno, Bronwyn Brady, and William Peden: 'Second Report on British Nuclear Weapons Safety: A Response to the Oxburgh Report'. British American Security Council report 92.4, 1992. P21.

98 Nuclear Information Service: 'Ministry of Defence uses trucks which should have been scrapped five years ago to transport nuclear weapons'. 24 September 2014. http://www.nuclearinfo.org/article/transport/ministry-defence-uses-trucks-which-should-have-been-scrapped-five-years-ago

99 Rob Edwards: 'Nukes of Hazard: The nuclear bomb convoys on our roads'. International Campaign for the Abolition of Nuclear Weapons, 2016. Pp12-18 http://nukesofhazard.gn.apc.org/wp-content/uploads/2016/09/NoH-Report-Final.pdf

100 Rob Edwards, op cit.

routed or delayed to avoid road traffic accidents or heavy congestion on the route ahead: in March 2005 there was a "vehicle fire on hard shoulder", and in July 2004 a major accident on the opposite carriageway caused a 39-minute delay.[101]

Minor breakdowns continued to cause problems: in January 2009 a fuse box failure left the tractor unit of one warhead carrier truck unusable, requiring a spare unit to be used to complete the journey, and in November 2010 the spare tractor itself broke down during a convoy journey. In October 2003, an axle began smoking due to "excessive use of wheel brakes" coming down a steep hill. In February 2003 a warhead carrier's clutch failed and in January 2005 a fuse box started smoking when a heated windscreen was turned on. Recurring problems with warhead carrier trailer heat monitor alarms, which were triggered four times on false alerts between September 2011 and December 2012, resulted in the alarm system software needing an upgrade, and problems with ageing vehicle location systems on the warhead carriers also required installation of a replacement system.[102]

As well as the trucks carrying the warheads themselves, vehicles in the convoy's security escort also suffered problems. In June 2012 a convoy was halted to investigate a "suspension system defect" in one of the armoured escort vehicles which accompany the warhead carriers. During the unplanned stop a manhole cover collapsed underneath a second escort vehicle, requiring a vehicle safety check. During a convoy run in January 2012 a gun port flap on a convoy escort vehicle "opened inadvertently", and during the same operation a "brake fault" was discovered on a fire tender accompanying the convoy.[103]

Defence Minister Penny Mordaunt has described these incidents as "very low-level" and said that "they have not in any way threatened the safety or security of the material in transit."[104] Nukewatch, on the other hand, point out that "had bad luck caused events to play out in a different way" they could have resulted in "harm to motorists or the convoy crew or damage to the deadly cargo being carried by the convoy."[105]

Records of operational incidents record that convoys have been dogged by numerous protest actions over the years, resulting in delays or causing the convoy to change its route. Protest actions raise security concerns if they result in significant delays to convoy journeys. In February 1997 fifty anti-nuclear protesters stopped a nuclear weapons convoy travelling to Scotland close to Hadrian's Wall following an overnight stop at Albermarle Barracks near Newcastle. Ten protesters chained themselves onto convoy vehicles to prevent them from moving and three more locked themselves to trucks while others climbed onto their roofs. Nine people were arrested. The convoy was stopped for a large part of the morning while police cleared the demonstrators away, and convoy security procedures were said to have been reviewed following the incident.[106] Special nuclear materials convoys have also been stopped for extended periods by protesters on at least one occasion. On 15 March 1995 a Greenpeace road block trapped a special nuclear materials convoy carrying plutonium from the Sellafield reprocessing plant in Cumbria to AWE Aldermaston in Berkshire. The convoy was stopped close to the M6 near Stafford and was delayed for two hours when protesters used industrial staple guns to fix themselves to the tarmac roadway in front of the vehicles. 46 activists were arrested during the action.[107]

101 Rob Edwards, op cit.
102 Rob Edwards, op cit.
103 Rob Edwards, op cit.
104 Westminster Hall Debate: 'Nuclear Weapons (Transportation)'. Hansard, 7 July 2015, Column 34WH http://www.publications.parliament.uk/pa/cm201516/cmhansrd/cm150707/halltext/150707h0001.htm#15070737000001
105 Nukewatch: 'FOI records reveal nuclear warhead convoy safety faults'. 3 August 2014. http://www.nukewatch.org.uk/?p=475
106 Scottish CND: 'Bravehearts stop nuclear convoy'. 27 February 1997. http://www.banthebomb.org/archives/news/970227.htm 'Braveheart convoy': https://www.youtube.com/watch?v=Jb-Fw7kHtQ8
107 Greenpeace media library image GP0E5W, 15 March 1995. http://media.greenpeace.org/archive/Plutonium-Lorry-Blockade-in-UK-27MZIF7PHMQ.html

EMERGENCY ARRANGEMENTS

There have been a number of accidents involving nuclear convoys over the years, but as the MoD points out, none of these has resulted in a release of radioactive material into the environment. What would happen if, heaven forbid, a warhead convoy was involved in an accident which did result in a radioactive release?

The answer is given in the 'Local Authority and Emergency Services Information' (LAESI) document – MoD guidelines which provide instructions for the emergency services, local authorities and health authorities on contingency arrangements to be implemented during an emergency during the transportation of defence nuclear material.[108] Now in its tenth edition, the LAESI guidelines specify that in the event of a radiation emergency involving a nuclear weapon, a circular exclusion zone should be set up at a radius of 600 metres from the site of the accident from which members of the public should be evacuated. A downwind shelter zone covering a 45 degree sector out to a distance of fivve kilometres should also be drawn up, in which people would be advised to take shelter indoors to reduce the risk of radioactive contamination.

The LAESI guidelines and other warhead convoy emergency arrangements are exercised regularly through a series of national level 'Senator' exercises which take place on a regular basis, involving personnel from the various military and civilian agencies that would contribute to the response to such an accident.[109] One of the accident scenarios which has been rehearsed by the MoD in a Senator exercise is a disaster where a warhead convoy is hit by a crashing aircraft. Far-fetched though this scenario may seem, an aircraft crash took place close to a warhead convoy in a near-miss incident in the autumn of 1997.

At 4.20 pm on 31 October an RAF Harrier jet came in to land at RAF Wittering in Cambridgeshire in poor weather. During the approach the Harrier's engine began to lose power and the pilot ejected. The aircraft crashed into woodland near the base and was destroyed.[110] Earlier that same afternoon a convoy with four trucks carrying Trident nuclear warheads from AWE Burghfield to RNAD Coulport had entered RAF Wittering for an overnight stop. The location where the Harrier crashed was just 100 metres from the A47 road used by the convoy two hours previously, and half a mile from a secure area on the base where the convoy vehicles were parked.[111]

After the accident Group Captain Chris Moran, the Base Commander at RAF Wittering said that "RAF Wittering has Special Duties towards nuclear weapons carriers, and Special Contingency Plans for emergencies", but there was no danger, "because aircraft are always kept away from the High Security Area". He said he could "make no comment" on the convoy movement earlier in the day.[112] The MoD later admitted that "a review of the safety of nuclear weapons convoys was not carried out as a result of the aircraft crash" as they considered that "one aircraft crash that did not jeopardise the safety of a nuclear convoy" would not be sufficient to prompt a specific review, and because the Operational Safety Case for the Transport of Nuclear Weapons already took account of the risk of an aircraft crash.[113] Nevertheless, measures are now taken to ensure that warhead convoys are kept away from military establishments when low flying is underway: records show that in March 2012 a convoy was re-routed "due to proximity of low flying" at a MoD establishment.[114]

108 Ministry of Defence: 'Local Authority and Emergency Services Information'. August 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/361976/LAESI_10.pdf
109 Rob Edwards, op cit. Pp 9-12
110 Ministry of Defence: 'Military Air Accident Summary: Aircraft Accident to Royal Air Force Harrier ZD324'. October 1999.
111 Interview with Kate Riley, 8 January 2013.
112 Nukewatch: 'Harrier jet crashes 400 yards from nuclear warheads in transit, Friday 31.10.97' Press release, 31 October 1997.
113 Ministry of Defence: Response to Freedom of Information Act request DES Pol Sec/ 093729-006, 21 November 2008.
114 Rob Edwards, op cit. P16.

CASE STUDY 2

Date: 10 January 1987

Location: West Dean, Wiltshire

Weapons involved: Four Royal Navy WE177A tactical nuclear bombs

The truck being raised by crane the morning after the accident. Image credit: Bob Naylor: WaterMarx

SLIPPING OFF THE ROAD

It was described by a leading politician as "one of the most serious accidents involving nuclear material ever to be made public". Certainly it was the most visible – and embarrassing – accident involving UK nuclear weapons which has yet occurred[115].

The West Dean transport accident occurred on a wintry day in January 1987 when an RAF nuclear weapons convoy was moving WE177A tactical nuclear weapons from Portsmouth Naval Base to the Royal Naval Armaments Depot at Dean Hill as part of "routine Naval transfers" of the weapons. The aircraft carrier HMS Illustrious was berthed at Portsmouth at the time, and it is thought that the weapons were being moved into onshore storage while the ship was at the port.

Shortly after turning off the main A36 road at around 3.45 pm, the convoy moved down a narrow country lane between the villages of West Grimstead and West Dean on the final stage of its journey to Dean Hill. A car approaching from the opposite direction stopped to let the heavy lorries pass, and the convoy escort vehicles and two of the four warhead carriers went by safely. However, as the third carrier approached the car the driver lost control and a combination of icy road conditions and the road camber caused it to slide off the road. According to the official inquiry report into the accident, "Both front and rear nearside wheels of the TCHD [Truck Cargo Heavy Duty – warhead carrier] ran onto the verge, which gave way. The TCHD toppled to its left, coming to a halt on its side in a field three feet below the level of the road". The driver of the civilian car told the inquiry "I heard a sliding noise and a thump and I looked round and saw the vehicle lying on its side in a field". The fourth warhead carrier in the convoy

slewed across the road on the ice as the driver braked and came to rest precariously balanced on the verge, with its front wheels off the road.[116]

Troops from the Royal Air Force Regiment and Royal Marines who were travelling with the convoy immediately placed a security cordon around the site and were soon joined by reinforcements from the MoD Police based at Dean Hill. The convoy crew alerted the civilian emergency services and experts from the Atomic Weapons Research Establishment (AWRE) were called out to advise on whether the stricken trucks could be moved safely.

The fourth truck, still on the roadway, was winched back on to the road and was able to move away under its own power but the vehicle which had fallen into the field proved more of a problem. Heavy lifting gear was called for, arc lights set up, and the recovery team worked through the night in temperatures of –10 degrees Celsius, first inspecting the warheads and then packing the back of the truck with padding to prevent them from moving when it was lifted. At first light the truck was righted and lifted back onto the road by a 50 ton crane and then, 18 hours after the accident, it was towed ignominiously into the Dean Hill base under heavy military escort with helicopters hovering overhead.[117]

When the accident happened the warhead convoy was being tracked by members of the 'Polariswatch' monitoring group, who immediately alerted the media. As a result film footage of the night-time recovery operation was broadcast as the lead story on prime time news bulletins and made the front page of the following day's newspapers. Protesters managed to infiltrate the police cordon around the crash site and get to within 50 metres of the toppled lorry where they were stopped by armed soldiers. One of the protesters, Sarah Graham, said "we were

The truck being raised by crane. Image credit: Bob Naylor: WaterMarx

115 Atomic Weapons Research Establishment: 'TCHD Accident – West Dean, 10.1.87. AWRE View'. Document reference SDE/PFG/105/07, 16 January 1987.
Royal Air Force: 'Board of Inquiry Assembled at Headquarters Royal Air Force Support Command on 11 January 1987'. Document reference MoD/F102 S no.569, 11 January 1987.
Peter Davenport: 'Recovery of stricken truck lasts 18 hours'. The Times, 12 January 1987.

116 Royal Air Force, op cit.

117 BBC Television news report: 'West Dean Warhead Convoy Accident January 1987'. 10 January 1987. https://www.youtube.com/watch?v=luvknRCyD-o

told if we advanced any further they'd shoot us, they were carrying live ammunition". The troops told her that she knew "even more than they do" about what was happening as the situation developed.

The MoD sent a media team to the crash site, but refused to say whether the convoy had been carrying nuclear weapons. MoD spokesperson Keith Ansell said: "All I can tell you is that a military transport vehicle suffered an accident this afternoon and we are now endeavouring to put it right". When asked by reporters whether local people were at any risk, he replied "I can tell you there were no casualties."[118]

> *"We were told if we advanced any further they'd shoot us, they were carrying live ammunition"*

Documents subsequently released by the MoD under the Freedom of Information Act revealed that the convoy had been transporting six WE177A nuclear weapons and that each of the two trucks involved in the crash had been carrying two warheads. The four weapons involved in the accident were inspected over the next few days at the Dean Hill base by personnel from AWRE and the Royal Aircraft Establishment and were deemed to be "safe for movement and storage in the magazines", although as two of them were approaching their refurbishment date, "it would be prudent to refurbish prior to Service return."[119]

The MoD was heavily criticised for allowing the convoy to take to the road in poor weather. Opposition defence spokesperson Martin O'Neill said that if nuclear material had been involved in the incident, it would be "one of the most serious such accidents ever made public" and said that it "defied reason" for the convoy to have been sent out in such treacherous weather. ITN News asked whether, "faced with last night's icy conditions, should the convoy have moved at all?"[120]

An RAF Board of Inquiry was set up to investigate the incident and found the cause of the accident to be "a combination of slow forward speed, the camber of the road, slippery conditions, the soft verge, and the position of the stationary civilian car." All personnel involved "were considered to have shown adequate care" and "no person was held to be blameworthy". However, the inquiry team heard evidence from the MoD Police officer in charge of policing at Dean Hill who told them that "the road from West Grimstead is particularly prone to icing" and that the local Council was "notorious in this area for failing to grit the minor roads". He said that he was "not advised of the route the convoy was taking" and was "very surprised, as this road had never been previously used in my experience". The Board of Inquiry recommended that in future Convoy Commanders should confirm with their destination base that there were no local factors which might affect their journey, and that country roads taken by warhead convoys should be resurveyed to ensure they were safe to use.[121]

118 BBC television news report, op cit.
119 Atomic Weapons Research Establishment, op cit.
120 ITN news report: ''West Dean Warhead Convoy Accident January 1987'. 10 January 1987. https://www.youtube.com/watch?v=luvknRCyD-o
121 Royal Air Force op cit.

STORAGE AND HANDLING OF NUCLEAR WEAPONS

For large periods during their lives nuclear weapons are not usually deployed on submarines, ships, or aircraft. During peacetime, they are likely to spend a significant amount of time in storage. This was certainly the case during the Cold War when the UK held much larger numbers of nuclear weapons than it does now – although it is less so today following reductions in warhead numbers. The number of weapons now deployed on board submarines, though smaller in absolute terms than during the Cold War, represents a greater proportion of the total UK nuclear arsenal.

Whilst in storage nuclear weapons are in a relatively low risk environment, as they will not normally be moved around or subjected to human interaction, and so they should be relatively safe unless an accident occurs to the storage magazine itself – such as a fire or lightning strike. However, the weapons will inevitably need to be moved at some point for maintenance, inspections, exercises, or deployment. The handling and movement of nuclear weapons introduces new risks – especially during lifting operations, where there is a risk that the weapon may be dropped. This section of the report looks at instances where accidents have occurred during the storage and handling of British nuclear weapons.

8 INCIDENTS, INCLUDING:

- **2** Incidents involving failure or degradation of infrastructure or equipment
- **2** Incidents where there was a risk of unintentional nuclear detonation
- **8** Incidents involving mishandling of nuclear weapons
- **4** Incidents where a nuclear weapon was damaged

INCIDENTS INVOLVING ROYAL AIR FORCE NUCLEAR WEAPONS

The early 'Green Grass' warhead, carried in the Mark 1 version of the RAF's 'Yellow Sun' nuclear bomb, was designed to far less stringent safety standards than modern nuclear weapons. An accident which crushed or collapsed Green Grass's hollow core of highly enriched uranium, such as a sudden shock or a fire, could have caused a spontaneous nuclear chain reaction, so to prevent this from happening the warhead employed a rudimentary safety feature: when in an unarmed condition it was filled with a large number of ball bearings to prevent it from becoming compressed. The ball bearings would have been tipped out of the weapon to arm it after it had been loaded onto an aircraft. On at least one occasion the ball bearings from a Yellow Sun bomb were accidentally dropped out of a weapon and scattered across a hangar floor, leaving the bomb armed and vulnerable.[122]

Another early incident took place in 1963 at RAF Coningsby during an exercise in the small hours of the morning. A number of nuclear bombs were being towed together out of the base's Special Storage Area (SSA) when the rear trolley in the chain unhitched and broke free, rolling into a ditch 50 metres from the storage area. To make matters worse, the loss of the weapon was not observed at the time and was only discovered

122 Brian Burnell: 'Violet Club'. Nuclear Weapons website, http://www.nuclear-weapons.info/vw.htm#Violet%20Club ''Proceedings of the RAFHS Seminar on the RAF and Nuclear Weapons, 1960 – 1998'. Royal Air Force Historical Society Journal No. 26, 2001. Account by Air Commodore Owen Truelove, p96. http://www.raf.mod.uk/rafcms/mediafiles/F0B8FBE8_5056_A318_A85757EE24B2B010.pdf

123 Chief Scientific Adviser: 'Report on the Safety of Nuclear Weapons' (the 'Oxburgh Report'). Ministry of Defence report CSA 42/5/1/1 (46/62), 12 February 1992. Para F2.1, p12, Appendix F.

at day-break. There are no records about the extent of any damage caused to the weapon.[123]

On at least six occasions WE177 nuclear weapons were suspected of leaking tritium – a radioactive gas which contributes to the fusion stage of the thermonuclear reaction. The first leak was discovered in a bomb store in RAF Akrotiri on Cyprus on 3 September 1973. UK based personnel from AWRE were deployed to Akrotiri in response to the incident and removed a suspected faulty seal, which they brought back to Britain with them. No one was reported contaminated or injured in the incident. A second, similar incident occurred at Akrotiri on 25 March 1974. The government of Cyprus was not told of either incident, and Ivor Davies, the deputy commanding officer of the RAF's Near East Bomber Wing said that "nothing happened and there were no accidents at all".

> ***To make matters worse, the loss of the weapon was not observed at the time and was only discovered at day-break***

The Ministry of Defence later described these incidents as "spurious radiation monitor alarms" resulting from incorrect operation of monitoring equipment, and said that no nuclear weapons had been damaged. As a result of the false alarms the pre-use check procedure for radiation monitors was modified. The MoD later admitted that a total of six such alarms took place, with two of the suspected tritium leaks taking place at RAF Honington, Suffolk, on 2 November 1973 and at RAF Waddington in Lincolnshire on 13 August 1975.[124]

A number of accidents have been recorded during lifting operations involving nuclear weapons. On 2 November 1974 an RAF WE177 weapon was being loaded onto an aircraft at RAF Laarbruch in Germany for a routine logistical flight. During the operation the weapon, in its transport container, was being moved by a jib crane between trolleys. The crane gear failed as the hoisting cable slipped on its drum, causing the container to fall and hit the ground. The extent of any damage was unknown, but according to the Oxburgh report it is believed that an AWRE team was called to attend the incident.[125] Other similar episodes happened: a live WE177 bomb was dented when it fell off its work stand at RAF Honington on 2 June 1976 while being loaded onto a Buccaneer aircraft, and on 20 July 1988 another WE177 was dropped at RAF Marham when the ground crew handling it failed to line up the weapon's centre of gravity properly.[126] The bomb was dented and was taken back to the Atomic Weapons Establishment for repairs. A more worrying accident took place at RAF Bruggen in Germany when a nuclear bomb slid off a trolley under tow by a Landrover as it was driven round a corner (see case study 3). The incident exposed routine breaches of safety regulations and staff and equipment shortages in the Special Storage Area at Bruggen where nuclear weapons were stored and maintained. Following the incident seven RAF personnel were disciplined for negligence.

INCIDENTS INVOLVING ROYAL NAVAL NUCLEAR WEAPONS

The Royal Navy also had problems in looking after its nuclear weapons. Various incidents have been recorded at the Royal Naval Armaments Depot at Coulport, the purpose-built facility near the Faslane submarine base in Scotland where warheads for the Navy's submarine-launched Trident missiles are stored. The Coulport depot was originally built in the 1960s to store Polaris missiles and warheads

124 Chief Scientific Adviser, op cit, p12, Appendix F.
Nukewatch UK: 'UK Nuclear Weapon Safety'. Undated. http://www.nukewatch.org.uk/?page_id=178
Andrew Gilligan and Rob Evans: 'How Britain hushed up nuclear accidents'. Sunday Telegraph, 28 June 1998.

125 Chief Scientific Adviser, op cit, p12, Appendix F.
Nukewatch UK, op cit.

126 Andrew Gilligan and Rob Evans, op cit.
Ewen MacAskill, Lucy Ward and Rob Evans: 'No 10 blocks move to end nuclear secrecy'. Guardian, 15 November 1999. https://www.theguardian.com/politics/1999/nov/15/freedomofinformation.uk

Polaris submarine HMS Repulse in the Firth of Clyde in 1979
Image credit: US DoD

for deployment on Resolution class submarines. In January 1968, when construction work for the Polaris programme was under way at Faslane and Coulport, a severe storm hit central and western Scotland. Coulport was badly damaged by the storm and the building programme suffered serious setbacks. The depot was intended to provide limited support from mid 1967 and to have been fully operational by March 1968, but by June 1968 the programme was running 12 - 15 months behind schedule, and Coulport had to commence work in "highly unsatisfactory conditions". As a result of the problems the US authorities, who had provided the Polaris missiles and technology, were unwilling to agree to nuclear safety certification for the Coulport base. Concerns remained right up to the moment it was necessary to load missiles onto the submarine HMS Resolution for the first ever Polaris patrol, and the missiles were only allowed to be loaded on board the submarine with extensive US oversight.[127]

The Oxburgh report discloses that in 1977 an accident occurred when a weapon was being winched on board the Polaris submarine HMS Renown at Coulport. The accident happened on 7 August, when a hoist which was being used to lift a Polaris missile broke, causing the missile to fall "a few inches". The missile did not impact upon any other object and there was no damage to either the missile or its warheads. An investigation revealed that a hoist fixture had been incorrectly assembled, causing the threads on a securing pin to strip and the hoist to fail. Following the inquiry improvements in documentation, test procedures, and inspection and working practices were implemented.[128]

Another Polaris missile was dropped at Coulport during an incident which took place in December 1987. Papers relating to this incident have been released following a request made under the Freedom of Information Act,[129] and it is now possible

127 Peter Hennessy and James Jinks: 'The Silent Deep: The Royal Naval Submarine Service since 1945'. Penguin Books, 2016. P250.
128 Chief Scientific Adviser, op cit, p12, Appendix F.
Nukewatch UK, op cit.
129 Ministry of Defence: 'Missile Loading Incident'. Undated and unattributed paper.
Ministry of Defence: 'RNAD Coulport. Jetty Missile Loading Incident. 3 December 1987'. Report of the Board of Inquiry. SDG9003A, 14 December 1987.
Ministry of Defence Head of Sec (FS): 'RNAD Coulport – Missile Loading Incident on 3 December 1987.' Loose Minute D/Sec (FS)/48/16 (AYA/0632/88), 10 February 1988.
130 Ministry of Defence undated and unattributed paper, op cit.

to piece together how the accident occurred. The submarine HMS Repulse had moored at the Coulport explosives handling jetty on 2 December, requiring an unplanned "short notice" exchange of Polaris missiles because one of the missiles on the submarine had suffered a "series of test failures".[130] A replacement missile was therefore scheduled to be lifted into one of the submarine's missile tubes in an operation which required it to be raised vertically from a trailer and then lowered into the tube.

> ***There was "clear evidence" of "delay, frustration, and an urgency to complete the operations quickly", which was "not conducive to the safe exchange of missiles"***

On the morning of 3 December a 50 ton jetty crane which was usually used for weapon loading was out of service for maintenance at the time, and so an older 40 ton standby crane was used for the job. The missile inside the submarine was successfully removed, but when the crane driver attempted to lift the replacement missile it failed to ascend. The work team decided to lower the missile to the horizontal position to investigate the problem. However, as the missile was being locked securely into place on its trailer, it began to rise without warning, and the rear wheels of the trailer's prime mover were lifted two to three inches off the ground. The locks broke, causing the trailer to fall to the ground as the missile twisted and oscillated and collided with supports on the trailer. The dangling missile was brought under control and recovered and the Coulport emergency headquarters was rapidly activated to deal with the incident. Subsequent checks showed that there was "absolutely no damage" to the missile.

Despite this, a Board of Inquiry investigation into the accident concluded that the lifting operation "was inherently high risk" and that personnel in the immediate vicinity of the lifting operation "were subjected to a high risk of injury".[131] "Excessive pressure" was put on staff at Coulport to exchange the missile in the submarine rather than consider other options for fixing the problem. There was "clear evidence" of "delay, frustration, and an urgency to complete the operations quickly", which was "not conducive to the safe exchange of missiles".

The inquiry concluded that the accident was the result of "human error on the part of the crane driver, following the development of a defect in the 40 ton crane". The crane driver had operated his crane in the hoist mode when no longer receiving directions to do so, but the Board were also "very concerned" about the condition and maintenance records of the 40 ton crane used for the lifting operation, for which "two major safety features were inoperative". The crane used for the lift had "suffered a long period of unreliability". The Board discovered that 40% of mechanical and electrical preventative maintenance routines for the crane were outstanding, and "had these been completed, and had the defects in control and instrumentation been reported and rectified it is highly probably that the incident would not have occurred". Controls on maintenance and defect repairs were "inadequate" and had a certification procedure to approve the use of the crane been in place "the crane would not have been cleared for use at the time of the incident".

A follow-up report revealed further concerns, with a senior manager expressing doubts that "a task of such high importance and risk potential should be entrusted to young Leading Hands who do not have the background and experience in Polaris to understand the full ramifications of departure from authorised procedures".[132] There was a lack of a "clear hierarchy of command" on the jetty on 3 December, with the Royal Navy Lieutenant who normally supervised the jetty being absent, and there were "shortcomings" in maintenance arrangements for the crane used to lift the missile. Procedures on deciding whether the missile needed replacing "were not followed" and "this led to the pressures surrounding the transfer". After the inquiry "substantial changes" were made to management responsibilities, training, command and control arrangements, and procedures for consultation with the Royal Navy.

131 Ministry of Defence Report of the Board of Inquiry, op cit.
132 Ministry of Defence Head of Sec (FS)

CASE STUDY 3

Date: 2 May 1984

Location: RAF Bruggen, Germany

Weapons involved: One WE177A free-fall nuclear bomb

The last WE177 shortly before it was taken out of service. A WE177 was involved in this case study as well as many other incidents

ROUGH HANDLING AT RAF BRUGGEN

In the afternoon of 2 May 1984 a Hercules transport aircraft landed at RAF Bruggen - on the front line in West Germany during one of the most intense periods of the Cold War.[133] The Hercules was on a 'routine logistical flight' to deliver a cargo of WE177 nuclear bombs from the UK to Bruggen. The bombs were unloaded from the aircraft later that evening and moved to the 'Special Storage Area' (SSA) at the base – the high security area where nuclear weapons were stored.

During the unloading job one of the WE177 bombs was loaded onto a flat top trailer towed by a Landrover to be driven to a storage building. As the Landrover turned a corner on its way to the bomb store the container holding the bomb "slid from the trailer; fell some 3.5 feet, and slid about 20 feet, coming to rest after rolling through 270 degrees". The container was recovered and moved into a servicing building where the bomb inside it was inspected. An impact mark three inches long was discovered on the body of the bomb, corresponding to damage to a tool box mounted inside the container. At this point the RAF decided that the weapon was unserviceable and called in experts from AWRE for advice. "They flew in a Hercules with

133 Ministry of Defence AC (Nuc): 'Accident to a containerised WE177 on 2 May'. Reference D/DP(N)/16/1/4, 30 May 1984.
Atomic Weapons Research Establishment: 'Incident at RAF Bruggen – A Viewpoint'. Reference SDE/WHJ-JRG/15/01/84, 6 June 1984.
134 Andrew Gilligan and Rob Evans, op cit.
135 Ewen MacAskill, Lucy Ward and Rob Evans
136 Royal Air Force: 'Board of Inquiry convened at RAF Bruggen at 1430 hours on 3 May 1984'.

a special decontamination unit and cordoned the whole area off", said one RAF mechanic who was serving at Bruggen at the time of the incident.[134]

The AWRE response team took a series of radiographic images to examine the interior of the warhead, revealing a "crack-like feature" in the warhead's high explosive assembly. However, it was eventually concluded that the feature corresponded with an abutment where three explosive tile edges met and was quite normal. After three weeks of investigations the AWRE team concluded that the bomb was safe to move by normal means and it was returned to the UK for servicing. Air Chief Marshall Sir Patrick Hine, the RAF's commander-in-chief in Germany, inspected the damaged weapon and was given a comprehensive briefing about the results of the investigation. He afterwards said that the accident was "not serious", and added that the weapon was only superficially damaged.[135]

A Board of Inquiry was convened to look into the causes of the accident, and came to some disturbing conclusions.[136] The inquiry found that, contrary to regulations, the container had not been secured to the trailer before it was moved by the Landrover. Unsecured containers "were being moved regularly" within the Special Storage Area where nuclear weapons were stored, and personnel working in the storage area had not brought this to the attention of a higher authority. The engineering squadron responsible for explosives storage had been understaffed by 20% over the previous year, adding to the pressure to cut corners, and the practice of moving unsecured containers had been "accepted by the SSA staff as common practice for some considerable time".[137]

Unsecured containers "were being moved regularly" within the Special Storage Area where nuclear weapons were stored, and personnel working in the storage area had not brought this to the attention of a higher authority

There was "no justification" for failing to comply with mandatory requirements to secure containers holding nuclear weapons to trolleys before moving them. Although staff working in the storage area had complained that there was a shortage of restraining kits used to tie down the containers, no-one had made "any determined effort" to address the problem. The inquiry found that non-compliance with regulations directing the transport of nuclear weapons had been "directly and wholly responsible" for the damage to the bomb, and concluded that seven RAF personnel, including two officers, had been negligent in their duties.[138]

The Bruggen Station Commander agreed with the inquiry finding that the movement of unrestrained containers was "inexcusable" and was "disappointed" that "this malpractice had become routine". The non-commissioned officers in the SSA who allowed the movement of unrestrained containers knew that it was dangerous but "took no action to stop this malpractice". The Warrant Officer in charge of handling nuclear weapons had condoned a "flagrant disregard" of mandatory regulations and was suspended from his duties and moved to a new post "because I have lost confidence in him to run my SSA". The base's Deputy Commander added that "not one of those directly involved at Bruggen was or had been very concerned about the breach of this particular regulation". Officers knew that rules were being broken but failed to report the effects that lack of staff and equipment were having on compliance with safety procedures and also failed to provide adequate supervision. The officers involved were considered by the Deputy Commander to have "forfeited the trust" required from those responsible for handling special weapons and both were removed from their posts.[139]

137 Royal Air Force, op cit.
138 Royal Air Force, op cit.
139 Royal Air Force, op cit.

IN THE FIELD: INCIDENTS INVOLVING AIRCRAFT AND SHIPS

As the UK's nuclear weapons programme expanded at the beginning of the 1960s the Ministry of Defence began to develop a series of new nuclear weapons intended for battlefield use. These entered service as the WE177 family of free-fall nuclear bombs. There were three versions of the WE177.[140] The first version to be deployed was WE177B, delivered to the Royal Air Force in 1966 as a stop-gap measure intended to maintain the nuclear capability of the UK's V-bombers over the period immediately before Polaris submarines entered service. WE177A was designed to replace the 'Red Beard' tactical nuclear weapon and had a dual role with both the RAF and the Royal Navy for use against surface targets on either land or sea, delivered by fixed-wing aircraft, or as an anti-submarine nuclear depth bomb delivered by helicopter. WE177A entered service with the Navy in 1969 and the RAF in 1971. The WE177C variant was deployed with the Royal Air Force in Germany as a tactical strike weapon in the 1970s. The Navy's WE177 weapons were retired by 1992 and all RAF variants had been retired by 1998.

The growing size of the UK's arsenal, and the deployment of tactical nuclear weapons on board ships and aircraft increased the potential for accidents to occur in the field. NIS is only aware of two incidents involving a British nuclear weapon loaded onto an aircraft,[141] although records exist of a number of events when ships which carried, or may have been carrying, nuclear weapons were involved in hazardous situations.

21 INCIDENTS, INCLUDING:

- 5 Fires
- 2 Explosions
- 2 Aircraft crashes
- 1 Incidents where there was a risk of unintentional nuclear detonation
- 2 Incidents involving mishandling of nuclear weapons
- 2 Incidents where a nuclear weapon was damaged
- 1 Incident involving a lightning strike
- 7 Incidents involving a collision between ships and/or submarines

LIGHTNING STRIKES

The weather on the night of 8 August 1967 in Lincolnshire was as filthy as it could possibly get. It was a stormy evening, and heavy rain lashed across the open countryside. Four miles south of the city of Lincoln, thunderclouds emptied their contents onto the Royal Air Force airbase at Waddington and onto the aircraft parked in the base's ground alert area – Vulcan V bombers ready to take

140 Brian Burnell: 'WE177'. http://www.nuclear-weapons.info/vw.htm#WE.177

141 There is a number of cases where RAF nuclear weapons were involved in dangerous occurrences away from aircraft which are discussed in section 4 of this report.

A Vulcan V bomber shortly after takeoff.
© Crown copyright IWM (tr 34537)

off at an instant's notice. Throughout the 1960s Waddington's Vulcans stood on a 24 hours-a-day, 7 days-a-week 'Quick Reaction Alert', able take off within 2 minutes in the event of war to spearhead a nuclear attack on the Soviet Union.

As the rain fell the station's ground crew hugged whatever shelter they could find as they went about their duties. A sudden bolt of lightning flashed shockingly close by – and the ground staff looked on aghast as it struck one of the fully armed Vulcan jets loaded with a WE177 nuclear bomb in the ground alert area. The base personnel could only hold their breath and watch helplessly. "It was a bit like a firework which you have lit and it has not gone bang", said one of the airmen afterwards. To everyone's immense relief nothing happened: despite receiving a direct hit from the lightning bolt, the aircraft did not catch fire or explode. A thorough inspection afterwards revealed that although the aircraft had been scorched by the flash, the nuclear bomb it carried had not been damaged.[142]

A sudden bolt of lightning flashed shockingly close by and the ground staff looked on aghast as it struck one of the fully armed Vulcan jets loaded with a WE177 nuclear bomb in the ground alert area

This does not appear to have been the first dangerous incident that had occurred involving an RAF aircraft loaded with nuclear weapons. Newspaper reports in 1999 claimed that documents in the National Archives had revealed that in 1959

142 Ewen MacAskill, Lucy Ward and Rob Evans: 'No. 10 blocks move to end nuclear secrecy'. Guardian, 15 November 1999. https://www.theguardian.com/politics/1999/nov/15/freedomofinformation.uk
Defence of the Realm: 'Nuclear armed Vulcan bomber struck by lightning (1967)' https://www.youtube.com/watch?v=Hp6932yskMg

A Vulcan V bomber at an air show in 1984
Image credit: US DoD

"a 2000-pound nuclear weapon was accidentally jettisoned from the bomb bay" of a Valiant V-bomber returning from an exercise.[143] Although no official inquiry was conducted, the entry for the station log-book at RAF Wittering for 7 May 1959 records that "severe damage resulted to the weapon upon hitting the hard standing". The account was corroborated by Squadron Leader Del Padbury, who witnessed the incident. The MoD stated that the weapon that was dropped was a training round containing no explosives or radioactive materials, although it is not clear on what basis this claim was made given the lack of surviving documentation about the incident.

As far as we are aware, these are the only recorded cases of accidents involving British nuclear weapons loaded onto an aircraft. The US Air Force has a far more chequered record. This is partly because the American nuclear arsenal was much larger than Britain's, but it was also a consequence of the Strategic Air Command's posture of 'airborne alert' through most of the 1960s – the practice of ensuring that at all times nuclear armed B52 aircraft were in the air ready to launch an immediate strike on the Soviet Union.

With hindsight it is not surprising that some of the most serious accidents involving US nuclear weapons occurred to bombers in flight on airborne alert missions. 'Broken Arrow'[144] incidents resulting from airborne alert flights occurred in 1961 in Goldsboro, North Carolina and Yuba City, California; in 1964 at Savage Mountain, Pennsylvania; in 1966 at Palomares in Spain, and in 1968 at Thule in Greenland.[145] The day after the Thule accident the airborne alert programme was terminated, having been deemed to pose unacceptable safety risks.

143 Duncan Campbell: 'Nuclear missile error that could have ravaged Lincolnshire was kept secret'. Independent, 6 October 1999. http://www.independent.co.uk/news/science/nuclear-missile-error-that-could-have-ravaged-lincolnshire-was-kept-secret-738686.html Ewen MacAskill, Lucy Ward and Rob Evans, op cit.

144 US military terminology for an accident involving a nuclear weapons which causes the unauthorised launch or jettison of a weapon, a fire, an explosion, a release of radioactivity, or a full-scale detonation.

INCIDENTS ON BOARD SHIPS

A variety of Royal Navy ships carried helicopters or aircraft - destroyers, cruisers, and aircraft carriers - and these were all in theory capable of deploying nuclear free-fall bombs and depth charges. In practice the MoD adopted a policy to 'neither confirm nor deny' the presence of nuclear weapons at any given location, and this policy applied to commenting on whether any individual ship carried nuclear weapons at a particular time. Nevertheless, Royal Naval ships routinely carried nuclear weapons throughout the 1980s - sometimes in the most unexpected of circumstances, such as during overseas 'goodwill' tours, and into war zones, including the South Atlantic Ocean during the 1982 Falklands war (see case study 4). The practice continued until 1993, at which point all the Navy's WE177 weapons had been withdrawn from service.

The earliest incident involving a naval nuclear weapon on board a ship which has been acknowledged by the MoD took place in January 1960, when a component in a Red Beard weapon on board the aircraft carrier HMS Victorious jammed following its removal for routine testing at sea.[146] The component was removed for examination and there was an initial concern that the assembly might have overheated. However, an investigation by AWRE determined that this had not been the case and concluded that there were no safety implications arising from the incident. The problem with the weapon on board the aircraft carrier was judged to have been caused by incorrect manufacture of the equipment used to remove the component. The fault was corrected and the problem did not occur again.

Another accident occurred in February 1974 as the cruiser HMS Tiger was visiting Malta. Whilst the ship was off Valetta harbour torpedoes were being moved in the ship's magazine. As two Mark 44 torpedoes were being lifted from a storage rack a hoist rail collapsed, and the torpedoes fell a few inches onto a live WE177 nuclear weapon. The drop could have caused both the torpedoes and the WE177 to explode, but fortunately damage was limited to "superficial scratching" to plastic protective strips on the WE177's tail fin. A witness to the incident told the Sunday Telegraph newspaper: "It was a mistake. A couple of sailors were hurt, but not badly." A Board of Inquiry investigation into the incident concluded that crew members had incorrectly rigged the torpedo handling equipment, and modifications were made to the hoist design as a result.[147]

HAZARDS TO SHIPS

As well as on-ship events during the routine handling of nuclear weapons, dangerous situations arose where the fate of an entire ship was at stake. Unfortunately accidents are a feature of life on the high seas. The oceans and weather can be hostile and intense, and the nature of naval operations and the hazardous materials carried on board warships add to the dangers. Sinkings, groundings, collisions, fires, and explosions have occurred in dockyards and ports, coastal waters, and far out at sea. Many maritime accidents have been spectacular and are well known, but even more are obscure and unpublicised - especially when they relate to sensitive naval operations.

In 1989 William M. Arkin and Joshua Handler undertook a study into naval accidents over the period 1945 – 1988 on behalf of Greenpeace and the Institute for Policy Studies. A comprehensive register of naval accidents does not exist, but Arkin and Handler reported that, over the 43 year period that they studied, the world's largest navies had

145 Michael Krepon: 'Broken Arrows'. Arms Control Wonk blog, 26 December 2011. http://www.armscontrolwonk.com/archive/403310/broken-arrows/

146 Nukewatch UK: 'UK Nuclear Weapon Safety'. Undated. http://www.nukewatch.org.uk/?page_id=178

147 Nukewatch UK, op cit.
Andrew Gilligan and Rob Evans: 'How Britain hushed up nuclear accidents'. Sunday Telegraph. 28 June 1998.

TABLE 1:
ACCIDENTS INVOLVING NUCLEAR CAPABLE ROYAL NAVY WARSHIPS, 1962-1988:[148]

DATE	SHIP	DETAILS
29 April 1962	HMS Ark Royal	A Gannet aircraft crashed onto the aircraft carrier Ark Royal while the ship was participating in a SEATO exercise in the South China Sea, killing one person.
3 May 1962	HMS Eagle	Damage to electrical cables on board the aircraft carrier HMS Eagle was investigated by police.
14 October 1970	HMS Eagle	Aircraft carrier HMS Eagle was placed in dry dock following a collision.
9 November 1970	HMS Ark Royal	Aircraft carrier HMS Ark Royal collided with a Soviet Kotlin class destroyer in the eastern Mediterranean Sea. The Ark Royal was only slightly damaged, but the destroyer was badly scraped along the port side.
26 March 1971	HMS Albion	Aircraft carrier HMS Albion developed a fault in a drive shaft bearing and was forced to return to Portsmouth for repairs.
15 October 1971	HMS Ark Royal	Fire broke out on board aircraft carrier Ark Royal in Portsmouth naval base.
21 October 1971	HMS Ark Royal	A second fire broke out on board the Ark Royal, taking six hours to bring under control.
19 July 1978	HMS Devonshire	A helicopter crashed after striking County-class destroyer HMS Devonshire whilst undertaking a fly-past during an air display.
13 December 1978	HMS Hermes	Helicopter carrier HMS Hermes was damaged by fire in a mess deck. Damage was not severe.
1 May 1981	HMS Glasgow	Type 42 destroyer HMS Glasgow collided with Soviet cruiser Admiral Isakov in the Barents Sea as the cruiser was manoeuvring dangerously.
19 October 1984	HMS Glamorgan	County-class destroyer HMS Glamorgan collided with the German frigate Bremen in a gale.
5 August 1985	HMS Ark Royal	Aircraft carrier HMS Ark Royal was blown from its berth at Portland by 50 mile-per-hour winds. No damage was done and the ship was moved back into place by two Navy tugs.
1 September 1988	HMS Southampton	Type 42 destroyer HMS Southampton collided with the container vessel Torbay 70 kilometres north of the United Arab Emirates, injuring three of the destroyer's crew.

Aircraft carrier HMS Ark Royal
Image credit: Ian Visits/Wikipedia

had over 1,200 documented major accidents. They concluded that routine naval activity "carries with it unequalled potential for crisis or crisis escalation", and that the deployment of nuclear weapons "brings an added dimension to naval accidents, namely the potential for nuclear weapons or reactors being damaged, destroyed, or lost".

Not surprisingly, Arkin and Handler's study lists a number of accidents which involved nuclear capable Royal Navy warships. The 'neither confirm nor deny' policy of the time, combined with the limited archive material available, means that it is difficult to know for certain whether or not an incident on board a particular ship at a particular time would, in fact, have posed a hazard to nuclear weapons. However, during the Cold War nuclear weapons were routinely deployed on the Royal Navy's ships, so it is likely that at least some of these incidents took place on ships loaded with nuclear weapons. Table 1 details accidents catalogued by Arkin and Handler which are known to have occurred on board nuclear capable Royal Navy ships, although it is not known whether nuclear weapons were actually deployed on board at the time of the incident.

The entire ship was brought to emergency stations to fight the fire, which was contained within the area of the plant and eventually brought under control

Some of the accidents involving British warships were potentially serious. In 1971 the aircraft carrier HMS Eagle set sail for Australia. Whilst crossing the Java Sea an explosion occurred and a fire broke out in one of the ship's liquid oxygen plants - a "very serious and potentially extremely dangerous" occurrence.[149] The entire ship was brought to emergency stations to fight the fire, which was contained within the area of the plant and eventually brought under control. The damage was severe but localised. Two crew members were injured in the explosion seriously enough to require airlift to the British Military Hospital at Singapore, where one of them later died.[150]

Another serious incident involving a nuclear-capable aircraft carrier took place on the night of 3 April 1986 as HMS Illustrious set off on a 'fly the flag' round-the-world tour. As the engine reached

148 William M. Arkin and Joshua Handler, op cit. Pp 29, 43, 44, 45, 56, 57, 61, 67, 68, 72.
149 Anonymous: 'HMS Eagle 1970 – 1972'. P8. http://www.axfordsabode.org.uk/pdf-docs/eagle05.pdf
150 Anonymous, op cit.

full power after it had left harbour oil vapour surrounding the gearbox exploded, causing a fire which lasted well over four hours. At one point during the fire the captain began preparations to abandon ship, but was over-ruled by the Admiral in charge of the expedition who believed that the ship could be saved. Fortunately the incident did not result in loss of life or any serious injuries, but the tour was postponed for several months while Illustrious was taken out of service for extensive repair work, which cost four million pounds.[151]

We now know that Royal Navy warships routinely carried nuclear weapons during such round-the-world deployments. In June 1988 a flotilla of Royal Navy ships set sail from Portsmouth as Task Group 318.1 - a round-the-world deployment code-named Outback 88.[152] The purpose of the mission was threefold: to 'fly the flag' at overseas ports as a signal to demonstrate British goodwill; to participate in exercises with ships from allied nations, including the US Navy and the Royal Australian Navy, and to act as a showcase to display British military equipment in the hope of promoting arms sales. Among the countries that the task group would visit on its tour were Malta, Singapore, Brunei, Hong Kong, Thailand, and Papua New Guinea. The cruise culminated in a visit to Australia to participate in celebrations to mark the Australian bicentenary. The task group was led by the aircraft carrier HMS Ark Royal, accompanied by two warships – HMS Edinburgh and HMS Sirius – and three Royal Fleet Auxiliary ships: Fort Grange, Orangeleaf, and Olwen.

Before the Outback 88 deployment set off it had been the subject of questions in Parliament from Harry Cohen MP. Mr Cohen asked whether any of the ships in the task group would be carrying nuclear weapons, and what impact their six-month absence would have on NATO capabilities. He was given the standard answer at the time for questions relating to the presence of nuclear weapons on board Royal Naval ships - that it was government policy to neither confirm nor deny their presence - and told that the ships would remain assigned to NATO and could be redeployed to the NATO area in the event of an emergency.

But two of the warships in the task group – HMS Ark Royal and HMS Edinburgh – were nuclear capable, as was RFA Fort Grange, and the flotilla was carrying nuclear weapons. During a visit to Hong Kong Harbour RFA Fort Grange, with nuclear weapons among its load, was involved in a collision with a US Navy nuclear powered submarine, the USS Omaha, and a US ocean going tug, the USNS Sioux. The two American ships dragged anchor for a distance of one kilometre before colliding with the Fort Grange. All three vessels were damaged, but not seriously, and there was no radiological hazard. However, the collision was reported by the local press and the presence of nuclear weapons on board Fort Grange "was hinted at, but not confirmed", to the US authorities.[153] Although the Oxburgh report gives details of the vessels involved and the location of the incident, it was described in the list of nuclear accidents provided to Parliament as a "minor collision of a non-UK vessel with a moored UK vessel which was carrying nuclear weapons, about which "no specific information" was available.

Following the end of the Cold War the Navy's tactical nuclear weapons were redundant, and by 1992 the Naval WE177A weapon had been withdrawn from service. By 1993 the Navy felt able to relax the neither confirm nor deny policy on the presence of nuclear weapons, and stated that its surface warships no longer carried nuclear weapons. The risk of a nuclear weapons emergency involving a Royal Navy surface warship has now been eliminated – unless, of course, it collides with a nuclear-armed submarine.

151 'R 06 HMS Illustrious'. Seaforces-online website. http://www.seaforces.org/marint/Royal-Navy/Aircraft-Carrier/R-06-HMS-Illustrious.htm
William M. Arkin and Joshua Handler, op cit. P69.

152 Parliamentary written question: 'Exercise Outback 88'. Hansard, 28 March 1988, Columns 358-9W. http://hansard.millbanksystems.com/written_answers/1988/mar/28/exercise-outback-88
Historical RFA website: 'Fort Grange'. http://www.historicalrfa.org/rfa-fort-grange-ship-information

153 Chief Scientific Adviser: 'Report on the Safety of Nuclear Weapons' (the 'Oxburgh Report'). Ministry of Defence report CSA 42/5/1/1 (46/62), 12 February 1992. Para F2.1, p13, Appendix F.

CASE STUDY 4

Date: April - July 1982

Location: South Atlantic

Weapons involved: Unknown number of Royal Navy WE177A nuclear depth bombs

HMS Brilliant was hit by enemy fire during the Falklands War, but the nuclear weapons on board had already been transferred to another ship
Image credit: US DoD

NUCLEAR WEAPONS AND THE FALKLANDS WAR

On Friday 2 April 1982 Argentina invaded the Falklands Islands, triggering the start of the Falklands War. The British government was quick to respond, and by 5 April had dispatched a task force of Royal Naval, Royal Fleet Auxiliary, and requisitioned civilian vessels to the South Atlantic to retake the islands. The task force was assembled with great haste, and ships were ordered south from their routine deployments with little notice and minimal preparation time.

Throughout the Falklands war and for many years afterwards newspapers regularly reported that ships in the task force had sailed for the Islands loaded with nuclear weapons. These reports included speculation that the Navy was prepared to use the weapons if necessary to retake the Islands; that the UK was in breach of the Treaty of Tlatelolco, which established a Nuclear Weapons Free Zone in Latin America, and to which the UK was a signatory; and that nuclear weapons had been lost when HMS Coventry, a nuclear-capable Type 42 destroyer, was sunk by enemy action. The MoD's policy to 'neither confirm nor deny' the presence of nuclear weapons at any place or time merely added to the rumours.

In 2005, under Tony Blair's government, the MoD published its definitive account of the carriage of nuclear weapons by the Falklands task force.[154] The report confirmed that some of the ships in the task group assembled to undertake Operation Corporate - the military campaign to recapture

154 CBRN Policy, Ministry of Defence: 'Operation CORPORATE 1982: The carriage of nuclear weapons by the Task Group assembled for the Falklands campaign'. 2005. http://webarchive.nationalarchives.gov.uk/20121026065214/http://www.mod.uk/NR/rdonlyres/4625B8A4-C533-4DAD-9FA5-0BFEE58F8D69/0/op_corporate1982_nuclear_weapons.pdf

the Falklands - did indeed carry nuclear weapons. These were WE177A nuclear depth bombs and were deployed on board the aircraft carriers HMS Invincible and HMS Hermes and the Type 22 frigates HMS Broadsword and HMS Brilliant. The loss of Hermes or Invincible during the conflict would have had extremely serious implications: Hermes was carrying 40% of the Royal Navy's entire stockpile of nuclear depth bombs, and Invincible was carrying a further 25% of the stockpile.[155]

For a combination of operational, safety, and security reasons a decision was taken not to remove the weapons from the task group but to concentrate them on board larger ships with armoured deep magazines which were considered to be able to withstand attacks by air, torpedo, or Exocet missile.

The weapons in Broadsword and Brilliant were transferred at sea by heavy jackstay to Hermes and Invincible, and to the Royal Fleet Auxiliary ships Fort Austin, Regent and Resource. Surveillance and training rounds were also removed from HMS Sheffield, HMS Coventry, and HMS Glamorgan. A further "complex series of movements" between ships in the later stages of the war allowed vessels to temporarily offload nuclear weapons and enter territorial waters around the Falklands Islands to engage in conflict operations without breaching the Treaty of Tlatelolco.

A heavy jackstay in use in 2012. A device of this type was used to transfer nuclear weapons at sea between ships that went to the Falklands

Image credit: Royal Navy Media Archive/Flickr

155 On the basis of these figures and other information in the Ministry of Defence report on Operation Corporate and nuclear weapons, NIS estimates that when the task force set off HMS Hermes was carrying 16 nuclear weapons; HMS Invincible was carrying 10, and the frigates HMS Broadsword and HMS Brilliant were each carrying one.

156 BBC News: 'HMS Coventry diver searched wreckage after ship sank'. 25 May 2012. http://www.bbc.co.uk/news/uk-england-coventry-warwickshire-18195170

157 Parliamentary Written Questions: 'HMS Sheffield'. Hansard, 17 May 1996. Vol 277, Columns 621-2W. http://hansard.millbanksystems.com/written_answers/1996/may/17/hms-sheffield

The MoD account states categorically that no task force ship was sunk while carrying a nuclear weapon: although HMS Sheffield and HMS Coventry were both lost to enemy action, the surveillance rounds that they carried had been offloaded before they sunk. HMS Brilliant was "hit by enemy fire" and "suffered relatively minor action damage" on 21 May whilst carrying a training round, but the training round contained no nuclear material. All the weapons were returned to Devonport at the end of the conflict in Fort Austin and Resource. A post-war Royal Navy diving operation to the wreck of HMS Coventry, rumoured by some to be a mission to recover a lost nuclear weapon, was in fact intended to recover or destroy sensitive information - believed to be secret signals coding documents[156] - whilst HMS Sheffield sunk in very deep water and no similar operations were attempted on the wreck.[157]

The loss of Hermes or Invincible during the conflict would have had extremely serious implications: Hermes was carrying 40% of the Royal Navy's entire stockpile of nuclear depth bombs, and Invincible was carrying a further 25% of the stockpile

However, during the various ship-to-ship transfers at sea, seven nuclear weapon containers received external damage in individual incidents. Sir Ron Oxburgh's report describes the damage as "ranging from minor damage to one container having its door housing severely distorted", and states that warhead casings received "only minor superficial damage".[158] This conflicts with an earlier report from AWRE, which stated that a detailed strip-down of at least one weapon had been undertaken and that "significant damage to the bomb casing" had been caused, although the warhead internals were undamaged.[159] All of the weapons involved were examined upon their return from the South Atlantic and were found to be "safe and serviceable".[160] As a result of these incidents the Commander-in-Chief Fleet "made a number of recommendations regarding weapon transfers".[161]

The MoD report on nuclear weapons and the Falklands acknowledged the considerable risks involved in taking nuclear weapons to the South Atlantic. The consequences if a ship carrying nuclear weapons was damaged or sunk during the conflict "could be serious", and it was "also conceivable that weapons might fall into the hands of the Argentines, by salvage" if a ship had been sunk, stranded or captured. "However unlikely, the consequences of this would be most serious and the acquisition of UK nuclear weapon technology in this way by a state which had no such weapon would have damaging consequences."[162] Ultimately, however, the decision was made to take the weapons south: the operational imperative to dispatch the task force as rapidly as possible was judged by Admirals and Ministers to take precedence over the safety advantages of returning the weapons to a home base.

158 Chief Scientific Adviser, op cit. Para F2.1, p13, Appendix F.
159 Atomic Weapons Research Establishment: 'TCHD Accident – West Dean, 10.1.87. AWRE View'. Document reference SDE/PFG/105/07, 16 January 1987. P3.
160 CBRN Policy, Ministry of Defence, op cit, p6.
161 Nukewatch UK, op cit.
162 CBRN Policy, Ministry of Defence, op cit, p4.

UNDER THE WAVES: ACCIDENTS INVOLVING NUCLEAR-ARMED SUBMARINES

In 1968 the Royal Navy took over responsibility for operating the UK's strategic nuclear weapons, first with the Polaris missile system and more recently through the Trident system. Both Polaris and Trident are submarine based platforms, operating from deep under the waves in the hope of evading detection by an enemy.

Submarines are inherently dangerous vessels – they operate deep under water, are armed with conventional weapons containing high explosives, require high pressure gases and pressurised steam to function, and are powered by a nuclear reactor.[163] During wartime they are a target for enemy action. Any fire, collision, loss of power, or reactor fault has the potential to develop into a major incident with serious consequences for the safety of the submarine. If a submarine were to find itself in trouble at sea then not only could the boat and its crew be lost - in itself a national disaster - but so would its complement of nuclear weapons and its nuclear propulsion plant. The dire political consequences of such a calamity were appreciated by Alan Clark, a junior Defence Minister in Margaret Thatcher's government, who wrote "If - if there is an accident, it's not just you who resigns; the Government falls".[164]

The Ministry of Defence considers its submarine operations to be highly sensitive. "We do not comment on matters relating to submarine operations as this would, or would be likely to, prejudice the capability, effectiveness and security of our Armed Forces" is the usual response to any questions relating to matters concerning Royal Navy submarines.[165] Although the Oxburgh report on the safety of UK nuclear weapons reviewed collisions and near misses which had involved nuclear powered and nuclear armed submarines, details of these accidents were redacted by the MoD from a copy of the report released more than twenty years after it was originally written. Despite this, information about accidents involving nuclear

24 INCIDENTS, INCLUDING:

- 11 Fires
- 1 Explosions
- 2 Incidents involving radioactive contamination
- 1 Incidents involving failure or degradation of infrastructure or equipment
- 2 Incidents where nuclear reactors malfunctioned or went wrong
- 3 Incidents involving a collision between ships and/or submarines

163 Readers who are unfamiliar with the component parts of nuclear powered submarines and the principles on which they operate are referred to the following articles for more information:
'Submarine'. Wikipedia. https://en.wikipedia.org/wiki/Submarine
'Nuclear Propulsion'. Federation of American Scientists. https://fas.org/man/dod-101/sys/ship/eng/reactor.html

164 Alan Clark: 'Diaries: In power 1983-1992'. Cited in John Ainslie: 'Substandard'. Scottish CND, 28 May 2015. P9. http://www.banthebomb.org/images/stories/pdfs/Substandard1.pdf

165 See for example 'Astute Class Submarines'. Parliamentary written question 56322. 6 December 2016. http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2016-12-06/56322

armed submarines has emerged from official records, media reports, and the accounts of submariners who witnessed them. In May 2015 the Sunday Herald newspaper published a series of allegations about safety and security weaknesses on Britain's Trident submarines. The article was based on an 18-page report from Able Seaman William McNeilly, a junior rating who was training to be a missile technician on a Trident submarine.[166] McNeilly's account mentions a number of accidents which have occurred on board Trident submarines and includes details he heard from other submariners, which together with material from other sources helps in developing a picture for the accident history of the Royal Navy's Trident submarines.

> *"If - if there is an accident, it's not just you who resigns; the Government falls"*

Because of the secrecy associated with submarine operations we do not know for certain whether all the accidents discussed below actually involved nuclear weapons. All the incidents involved submarines which were capable of firing nuclear-armed missiles, rather than nuclear-powered submarines armed with conventional weapons but not nuclear weapons. In general terms, nuclear weapons would almost certainly have been on board a submarine if it was on active patrol, but are less likely to have been on a submarine which was on a 'work up' routine or exercise, and would not have been present on a submarine which was undergoing a refit. Despite this, in our assessment all the accidents we describe had the potential to involve nuclear weapons and are illustrative of the hazards which face the Royal Navy's nuclear armed submarines.

THE POLARIS PROGRAMME

The US government agreed to sell Polaris submarine-launched missile technology to the UK in December 1962, heralding a move in the deployment of the UK's strategic nuclear weapons from the Royal Air Force's V-bombers to the Royal Navy's submarines. The first Polaris submarine, HMS Resolution was scheduled to enter service by June 1968 - a very ambitious timetable. Resolution was launched in September 1966 and after a series of sea trials fired its first Polaris missile in a test flight in February 1969. The first operational patrol took place on 15 June 1968, heralding the start of 'Operation Relentless' – a programme of continuous round the clock nuclear armed patrols by Royal Naval submarines which has continued unbroken to this day.

In the race to complete the Polaris programme by its June 1968 operational deadline a number of embarrassing setbacks occurred. HMS Repulse, the second Polaris submarine to be built, ran aground just thirty minutes after it was launched at the Vickers Armstrong shipyard at Barrow-in-Furness on 4 November 1967. The submarine was refloated on the next tide, twelve hours later, with the assistance of seven tugboats and was undamaged following the incident. "Her paint has hardly been scraped", said a Vickers official.[167]

At the beginning of January 1968 HMS Resolution set sail for Florida to undertake its first Polaris missile test firing at the US Navy's missile test range at Cape Canaveral. The voyage was not without incident. On 8 January the submarine was forced to turn back to the Faslane naval base for repairs after developing a defect in its electrical generator.[168] The repairs did not delay the arrival at Cape Canaveral, but further misfortune lay ahead. The first missile test firing on 15 February was successful, but a second test firing nearly ended badly. The weather was poor, with choppy seas and strong

166 William McNeilly: 'The Secret Nuclear Threat'. 12 May 2015. P7. http://www.nuclearinfo.org/sites/default/files/William%20McNeilly%20Secret%20Nuclear%20Threat%20120515.pdf

167 William M. Arkin and Joshua Handler: 'Naval Accidents 1945 – 1988'. Neptune Paper No. 3. Greenpeace / Institute of Policy Studies, June 1989. P37. https://fas.org/wp-content/uploads/2014/05/NavalAccidents1945-1988.pdf . Peter Hennessy and James Jinks: 'The Silent Deep: The Royal Naval Submarine Service since 1945'. Penguin Books, 2016. P249-250.

168 William M. Arkin and Joshua Handler op cit. P38.

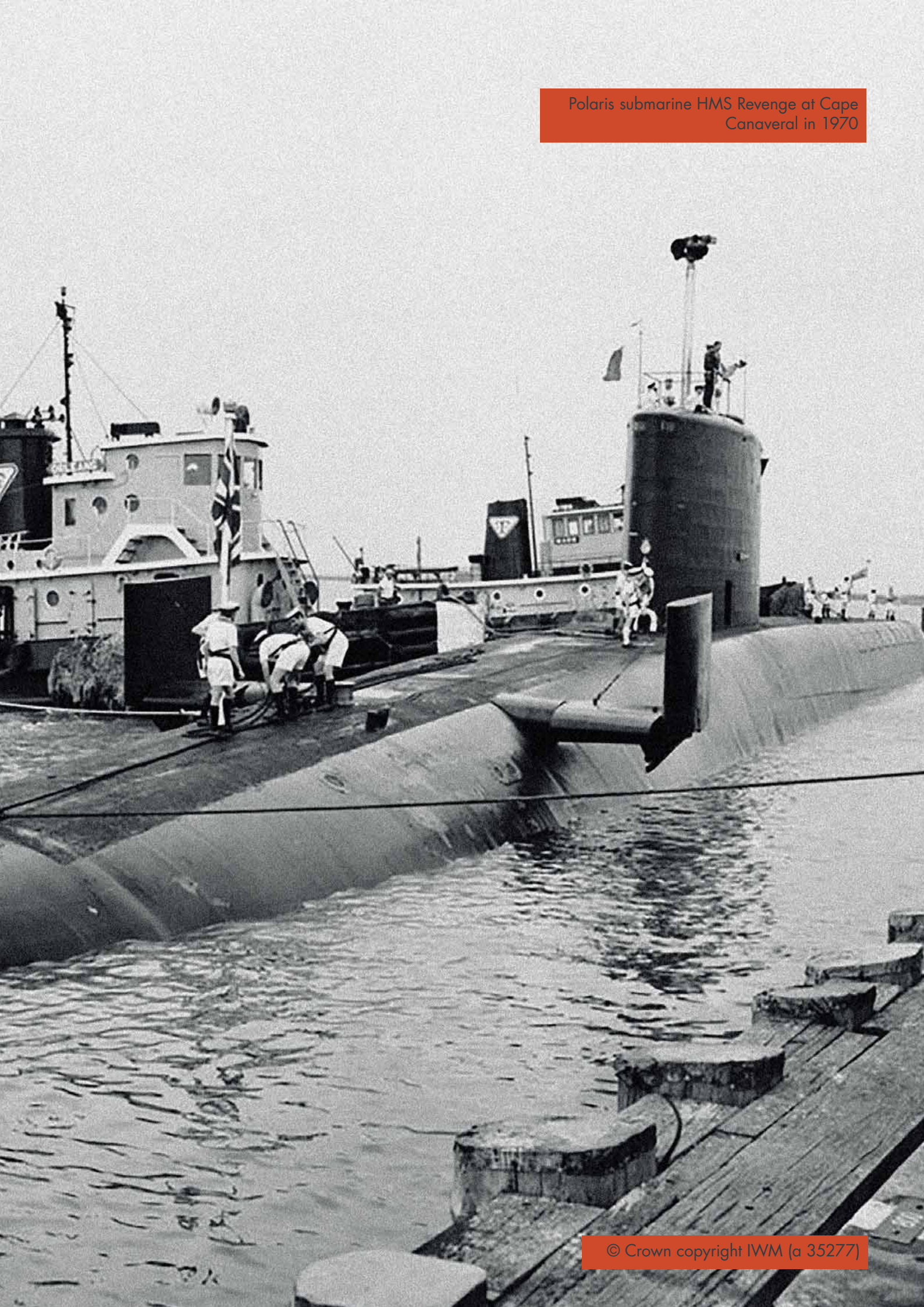
winds, and when Resolution submerged a US Navy destroyer on escort duty, the USS Fred T Berry, lost visual and radar contact with the submarine's 100 foot telemetry mast, specially installed to track the missile in flight. The destroyer passed down Resolution's starboard side and then sailed over the submarine, colliding with the telemetry mast and knocking it off. Engineers were able to fit a replacement mast and complete the test to schedule in front of a delegation of news reporters.[169] Resolution was involved in another collision en route to a missile test firing at Cape Canaveral seventeen years later when it struck the yacht 'Proud Mary' in an early morning accident on 10 June 1985. The submarine suffered minor damage, but the yacht had to be towed back to port.[170]

Over the duration of the Polaris programme Resolution class submarines suffered from a number of collisions, fires, breakdowns, and reactor incidents - some trivial, some more serious (see Table 2). HMS Renown was particularly accident-prone, earning the dubious privilege of being dubbed "Britain's unluckiest nuclear submarine" by the newspapers.[171] Renown's career started badly, after crashing into the entrance to Number 7 Dock at the Cammell Laird shipyard in Birkenhead when leaving the yard for acceptance trials in February 1969. The collision caused internal bulkheads to buckle and damaged torpedo tube bow shutters, requiring four weeks of repairs.[172] Later that same year Renown collided with the Irish boat MV Moyle whilst undertaking work-up trials off the west coast of Scotland before departing on its first operational patrol. The accident happened on 7 October while the submarine was surfacing during the night in the Mull of Kintyre. Although damage to the submarine was slight, commanding officer Kenneth Mills was court-martialled, found guilty of hazarding his submarine, and relieved of his command following the incident.[173] Renown was involved in yet another collision on 17 April 1974, which caused "intensive structural damage" when the submarine struck the seabed during an exercise in the Firth of Clyde. The submarine had just left a refit in Rosyth dockyard. The captain, Commander Robin Whiteside, was court-martialled after the accident.[174]

Renown's third refit, scheduled to take two years, took five years to complete and was dogged by misfortune.[175] In October 1987 the submarine suffered a leak of reactor coolant during tests in the reactor compartment. By early 1990 the refit had almost been completed and the submarine had been taken out of the refuelling dock ready to leave. However, just days beforehand cracks had been discovered in the reactor pipework of another submarine, HMS Warspite, causing alarm within government that the fault might be a generic problem across the entire fleet of Royal Naval submarines. Renown's refit was extended for a further two years to address the cracking fault, and possibly also further defects that had been identified. Despite this, the refit failed to correct all Renown's problems and the submarine only remained operational for a further 18 months. In December 1991 the MoD announced that another of the Resolution class submarines, HMS Revenge, would not receive a third refit but would be withdrawn from service early.

The cracking problems in the reactor pipework posed huge operational difficulties for the Royal Navy's submarine fleet. Although all the Navy's other nuclear powered submarines were temporarily withdrawn from service for inspection and repairs, a decision was made at the highest level to keep the Resolution class boats which carried the UK's strategic nuclear weapons in service, raising significant questions about whether safety concerns

169 Peter Hennessy and James Jinks op cit. P250.
170 William M. Arkin and Joshua Handler op cit. P68.
171 Christopher Bellamy: 'Ill-fated nuclear sub has taken last dive'. Independent, 23 February 1996. http://www.independent.co.uk/news/ill-fated-nuclear-sub-has-taken-last-dive-1320467.html
172 Peter Hennessy and James Jinks op cit. P252.
173 William M. Arkin and Joshua Handler, op cit. P41.
Peter Hennessy and James Jinks op cit, P252.
174 William M. Arkin and Joshua Handler, op cit. P49.
Peter Hennessy and James Jinks op cit, p 252.
175 John Ainslie: 'Cracking Under Pressure: The Response to Defects on British Nuclear Submarines'. Scottish CND, undated. http://www.banthebomb.org/archives/magazine/cracking.htm
Christoper Bellamy op cit.



Polaris submarine HMS Revenge at Cape Canaveral in 1970

were forced into second place behind operational imperatives. Alan Clark, at the time a junior Defence Minister, wrote in his diary on 31 January 1990: ".. news is about to break concerning the trouser-leg fractures in Warspite's cooling system. This could affect every nuclear-powered submarine. The whatever-it-is Authority have already given their advice that we should 'cease to operate' them until the condition is 'rectified'".[176] Clark speculated that the decision to keep the Polaris submarines in service despite the fault was taken personally by Prime Minister Margaret Thatcher.[177]

Concerns over cracking, combined with loss of availability and increasing maintenance and reliability problems as the Resolution class submarines reached the end of their lives, meant that during the early 1990s the Navy struggled to achieve Operation Relentless's objective of keeping a nuclear armed submarine on patrol at all times. "We have no wish to repeat that experience", the MoD told the House of Commons Defence Committee in 2007 during an inquiry into the service life of Trident submarines.[178] There is evidence that towards the end of the service life of the Resolution class submarines the operating difficulties were so great that a submarine was required to 'sit' at the bottom of the ocean without moving on patrol on at least one occasion.[179]

Clark speculated that the decision to keep the Polaris submarines in service despite the fault was taken personally by Prime Minister Margaret Thatcher

It wasn't just nuclear reactors which suffered from faults. Sometime in 1978 an explosion and steam burst occurred in the engine room of HMS Revenge while the submarine was at sea. Disaster was averted by an engineer who crawled along a foot-wide catwalk beneath a scalding cloud of escaping high pressure steam in the turbo-generator room to search for the source of the leak. In January 1979 he was awarded the Queen's Gallantry Medal for his actions.[180] Polaris missiles were also involved in accidents: in 1974 the diaphragm in a missile tube on board HMS Revenge compressed onto a nuclear weapon mounted on a Polaris missile.[181] A similar episode happened on board a submarine at sea in 1981, when a number of missile diaphragms compressed onto Polaris missiles. An inquiry determined that the incident had been caused by a procedural error and a modification to the design of the missile tube pressurisation system was made to prevent the problem from reoccurring. In neither incident were nuclear warheads damaged.

176 Alan Clark, op cit.
177 This has since been confirmed to the author in confidential conversation with a former civil servant who was involved in the decision.
178 Ministry of Defence: 'Response to House of Commons Defence Committee's Request for Further Information in the Clerk's Letter of 17 January'. Memorandum to the House of Commons Defence Committee, 1 January 2007. http://www.publications.parliament.uk/pa/cm200607/cmselect/cmdfence/ucwhite/ucm1702.htm
179 John Baylis and Kristan Stoddart: 'The British Nuclear Experience: The Roles of Beliefs, Culture, and Identity'. Oxford University Press, 2015. P258, note 71.
180 William M. Arkin and Joshua Handler, op cit. P57.
181 Chief Scientific Adviser: 'Report on the Safety of Nuclear Weapons' (the 'Oxburgh Report'). Ministry of Defence report CSA 42/5/1/1 (46/62), 12 February 1992. Para F2.1, p12, Appendix F.
Nukewatch UK: 'UK Nuclear Weapon Safety'. Undated. http://www.nukewatch.org.uk/?page_id=178
182 Information compiled from the following sources:
William M. Arkin and Joshua Handler op cit.John Ainslie: 'Cracking Under Pressure: The Response to Defects on British Nuclear Submarines'. Scottish CND, undated. http://www.banthebomb.org/archives/magazine/cracking.htm and http://www.banthebomb.org/archives/magazine/crackin2.htm
Peter Hennessey and James Jinks op cit. PP250-252.
Christopher Bellamy op cit
Rob Edwards: 'Mod admits to 16 nuclear submarine crashes'. Sunday Herald, 7 November 2010. http://www.robedwards.com/2010/11/mod-admits-to-16-nuclear-submarine-crashes.html
Parliamentary written question: 'Nuclear submarines'. Hansard, 16 September 2009, Column 2222W. http://www.publications.parliament.uk/pa/cm200809/cmhansrd/cm090916/text/90916w0009.htm

The missile monitoring compartment on Polaris submarine HMS Revenge

TABLE 2:
28 INCIDENTS IN 24 YEARS: REPORTED ACCIDENTS INVOLVING THE ROYAL NAVY'S RESOLUTION CLASS NUCLEAR-ARMED SUBMARINES:[182]

DATE	SHIP	DETAILS
4 November 1967	Grounding	HMS Repulse ran aground in Walney Channel, Barrow-in-Furness, after launching.
8 January 1968	Breakdown at sea	HMS Resolution developed a defect in an electrical generator at sea and was forced to return to Faslane base.
15 February 1968	Collision	US Navy destroyer collided with telemetry mast of HMS Resolution during missile test firing.
February 1969	Collision	HMS Renown's port bow hit side of dock entrance when leaving Birkenhead for trials.
7 October 1969	Collision	HMS Renown collided with MV Moyle when surfacing in the Mull of Kintyre.
August 1970	Fire	Fire in control room of HMS Resolution whilst undergoing refit at Rosyth.
3 July 1972	Fire	Fire reported on board HMS Repulse whilst undergoing refit at Rosyth.
January 1973	Collision	HMS Revenge collided with HMS Repulse when leaving dry dock at Faslane, damaging Repulse's hydroplanes.
17 April 1974	Collision	HMS Renown struck the seabed while carrying out an exercise in the Firth of Clyde.
January 1975	Fire	Fire on board HMS Repulse caused by equipment overheating whilst alongside at Faslane.
1975-76	Reactor incident	Reactor welders brought from Chatham and Devonport to tackle problems during final reactor power testing during refit of HMS Resolution at Rosyth.
1976-77	Fire	Fire on board HMS Repulse caused damage costing £200,000 pounds.
1978	Breakdown at sea	Explosion and high pressure steam leak in the engine room of HMS Revenge.
1980	Reactor incident?	'Major technical problem' identified at end of HMS Renown's refit at Rosyth. 150 workers sent to Faslane after refit completed to deal with the problem.
March 1980	Fire	Electrical fire whilst HMS Revenge was alongside at Faslane.

DATE	SHIP	DETAILS
May 1980	Reactor incident	High radiation levels recorded during refit of HMS Revenge at Rosyth. Large amounts of radioactive waste produced during decontamination.
1983	Reactor incident	Problems with welding and reactor pipework experienced during refit of HMS Resolution at Rosyth. Workers received high radiation doses.
1984-86	Reactor incident	'Major innovative repair' required to deal with stress corrosive cracking from steam generators during refit of HMS Repulse at Rosyth.
10 June 1985	Collision	HMS Resolution struck the yacht Proud Mary off Cape Canaveral during missile test firing.
September 1985	Fire	Fire on jetty heating system whilst HMS Repulse was undergoing refit at Rosyth.
1 October 1987	Reactor incident	Reactor coolant leak on board HMS Renown during tests whilst submarine was undergoing refit at Rosyth.
15 November 1987	Fire	'Medium scale fire' on board HMS Renown.
26 January 1988	Reactor incident	Electrical malfunction shut down reactor primary coolant pumps on board HMS Resolution whilst docked at Faslane. Back-up pumps and emergency power supply also failed and crew members raced to start a diesel generator to prevent a reactor crisis.
10 October 1988	Fire	'Medium scale fire' on board HMS Renown whilst at Clyde base.
17 February 1992	Fire	Fire on board HMS Renown whilst in the Clyde. External assistance, as well as the submarine's own fire-fighting equipment was needed to tackle the blaze.
29 July 1993	Fire	'Medium scale fire' on board HMS Revenge whilst at sea.
1994	Reactor incident	Crew members on board HMS Renown were given potassium iodate tablets following a scare over radiation exposure during a patrol at sea.
July 1996	Grounding	HMS Repulse grounded in the North Channel off South West Scotland whilst on its final patrol.

TRIDENT TAKES OVER

HMS Vanguard, the first of four new Trident submarines, undertook its first missile test firing in May 1994 and conducted the first operational Trident patrol in early 1995. Over the next two years Vanguard class submarines progressively replaced the ageing Resolution class boats. The last Polaris patrol was conducted by HMS Repulse in May 1996 and the Polaris programme came to an end on 28 August 1996 when Repulse was decommissioned. Like their predecessors, the Trident submarines have had some close calls. The most well known of these is probably a collision which took place in the Atlantic Ocean in February 2009 between HMS Vanguard and the French navy submarine Le Triomphant (see case study 5). However, other incidents have occurred which have also jeopardised the safety of Trident submarines.

> *"If it had not pulled out of its dive, it would have headed down and probably imploded, killing the crew and spreading radioactivity over a massive area"*

In July 1998 HMS Vanguard came close to disaster when a training exercise went badly wrong. The vessel was in the Celtic Deep, an area of the Atlantic Ocean between the south coast of Ireland and Land's End, when the emergency happened. According to a report in the Sunday Mail newspaper the submarine went into an uncontrolled dive after a power failure.[183] The emergency began when the nuclear reactor which powered the submarine was shut down, possibly deliberately as part of the training exercise, and the crew tried to switch to back-up electrical power. The back-up system failed to work and the submarine, already in a fast dive, plunged out of control. Officers switched back to steam power from the reactor, which only came back on stream after a delay but allowed the crew to regain control of the submarine.

A member of the crew told the Sunday Mail "The boat was shuddering and shaking. We were on our knees praying. Everyone was scared out of their wits because we had never experienced anything like this." A former Royal Navy submarine commander was quoted as saying "Apart from a fire on board, I cannot think of anything more horrific than this. If it had not pulled out of its dive, it would have headed down and probably imploded, killing the crew and spreading radioactivity over a massive area". The Royal Navy admitted that HMS Vanguard had been forced to make "an unscheduled surface during a training exercise", but denied there was any risk of a nuclear incident or any cause for concern over the incident.[184]

Fears over deep depth incidents of this nature were raised in a 2009 advice note from the Defence Nuclear Safety Regulator (DNSR) to the Defence Board advising on selection of the nuclear propulsion plant for the proposed new 'Successor' submarine.[185] The paper was released to the public following a Freedom of Information Act request but had been incorrectly redacted, allowing sensitive sections of the document to be read. The DNSR paper noted that the reactors for American nuclear powered submarines are designed to deliver a high reliability of propulsion even under fault conditions. British submarines, on the other hand, are designed "to accept a much lower reliability from the main propulsion system", backed up by a low power emergency propulsion system. Under low power conditions, the submarine will not achieve sufficient dynamic lift from its hydroplanes, "so safety is achieved by procedural controls constraining the combinations of speed and depth, backed up by the use of ballast systems (but this may not be

183 Angus Macleod: 'Seconds from ocean tomb'. Sunday Mail, 19 July 1998. https://www.thefreelibrary.com/SECONDS FROM OCEAN TOMB; Terror as nuclear sub plunges in training...-a060754073

184 Angus Macleod op cit.

185 Defence Nuclear Safety Regulator: 'Successor SSBN – safety regulator's advice on the selection of the propulsion plant in support of the future deterrent review note'. Paper to Defence Board DNSR/22/11/2, 4 November 2009.
John Ainslie: 'Substandard Submarines'. Scottish Campaign for Nuclear Disarmament, 24 April 2011. http://www.banthebomb.org/images/stories/pdfs/substandardsubmarines.pdf

sufficient under all circumstances)". Whereas safety is engineered into US submarines, on British submarines it requires the crew to follow procedures properly. The DNSR report commented that, when compared with US standards, "it is clear that the UK programme currently falls short of current relevant good practice."

It appears that during the Vanguard deep depth incident the submarine strayed beyond the speed and depth control limits, and thus got into difficulties. According to submariner William McNeilly, the 'Trident whistleblower', Vanguard dived to a depth of greater than 300 metres – far below its safe dive limit. A combination of high water pressure and the submarine's low speed made it difficult for the submarine's hydroplanes to generate enough lift to raise the submarine, and ballast water could not be pumped out fast enough to allow the submarine to rise. "The submarine was extremely close to being lost", claimed McNeilly.[186] A US Navy submarine, the USS Thresher, was lost at sea with all hands under similar circumstances when it went into an uncontrolled dive in April 1963. A court of inquiry concluded that Thresher's reactor had probably shut down, resulting in a loss of propulsion, and that the ballast system had also failed.[187]

GROUNDINGS, FIRES, AND STAFF SHORTAGES

Skelmorlie Bank is a sandbank in the Clyde estuary which is clearly marked with a large buoy. It has been shown on Admiralty charts since 1852[188] and is safely navigated by Royal Naval ships and submarines on a daily basis. Nevertheless, on 29 November 2000 the crew of the Trident submarine HMS Victorious succeeded in grounding their vessel on the bank.

The accident took place as Victorious was sailing on the surface from its Faslane base to take part in an exercise.[189] As it departed from the Clyde a towed array – a long cable carrying sonar sensors which is towed along behind the vessel – was to be fitted to the submarine. The array was to be fitted by a tug near the island of Bute, but the sea at the designated point was too choppy to allow this so the submarine and tug headed to a new location north of Great Cumbrae island to try again. Conditions were still unsuitable, so a decision was made to head north to seek calmer water in Loch Long. The submarine increased speed to 10 knots to move to the new position but the Petty Office of the Watch who was logging its position was unaware of this, "and remained under the mistaken impression that the submarine was loitering". An error was also made in taking a bearing to determine the vessel's position, and as a result the submarine mistakenly approached the sandbank. The echo sounder operator in the control room raised his voice to report every metre as the depth decreased until, when the sounding was only one metre deep, he shouted to the Officer of the Watch to bring the submarine to emergency stations. Senior officers managed to refloat the submarine after it had grounded and it subsequently returned to the Faslane base.[190]

A Board of Inquiry investigation concluded that the primary cause of the grounding was "a failure of standard navigational practice" and a lack of awareness within the navigation team of the dangers resulting from the submarine's departure from its pre-arranged plan.[191] The Board found that it had been "inappropriate" to allow the Petty Officer of the Watch to undertake chartwork during the manoeuvres and that once the submarine began to head away from Great Cumbrae he was "unable to safely continue executing the chartwork". Navigational records were "barely adequate" and there was a "woeful lack of understanding"

186 William McNeilly op cit. P7.
187 Arlington National Cemetery blog: 'USS Thresher (SSN-593), 1961-1963'. http://www.arlingtoncemetery.net/uss-thresher.htm
188 Hydrographic Office: 'Firth of Clyde, between Little Cumbrae and Toward Point'. Surveyed 1846, published 1852. http://maps.nls.uk/coasts/admiralty/1254
189 Captain (SM), Second Submarine Squadron: 'Board of Inquiry into the circumstances surrounding the grounding of HMS Victorious on Skelmorlie Bank on 29 November 2000'. SM520/02. Royal Navy, 19 December 2000.
190 Captain (SM), Second Submarine Squadron, op cit.

between the Officer of the Watch and the Petty Officer which was "indicative of a widespread lack of navigational awareness amongst the team on watch". This was compounded by "poor communications and teamwork" between personnel on the Bridge and in the submarine's control room.[192]

The officers in charge "failed to take a purposeful interest in the navigation at a time when the plan was being constantly modified".[193] Two officers who had been on duty as Officers of the Watch had not completed their Basic Submarine Qualification and so were not strictly authorised to act in this role. "No clear plan was conceived, planned or executed" as to how the submarine should transit between Great Cumbrae to Loch Long and there was "a general failure to recognise that, in deviating from the previously planned and briefed navigational plan, Victorious was at increased risk". Consequently, there was "wholly inadequate" attention to and supervision of the submarine's navigation. The awareness of those on the Bridge of the submarine's position "was disappointing" and the decision to steer north to Loch Long was "illogical and unsafe". Three officers and one senior rating were deemed to have "fallen short of the standard that could be expected of officers of their seniority and experience" and they were subsequently court-martialled for hazarding the submarine.[194]

Other accidents – without quite such a high profile – have also occurred on board Trident submarines. The MoD has admitted that three "medium scale" fires - categorised as a localised fire such as a failure of mechanical equipment creating smoke and flame which required use of "significant" on board resources[195] – have broken out on Trident submarines: on HMS Victorious whilst berthed on 16 October 1995; on HMS Victorious whilst at sea on 22 April 2002; and on HMS Vigilant whilst at the Clyde submarine base on 11 October 2006.[196]

One of these was probably an incident described by William McNeilly which took place when toilet rolls stored in a submarine caught fire.[197] The toilet rolls had been stacked from deck to deck-head beside the submarine's Trident missiles and firing units, and were believed to have been ignited by heat generated by electrical cabling. The fire broke out shortly before an emergency exercise was scheduled to take place, and when the alarm was sounded the crew did not at first believe it signalled a real incident. According to McNeilly "4 deck was filled with smoke" and a Chief Petty Officer who had been present during the emergency told him that there would have been "about 50 dead bodies on 3 deck because of the amount of people struggling to find an EBS [emergency breathing supply] coupling". The fire was finally extinguished "using almost every portable extinguisher onboard". Despite the incident, McNeilly claimed that flammable rubbish was stored beside electrical cabling and heat-generating equipment whilst he was on patrol on board HMS Victorious. McNeilly also expressed concern about an incident during the same patrol when a control room panel operator accidentally operated a fire-fighting fog spray in the submarine's weapon stowage compartment. Seawater "sprayed over everything in the compartment: torpedoes, lights, torpedo monitoring panel, everything". None of the electrical equipment in the compartment had been isolated, "creating a high risk of fire in a compartment which contains torpedoes".[198]

The possibility of a fire in the missile compartment is a particularly significant risk on board a Trident submarine because of the design of the Trident D5 missile.[199] On most types of missile the warhead is mounted on top of the rocket motors, but the Trident missile is different. The missile is designed as a short, compact missile to fit inside a submarine, and to reduce its height the nuclear warheads are mounted surrounding the third stage rocket motor.

191 Flag Officer Submarines: 'HMS Victorious Grounding – Findings of Board of Inquiry'. D/FOSM/X/5200/26. Royal Navy, 1 February 2001
192 Flag Officer Submarines, op cit.
193 Flag Officer Submarines, op cit.
194 Flag Officer Submarines, op cit.
195 Parliamentary written question: 'Nuclear submarines'. Hansard, 2 April 2009, Column 1396W. http://www.publications.parliament.uk/pa/cm200809/cmhansrd/cm090402/text/90402w0024.htm#09040272000014
196 Parliamentary written question: 'Nuclear submarines', 16 September 2009. op cit.
197 William McNeilly op cit, P8.
198 William McNeilly op cit, P8.
199 John Ainslie: 'Substandard', op cit. P9-10.

An aerial view of the Faslane base

Image credit: US DoD

The propellant used in the rocket motor is a high energy propellant designed to maximise the missile's range – but its high energy properties also mean that the propellant is particularly susceptible to an accidental detonation. Because the third-stage rocket is surrounded by nuclear warheads, an explosion of the rocket propellant will also cause the explosive components in the warheads to explode, dispersing their radioactive contents. This risk is acknowledged in the Royal Navy's procedures for the safety and security of the Trident II D5 strategic weapon system, which are said to state: "The chief potential hazard associated with a live missile is the accidental ignition of the first, second or third stage rocket motor propellant … When installed in a Trident II D5 missile, RBs [re-entry bodies] clustered around the Third Stage Rocket Motor are at risk from a rocket motor propellant fire … An accident or enemy action may cause rupture of the RB, burning or possible detonation of the HE [high explosive] and release of radioactive contamination".[200]

Risk assessments conducted for a Trident submarine in the Faslane shiplift assume that the detonation of one missile will result in the explosion of all the missiles on board a submarine and the dispersal of plutonium from all of the nuclear warheads.[201] Such an event – the detonation of missile propellant on board a fully armed Trident submarine - is probably the most serious accident scenario facing the entire Trident programme.

McNeilly also refers to staff shortages within the Trident programme, saying that the programme is "so short on man power it's unbelievable" [sic].[202] Information in annual reports and accounts published by the MoD confirm that the Trident Strategic Weapon System is a 'pinch point' where there is a shortage of personnel. The report for 2014-15 revealed that there was a 35% shortage in the number of Strategic Weapon Systems engineers between the ranks of Leading Hand to Warrant Officer 1, and a 20% shortage of nuclear watchkeepers (reactor engineers) between the ranks of Petty Officer to Warrant Officer 1.[203] Equivalent figures are not given in the report for 2015-16, which merely states that the key Royal Navy pinch points relate to "engineering roles plus some specialist roles".[204] The MoD's Defence Nuclear Safety Regulator confirms that there are "ongoing challenges" in retaining sufficient Royal Naval nuclear qualified and experienced personnel (NSQEP) to maintain safety performance, and describes shortages of NSQEP as "the principal threat to the delivery of nuclear safety".[205] Personnel shortages in this area have been an issue since 2006 and "vulnerability remains in this small and highly skilled group".

As discussed above, the Navy experienced considerable difficulties in keeping the Resolution class submarines going towards the end of their operating lives. It now appears that, as the Vanguard class submarines age, the Navy is beginning to experience similar problems again. On 6 March 2014 the Defence Secretary, Philip Hammond, made a special announcement to Parliament. In a formal oral statement he told MPs that, because of potential problems with the Navy's PWR2 reactor design, the MoD had decided to commission an unplanned refuelling for the reactor on board HMS Vanguard at a cost of £120 million.[206] The refuelling was necessary because in January 2012 radioactivity had been detected in the cooling water surrounding the core of a prototype PWR2 reactor operating at the Naval Reactor Test Establishment at Dounreay in Scotland. The fact that radioactivity had been detected "means that the reactor is not operating as planned", said Hammond. Investigations had identified "a microscopic breach in a small area of

200 William McNeilly op cit, P9, 11.
201 John Ainslie: 'Substandard' op cit, p10
202 William McNeilly op cit, p12.
203 Ministry of Defence: 'Annual Report and Accounts 2014-2014'. 13 July 2015. P43. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/482894/19_MOD_ARAc_combined_at_02_Dec_2015_for_web.pdf
204 Ministry of Defence: 'Annual Report and Accounts 2015-2016'. 14 July 2016. P31. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/558559/MoD_AR16.pdf
205 Defence Nuclear Safety Regulator: 'DNSR Annual Report 2014/15'. Defence Safety Authority, 26 May 2016. P7-8. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526138/20160520-DNSR_Annual_Report_2014-15-RT.pdf
206 Secretary of State for Defence: 'Nuclear Submarines'. Oral statement to Parliament. Hansard, 6 March 2014, Column 1077. http://www.publications.parliament.uk/pa/cm201314/cmhansrd/cm140306/debtext/140306-0002.htm#14030652000003

Submarines docked at Faslane

Image credit: Greame Phanco (seapigeon/Flickr)

the metal cladding that surrounds one fuel element within the core of the reactor", but it was "not yet clear" why the breach had occurred. Hammond told the House that the incident would "potentially present additional risks to future submarine availability" and so, as a "precautionary measure" the MoD had decided to refuel HMS Vanguard, the oldest of the submarines with the PWR2 reactor design, when it entered dry dock for deep maintenance at the end of 2015. This will be the second time that Vanguard's reactor has been refuelled since it entered service: the first refuelling in 2002-04 was intended to ensure that no further refuelling operations would be needed before the submarine retired from service. Hammond said that a decision on whether to refuel the next oldest submarine, HMS Victorious, did not

207 Kate Devlin: 'MSPs unite in anger at Dounreay radiation 'cover-up''. Herald, 7 March 2014 http://www.heraldscotland.com/politics/wider-political-news/msps-unite-in-anger-at-dounreay-radiation-cover-up.23624035

208 Secretary of State for Defence, op cit.

209 Rob Edwards: 'Salmond accuses UK Defence Secretary of Deception over Dounreay radioactive leak'. Sunday Herald, 9 March 2014. http://www.heraldscotland.com/news/13149571.Salmond_accuses_UK_Defence_Secretary_of_deception_over_Dounreay_radioactive_leak/

210 Sunday Times: 'Nuclear cover-up'. 22 January 2017. http://www.thetimes.co.uk/edition/news/nuclear-cover-up-ffrgjxn97

211 Rowena Mason: 'Committee chair attacks government for Trident malfunction secrecy'. Guardian, 24 January 2017. https://www.theguardian.com/uk-news/2017/jan/24/commons-watchdog-criticises-unnecessary-surreptitiousness-trident-missile-malfunction

212 BBC News: 'Opposition seek explanation over Trident test 'fail''. 23 January 2017. http://www.bbc.co.uk/news/uk-38714047

need to be made until 2018 and would be informed by further examination of data from the Dounreay and Vanguard reactors. In addition to the refuelling work, a further £150 million would need to be spent at the Devonport dockyard and the Rolls-Royce submarine reactor plant in Derby "to preserve our ability to conduct nuclear refuelling into the future".

Hammond's announcement caused a furore – not just because of the large amount of unplanned spending that would be necessary, but because the Dounreay leak had obviously been concealed from the public, the Scottish Government, and the Dounreay Site Stakeholder Group for over two years.[207] Even safety and environmental regulators had not been told about the problems until nine months after they had been discovered, and then only "on a confidential basis".[208] It also emerged that, contrary to the Minister's statement, radioactive emissions at Dounreay had increased as a result of the leak.[209]

The Dounreay incident, viewed in the context of the problems of cracking in reactor pipework which plagued an earlier generation of submarines in the 1990s, suggests that the design and operation of naval nuclear reactors is stretching the technological capability of the UK nation to the limit. Only time will tell how serious the problem is and whether further repair work and expenditure will be necessary to keep the Vanguard class submarines afloat, but few doubt that the challenges in keeping them in operation until replacement Dreadnought class submarines take over sometime in the 2030s will be severe.

As a brief post-script to this chapter, it is worth referring to an incident which was disclosed to the public shortly before this report went to press. In January 2017 a report in the Sunday Times newspaper revealed that a test-firing of a Trident missile by the submarine HMS Vengeance had not gone to plan.[210] The practice launch took place in June 2016 as Vengeance was about to return to service following a three year refit. The submarine had sailed to the Cape Canaveral missile test range and fired the missile as scheduled, but unusually the firing took place with no media fanfare. The Sunday Times disclosed the reason for this: the missile had deviated from its scheduled flight path and had then self-destructed. The cause of the misfiring remains a secret, but it was clear that the test had failed and the government did not want this to become widely known, perhaps because a vote on replacing the Trident submarines was scheduled to take place in Parliament shortly afterwards.

Predictably, the government was accused of a cover-up when the story broke, and matters became worse when the Prime Minister and Defence Secretary both refused to comment on the missile launch. Julian Lewis MP, Chair of the House of Commons Defence Committee, criticised the government's "unnecessary surreptitiousness" over the failure.[211] Former First Sea Lord Sir Alan West said it was "bizarre and stupid" and pointed out that the missile launch would certainly have been monitored by the Russian government, and thus those whom Trident was intended to deter would be aware of the failure.[212]

The incident is important not so much because of its safety implications but because it is illustrative of a broader approach to nuclear matters within the MoD. The test failure was hushed up, even though there was little obvious advantage to the government in doing this, the security implications were minimal, and there was a high likelihood that the concealment would be exposed. This is a theme that is repeated over and over again with the accidents described in this report. It suggests that there is a broader 'cover-up culture' within the MoD over nuclear safety, and a lack of openness and transparency on nuclear matters in general. We will return to this point in the conclusion to the report.

CASE STUDY 5

Date: 3-4 February 2009

Location: Unknown location in the Atlantic Ocean

Weapons involved: Royal Navy submarine HMS Vanguard armed with up to 48 UK Trident nuclear warheads

Marine Nationale submarine Le Triomphant armed with up to 48 TN75 nuclear warheads

Still taken from a video of HMS Vanguard being moved to the ship lift in Faslane to inspect damage after the collision. Image credit: Scottish CND

COLLISION IN THE OCEAN DEPTHS

To this day the full details of the incident remain a closely-guarded secret. On a stormy night in February 2009, deep in the Atlantic Ocean, two nuclear-armed submarines collided: one British and one French. Was it a chance-in-a-billion accident, or was it more than co-incidence that the two submarines were in the same place at the same time?

Both the French government and the British government have remained tight-lipped about the underwater collision. The French navy issued only a terse five-sentence statement about the accident[213] and the British Ministry of Defence initially refused to say anything at all. Defence Minister, Bob Ainsworth, told Parliament in March 2010 that he was withholding "all particulars" of the collision from release on grounds of national security after being asked to publish a summary of an inquiry report into the collision.[214] Following the accident personnel at the Faslane Trident submarine base were ordered to stay silent. Workers were asked to sign a form stating they would not speak out about the incident and notices were posted in staff rooms warning that anyone talking about the matter could face dismissal.[215]

The collision between HMS Vanguard and Le Triomphant took place in the Atlantic Ocean in early February – although precise details of the date and location of the accident have never been formally revealed. News reports at the time of the collision

stated that it took place deep underwater in heavy seas in the Eastern Atlantic in the middle of the night between 3 and 4 February 2009. Le Triomphant was returning from a 70 day patrol when the crash happened. The French Navy initially stated that their submarine had collided with an "immersed object (probably a container)" and that the sonar dome at the front of the submarine had been damaged.[216] The collision "did not result in injuries among the crew and did not jeopardise nuclear security at any moment". Le Triomphant took three days to struggle back to the French submarine base at Ile Longue near Brest, where it became apparent that the damage to the submarine was greater than had at first been reported: both the conning tower and the starboard hydroplane mounted on the conning tower were visibly deformed.[217]

Intriguingly, HMS Vanguard took much longer to limp back home, arriving at the Faslane submarine base in Scotland on 14 February, ten days after the collision, and proceeding straight to the explosives handling jetty at the Coulport armaments depot for an inspection of its Trident missiles and nuclear warheads. The submarine then entered the Faslane shiplift for repairs to visible dents and scrapes caused by the collision on the outer casing on the starboard side of the missile compartment. Vanguard re-entered service in June 2009, and later that year the submarine's captain, Commander Richard Lindsey, was awarded the Queen's Commendation for Valuable Service for "exceptional service in difficult circumstances in early 2009".[218]

French Defence Minister Herve Morin said afterwards that the collision was a freak accident which occurred because neither submarine was aware of the presence of the other. "We face an extremely simple technological problem, which is that these submarines are not detectable", he said. "They make less noise than a shrimp". He denied that the two submarines may have been operating in concert, saying that there was "no story to this - the British aren't hunting French submarines, and the French submarines don't hunt British submarines".[219]

As a result of information obtained by Nuclear Information Service using the Freedom of Information Act and a second-hand account of the accident given by Trident whistleblower William McNeilly, it is now possible to piece together more details about the underwater collision. Full details of the circumstances of the crash still remain shrouded in mystery, but the FOI papers reveal that Ministers were advised to take a "consistent and robust" approach that it was "an unfortunate and highly unlikely accident" following an MoD investigation into the incident which concluded that "at no time was nuclear safety compromised".[220]

Workers were asked to sign a form stating they would not speak out about the incident and notices were posted in staff rooms warning that anyone talking about the matter could face dismissal

The documents released under the FOI Act include excerpts from a briefing to Ministers dated 17 February 2009 - the day after reports of the collision appeared in newspapers - which noted "that HMS Vanguard and her crew are safe and no damage to nuclear weapons or propulsion plant occurred" and "that Continuous At Sea Deterrence was not broken and is being maintained." Ministers were assured that an investigation with "a full review of decision making at all levels" would be rapidly undertaken to establish the causes of the incident. The papers reveal that a press line was agreed by

213 Marine Nationale: 'Incident sous-marin'. 6 February 2009. http://www.defense.gouv.fr/marine/a-la-une/incident-sous-marin
214 Parliamentary written question: 'HMS Vanguard: accidents'. Hansard, 30 March 2010, Column 872W. http://www.publications.parliament.uk/pa/cm200910/cmhansrd/cm100330/text/100330w0005.htm#10033061000697
215 Tina Kemp: 'Faslane staff warned to stay silent on nuclear submarine collision'. Lennox Herald, 20 February 2009.
216 Marine Nationale, op cit.
217 'Submarines 'may have hit each other several times''. Scotsman, 19 February 2009. http://www.scotsman.com/news/submarines-may-have-hit-each-other-several-times-1-830271
218 Jenny Foulds: 'Faslane submarine captain given special award'. Lennox Herald, 18 September 2009.
219 Sophie Hardach: 'France and UK may coordinate submarine routes'. Reuters, 17 February 2009. http://uk.reuters.com/article/uk-britain-france-submarines-idUKTRE51G2ES20090217
220 'Nuclear Information Service: 'FOI release sheds new light on nuclear missile submarine collision'. 4 September 2013. http://nuclearinfo.org/article/uk-trident-safety-uk-fleet/foi-release-sheds-new-light-nuclear-missile-submarine-collision Article includes downloadable papers released under the Freedom of Information Act by the Ministry of Defence.

Ministers and shared with the French government, stating that the two submarines "were conducting routine national patrols in the Atlantic Ocean" and "came into contact at low speed", but that there had been "no compromise to nuclear safety".

A further briefing to Ministers dated 23 March 2009 reported that a "comprehensive analysis" of the circumstances surrounding the collision had by then been completed, and confirmed that "nuclear propulsion and weapon safety was not compromised during this incident … the shock received and logged by the Strategic Weapon System were within normal tolerable limits." Ministers were advised that, "as a department, we should be consistent and robust that this was an unfortunate and highly unlikely accident involving two vessels operating totally independently as they conducted national deterrent patrols." The investigation into the incident took evidence from the submarine's crew and Commanding Officer as well as reviewing signal logs, records of the incident, and 'black box' type computer data from the submarine which was analysed by the MoD's Strategic System Performance Assessment and Analysis Group and the Military Data Analysis Group. Media speculation at the time of the collision discussed the apparent failure of each submarine to detect the other, despite carrying state-of-the art technology for detecting other vessels. However, Vanguard's Sound Room sonar team were described by the analysts as "the strongest of operators he had seen". The team "performed well at sea and were assessed as Very Satisfactory."

Following the collision a secondary shield survey, a reactor core integrity check and missile testing were undertaken, confirming that "both the Reactor and Strategic Weapons were safe and that no compromise to nuclear safety had occurred". The investigation report concluded: "At no time was nuclear safety compromised and the Strategic Weapon System remained inside tolerable limits at all times".[221]

An account by Trident whistleblower William McNeilly suggests that the accident was far more serious than has been acknowledged by the MoD. McNeilly claimed he had spoken to a Chief Petty Officer who had been on board HMS Vanguard at the time of the collision. "He said "We thought, this it we're all going to die""[sic].[222]

During the collision the French submarine had taken a "massive chunk" out of the front of HMS Vanguard and had then grazed down the side of the boat. Compressed air bottle groups had been dislodged by the collision and "were hanging off and banging against the pressure hull". The submarine had to return to base slowly because "if one of HPA [high pressure air] bottle groups exploded it would've created a chain reaction and sent the submarine plummeting to the bottom".[223]

On returning to Faslane "there was a massive cover-up of the incident". McNeilly's informant said "they told him if he told anybody about it he'd faced a prison sentence". MoD statements and media coverage of the incident have made no mention of the explosion risk or the submarine's perilous journey back to base, and McNeilly's version of events shines some light on why the submarine took ten days to return to Faslane after the collision and why Commander Lindsey was decorated following the incident.

The Daily Telegraph newspaper estimated that the cost of repairs to the two submarines after the collision would cost around £50 million. No information about the lessons learnt following the accident inquiry has been released to date, but it is believed that the incident was reviewed by the Franco-British Joint Nuclear Commission, which was established in 1992 and meets regularly to allow discussion of nuclear policies and doctrines between senior civil servants. Following the collision Herve Morin conceded that "Between France and Britain, there are things we can do together.... one of the solutions would be to think about the patrol zones",[224] and there has been speculation that efforts have since been made to include the French Navy in NATO 'water space management' arrangements for the Atlantic Ocean which are aimed at preventing submarine collisions.

221 Nuclear Information Service, op cit.
222 ''Massive cover-up over UK – France submarine collision'. Nuclear Information Service, 17 May 2015. http://nuclearinfo.org/article/uk-trident/massive-cover-over-uk-%E2%80%93-france-submarine-collision
223 William McNeilly op cit, p7.
224 Sophie Hardach, op cit.

SECRETS AND SPIES: NUCLEAR SECURITY

Nuclear security is considered to be a highly sensitive matter by the government, and so even less information is available about incidents where the security of nuclear weapons is at stake than for cases when their safety has been compromised. The government's official position is that no serious nuclear security incidents have taken place over the last twenty years. In response to a request made under the Freedom of Information Act in 2013 asking for information on accidental or unauthorised access to UK nuclear weapons or defence special nuclear materials and the loss or theft of any defence special nuclear materials, the Ministry of Defence replied that it held no information that fell within the scope of the request.[225]

However, this does not mean that serious and noteworthy incidents have not occurred. Although nuclear materials from the UK's weapons programme have not been lost or stolen, secure equipment and information has been stolen or misplaced and intruders have gained unauthorised access to secure sites.

UNAUTHORISED ACCESS TO SECURE AREAS

Despite the official narrative that no-one has had unauthorised access to a British nuclear weapon, a string of incidents took place throughout the late 1990s and early 2000s when protesters gained access to high security areas at nuclear bases. At the Faslane Trident submarine base anti-nuclear activists succeeded in getting into secure Trident submarine berthing areas and damaged submarines on a number of occasions. Protesters have also managed to board submarines under construction and during refit and have succeeded in entering secure areas and buildings at the Atomic Weapons Establishment and other establishments associated with the Trident programme.

Probably the most serious incident to challenge the security of the UK's nuclear weapons programme occurred on 11 October 1988, when three protesters managed to enter the control room of HMS Repulse, one of the UK's nuclear-armed Polaris ballistic missile submarines. Nearly 30 years later one of the protesters, Phill Jones, recalled the incident in an interview with NIS which is published in the case study for this section (case study 6).

21 INCIDENTS, INCLUDING:

- **16** Incidents where unauthorised people breached a secure area or entered a military vehicle
- **3** Security issues caused by the activities of staff working at nuclear or defence sites
- **3** Cyber security issues

At the end of the 1990s Trident Ploughshares, an activist group campaigning for nuclear disarmament, embarked on a determined programme of non-violent direct action aimed at obstructing operations involving the UK's nuclear weapons. During a series of protests at the Faslane submarine base in August 1998 three campaigners managed to

225 Ministry of Defence Freedom of Information Act request response 13-11-2013-153651-008.
226 'Trident Ploughshares Disarmament Activists Reach Nuclear Submarine in Faslane Naval Base'. Trident Ploughshares News Index 1998 April to December, 18 August 1988. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-1998.pdf
227 'Activists charged with £25000 worth of damage to Trident submarine'. 2 February 1999. Trident Ploughshares News Index 1999 December to January. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-1999.pdf

Ulla Roder, Angie Zelter
and Ellen Moxley after their acquital
Image credit: Trident Ploughshares

swim into the security area at the base and get to within ten metres of HMS Vigilant, a Trident submarine berthed at the base. The intrusion caused panic among the security forces guarding the base. An observer from Faslane Peace Camp said that the moment the protesters were spotted was "like a pin-ball machine. All the lights went on and the alarms went off. All hell broke loose".[226]

A few months later, in February 1999, Rachel Wenham and Rosie James succeeded in swimming undetected across a 300 metre stretch of water to HMS Vengeance in the final phase of the submarine's construction at the VSEL dockyard (now owned by BAE Systems) at Barrow-in-Furness. The two women were able to board the submarine and hang a banner reading 'Women Want Peace' on the conning tower, and then spray painted the slogan 'Illegal Death Machine' on the hull and smashed testing equipment valued at £25,000 on the conning tower using hammers they had brought with them, before they were arrested. According to evidence later given in court, their action delayed the submarine's entry into service by at least a month.[227]

> ***... the moment the protesters were spotted was "like a pin-ball machine. All the lights went on and the alarms went off. All hell broke loose"***

In June 1999 Angie Zelter, Ulla Roder, and Ellen Moxley made their way across Loch Goil on an inflatable boat to the 'Maytime', a floating laboratory which conducts "silent running" trials to test the sonar signature of the Royal Navy's submarines. In a bid to disrupt forthcoming acoustic trials for HMS Vengeance at Loch Goil they cut their way into the laboratory with cold chisels and wrecking bars and damaged testing equipment with hammers, cut wires to an antenna, poured a mixture of sand, superglue, and syrup into other equipment, and threw computers, electronic equipment, and manuals overboard into the loch. They remained on board for over three hours before police, apparently alerted by a media enquiry, arrived to arrest them. Despite causing damage valued at £100,000 the three women were found not guilty of criminal offences when Sheriff Margaret Gimblett instructed the jury at their trial to acquit them of the charges against them.[228]

Trident Ploughshares activists managed to breach submarine security arrangements in Faslane again on 7 August 2000, when Ulla Roder and Marcus Armstrong were arrested after swimming into the main security area of the base, getting close to the

228 'Peace Activists Disarm UK Trident Test Station', 8 June 1999. 'Ploughshares Three Acquitted', 20 October 1999. Trident Ploughshares News Index 1999 December to January. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-1999.pdf

shiplift and within metres of a Trident submarine.[229] Ulla Roder swam into the Trident secure area at Faslane for a second time in April 2001, and this time succeeded in reaching a submarine, spray-painting the word 'Useless' on the hull of HMS Vanguard before being apprehended. Roder – described as "the new James Bond" by a Scottish newspaper following the action – said that getting into the Faslane base was "a lot easier than I had expected" and that reaching the high security zone where two nuclear-powered submarines were berthed had been "easy-peasy". Although the Royal Navy claimed that the incident did not indicate that Trident submarines might be vulnerable to a terrorist attack, a Navy source described the case as "an embarrassment" and an inquiry was launched.[230] Despite this, barely three months later protesters again managed to swim to a Trident submarine at Faslane and paint on the hull. Rachel Remnant and Marcus Armstrong were arrested at gunpoint by "surprised and amused" officers as they painted "Illegal" on the side of the submarine.[231]

It has been possible in the past for intruders to get onto nuclear armed submarines and into highly guarded sensitive areas at nuclear weapon sites

Security at Faslane was breached again in August 2002 when Gillian Sloan and Dave Rolstone swam into the base and painted the word 'Vile' on the hull of a Trident submarine.[232] Another incident took place in November 2002 on board HMS Vanguard, at the time under refit at HM Naval Base Devonport.[233] Elisa Silvennoinen and Petter Joelson climbed over a fence into the dockyard, cut through an internal security fence with boltcutters, and walked onto the submarine. At this point, according to Joelson, they were "not really sure what to do", so they went inside the submarine to explore and eventually decided to press an alarm button to draw attention to themselves. "The first alarm button we found didn't work, so we went to the other side of the submarine and found two fire alarm buttons". After they had pressed the first of these alarm buttons "nothing happened in a couple of minutes, so we pressed the other alarm too". Workers then came up from the lower parts of the submarine "but they seemed to be more keen on having a break than to discuss legal matters". Eventually the two protesters were escorted off the submarine by security staff, having by now been aboard for around thirty minutes, and held in an office where "the walls were covered with electrical diagrams of the missile system and other things I didn't understand" until police arrived to arrest them.

Meanwhile the Atomic Weapons Establishment, where the UK's nuclear warheads are designed and built, was the focus of protests and intrusions from women at the Aldermaston Women's Peace Camp. One of the regular campers, Juliet McBride, recalls that her incursions into AWE sites were "so common".[234] On one occasion she succeeded in climbing fences to gain entry to the high security area surrounding the warhead assembly / disassembly facilities at AWE Burghfield and was apprehended by armed police who "got terribly upset" upon finding her there. McBride also succeeded in entering secure areas at the AWE Aldermaston site a number of times. During one such visit she entered a building in the hydrodynamics research area and climbed over a counter dividing a room into two parts, one of which was apparently a restricted entry area. After being escorted out of the building by police "I was given a 'wave over' with a radiation monitoring wand" before being allowed to leave the premises.

McBride also managed to enter the secure 'Citadel' nuclear storage and processing area at Aldermaston,

229 'Pressure For Nuclear Disarmament Continues at Faslane'. 7 August 2000. Trident Ploughshares News Index 2000 December to January. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-2000.pdf

230 'Trident Three Activist Spray-Paints UK Nuclear Weapon Submarine'. Trident Ploughshares News Index 2001 December – January, 27 April 2001. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-2001.pdf

231 'Hiroshima anniversary marked with vigils and direct action'. Trident Ploughshares News Index 2001 December – January, 6 August 2001. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-2001.pdf

232 'Faslane security breached again as protesters paint on Trident'. Trident Ploughshares News Index 2002 December – January, 8 August 2002. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-2002.pdf

233 ''We were inside Trident sub', say activists'. Trident Ploughshares News Index 2002 December – January, 18 November 2002. http://tridentploughshares.org/wp-content/uploads/2013/03/News-index-2002.pdf

where she was detained by police after telephoning them from inside the zone to ask them to come and collect her and give her a cup of tea. Following the incident she was again required to have a radiation monitoring 'wave over'. At other times she entered various other buildings inside the Aldermaston wire including an open-plan office used by environmental management staff, classrooms used by apprentices studying at the base, and a building which was "very noisy, with a huge piece of machinery inside" which she believes was some kind of electricity generating plant. On another occasion McBride recalled entering the North Ponds effluent processing area inside the wire. "It was a very hot day and I had brought an inflatable dinghy with me. I blew up the dinghy and rowed onto one of the ponds with a big red banner saying 'No Nukes'. No-one saw me – a police dog handler walked past but didn't notice anything. A photographer from the Newbury Weekly News took a photo of me from outside the base, then eventually I got bored and climbed out again". As well as entering secure AWE sites McBride also managed to climb into the secure garaging areas at RAF Wittering for warhead convoy trucks used to transport nuclear weapons on the public highway. She also went into the accommodation area upstairs from the garage "where I made myself a cup of coffee and looked in the daily log book".

McBride's entries to supposedly secure nuclear sites became so frequent that they were the subject of questions by the House of Commons Defence Committee after a visit to Aldermaston when "some of the members were lucky enough to watch, or unlucky enough to be able to watch, a video of [her] climbing the fence".[235] McBride says that, rather than arrest her, most of the time police officers just walked her out of the base after apprehending her, "even when they gave me a wipe-down with the Geiger counter. Sometimes I insisted on being monitored, sometimes they insisted on monitoring me." A request to AWE to provide her with a radiation monitoring badge to wear whilst inside the base received no reply, although AWE did warn their employees about McBride's incursions into the Establishment and apparently provided them with instructions on how to respond if they encountered her on the premises.

Regardless of the efforts of protesters, security arrangements at the Atomic Weapons Establishment did not always meet requirements. On 21 August 2013 a deputy facilities manager at the AWE Burghfield reported a number of "irregularities" in patrols undertaken by the Ministry of Defence Police (MDP) officers responsible for guarding the site.[236] Investigation of CCTV footage covering a certain building on the site subsequently revealed that officers had been skipping patrols and other duties at Burghfield over a four month period between May and August 2013. A total of 66 police officers were investigated for failing to conduct duties at AWE as part of an operation conducted by the MDP's Professional Standards Department. Six officers were found to have committed gross misconduct and were dismissed, and a further 25 resigned as a result of the incident. 19 more officers were required to attend misconduct meetings, six required 'management action', and 10 cases were dropped and considered to require no further action.

After the discovery the MoD claimed that "at no point was the security of the site or its nuclear assets compromised".[237] However, it is now apparent that the case was deemed a "critical" incident within the MDP. Police officers under investigation were placed on duties away from AWE Burghfield and as a result it was necessary to draft in large numbers of other officers from other MoD establishments to provide cover for their absence. A special "gold cell" was set up at the Defence Equipment and Support headquarters at Abbey Wood near Bristol to handle operational issues arising from the affair.

234 Interview with Juliet McBride, 6 December 2016.

235 House of Commons Defence Committee: 'Defence and Security in the UK. Sixth Report Session 2001-2'. 17 July 2002. Evidence from Ms Gloria Craig, Mr Lloyd Clarke, and Mr John Cochrane, Questions 300 – 313. http://www.publications.parliament.uk/pa/cm200102/cmselect/cmdfence/518-ii/2013018.htm

236 Len Jackson: 'MoD Police Committee Work Programme 2015-16: Review of MoD Police Professional Standards Department handling of misconduct at Atomic Weapons Establishment Burghfield (Operation Pease)'. Report to Mod Police Committee, 31 May 2016, reference DBR-Def Sy-4-2-3.
Ministry of Defence Police: 'AWE (Burghfield) 'Operation Pease' Investigation Final Report'. IPCC Reference 2013/016988.

237 Vicky Smith: 'Ministry of Defence security 'asleep on the job' guarding a nuclear bomb factory'. Mirror, 14 December 2013. http://www.mirror.co.uk/news/uk-news/ministry-defence-security-asleep-job-2924587

An internal review of the case conducted by Len Jackson, an independent member of the MoD Police Committee, was highly critical of the conduct of the investigation[238]. Mr Jackson's report concluded that there had been "potentially systemic and long-running failures in duty and supervision by officers" and highlighted concerns expressed by many MDP officers and by the MoD Police Federation that no-one above the rank of sergeant was disciplined regarding the matter. The Head of Nuclear and Physical Security at AWE felt that the investigation had focused on "the low-hanging fruit" rather than address the root cause of the problems, and that there had been "a lack of supervision" in the specific building involved in the misconduct allegations "over a number of years". Jackson's report stated that he agreed with this view "and can see why it has created so much anger and frustration". This, together with other flaws in investigation, had "created an atmosphere of resentment" which, two and a half years later, "still remains at Burghfield".

Such incidents demonstrate that security arrangements at nuclear bases are far from infallible. It has been possible in the past for intruders to get onto nuclear armed submarines and into highly guarded sensitive areas at nuclear weapon sites. A combination of new legislation and improved physical security measures eventually put a halt to the frequent incursions which took place in the early 2000s, but it remains to be seen whether these will be sufficient to stop more determined intruders in the future.

ESPIONAGE ...

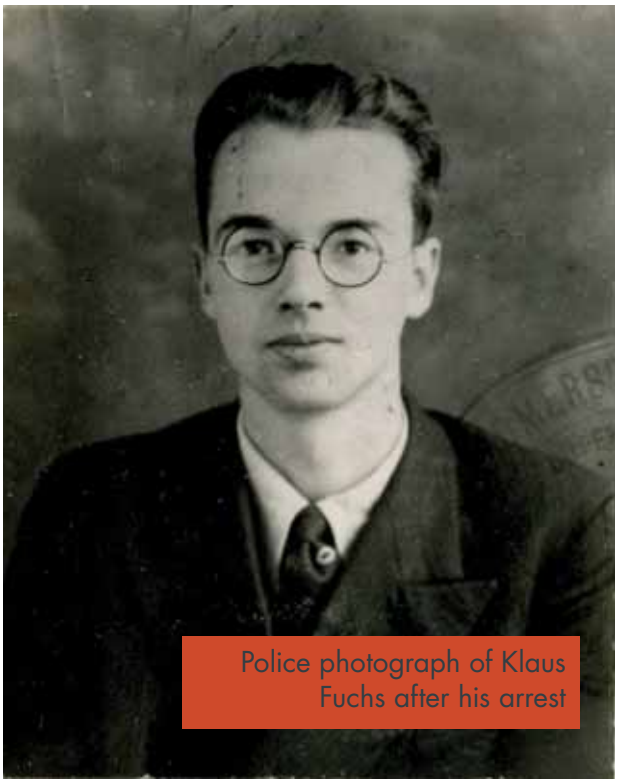
Top secret information about nuclear weapons has always been of interest to states aiming to develop their own nuclear weapons programmes and counter the capabilities of their adversaries. Over recent years international terrorist networks have apparently also been seeking to acquire such information. Quite rightly, details relating to nuclear weapon design, stockpiles, delivery systems, command and control arrangements, and deployment have always been given the highest security classification by the British government in order to safeguard national security and prevent the proliferation of military nuclear knowledge. Nevertheless, there have been occasions when sensitive information from the UK nuclear programme has been obtained and passed on to outside sources by spies and whistleblowers.

Despite the secrecy and security arrangements under which Britain's World War II and post-war research on nuclear weapons took place, a number of 'atom spies' working on behalf of the Soviet Union were able to pass secrets on to the Kremlin, supporting the development of a Soviet nuclear weapons programme. The leaks were a severe embarrassment to the British government, and jeopardised US - UK co-operation on the development of nuclear weapons for over a decade.

The first of the atom spies to be discovered was Alan Nunn May, a nuclear physicist at Kings College London who was recruited to work on early studies for the atom bomb and then became part of the research team at the Chalk River reactor in Canada.[239] A Communist Party member, May started passing information to the Soviets in 1941 and also provided them with samples of processed uranium isotopes U-235 and U-233. He was caught after a Soviet cipher clerk defected to the West and revealed his role, and was jailed in 1946 for espionage offences and spent seven years in prison. The news of May's spying became public at a critical juncture in the passage of the McMahon Bill through the US Congress, and reinforced views within the American political establishment that atomic secrets should not be exchanged with Britain or other nations.

The case of Klaus Fuchs did considerably more

238 Len Jackson, op cit.
239 Brian Cathcart: 'Obituary: Alan Nunn May'. Independent, 29 January 2003. http://www.independent.co.uk/news/obituaries/alan-nunn-may-36209.html
240 Security Service MI5: 'Klaus Fuchs'. https://www.mi5.gov.uk/klaus-fuchs
241 John Baylis: 'Ambiguity and Deterrence: British Nuclear Strategy 1945–1964'. Clarendon Press, 1995. P76, 141.



Police photograph of Klaus Fuchs after his arrest

damage to US – UK nuclear relations. Fuchs was a German scientist who joined the German Communist Party in the 1930s and fled to Britain in 1933 when the Nazis came to power.[240] He was recruited to join the British 'Tube Alloys' nuclear development programme during World War II because of his expertise in theoretical physics and in 1943 joined the British mission contributing to the Manhattan Project, where he played a key role in developing many of the designs, equations and implosion techniques used to build the first atomic bombs. Fuchs worked as a spy for the Soviet Union from 1941, when he first contacted a fellow German Communist exile to offer the Russians information about the Tube Alloys project. While working on the Manhattan Project he provided the Soviets with information which helped them make rapid progress in developing their own atomic weapons.

After returning to the UK in 1946 he continued to work on secret nuclear matters. Despite an MI5 investigation into his pre-war communist activities he was allowed to work on the emerging UK nuclear energy and weapons programmes at the UK Atomic Energy Research Establishment at Harwell, Oxfordshire. Fuchs was exposed as a spy when US codebreakers succeeded in decoding intercepted Soviet radio transmissions. He was confronted by the security service in 1949 and after confessing to breaching the Official Secrets Act was sentenced to fourteen years imprisonment. It is likely that concerns about Fuchs' spying caused the US government to abandon plans for a 1949 agreement to provide the UK with a stock of American-made atomic bombs to be held in the UK under British control.[241]

When Bruno Pontecorvo, a brilliant physicist who had worked with May in Canada and Fuchs at Harwell, disappeared to the USSR in October 1950, the British government's inquiry was specifically designed to avoid further damage to relations with the United States.[242] Pontecorvo was a pupil of the Nobel prize-winning nuclear physicist Enrico Fermi who later worked in Paris alongside two other world-class scientists, Irène and Frédéric Joliot-Curie. He joined the French Communist Party and fled to the USA when the Nazis invaded France. In 1943 he joined the Tube Alloys project in Canada and worked on reactor design at Chalk River Laboratories, but despite his high academic credentials he was not invited to join the Manhattan Project because of his communist sympathies. In 1949 he moved to Britain and took up work in a senior post at the AERE at Harwell with full access to atomic secrets. He is said to have made a "crucial" contribution to the British nuclear programme, contributing to the design of nuclear piles for the production of fissile materials and the development of instrumentation for the detection of natural radioactive deposits. Following the arrest of Fuchs, Pontecorvo was deemed to be a

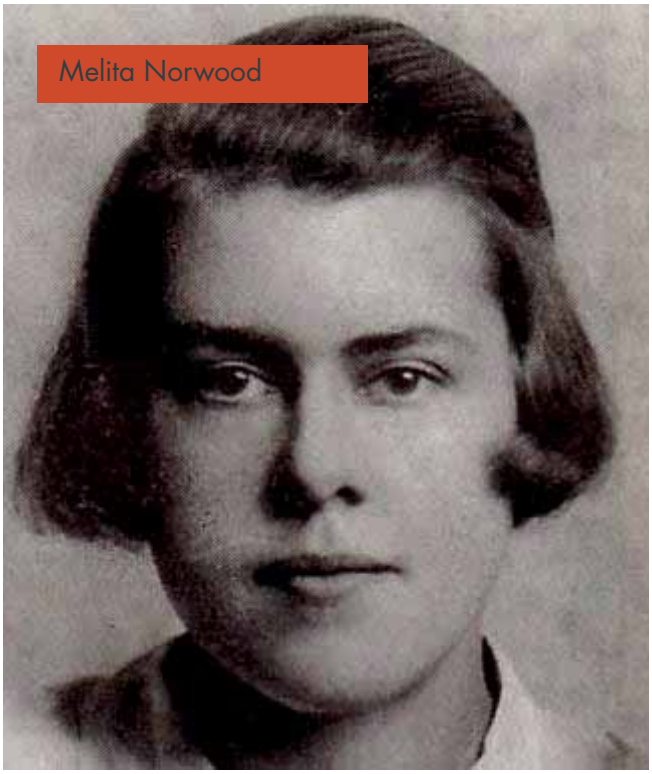
It is likely that concerns about Fuchs' spying caused the US government to abandon plans for a 1949 agreement to provide the UK with a stock of American-made atomic bombs to be held in the UK under British control

242 Simone Turchetti: 'Atomic secrets and governmental lies: nuclear science, politics, and security in the Pontecorvo case'. British Journal of the History of Science, Volume 36(4), 2003. Pp389-415. eprints.whiterose.ac.uk/4610/1/Atomic_secrets.pdf
Charles Richards: 'Confessions of an atom spy'. Independent, 1 August 1992. http://www.independent.co.uk/news/world/confessions-of-an-atom-spy-forty-years-after-bruno-pontecorvo-a-british-scientist-went-to-work-for-1537646.htm

security risk because of his communist connections and he was offered a professorship at the University of Liverpool where he would not have access to top secret material. In September 1950 he disappeared abruptly while holidaying in Italy, and subsequently reappeared in the Soviet Union, where he was welcomed with honours and placed to work in a Soviet nuclear research institute. Wary of the impact of Pontecorvo's defection on nuclear co-operation with the USA, the government claimed that he had had very limited access to secret research. Although it certainly appears that he did not work directly on the design of nuclear weapons, the media portrayed him as yet another atom spy and following his defection atomic security was reformed, with the introduction of tighter controls and positive vetting and government nuclear laboratories.

American annoyance about the poor state of British security increased still further in 1951 with the defection of Donald Maclean, the civil servant at the British Embassy in Washington who was in charge of atomic energy affairs from 1944 to 1948.[243] Maclean had been Secretary of the US – UK Combined Policy Committee on atomic energy matters and had access to classified information about British and American nuclear weapons. As a spy for the Soviet NKVD security agency, the fore-runner to the KGB, and one of the so-called Cambridge Spy Ring alongside Guy Burgess and Kim Philby, he was able to provide the Soviet Union with information on the quantity of plutonium available to the USA. This assisted Soviet scientists in identifying the number of nuclear bombs that the US could build and assessing the strength of the American nuclear arsenal against their own.

Fortunately, perhaps, for US-UK nuclear co-operation, one of the most significant Soviet atom spies was not discovered until 1992. Melita Norwood, another Communist Party member, was recruited as an agent of the NKVD in 1936.[244] She worked as secretary to Dr G.L. Bailey,


Melita Norwood

director of the British Non-Ferrous Metals Research Association, which in the 1940s began undertaking metallurgical research for the UK's atom bomb programme. Photocopying secret documents kept in her boss's office safe, she passed information to the Soviets about the corrosive nature of uranium at high temperatures and other properties of the metal which some analysts consider to have been at least as important to the Soviet nuclear programme as the information provided by Fuchs.

Working close to highly classified research Norwood had to go through security vetting, but despite doubts about her Communist sympathies she was cleared by the security services. She was exposed after Vasili Mitrokhin, an archivist with the KGB, defected to the United Kingdom in 1992, bringing with him a collection of documents which allowed her to be identified as a KGB collaborator. She was outed as

243 Spymuseum.com: 'Donald Maclean'. http://spymuseum.com/donald-maclean/
Wikipedia.com: 'Donald Maclean (spy)'. https://en.wikipedia.org/wiki/Donald_Maclean_(spy)

244 Francis Beckett: 'Secrets and Spies'. Guardian, 7 March 2009. https://www.theguardian.com/books/2009/mar/07/melita-norwood
Chris Hastings: 'British spy Melita Norwood helped speed up USSR's atomic bomb programme'. Daily Telegraph, 30 August 2008. http://www.telegraph.co.uk/news/worldnews/europe/russia/2650886/British-spy-Melita-Norwood-helped-speed-up-USSRs-atomic-bomb-programme.html

245 Avner Cohen and Meirion Jones: 'The sudden death of U.K.'s nuke chief, suspected of spying for Israel's A-bomb program'. Haaretz, 24 September 2016. http://www.haaretz.com/israel-news/.premium-1.743722
The Seventh Eye: 'It Never Happened'. 5 October 2016. http://www.the7eye.org.il/220586

a Soviet agent in 1999 but then Home Secretary Jack Straw decided that it was not in the public interest to prosecute her. The atomic intelligence she gave to the Soviet Union was important enough for the Russians to declare that she had made "a valuable contribution to the development of work in this field", and she was offered the award of the Order of the Red Banner by the KGB.

It is possible that, as well as providing clandestine information to help the Soviet Union develop nuclear weapons, British nuclear scientists also helped the Israeli nuclear programme. In the early 1960s three Jewish scientists working on nuclear weapon issues were investigated by the security service MI5. One of them was Nyman Levin, who in 1958 was appointed Deputy Director of the Atomic Weapons Research Establishment and a year later was promoted to become the Establishment's Director.[245] As the Director of AWRE Levin would have known a wealth of technical detail about the UK's nuclear weapons – and a great deal about the US nuclear weapons programme, too. However, MI5 was suspicious of Levin, whose family had strong connections in the anti-fascist movement. Levin had himself briefly been a member of an anti-fascist group in London's East End, and had holidayed in Israel at the time the Dimona nuclear plant was under secret construction. Although his Israeli connections were not unusual for British Jews at the time, Levin was interviewed by MI5 in 1965 about his communist and Israeli connections and was said to be "shaken" by the questioning. Soon afterwards he was abruptly moved from his job at AWRE, and three days later suffered a severe heart attack while attending a meeting at the Cabinet Office. He died a couple of days later, before MI5's investigation had been completed.

Even today, more than half a century later, the government refuses to release information about the investigation into Levin. Investigative journalist Meirion Jones, who has researched into the Nyman affair, believes there was "a very strong circumstantial case" against Nyman and that the MI5 investigation was justifiable, but "on the other hand MI5 at that stage were very prejudiced against Jews". He has concluded that "we are never going to be able to prove one way or the other what happened" and whether Nyman was indeed passing nuclear information on to Israel.

... AND WHISTLEBLOWERS

"My name is William McNeilly. I am an Engineering Technician Submariner for the UK's Trident II D5 Strategic Weapons System. I sent this report on the 05/05/15 to every major newspaper, freelance journalists, and whistle-blower I could find".[246]

> ***"it's only a matter of time before one of the Trident submarines are lost"***

So begins an explosive account published on the internet by a junior sailor which reveals the full, formidable extent of the problems the Royal Navy faces in undertaking 'Operation Relentless' – the enterprise to ensure that a nuclear armed submarine remains at sea, able to fire its missiles, at any time. The release of McNeilly's dossier about the faults, failures, and mishaps he witnessed during a patrol on board Trident submarine HMS Victorious was probably the most serious nuclear security incident the Navy has experienced so far this century – and proved to be a huge embarrassment to the government when the story of the 'Trident whistleblower' hit the news headlines.[247]

McNeilly's 18 page account describes a number of safety incidents which have occurred on board Vanguard class submarines (some of which are described in section 6) and a catalogue of security lapses and shortfalls on board submarines and at

246 William McNeilly: 'The Secret Nuclear Threat. 18 May 2016. https://www.scribd.com/document/265769050/The-Secret-Nuclear-Threat-Trident-Whistleblower-William-Mcneilly

247 William McNeilly, op cit.
Nuclear Information Service: Submariner: Trident is "so broken it can't even do the tests to prove it works". 17 May 2015. http://nuclearinfo.org/article/uk-trident/submariner-trident-%E2%80%9Cso-broken-it-cant-even-do-tests-prove-it-works%E2%80%9D

Photograph William McNeilly took of his identity card

the Faslane submarine base. The report gave details of a series of alarming incidents and described the submarine as being "in the worst of the worst condition", giving the grim warning that "it's only a matter of time before one of the Trident submarines are lost". It was also highly critical of lax security standards at the Faslane base, declaring that "it's harder to get into most nightclubs than it is to get into the Green Area" which controls access to Vanguard class submarines. He warned that identification was rarely checked, equipment and baggage was not searched, and PIN code security apparatus at gates was not working.[248]

The first page of McNeilly's report showed a photo of his Royal Navy identity card – in itself a breach of Naval security procedures – and it is obvious from its contents that McNeilly had ample opportunity to access top secret information which, as a sailor who had not been granted Developed Vetting security clearance, he should not have seen. In a number of places the dossier quoted from the MoD's manual CB8890, 'The instructions for the safety and security of the Trident II D5 strategic weapon system', a classified document kept within a safe in the submarine's Missile Control Centre (MCC). McNeilly claimed that he had made a copy of the entire manual by photographing it on his Samsung Galaxy mobile phone, even though electronic and recording devices were not permitted in the MCC, and that the video he recorded shows other ratings chatting beside him while he did so. He explained how he eavesdropped on 'O Group' planning meetings, held in the submarine's top secret Navigation Centre, which he should not have been permitted to enter, by sitting at a computer at the back of the room and remaining in the room undetected during the briefings. His

248 William McNeilly op cit, pp3, 4, 7.
249 William McNeilly op cit, pp2, 11.
250 William McNeilly op cit, p16.
251 Rob Edwards: 'Trident whistleblower William McNeilly 'discharged' from Royal Navy'. Guardian, 17 June 2015. https://www.theguardian.com/uk-news/2015/jun/17/trident-whistleblower-william-mcneilly-discharged-from-royal-navy

report also claims that Navigation Centre personnel let him see highly confidential information such as the location of the Precise Bathymetric Navigation Zone (PBNZ: the accurately charted area of the ocean in which UK Trident submarines patrol) and the submarine's current location. On one occasion he was left alone in the compartment with the PBNZ folder and a laptop containing top secret navigational data – information "that would sell for millions" to an enemy government.[249]

However, McNeilly was not motivated by personal gain and took care not to publicise any information which would jeopardise the safety or security of Trident submarines. According to his account, what he saw shocked him so much that he felt he had to blow a whistle and reveal the conditions on the submarine to the public and politicians. Having raised his concerns through the chain of command on "multiple occasions" without success, he concluded that the only option he had left was to "risk everything I have to inform the Government and the people."[250]

McNeilly passed his dossier on to a number of journalists and the contents were eventually published in Scotland's 'Sunday Herald' newspaper and then picked up by the rest of the UK media. He was absent without leave from his post and out of the country when the story broke, and handed himself into police at Edinburgh Airport on his return. He was arrested for failing to report for duty and confined to military accommodation at HM Naval Base Portsmouth while he was debriefed. Following a brief inquiry the MoD dismissed McNeilly's allegations as "factually incorrect or the result of mis- or partial understanding".[251] McNeilly was subsequently given a dishonourable discharge from the Navy but was not charged with any criminal offences. He believes that "all of my charges were dropped because I carefully selected information" on what to publish and what not to publish.[252]

At a time when the British government is concerned with potential terror threats against both civilian and military infrastructure, McNeilly's description of elementary security failures and the ease with which he obtained sensitive information makes for difficult reading, exposing the potential security risks posed by nuclear insiders.

INFORMATION SYSTEMS AND CYBER SECURITY

The widespread use of networked information systems is a rapidly emerging area of security concern in the internet age, and the security of networks in the defence and nuclear sectors is of particular significance. Like all information networks, systems in the defence and nuclear sectors are at risk from cyber attack from actors ranging from individual hackers through to organised criminals, terrorists, and sophisticated state-sponsored groups. Statistics on numbers and categories of cyber attacks on the MoD and its contractors are not published because the government believes that such information could enable opponents to deduce how successful the UK is in detecting such attacks, and enhance their ability to conduct damage assessments on attacks they have conducted.[253] However, the civil sector Nuclear Decommissioning Authority's network is subject to 30,000 automated cyber attacks or scans every day,[254] and without doubt networks operated by government agencies and contractors involved in the UK's nuclear weapons programme face a similar or greater level of threat. The MoD 'Cyber Primer' cites as a case study the example of the 'Conficker' virus which in 2008 infected many systems globally, including MoD's own administrative systems and the Royal Navy's Navystar/N desktop computers, although it is not known whether this had any impact on systems associated with the Trident programme.[255]

252 William McNeilly: 'The Art of War'. 16 June 2015. P6. robedwards.typepad.com/files/the-art-of-war-by-william-mcneilly.pdf
253 Parliamentary Written Question: 'AWE'. Hansard, 21 January 2014. Column 111W. http://www.publications.parliament.uk/pa/cm201314/cmhansrd/cm140121/text/140121w0001.htm#140121w0001.htm_wqn43
254 Cumbria Business Growth Hub: 'Nuclear Contract Essentials'. http://www.cumbriagrowthhub.co.uk/Discussion/0811_Nuclear_Contract_Essentials

In 2011 the then Foreign Secretary, William Hague, told an international security conference that a UK defence contractor had been deliberately targeted in an attempted cyber attack which had taken place the year before. A malicious file posing as a report on a nuclear Trident missile was sent to a defence contractor by someone masquerading as an employee of another defence contractor. The email was detected and blocked, but its purpose was apparently to steal information relating to sensitive defence projects.[256]

Sensitive data from around 170 major companies, including the UK's Atomic Weapons Establishment and UK Trident contractor Lockheed Martin, may have been compromised after British Telecom web traffic was accidentally rerouted through Ukraine and Russia in 2015.[257] According to internet performance management company Dyn, diversion of the data took place over a 90-minute period on 12 March 2015. The redirection was caused by bad routing announced by the Ukraine's Vega telecom company. Doug Madory, director of internet management at Dyn said the incident was most likely "an innocent mistake by Vega", but was "concerning nonetheless". It is impossible to tell if any information was lost or compromised, but unnecessarily sending the data to Ukraine may have made it possible for anyone with privileged access to Vega's networks to insert malware into the stream or monitor, download, or tamper with any data that was not encrypted. Although sensitive traffic from AWE is routinely encrypted, the incident highlights a significant security concern in the way internet traffic is routed, with the stakes becoming higher when the traffic is from agencies involved in the management of nuclear weapons.

The theft of two computers from the Atomic Weapons Establishment in 2015 also exposed failures in information security procedures. The computers were removed from the AWE Aldermaston site by Graham Heaysman, an information technology contractor working at the site, who failed to go through the correct channels to request permission to take the computers home. The computers were kept at his home for a number of months and their loss was not reported by AWE to MoD until January 2015. Heaysman was arrested for the theft and was eventually convicted and fined £250 at Guildford Magistrates Court in August 2015. Following the incident internal MoD investigations revealed "poor asset management of AWE IT equipment" and "failings in the authorisation process for the removal of IT Equipment from site". AWE was forbidden from placing IT contracts for non-consumables without prior approval from MoD's Strategic Weapons Project Team until improvements in procedures had been put into place.[258]

As far as we know, nuclear weapons and military nuclear materials have never been lost or stolen in Britain. However, serious security incidents have occurred and information has been stolen from UK sources which has assisted other states, notably Russia, in designing and building nuclear weapons. The information age provides new opportunities for the theft of sensitive information and clandestine attempts to sabotage nuclear programmes. Protesters have managed to gain entry to secure areas and, although they pose a low level of security threat, where they enter others may follow with more malicious intentions. Nuclear security is a fast-moving and potential high risk issue for the UK's Trident programme, and there is certainly no room for complacency in future.

255 Ministry of Defence: 'Cyber Primer: Second Edition'. July 2016. https://www.gov.uk/government/publications/cyber-primer

256 Richard Norton-Taylor and Julian Borger: 'Chinese cyber-spies penetrate Foreign Office computers'. Guardian, 4 February 2011. https://www.theguardian.com/world/2011/feb/04/chinese-super-spies-foreign-office-computers

257 Griffin, Andrew: 'UK's nuclear weapons data and other sensitive internet traffic accidentally sent through Ukraine'. Independent, 13 March 2015. http://www.independent.co.uk/life-style/gadgets-and-tech/news/uks-nuclear-weapons-data-and-other-sensitive-internet-traffic-accidentally-sent-through-ukraine-10107168.html
'Network Error Routes Confidential UK Nuclear Weapon Traffic Through Russia'. TechNewsToday.com, 13 March 2015. http://www.technewstoday.com/22050-network-error-routes-confidential-uk-nuclear-weapon-traffic-through-russia/

258 Natasha Salmon: 'Guildford man pleads guilty to theft of Atomic Weapons Establishment computers'. Get Surrey, 7 August 2015. http://www.getsurrey.co.uk/news/surrey-news/guildford-man-pleads-guilty-theft-9808101
Nuclear Information Service: 'Computer theft exposes computer shortfalls at AWE'. 14 September 2016. http://nuclearinfo.org/article/awe-aldermaston/computer-theft-exposes-security-shortfalls-awe

CASE STUDY 6

Date: 11 October 1988

Location: Faslane submarine base

Weapons involved: Polaris submarine armed with up to 32 Chevaline nuclear warheads

Control room of a different Polaris submarine, HMS Revenge, in 1975. © Crown copyright IWM (TR 42813)

"WE'RE HIJACKING THIS SUBMARINE. TAKE US TO CUBA"

"It was 1988 October the eleventh.
That's a date I'll remember."[259]

Phill Jones chuckles as he recalls the night he and two other campaigners from Faslane Peace Camp pulled off a protest action the like of which no-one had ever achieved before – gaining entry to the control room of HMS Repulse, one of Britain's nuclear armed submarines. The protest revealed that, despite government claims to the contrary, it was possible for intruders to reach the most sensitive and heavily guarded areas at the heart of the UK's nuclear weapons programme, and highlighted major security concerns at the Faslane base.

Jones had been living at Faslane Peace Camp, next to the home base for the Royal Navy's Polaris submarines, for several years before the incident and along with others at the camp had broken into the base on a number of previous occasions. As a result of their actions security measures at the base had recently been upgraded.

"A year before they'd built a new super-fence at Faslane which they'd said was unclimbable and uncuttable. What we didn't realise was that the security sensors on the fence had been switched off that night as workers had been doing a job on it."

That autumn night the campers had decided to try to undertake a non-violent direct action protest on a Polaris submarine which was in a

259 Interview with Phill Jones, 8 December 2016.

dry dock at the base. One of the campers was going to try to swim to the dock, and Jones and two friends – Chipper Mills and Tony Vallance – were to act as a decoy, climbing the fence to draw attention away from the swimmer.

The three campers cut through the outer fence with boltcroppers without triggering the alarms, and then followed a drunken sailor down towards the heart of the base - "he was wearing a white leather jacket with tassels and cowboy boots, and swaying all over the road" - until the sailor used a pass card to get through a security turnstile and they were no longer able to follow him. At this point they decided to hand themselves in at the Faslane base police station. "We were about to go in and ask for directions, or something stupid like that, and I actually had my hand on the door and could see the police officers chatting inside, when I decided 'no, let's not make it too easy for them.'"

The three walked round the edge of the construction site for the new Trident training school where they found ladders which they used to climb over another fence. "While we were climbing Chipper got caught in the razor wire and just as we were trying to free him, a police van drove past at around five to ten miles per hour. They were so close I could recognise the police officers inside it. But they just blanked us – even though they were only the width of the pavement away from us they didn't spot us."

... workers on the base ... mistook them for civilian crane operators - "even though it was the middle of the night and Valley had a 12 inch mohawk, Chipper was wearing a rainbow sweater and donkey jacket, and I had hair down to my shoulders"

They then crossed a jetty, where the same police van reappeared, catching them in its lights, and were spotted by workers on the base who mistook them for civilian crane operators - "even though it was the middle of the night and Valley had a 12 inch mohawk, Chipper was wearing a rainbow sweater and donkey jacket, and I had hair down to my shoulders". They considered climbing one of the huge dockside cranes, but instead continued along a jetty to where one of the Navy's conventionally-armed nuclear powered submarines was berthed. "There was a guy sitting on something like a copper water tank shouting to one of his colleagues, and we saw a red ribbon across the way and radiation symbols and signs, and realised this was a radiation zone for authorized personnel only. The workers saw us – we made eye contact – but they didn't say anything. I've no idea why they were working in the middle of the night – it wasn't any kind of emergency."

The three protesters then made their way to the Green Area where Polaris submarines were berthed. They used bins chained to a gate to climb into the area, then heard shouting – which they later realised was armed Royal Marine guards raising the alarm after sighting them. "We could see the fin of a submarine there" said Jones. "It looked far bigger than it should have and there was a banner with the submarine's name – HMS Repulse – on the gangway leading up to the deck."

Jones and his colleagues tiptoed up to a sentry box where the submarine's guards were smoking a cigarette together, and then ran onto the gangplank and onto the submarine's casement before they were spotted. "We could hear the sailors shouting 'Stop – you can't go up there', but we slid through a hatch and down a ladder into the submarine", said Jones. "We found ourselves in a narrow corridor and pelted back towards the fin and the control room, where I expected to be decked by a big hairy sailor."

Instead he found a rating with his feet up on a console with a cigarette in his mouth and a can of beer in his hand reading a book. The startled sailor rolled off his chair, slipped everything into a bin, and came to attention in a single smooth motion - "he obviously thought I was the officer of the watch doing the rounds."

"I said 'We're from the Peace Camp and we're hijacking this submarine. Take us to Cuba', and then they completely freaked. One of them called for help, saying 'Stevie, are you busy? Can you come here? I think we've got a problem." A half-clad officer arrived, obviously having been roused

from sleep, "and he was so startled and angry that his eyes were literally bulging out of his face."

"We could see the joysticks used to control the submarine's hydroplanes and a pedestal for the periscope in the middle. In the corner was a shuttered plywood area, which was the chart room where the secret charts of the submarine patrol area were kept. I went in there to try to take a look at the charts but was bundled straight out in five seconds. We sat on the chairs in the control room while the crew made jokes about not touching any of the buttons, and drew peace symbols and anarchy signs on the consoles with a marker pen we had with us."

The three were taken to the officers mess - "where there was a picture of the Royal Family on the wall - only it was the Spitting Image Royal Family, not a real photo" - where they were held while arrangements were made to allow Ministry of Defence Police officers special permission to board the submarine to arrest them.

The base was locked down for over twelve hours while police and marines searched for the swimmer and other intruders who they believed had also entered the base but had not been detected, dropping stun grenades into the loch in attempts to flush them out. The story hit the front page of the tabloid newspapers in Scotland and Defence Secretary George Younger, attending the Conservative Party Conference in Brighton, was woken at 5 am to be informed about the incident.

Prime Minister Margaret Thatcher was said to be furious about the affair. In reply to a letter about the incident from her Private Secretary, Charles Powell, she wrote the words "I am utterly horrified", and warned that the action by the peace campers had posed a "grave danger". Shortly afterwards the rules of engagement for guards at the Faslane base were changed to allow them to shoot intruders on sight.[260]

Jones, Mills, and Vallance were charged under military lands byelaws for entering a prohibited area, but, at a trial where they faced 23 prosecution witnesses, succeeded in challenging the byelaws and were found not guilty of any criminal offences. Others did not get off so lightly: ten Royal Naval and Royal Marines personnel were disciplined following the incident, including the Commodore in charge of the Faslane base and the commander of the squadron of Marines charged with guarding the submarine. It later emerged that standing orders about submarine security had not been followed that night: among other failings, the number of marines on guard was fewer than it should have been.

Despite the elements of comic farce in his story, Jones points out just how serious the incident was. "We managed to get into the control room of a fully armed British nuclear submarine. The IRA were very active at the time, and if we had been an armed group – which we could easily have been – we would have been in control of British nuclear weapons. It would have been very difficult for security forces to get back into the steel hull of the submarine to get to us. We couldn't have gone anywhere or fired the missiles, but it wouldn't have been hard to detonate the explosive propellant of a missile and make a very big bang."

"They'd built a £10 million fence around the base but it didn't work. For me, the most serious aspect of the story was that two weeks later peace campers broke into the Coulport nuclear weapons store and managed to get up to the fourth level fence around the warhead stores. Nothing was learnt from what the three of us did.

260 Nick Higham: 'Cabinet files reveal plan to shoot nuclear intruders'. BBC News, 30 December 2016. http://www.bbc.co.uk/news/uk-38369742

261 US Department of Defense: "Narrative Summaries of Accidents involving U.S. nuclear weapons, 1950 -1980" (undated). The

OVER HERE: ACCIDENTS INVOLVING US NUCLEAR WEAPONS IN THE UK

The United States has maintained military bases in the United Kingdom since 1942, and throughout the Cold War many of these bases routinely handled nuclear weapons. Not surprisingly, a number of accidents and incidents involving US nuclear weapons have occurred at bases in the UK.

The 'official' list of nuclear weapon accidents published by the US Department of Defense provides summaries of thirty two accidents which took place between 1950 and 1980.[261] The list includes details of one 'Broken Arrow' incident which took place in the UK. The incident took place in July 1956 at the RAF Lakenheath air base in Suffolk, when a B-47 bomber crashed and collided with a storage igloo containing Mark 6 atomic bombs (see case study 7).

However, this is not the only incident involving American nuclear weapons which has happened in Britain. A number of less serious – but nevertheless worrying – incidents are known to have taken place, mostly in the early years of the Cold War when safety standards were far lower than would be acceptable nowadays.

At the end of the 1940s, when the USA was building up its nuclear arsenal, the Mark 3 atomic bomb (the 'Fat Man' design used to destroy the Japanese city of Nagasaki in 1945) was considered too dangerous to be flown fully assembled over American soil. However, no safety restrictions were imposed on flights carrying the bomb over the UK. In the event of an attack on the Soviet Union American B-29 aircraft would fly from the United States with partially assembled Mark 3s and land in Britain at air bases at Lakenheath and Sculthorpe, where atomic bomb assembly complexes had been secretly built. Fissile cores would be inserted into the weapons, and the aircraft would then continue on their missions to the Soviet Union. An armed B-29 crashing during take-off would have posed a serious potential hazard to a large area in the vicinity of the airbase.[262]

17 INCIDENTS, INCLUDING:

- 4 Fires
- 2 Incidents involving potential radioactive contamination
- 2 Aircraft crashes
- 1 Incidents where there was a risk of unintentional nuclear detonation
- 1 Incidents involving mishandling of nuclear weapons
- 5 Incidents where unauthorised people breached a secure area or entered a military vehicle
- 2 Security issues caused by the activities of staff working at nuclear or defence sites

report defines an accident involving nuclear weapons as "an unexpected event" that results in any of the following: "Accidental or unauthorised launching, firing, or use" … of a nuclear-capable weapons system that could lead to the outbreak of war; a nuclear detonation; "non-nuclear detonation or burning of a nuclear weapon or radioactive weapon component"; radioactive contamination; "seizure, theft, or loss of a nuclear weapon", including the jettison of a weapon; or a "public hazard, actual or implied".

262 Eric Schlosser: 'Command and Control'. Penguin, 2013. P97.

As well as the B-47 crash in 1956, another mishap involving a nuclear weapon occurred at Lakenheath in January 1961. The incident involved a F-100D Super Sabre aircraft which was armed with a Mark 28 hydrogen bomb. When the pilot started the aircraft's engines the underwing fuel tanks were accidentally jettisoned, hitting the runway and rupturing. The fuel ignited, and flames engulfed the nuclear bomb mounted underneath the aeroplane, scorching and blistering it. The fire burned for approximately two minutes but firefighters were able to extinguish it before the weapon's high explosives detonated or ignited or the fire caused the warhead arming components to function.[263]

On 26 May 1964 a visiting B-47 from the 509th Bomb Wing based at Pease AFB in New Hampshire crashed on landing at RAF Upper Heyford in Oxfordshire, killing the navigator. The aircraft had experienced problems with its rudder-elevator power control during the flight across the Atlantic. According to a witness, Technical Sergeant Raymond J. Tomory, the pilot "totally lost it on the left wing" when landing the aircraft. "As a result the left wing dropped, hit the runway and he cartwheeled through the alert area. He went between uploaded B-47s on his wingtip, wiped out a building that just a day before was loaded with JATO [Jet-assisted take off] bottles and came to rest".

The fuel ignited, and flames engulfed the nuclear bomb mounted underneath the aeroplane, scorching and blistering it

The aircraft that crashed was not carrying a nuclear weapon at the time of the accident, but during the crash its wreckage slid between two, and possibly more, B-47 aircraft parked in the 15 minute alert area. Each of these aircraft was armed with nuclear weapons: possibly two Mark 28 tactical nuclear bombs on each aircraft. One of the B-47s in the alert area suffered major damage when struck by a piece of wreckage but did not catch fire. If wreckage from the crashed aircraft had slid to the left or the right or caused a fire in the alert area, a number of Alert B-47s could have become involved, resulting in a major incident.[264]

An accident involving another B-47 which took place at RAF Greenham Common on 28 February 1958 is more controversial, and there is conflicting evidence as to whether or not nuclear weapons were involved. It is not disputed that a B-47 aircraft encountered engine problems immediately after taking off from Greenham Common and released two drop tanks containing jet fuel. The tanks ricocheted from the drop site onto a parked B-47 aircraft and a nearby hanger, which were engulfed in flames. Firefighters let the first aircraft burn but struggled to prevent flames from spreading to other aircraft on the reflex parking area beside it. Smoke obscured the runway, preventing the stricken aircraft from landing, and it was diverted to nearby RAF Brize Norton to land. The parked aircraft was destroyed and the hanger damaged. Two people were killed in the accident and another was seriously injured.[265]

Explosions could be heard for miles around and local firefighters at first believed there had been an atomic explosion at the base. However, the base commander, Colonel Arthur Cresswell, denied that the B-47 which was destroyed was carrying a nuclear weapon at the time. Although nuclear weapons were located at Greenham Common over this period and the aircraft which was destroyed was standing in the 'reflex parking area' intended for rapid deployment of nuclear-armed aircraft, there is as yet no conclusive evidence either way as to whether a nuclear weapon was directly involved in the incident.

In 1996 a report published by the Campaign for Nuclear Disarmament drew attention to a previously secret study conducted in 1961 by the Atomic

263 Eric Schlosser op cit, p195.
Maggelet, Michael H., and James C. Oskins: 'Broken Arrow Volume II. A Disclosure of Significant U.S., Soviet, and British Nuclear Weapon Incidents and Accidents, 1945-2008.' Lulu.com, 2008. Pp166-7.

264 Michael H. Maggelet and James C. Oskins: 'Broken Arrow: The Declassified History of U.S. Nuclear Weapons Accidents'. Lulu.com, 2007. Pp265-70.

265 Chris Baker: 'USAF report casts doubt on nuclear bomb claims'. Newbury Weekly News, 10 October 1996. Michael H. Maggelet and James C. Oskins 2007, op cit. Pp271-8.

Weapons Research Establishment (AWRE) into levels of uranium detected around the Greenham Common base.[266] The AWRE report suggested that there had been a release of radioactivity at Greenham Common, which could have been caused by damage to a nuclear weapon, subsequently spreading to the surrounding countryside, and stated that the 1958 incident was the only incident which may have been large enough to cause such a release. However, the AWRE report stops short of concluding that the 1958 incident was definitely responsible for the incident, and it appears that the report authors did not know for sure whether the aircraft involved had been carrying a nuclear weapon.

The matter was investigated by the Committee on Medical Aspects of Radiation in the Environment (COMARE) in 1998. COMARE's Fifth Report gives a brief summary of the incident based on the documentation available to them, which states that "we found nothing to suggest that a nuclear weapon was involved in the accident or subsequent fire". The COMARE report found an excess of leukemia in local authority ward 2 in Newbury but concluded that "the levels of radiation in the local area are so low that they could not be responsible for the local incidence of childhood leukemia."[267] A 1997 Southampton University survey in the area showed no increase in soil and humus of uranium over the presence of naturally occurring uranium.[268] Although the 1958 incident at Greenham Common was a very serious and dangerous incident at a base where nuclear weapons were stored, there is as yet no firm evidence to conclude that a nuclear weapon was directly involved.

Security concerns, as well as safety issues, have arisen in relation to US nuclear weapons held in the UK. In an incident which took place at RAF Sculthorpe in Norfolk on 30 October 1958, Master Sergeant Leander Cunningham locked himself inside a maintenance bay at the air base and threatened to shoot into a Mark 5 atomic bomb with his service issue pistol, blowing himself and other personnel up. The weapon was probably not fitted with the detachable nuclear capsule needed to arm a Mark 5 bomb, as capsules were at the time stored in a separate igloo with more controlled security. MSgt Cunningham is said to have climbed into the rafters of the building with his pistol and threatened to blow up the bomb. After eight hours he was coaxed down and surrendered his weapon, and was subsequently sent back to the USA.[269]

Between 1959 and 1963 American Thor intermediate range ballistic missiles were deployed in the UK under the terms of 'Project Emily'. The missiles were operated under 'dual key' arrangements, with the missiles operated by RAF Bomber Command while their W49 nuclear warheads remained under the control of US custodians. Deployment of the Thor missiles was not without incident.

A former Thor base commander, Group Captain George Aylett, has revealed how a mistake during a missile refuelling operation could have resulted in a major fire engulfing the missile and its 1.4 megaton nuclear warhead. The incident happened on 7 December 1960 at RAF Ludford Magna, 12 miles east of Lincoln, when RAF technicians fuelling the missile inadvertently allowed its liquid oxygen tank to empty on to the launch pad. Fire fighters called to the incident arrived to find the missile launch area enveloped in a cloud of evaporating vapour, and the leak could have caused the combustion of inflammable material in the area, leading to detonation of the rocket's liquid propellant. The US Air Force was shocked at the occurrence, and as a result "an awful lot of people were moved on" according to Group Captain Aylett.[270]

266 Eddie Goncalves: 'Broken Arrow. The secret of Greenham Common's nuclear accident'. Campaign for Nuclear Disarmament, 14 July 1996. http://www.cpeo.org/lists/military/1996/msg00205.htmlport

267 Committee on Medical Aspects of Radiation in the Environment: 'Fifth Report: The incidence of cancer and leukaemia in the area around the former Greenham Common Airbase. An investigation of a possible association with measured environmental radiation levels.' National Radiation Protection Board, 1998. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/366609/COMARE_5th_report.pdf

268 I.W. Croudace, P.E. Warwick, R.N. Taylor and A.B. Cundy: 'Investigation of an alleged nuclear incident at Greenham Common airbase using TI-mass spectrometric measurements of uranium isotopes'. Environmental Science and Technology, 2000, Vol 34, 4496-4503.

269 Michael H. Maggelet and James C. Oskins 2008, op cit, pp222-3.

270 Duncan Campbell: 'Nuclear missile error that could have ravaged Lincolnshire was kept secret.' Independent, 6 October 1999. http://www.independent.co.uk/news/science/nuclear-missile-error-that-could-have-ravaged-lincolnshire-was-kept-secret-738686.html

In another incident on 17 August 1962 at an unspecified location, the retrorockets of a Thor missile suddenly fired during a routine check, startling the crew. The launch pad was evacuated and when crew members returned to the site they found, fortunately, that safety pins were still holding the re-entry vehicle in place on top of the missile and that the warhead was undamaged. An investigation concluded that the cause of the incident "was failure to follow prescribed safety rules for the Thor missile."[271]

Despite the intention to safeguard Thor missiles against anything other than a mutually agreed launch, the dual key arrangements for the missiles were not infallible. Under the dual key system British and American personnel would each have to insert a separate key in order to fire a nuclear-armed missile as a safeguard against one of the allies ordering a launch without the permission of the other. However, the locks on all Thor missiles based in the UK had to be changed after an RAF technician discovered while servicing a missile that his British launch key also fitted the lock reserved for an American operator.[272] A check of the other missiles revealed that this was also the case for one other USAF lock. All locks were changed as a result, but RAF officers have claimed that they could have nevertheless overcome dual-key control. "You could have got round [American control of the warhead] just as if you want to start a car without the ignition key," according to Squadron Leader Frank Leatherdale, a former Thor base commander. "It was dangerous, and it was frowned upon, but it was done."[273]

From 1961 to 1992 the US Navy operated a submarine refit facility at the Holy Loch in Scotland, with Polaris and Poseidon nuclear-armed ballistic missile submarines operating from the base. On 29 November 1970 a fire broke out in a baggage storeroom on board the nuclear submarine tender USS Canopus at Holy Loch. Two Polaris submarines – the USS Francis Scott Key and USS James K. Polk - were moored alongside the Canopus. The Francis Scott Key cast off but the James K. Polk remained alongside as the fire burned out of control for four hours, killing three men and injuring 40 more who were overcome by smoke and fumes. The cause of the fire was unknown, but U.S. Navy documents record that "damage was extensive in the small area in which the fire was contained". The Canopus carried nuclear missiles and warheads and the two submarines together carried 32 Polaris A3 ballistic missiles with a total of 96 nuclear warheads.[274]

Another potentially serious incident took place at Holy Loch on 2 November 1981, when a Poseidon missile was dropped 13 to 15 feet as it was moved from a berthed submarine onto the tender ship USS Holland. An error by a crane operator caused the missile to slip, but the uncontrolled drop was halted by an arrester device. However, the missile then swung violently and hit the side of the tender ship. Had the missile fallen freely the missile propellant or explosive inside the warheads could have exploded, dispersing radioactive material from any warheads mounted on the missile over a wide area. The U.S. Navy refused to confirm or deny whether there were warheads on the missile and stated that "there was no damage done, no injuries occurred; there was no danger to personnel", although "personnel were required to report to duty stations to correct the problem". The episode was reputedly recorded as a 'Bent Spear' incident (an incident of "significant interest", but which did not result in radioactive contamination).[275]

... missile then swung violently and hit the side of the tender ship

271 Michael H. Maggelet and James C. Oskins 2008, op cit, p210-1.
272 Sam Marsden: 'Locks on nuclear missiles changed after launch key blunder'. Daily Telegraph, 1 August 2013. http://www.telegraph.co.uk/news/uknews/defence/10213524/Locks-on-nuclear-missiles-changed-after-launch-key-blunder.html
273 Duncan Campbell, op cit.
274 Hans M. Kristensen: 'Declassified: US Nuclear Weapons At Sea'. Federation of American Scientists Strategic Security Blog. 3 February 2016. https://fas.org/blogs/security/2016/02/nuclear-weapons-at-sea/
William M. Arkin and Joshua Handler: 'Naval Accidents 1945 – 1988'. Greenpeace/Institute for Policy Studies, June 1989. P43. fas.org/wp-content/uploads/2014/05/NavalAccidents1945-1988.pdf
275 William M. Arkin and Joshua Handler, op cit, p62.
Duncan Campbell: 'The Unsinkable Aircraft Carrier'. Paladin, 1986. P219.Hans M. Kristensen, op cit..
William M. Arkin and Joshua Handler, op cit, p50.
276 Matthew Weaver: 'Scottish cold war nuclear submarine collision kept secret for 43 years'. Guardian, 25 January 2017.

The nuclear armed submarines based at Holy Loch occasionally ran into trouble while on patrol, too. On 3 November 1974, shortly after sailing from Holy Loch, the USS James Madison, a ballistic missile submarine armed with 16 Poseidon missiles and 160 nuclear warheads, collided with a Soviet submarine. The James Madison was badly dented and returned to Holy Loch two days after the incident for a week of repairs and inspection. The collision left a nine-foot scrape in the Madison and according to reports in the American media the two submarines came within inches of sinking one another.[276] Press reports at the time said that the accident took place in the North Sea, but secret papers released by the US Central Intelligence Agency 43 years afterwards reveal that it actually occurred in shallow waters as the James Madison was leaving Holy Loch. A secret cable sent to the US Secretary of State Henry Kissinger said: "Have just received word from the Pentagon that one of our Poseidon submarines has just collided with a Soviet submarine. The SSBN James Madison was departing Holy Loch to take up station when it collided with a Soviet submarine waiting outside the port to take up trail. Both submarines surfaced and the Soviet boat subsequently submerged again. There is no report yet of the extent of damage. Will keep you posted." The cable was published by the CIA on 17 January 2017 as part of a mass release of 930,000 previously classified reports.[277]

In March 1986 the USS Nathanael Greene ran aground in the Irish Sea, suffering external damage to its ballast tanks and rudder. Although the U.S. Navy stated that the accident had no effect on the propulsion, and caused no injuries or damage to the submarine's Poseidon nuclear missiles, the extent of the damage subsequently led to a decision to decommission the vessel early, partly in order to meet arms control requirements.[278] The Nathanael Greene had been involved in a previous controversy in 1984, when the submarine had reportedly lost a propeller in the Irish Sea. It returned to Holy Loch, where repair facilities were temporarily unavailable, and so was towed on to the nearby Royal Naval submarine base at Faslane and dry-docked. On 18 August a fire broke out on the dry-dock, caused by an electrical fault in a capstan motor, which was quickly extinguished and did not damage the submarine. The US Navy refused to say whether the submarine had nuclear weapons on board at the time of the incident.[279]

Less has been published about nuclear safety at US bases in the UK in the latter part of the Cold War, and it is entirely possible that further incidents involving nuclear weapons which have not been reported may have taken place at US bases. During the deployment of nuclear-armed US cruise missiles at Greenham Common between December 1983 and March 1991 high profile protests took place which on a number of occasions brought campaigners within close proximity of cruise missile launchers. Although it is unlikely that the launchers were armed with nuclear warheads on these occasions, protests during cruise missile deployment exercises over this period raise a number of questions about both security and safety standards achieved by the US Air Force at Greenham.[280]

In March 1985 and again in February 1987 women protesters at Greenham Common entered hangers where missile launchers were based to disrupt preparations for a convoy dispersal exercise, and during a dispersal exercise in March 1985 a protester was able to climb unchallenged into the empty cab of a launch vehicle and leave a note for its crew. Protesters again entered the cabs of launch vehicles during an exercise on 11 October 1987, falling asleep for eight hours before being discovered by convoy personnel, and in January 1990, when they left peace stickers in the cab while its military occupant slept. Women peace protesters also succeeded in entering a Cruise convoy exercise site in July 1987 and were able to wander among missile launchers.[281]

https://www.theguardian.com/us-news/2017/jan/25/nuclear-submarine-collision-cold-war-cia-scotland

277 William M. Arkin and Joshua Handler, op cit, p69.

278 William M. Arkin and Joshua Handler: 'Naval Accidents 1945 – 1988', op cit, p67.
Thoralf Doehring: 'USS Nathanael Greene (SSBN 6363)'. Unofficial US Navy Site. http://www.navysite.de/ssbn/ssbn636.htm

279 Martin Baxendale: 'Cruisewatch. Civil Resistance Against American Nuclear Cruise Missile Convoys in the English Countryside'. S.B.D Publications, 1991.

280 Martin Baxendale op cit.

281 Martin Baxendale op cit.

282 Martin Baxendake op cit.

Submarine tender USS Hunley pictured with submarines in Holy Loch 1981. Another tender, USS Canopus, was involved in a serious fire here in 1970

Large night-time demonstrations invariably took place along the routes travelled by cruise missile convoys as they travelled to and from exercise areas, and demonstrators regularly complained about the poor driving standards of convoy personnel. On 4 September 1987, during a convoy dispersal exercise from Greenham Common, the main Cruise convoy drove through a major roundabout at high speed on the wrong side of the road, and a police officer had to be pulled out of the path of the vehicles by a protester. In April 1988 a missile launch vehicle returning to Greenham failed to brake when other convoy vehicles did and crashed into the back of a police car, crushing it. In September 1988 a British paratrooper was hit by a moving launcher vehicle as it entered military land at Salisbury Plain en route to an exercise deployment site and in February 1989 several missile launchers ran over the verge at a crossroads and collided with a pole carrying overhead power lines.[282]

Cruise missile convoys were regularly stopped by protesters and on 4 November 1986 a cruise missile convoy was stopped and immobilised for an hour and a half when the air-brakes of missile launch vehicles were disconnected. On another occasion, in May 1987, a launch control vehicle broke down and could not be restarted after a blockade, and had to be towed back to the Greenham base.[283]

Studies into nuclear risks posed by US Cruise missiles based in the UK undertaken for the government by scientists at AWRE Aldermaston warned there was a "credible" danger of a warhead accidentally catching fire or exploding, engulfing others in flames and sending a plume of radioactive contamination into the atmosphere. One report, dated February 11 1980, examined the risk of hazards from a fire involving a cruise missile. It found that a fire in a single silo, fed by fuel from the missiles, could release plutonium from eight warheads, creating a radioactive cloud that would be blown across much of the south-east of England and London. The study concluded that Greenham Common, near Newbury, was the worst of 11 sites under consideration to house the missiles, because of its proximity to urban centres. Another study, prepared in December 1980, concluded that "if one warhead were to detonate it is possible that the other seven warheads in the storage cell could be engulfed in the fire which is virtually certain to ensue from the rupture of the missiles' fuel tanks."[284]

As the Cold War ended the US military presence in the UK was wound down, and by 2008 all US nuclear weapons had been withdrawn from the UK[285]. Nevertheless, US aircraft transporting nuclear weapons are still able to overfly the UK,[286] and US nuclear weapons could be redeployed to UK bases at short notice during a crisis. Arrangements for dealing with an accident involving an American nuclear weapon on UK territory are set out in a formal agreement between the two governments – the so called 'Third Tier Arrangement', which sets out the various response procedures and responsibilities.[287] The arrangements specify that, in the event of an accident on a US military base, US authorities are responsible for all on-site emergency actions, with a British military officer responsible for joint forces co-ordination for an off-base incident. US personnel will be responsible for examining and rendering safe any damaged US nuclear weapons and components. Under the terms of the agreement joint command post and field training exercises take place in a six year cycle, the most recent of these being Exercise 'Diamond Dragon 15' which took place at RAF Honington in June / July 2015.[288]

283 Ian Sample: 'Greenham nuclear risk for millions uncovered". Guardian, 12 July 2007. https://www.theguardian.com/uk/2007/jul/12/freedomofinformation.military

284 Hans M. Kristensen: 'U.S. Nuclear Weapons Withdrawn From the United Kingdom'. Federation of American Scientists Strategic Security Blog. 26 June 2008. http://fas.org/blogs/security/2008/06/us-nuclear-weapons-withdrawn-from-the-united-kingdom/#more-259

285 RAF aircraft transporting nuclear materials between the USA and the UK also overfly parts of the UK roughly four to five times every year. See Rob Edwards: 'MoD admits flying nuclear materials between UK and US'. Guardian, 1 March 2016. https://www.theguardian.com/uk-news/2016/mar/01/mod-admits-flying-nuclear-materials-between-uk-and-us

286 'Arrangement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America for responding to an accident or significant incident involving United States nuclear weapons or nuclear components in the United Kingdom including its internal waters and territorial sea. Short title: Third Tier Arrangement.' 9 October 1997. Ministry of Defence Freedom of Information Act request response 08-06-2010-102200-002.

287 Ministry of Defence: 'Exercise Diamond Dragon 2015. Lessons Identified Report. April 2016. http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/520288/20160428-EX_DD-Lessons_Identified_Report-Final.pdf

288 Michael H. Maggelet and James C. Oskins 2007 op cit, pp83–87.

Protesters on top of a Cruise missile vehicle

Image credit: Bob Naylor: WaterMarx/Report Digital

CASE STUDY 7

Date: 27 July 1956

Location: Lakenheath, Suffolk

Weapons involved: Three US Mark 6 atomic bombs

BROKEN ARROW AT LAKENHEATH

On the morning of 27 July 1956 Captain Russell Bowling and his crew took off from the RAF Lakenheath air base in Suffolk in one of the US Strategic Air Command's B-47 bombers on a routine training flight.[289] During their six hour mission they took on fuel mid-flight from a KC-97 tanker aircraft south of London, rehearsed a low approach to the US air base at Burtonwood in Cheshire, and then returned to Lakenheath in the middle of the afternoon to practice 'touch and go' landings.

If the aircraft had collided with the igloo containing the three atomic bombs and ignited a fire, a cloud of toxic uranium could have drifted off the base across the surrounding countryside

The B-47 made three successful touch and go landings but on the fourth attempt disaster struck. The aircraft lost control and slid off the runway, ploughing into a storage igloo used to store unarmed Mark 6 atomic bombs. The crash was described in a top secret telegram to General Curtis Lemay, Commander of the Strategic Air Command:

"The B-47 tore apart the igloo and knocked about 3 Mark Sixes. A/C [aircraft] then exploded showering burning fuel overall. Crew perished. Most of A/C wreckage pivoted on igloo and came to rest with A/C nose just beyond igloo bank which kept main fuel fire outside smashed igloo. Preliminary exam by bomb disposal officer says a miracle that one Mark Six with exposed detonators sheared didn't go. Fire extinguishers extinguished fire around Mark Sixes fast".

The resulting fire destroyed the aircraft and killed the four crew members. The Mark 6 nuclear weapons were stored in the igloo without their fissile cores installed, although each bomb contained around 5,000 pounds of high explosive and depleted uranium components. The damaged weapons and components were returned to the US Atomic Energy Commission after the incident.

An Air Force officer present at the scene said that it was only through "a combination of tremendous heroism, good fortune and the will of God" that this incident did not become a nuclear accident on a larger scale. If the aircraft had collided with the igloo containing the three atomic bombs and ignited a fire, a cloud of toxic uranium could have drifted off the base across the surrounding countryside. The fissile cores for the three weapons were stored in a different igloo at Lakenheath, and if the aircraft had collided with that igloo instead an even more serious dispersal of radioactive material might have occurred.

289 Charles Perrow: 'Normal Accidents: Living with High-Risk Technologies'. Updated Edition. Princeton University Press, 1999. The implications of normal accident theory for nuclear weapon programmes are addressed in Scott D. Sagan: 'The Limits of Safety: Organisations, Accidents, and Nuclear Weapons'. Princeton University Press, 1993.

Boeing B-47E. Image credit: US DoD

CONCLUSIONS AND RECOMMENDATIONS

Although this report does not pretend to be a rigorous quantitative analysis of the accidents which have befallen the UK's nuclear weapons, it is possible to draw some general conclusions from the study. They may seem obvious to many, but they nevertheless deserve to be clearly stated and presented as lessons we can learn after 65 years of British nuclear weapons operations.

- The risk of failures and accidents increases when equipment reaches the end of its operating life – be it a submarine, truck, nuclear processing facility, or merely a length of pipework.
- Risks also increase when equipment is in short supply and is overused.
- Accidents are more likely to occur when operations are hurried or are conducted under pressure.
- Workers sometimes may not follow even the strictest instructions and procedures.

Accidents involving British nuclear weapons have happened for all these reasons. Simple though the lessons are, they are important for the government to bear in mind during an age of austerity and cuts in public spending. Resources in the Ministry of Defence, as in all government departments, are stretched, and there is a perception that the UK is struggling in its quest to remain a nuclear armed international power. However, nuclear safety needs constant investment and the highest of standards, which must be continually enforced and maintained.

Some broader themes also emerge. The first of these is that it is impossible to guard against completely unpredicted and unforeseeable chance accidents. A Board of Inquiry concluded that neither operators nor equipment were at fault in the West Dean nuclear warhead convoy accident, yet the accident occurred, largely through chance.

Nuclear weapons are complex technical systems, which themselves are part of wider systems of even greater complexity. Accidents occur not just as a result of human error, management failures, or mechanical faults, but because our understanding of the technology and systems involved is incomplete and inadequate to contain the dangers they may pose. High consequence – low probability risks are particularly difficult to judge under such circumstances. 'Normal accident theory', developed by Charles Perrow, postulates that accidents are inevitable in complex and tightly linked systems.[290] With nuclear weapons we are dealing with extremely complex systems, and the potential consequences if things go wrong are grave.

A second theme is that when operational needs come up against the demands of safety, operational imperatives consistently trump safety. The Windscale fire, Alan Clark's diary entries about Polaris submarine safety, and the dispatch of nuclear weapons to the South Atlantic during the Falklands war all point to corners being cut because someone somewhere felt that it was essential to 'keep the show on the road', come what may. 'Operation Relentless' is an apt name for the programme for keeping a British nuclear-armed submarine at sea at all times, as it imposes relentless pressures on managers, military commanders, and politicians to maintain the operation at all costs as a national imperative. Under these circumstances, when operational essentials confront safety needs the balance will always fall in favour of keeping the operation going.

The third theme to surface relates to the honesty with which the authorities will report on nuclear accidents. Government sources have invariably underplayed the seriousness of accidents involving nuclear weapons and refrained from telling the whole story. The "prudent" decision not to comment on flooding at the Atomic Weapons Establishment Burghfield, the two year delay in revealing the leak

290 Office for Nuclear Regulation: 'Quarterly statements of nuclear incidents at nuclear installations'. http://www.onr.org.uk/quarterly-stat/index.htm

291 See for example comments by Michael Fallon, Secretary of State for Defence. Parliamentary Debate on Trident Renewal. Hansard, 20

Trident submarine HMS Valiant at Faslane

in the Dounreay test reactor, and the MoD policy of neither confirming nor denying the presence of nuclear weapons all have the taint of attempts to conceal or cover up the truth. There is a consistent gap between the Ministry of Defence's commentary on an accident and the assessment of regulators and independent outsiders, and between MoD public statements and the picture revealed by confidential technical and inquiry reports. This is seldom justified by security requirements. Few of the incidents chronicled in this report were unavoidable, and it was often purely through luck that events did not take a slightly different course and result in a more serious accident. The MoD's bland summaries may provide reassurance that all is well in its nuclear programmes, but they obstruct scrutiny, cloud accountability, and prevent lessons being learnt from accidents. A change in culture is needed within the Ministry.

To address these concerns we make three recommendations to the government:

1. Introduce procedures for publicly reporting accidents involving nuclear weapons.

Secrecy is always bad for safety. In order to remove the cloak of official secrecy which surrounds nuclear safety in the Ministry of Defence, safety regulators should prepare a quarterly report describing and evaluating all accidents with an INES rating of one or more which have occurred within the MoD's nuclear programmes. The reports should be published on the regulators' websites. Such reports are prepared for the Secretary of State for Business, Energy, and Industrial Strategy and the Secretary of State for Scotland by the Office for Nuclear Regulation (ONR) covering incidents within the civil nuclear sector.[291] It would be a simple matter to extend reporting to cover military nuclear accidents as well. Security considerations may mean that it would occasionally be necessary to withhold the detail of an incident, but this should be the exception rather than the rule.

2. Place Ministry of Defence nuclear programmes under external regulation.

Although the Office for Nuclear Regulation is responsible for regulating some of the sites which control the MoD's nuclear weapons and submarines, the majority of the UK's military nuclear programme falls outside the scope of external regulation. Instead, it is regulated by a secretive department inside the MoD: the Defence Nuclear Safety Regulator. Unlike the ONR the Defence Nuclear Safety Regulator holds no meaningful enforcement sanctions against nuclear duty holders and publishes little about its work. We propose that regulation of the military nuclear programme should become the responsibility of an expanded ONR, and visibly subject to the same regulatory standards and enforcement sanctions as the civil nuclear sector. Such a step would help reduce the conflict of interest that the Secretary of State for Defence faces in managing nuclear programmes and redress the balance between meeting operational requirements and maintaining safety standards. It is telling that safety standards at the Atomic Weapons Establishment rose dramatically when the Establishment was required to comply with the civil sector nuclear licensing regime in 1997.

3. Support an international ban on nuclear weapons.

As discussed above, nuclear weapons are complex systems based on hazardous technology and can never be made fully safe. Although some may disagree, NIS believes that the only way of eliminating the risks posed by an accident involving one of Britain's nuclear weapons is to eliminate nuclear weapons themselves. Until now the government has been reluctant to take unilateral steps towards nuclear disarmament, fearing that this would compromise national security unacceptably. However, governments of all political complexions have said that they support the aim of a world without nuclear weapons and would participate in multilateral disarmament initiatives to reach this goal.[292] Now, at last, there is an opportunity to begin the process of eliminating nuclear weapons through a multilaterally agreed international treaty. This year negotiations will commence at the United Nations on a nuclear ban treaty which will prohibit the use, deployment, and manufacture of nuclear weapons. Such a ban is supported by a big majority of the world's nations, and the UK government should declare its support for the ban treaty and participate constructively in negotiations.

The ban treaty gives us an opportunity to get rid of nuclear weapons for once and for all, and Britain should embrace this opportunity. Otherwise the risk of a nuclear weapon accident somewhere, sometime in the future will continue to hang over us like the sword of Damocles.

January 2015, column 105. http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/debtext/150120-0002.htm

292 An official account of the hazards posed by nuclear weapons, on which this appendix is drawn, is given in: Ministry of Defence: 'Local Authority and Emergency Services Information'. August 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/361976/LAESI_10.pdf

AFTERWORD

Jonathon Porritt

This Report would be of critical importance whenever it was published. The multiple threats associated with the continued existence of nuclear weapons remain deeply disturbing – for us as individuals, as citizens of nation states (both nuclear and non-nuclear), and as human beings with profound moral responsibilities for the stewardship of life on Earth.

But right now, with an inexperienced and highly unpredictable President in the White House, its publication couldn't be more timely. President Trump made a number of comments about the role of nuclear weapons in US defence policy during the Election campaign, and most of them were of an extraordinarily haphazard and contradictory nature. The anti-scientific and anti-evidential orientation of the new US Administration has set alarm bells ringing around the world, both in nations hostile to the US and the West, and amongst its allies – particularly in NATO.

The Doomsday Clock (created by The Bulletin of the Atomic Scientists) has been updated regularly over the last 70 years. At the end of January 2017, they turned the hands of the clock to two-and-a-half minutes to midnight, a full 30 seconds closer to midnight than it was a year ago. The closest it ever got was two minutes to midnight, in 1953, after both the US and Russia had detonated their latest nuclear weapons.

The principal reason for the change this year is "the disturbing trend of world leaders espousing policies and making statements not tied to evidence". Donald Trump is not mentioned by name, but he doesn't need to be: "Nuclear weapons and climate change are precisely the sort of complex, existential threats that cannot be properly managed without access to and reliance on expert knowledge."

Against that backdrop, if you have read your way through right to the end of this Report without feeling deeply disturbed, with your fears about the possibility of a nuclear incident or conflagration amply reinforced, then you must somehow have succeeded in arriving at the following rationale: "Notwithstanding the inevitable accidents and near-misses, we've somehow avoided any nuclear disasters for the last 70 years – so who's to say we're not going to be able to continue in the same old way for the next 70 years?"

The vast majority of people in both the USA and Europe are walking around with precisely that kind of rationale in their minds, either explicitly articulated, in so many words, or just part of the implicit normalisation of our near-insane, day-to-day proximity to a potential nuclear apocalypse.

Our challenge today, in a world rendered even more unsafe by a new generation of 'strong men' intent on redefining their nations partly in terms of their military and nuclear prowess, is to abnormalise the continued existence of nuclear weapons – to seize on every incident and accident, on every half-suppressed denial from government sources, and use every opportunity to remind people, as pointedly as possible, that some kind of nuclear disaster is now inevitable. As we're reminded time after time through the pages of this Report, "normal accident theory" tells us that accidents in complex and tightly-linked systems are indeed inevitable. And that becomes more and more the case the older our nuclear weapons become, and the more we struggle, both financially and operationally, to retain our status as a nuclear-armed international power.

The Government's line on this is both simple and deliberately deceptive: "No serious nuclear security incidents have taken place over the last 20 years." But with its detailed analysis of one accident or incident after another, this report chillingly demonstrates that the lines between non-serious, serious, and potentially cataclysmic are very ill-defined, dependent more on some version of Sod's Nuclear Law than on watertight operating procedures, faultlessly implemented and rigorously monitored in all circumstances.

There's only one way out of this ongoing nuclear nightmare, and that is to get rid of the UK's notionally independent nuclear 'deterrent', while straining every sinew to move the rest of the world towards the total elimination of nuclear weapons.

Jonathon Porritt is a former Director of Friends of the Earth and former Chairman of the UK Sustainable Development Commission. He is co-founder of Forum for the Future and a Patron of Nuclear Information Service.

APPENDIX

Radiological hazards resulting from a nuclear weapons emergency[293]

The hazards associated with a nuclear weapon emergency result from the explosive, radioactive and toxic materials that the weapon contains. The explosive hazard is the same as that which is associated with any chemical high explosive. Chemical and toxic hazards are posed by materials such as beryllium and lithium which are used in the weapon. Conventional hazards can also be expected to arise in the event of an accident (fire, smoke and the remote possibility of explosively propelled debris) and these may also be severe.

The main radioactive materials in a nuclear weapon are plutonium, uranium, and tritium. The principal radiological hazard arising in an accident where a nuclear weapon is damaged would result from the combustion of plutonium and uranium and their subsequent release into the environment as airborne particles.

Plutonium

- Plutonium is an alpha particle emitter and small pieces of it, when exposed to oxygen or air, will ignite at about 500C giving off plutonium oxide smoke.
- Alpha particles emitted from plutonium are unable to penetrate ordinary clothing or the unbroken outer layer of a person's skin. Simple decontamination techniques, such as showering and washing with soap and water, are effective in removing plutonium particles. However, if alpha emitting particles are taken into the body this will pose a hazard to health. The entry routes for this are inhalation (with particles lodging in the lungs), ingestion (particles in the digestive tract) or deep wounds.
- Plutonium in the particulate form which might be produced by a nuclear weapon accident is insoluble. If taken into the body, the majority of the material will be excreted through the body's natural actions, but some will be deposited in body tissue, particularly the bones and liver. There is a risk that surrounding tissue will be damaged by alpha particles causing cancers to develop. In the event of a lung intake, there is also a possibility of developing lung fibrosis.
- Small quantities of water sprayed onto burning plutonium will worsen the fire because hydrogen is liberated and will ignite, but the copious use of water will extinguish burning plutonium by the process of cooling. However, there is a small possibility of forming a critical assembly if water is used in fighting a fire.
- As well as being radioactive, plutonium is also toxic and ingestion can cause a form of heavy metal poisoning.
- When fighting plutonium fires use of a self-contained breathing apparatus is recommended, but if this is not available it is essential to wear a respiratory device.

Uranium

Uranium is an alpha emitter and small pieces of it, when exposed to oxygen or air, will ignite at about 1000C giving off uranium oxide smoke. Although this oxide is less dangerous than that of plutonium, it nevertheless constitutes a breathing hazard and similar precautions are recommended.

Uranium in the particulate form which might be produced by a nuclear weapon accident is insoluble. If taken into the body, the majority of the material will be excreted through the body's natural actions, but some will be deposited in body tissue, particularly the bones and liver. There is a risk that surrounding tissue will be damaged by alpha particles causing cancers to develop.

Uranium also emits low quantities of beta and gamma radiation which can penetrate the

skin and present an external radiation hazard, damaging tissue without entering the body. Simple decontamination techniques, such as showering and washing with soap and water, are effective in removing uranium particles.

Uranium reacts similarly, but less actively, with water than does plutonium. Uranium 235 can also form a critical assembly either in solution or by melted metal running into a super-critical configuration.

As well as being radioactive, uranium is also toxic and ingestion can cause a form of heavy metal poisoning.

Again, use of a self-contained breathing apparatus is recommended when fighting uranium fires and it is essential to wear a respiratory device.

Tritium

Tritium is a radioactive form of hydrogen. Tritium can present a beta radiation hazard, but as it is rapidly dispersed this is likely to be significant only in the immediate vicinity of the accident. This hazard is enhanced if the tritium gas oxidises, for example by exposure to fire, turning it into tritiated water vapour.

Tritium is highly reactive and combines actively with other chemicals releasing large quantities of heat. It can combine with many metals, causing the surface of the metal to become radioactive.

Tritiated water is easily absorbed by the body via inhalation or absorption through the skin. The body does not discriminate between tritiated water and ordinary water and it is rapidly distributed through the body. Although most of it is eventually excreted, if tritiated water becomes part of the bound water around certain cell components it can cause radiological harm.

Respirators do not offer protection against tritium because it passes directly through the protective filters, but self-contained breathing apparatus will provide an effective means of protection against tritium gas. When fighting fires where tritium is present firefighters should wear appropriate personal protective equipment.

GLOSSARY

A/C	Aircraft
AERE	Atomic Energy Research Establishment
AWE	Atomic Weapons Establishment
AWE ML	Atomic Weapons Establishment Management Limited
AWRE	Atomic Weapons Research Establishment
BAE	British Aerospace
BBC	British Broadcasting Corporation
Bq	Becquerel (unit of radioactivity)
BRAE	Brown and Root and Atomic Energy (members of the Hunting BRAE consortium comprised of Hunting Engineering Ltd, Brown and Root Ltd, and the Atomic Energy Authority
CB8890	Serial number for the Royal Navy document 'The instructions for the safety and security of the Trident II D5 strategic weapon system'
CCTV	Closed Circuit Television
CIA	Central Intelligence Agency
CND	Campaign for Nuclear Disarmament
COMARE	Committee on Medical Aspects of Radiation in the Environment
DES	Defence Equipment and Support
EBS	Emergency Breathing Supply
FOI	Freedom of Information
HE	High Explosive
HERALD	High Energy Research Aldermaston (a nuclear reactor)
HM	Her Majesty's
HMS	Her Majesty's Ship
HPA	High Pressure Air
HSE	Health and Safety Executive
IT	Information Technology
ITN	Independent Television News
JATO	Jet-Assisted Take Off
KGB	Komitet Gosudarstvennoy Bezopasnosti (Committee for State Security) - Soviet security agency
LAESI	Local Authority and Emergency Services Information

MCC	Missile Control Compartment
MDP	Ministry of Defence Police
MoD	Ministry of Defence
MP	Member of Parliament
NATO	North Atlantic Treaty Organisation
NII	Nuclear Installations Inspectorate
NIS	Nuclear Information Service
NKVD	Narodnyi Komissariat Vnutrennikh Del (People's Commissariat for Internal Affairs) – Soviet security agency
NSQEP	Nuclear Suitably Qualified and Experienced Personnel
ONR	Office for Nuclear Regulation
PBNZ	Precise Bathymetric Navigation Zone
PIN	Personal Identification Number
plc	Public Limited Company
PWR	Pressurised Water Reactor
RAF	Royal Air Force
RB	Re-entry Body
RFA	Royal Fleet Auxiliary
RNAD	Royal Naval Armaments Depot
ROF	Royal Ordnance Factory
SSA	Special Storage Area
TCHD	Truck Cargo Heavy Duty
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
USA	United States of America
USAF	United States Air Force
USNS	United States Naval Ship
USS	United States Ship
USSR	Union of Soviet Socialist Republics
VSEL	Vickers Shipbuilding and Engineering Ltd
WE177	A family of UK tactical nuclear weapon designs in service between the 1960s and 1980s

Acknowledgments

Nuclear Information Service is grateful to the Andrew Wainwright Reform Trust, Joseph Rowntree Charitable Trust and the Lush Charity Pot for their generous support in undertaking this project.

We would like to thank Brian Burnell, David Cullen, Nigel Day, Louise Edge, Rob Edwards, Phill Jones, Juliet McBride, Ian Mills, Jonathon Porritt, Tim Street, Jane Tallents and Trish Whitham for advice and assistance in the preparation of this report. We would also like to thank the experts who reviewed the report for us and gave valuable feedback on its content. Any errors or omissions are Nuclear Information Service's responsibility, rather than theirs.

Design by John Lewicki/Transition by Design.

Comments on this study are invited and should be sent to David Cullen, Research Manager at Nuclear Information Service by email to david@nuclearinfo.org

We are delighted to offer this research report for free, but please consider making a donation to Nuclear Information Service to help us cover the costs of producing this report and the other materials and information services that we provide. You can donate online at www.nuclearinfo.org/donate

Nuclear Information Service is a not-for-profit, non-government information service which works to promote public awareness and foster debate on the risks and costs of the UK's military nuclear programme.

Nuclear Information Service
35 – 39 London Street
Reading
RG1 4PS
United Kingdom
Web: www.nuclearinfo.org
Telephone: +44 (0) 118 327 4935
Email: office@nuclearinfo.org
Twitter: @Nuclearinfo