# AWE: BRITAIN'S NUCLEAR WEAPONS FACTORY

# PAST, PRESENT, AND POSSIBILITIES FOR THE FUTURE

Nuclear Information Service
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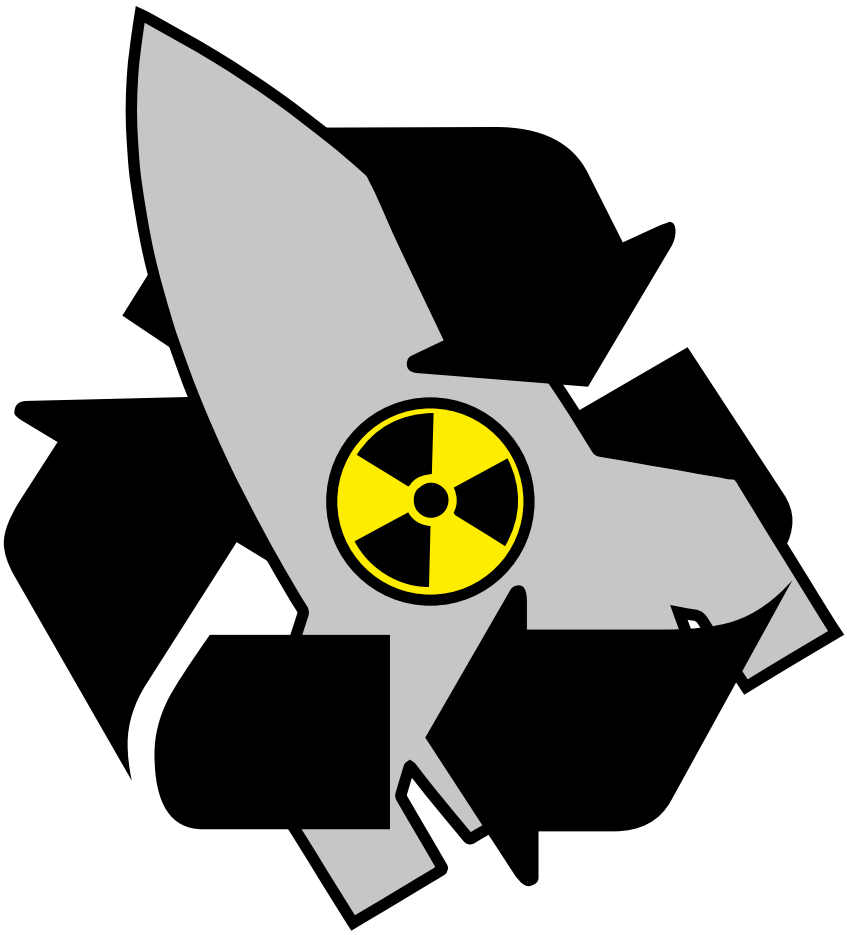

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# GLOSSARY

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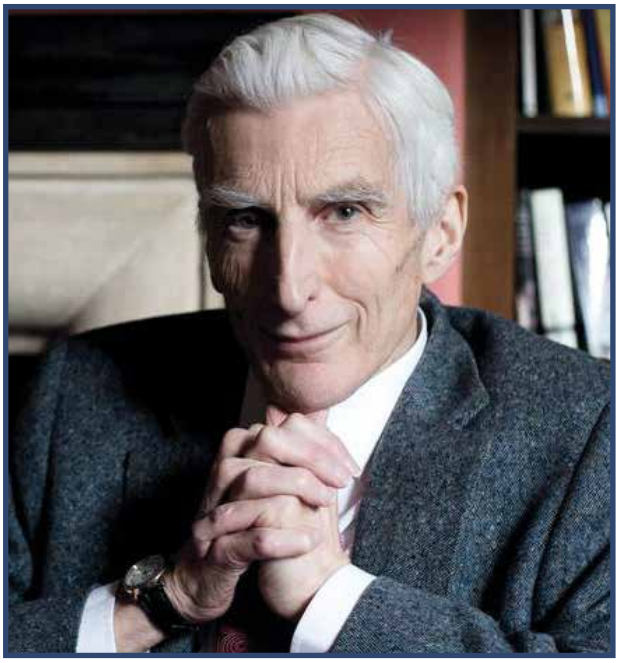
|---|---|
| ABL | AWE, Babcock, and Lockheed Martin |
| AEA | Atomic Energy Authority |
| AWE | Atomic Weapons Establishment |
| AWE | ML Atomic Weapons Establishment Management Limited |
| AWRE | Atomic Weapons Research Establishment |
| BASIC | British American Security Information Council |
| BRINPARDI | British International Non-Proliferation, Arms Reduction and Disarmament Institute |
| CBDE | Chemical and Biological Defence Establishment |
| CEA-DAM | Commissariat à l'Énergie Atomique - Direction des Applications Militaires |
| CNC | Computer Numerical Control |
| CTBT | Comprehensive Nuclear-Test-Ban Treaty |
| CTBTO | Comprehensive Nuclear-Test-Ban-Treaty Organisation |
| DARHT | Dual Axis Radiographic Hydrodynamic Test |
| DERA | Defence Evaluation and Research Agency |
| DstI | Defence Science and Technology Laboratory |
| EDC37 | A formulation of explosive |
| EPURE | Experimentations de Physique Utilisant la Radiographie Éclai |
| FTNW | Future Theatre Nuclear Weapon |
| HM | Her Majesty's |
| HSW | High Surety Warhead |
| LEP | Life Extension Programme |
| LMJ | Laser Megajoule |
| Mk4A | Mark 4A |
| MoD | Ministry of Defence |
| NPSA | Nuclear Protection and Storage Area |
| NWCSP | Nuclear Warhead Capability Sustainment Programme |
| ONR | Office for Nuclear Regulation |
| PBX | Polymer Bonded Explosive |
| PBX9501 | A formulation of explosive |
| plc | Public Limited Company |
| RAF | Royal Air Force |
| RES(O) | Re-entry Systems Options |
| RNAD | Royal Naval Armaments Depot |
| ROF | Royal Ordnance Factory |
| RRW | Reliable Replacement Warhead |
| SEP | Strategic Economic Plan |
| SSBN | Ship Submersible (Ballistic) Nuclear |
| SSN | Ship Submersible Nuclear |
| STEM | Science, Technology, Engineering, and Mathematics |
| STFC | Science and Technology Facilities Council |
| TASM | Tactical Air-to-Surface Missile |
| TCHD | Truck Cargo Heavy Duty |
| TNO | Tête Nucléaire Océanique |
| TVB | Thames Valley Berkshire |
| UK | United Kingdom |
| UKAEA | United Kingdom Atomic Energy Authority |
| USA | United States of America |
| WE177 | A family of UK tactical nuclear weapon designs in service between the 1960s and 1980s |
| WETL | Weapons Evaluation and Test Laboratory |

# FOREWORD

## LORD REES OF LUDLOW



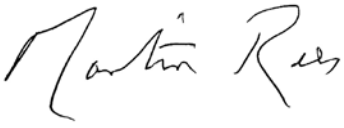
The Atomic Weapons Establishment (AWE) is one of the premier technological establishments in the United Kingdom. Its equipment and resources are the envy of many in the university sector, and its high calibre personnel include some of the brightest brains in the country. This report pays tribute to AWE as a centre of excellence, but reminds us that its 'mission' is controversial – and one that most people hope will not persist in future decades.

The future of Trident merits far wider and more open discussion than it is currently getting. It's a crucial strategic and ethical decision. Indeed, it's so important that it shouldn't be swung by concerns about sustaining the skills and employment of submarine-builders in the North East, or bomb-builders at Aldermaston. That is why it's highly relevant to consider how these skills and resources might be gradually redeployed in the civil sector. This report usefully addresses how AWE might respond to commercial opportunities - and how its current expertise could help tackle some of the pressing needs that humanity faces.

Continuing investment in science and technology will be crucial to the future success of the UK's economy. Yet the R & D at AWE currently makes limited contributions to mainstream technological development: partly because of its sensitivity and security classification, and partly because it occupies a highly specialised niche with limited civil applications. This report offers some optimism that, were its current mission to be attenuated, it could indeed transition towards a role that offered valuable expertise to the civil sector.

The report also addresses the need for AWE, a highly expensive institution, to be more politically accountable and more transparent. Parallel US institutions like Los Alamos are in a less 'closed' world; to a greater extent than at AWE their staff attend mainstream scientific conferences and contribute research on non-classified topics. A shift towards greater openness at AWE would have two benefits: it would render AWE posts more attractive; and it would widen the number of external experts who were well-enough informed to 'calibrate' the quality of the institution – something that politicians and 'lay' government officials should surely welcome. (There is, for instance, no analogue in this country of the Jason Group, whereby top-rate and well-briefed academics offer independent assessments of sensitive matters relating to military science and technology).

I hope this report will be studied (and welcomed) not only by policy makers and decision makers from all political parties, but also by members of the UK's scientific community – and especially colleagues from AWE.



Professor Martin Rees (Lord Rees of Ludlow) is Astronomer Royal and a former President of the Royal Society. He was a member of the independent BASIC commission which reported in 2014 on the future of Trident.

# KEY FINDINGS

- The Atomic Weapons Establishment (AWE) plays a key role in the UK's Trident nuclear weapons programme. The UK's Trident nuclear warheads are designed, manufactured, maintained, and dismantled at the Atomic Weapons Establishment (AWE) sites at Aldermaston and Burghfield in Berkshire.

- A major investment programme is currently under way at AWE, with around £1 billion per year scheduled for spending at AWE over the remainder of this decade to ensure that the UK maintains the capability to produce nuclear weapons well into the second half of this century. To date there has been minimal Parliamentary scrutiny of this programme.

- AWE is currently working on a programme to upgrade the current UK Trident warhead to the 'Mark 4A' modified warhead, which will have increased accuracy and destructive power and an extended lifetime. Parliament has never been formally notified of the Mark 4A modification programme and the costs and timetable for the programme have never been disclosed.

- AWE is also currently conducting studies to explore options for a potential future warhead as part of the ongoing Trident replacement programme. To date at least £85 million has been spent on such studies.

- Nevertheless, the policy of successive UK governments has been to achieve a world without nuclear weapons, so it is incontrovertible that at some point in the future nuclear weapons production and maintenance at AWE must cease.

- AWE is an important national resource in terms of its scientific expertise and equipment, and is a major local employer and a significant contributor to the local economy. Fears over the impact of cancellation of the Trident programme are a natural concern for those who depend on the Establishment for their livelihoods.

- This study examines alternatives for AWE's future in the event of a possible decision to cancel the Trident programme. It concludes that the likelihood of outright closure of the Establishment is low. Decommissioning of radioactively contaminated facilities is likely to last into the 2040s / 50s, with a need to hold radioactive wastes securely at the site until at least 2070. AWE's expertise on disarmament verification and nuclear threat reduction would most likely be retained by government regardless of any decision to cease warhead production.

- The prospects for a post-Trident AWE to move away from its current role into civil sector markets are good, and are compatible with regional economic development strategies.

- The report concludes that, in the event of cancellation of the UK Trident nuclear weapons programme, jobs and economic benefits at AWE need not be lost in the short to medium term and could be conserved in the long term by putting the Establishment's assets and skills to work in pursuit of innovative new civil sector business opportunities.

# EXECUTIVE SUMMARY

Important decisions on the UK's Trident nuclear warhead – whether to replace it, and if so, what with – are on the horizon and are likely to become pressing by the end of the current decade. The Atomic Weapons Establishment (AWE) will play a crucial role in these decisions.

The first part of this study reviews the role of AWE in the UK's nuclear weapons programme and describes the programme which is underway at AWE in preparation for developing a new UK Trident warhead. The second part of the study analyzes a series of future options for work at AWE and examines the consequences of a decision to cancel the Trident replacement programme, setting out a blueprint to show how the Establishment could successfully diversify its work into the civilian sector.

AWE's recent history since the 1980s onwards has been dominated by the development, manufacture, and maintenance of the UK Trident warhead. The Establishment's current programme is focused on the maintenance and upgrade of the UK Trident warhead and the decommissioning of a small number of warheads each year to meet a Strategic Defence and Security Review commitment to reduce the size of the UK's warhead stockpile. AWE is currently working on the UK Trident Mark 4A (Mk4A) warhead modification programme to modernise and upgrade the destructive capability of UK Trident warheads. Parliament has not been officially notified of this programme and no information on programme costs has yet been published.

A major investment programme is currently under way at the AWE sites at Aldermaston and Burghfield in Berkshire, with around £1 billion per year scheduled for spending over the remainder of this decade to deliver the Mk4A programme, build new research and production infrastructure, and ensure that the UK maintains the capability to produce nuclear weapons well into the second half of this century. This programme is reported to have been subject to delays and cost over-runs. AWE is also co-operating with the French government on warhead research under the terms of the UK-France 'Teutates' Treaty which was agreed in 2010, and continues to undertake long-standing research work in collaboration with US nuclear weapons laboratories under the terms of the 1958 US-UK Mutual Defense Agreement.

AWE is currently undertaking preparatory studies to inform a decision on the replacement or refurbishment of the UK Trident warhead, likely to be made sometime towards the end of this Parliament. Nevertheless, the policy of successive UK governments has been to achieve a world without nuclear weapons, so if this aim is to be met it is incontrovertible that at some point in the future nuclear weapons production and maintenance at AWE must cease.

AWE's future is closely linked to the future of the Trident programme, which raises questions about what might happen to the Establishment in the event of a future decision to cancel the Trident programme. AWE currently employs 4920 people directly and a further 890 contractors and is said to contribute £475 million annually to the local economy, so fears over the impact of cancellation of the Trident programme are a natural concern for those who depend on the Establishment for their livelihoods.

Options for the future for AWE can be summarised as:

- Business as usual: work continues as currently intended on the Trident warhead programme and development of a replacement Trident warhead.
- 'AWE lite': The Trident programme is downgraded but not cancelled, and AWE diversifies its work into new security related and nuclear fields.

- A 'post nuclear' AWE: The Trident programme is cancelled and AWE undergoes a transition to a commercially focused innovation and technology centre.

- Wind down: The Trident programme is cancelled and work at AWE is wound down.

The report argues that outright closure of AWE is highly unlikely, given the range of unique national scientific and engineering assets which are located at its sites. Even if such a decision is made by a future government the dismantling of the existing warhead stockpile is expected to take at least four years, guaranteeing work over the short to medium term. Decommissioning of radioactively contaminated facilities is likely to last into the 2040s / 50s, with a need to hold radioactive wastes securely at the site until at least 2070. Work at AWE on disarmament verification and nuclear forensics might be expected to continue regardless of the future of the Trident programme.

The report examines the prospects for converting AWE to a set of commercially viable business enterprises which are able to compete in civil sector markets. This objective is compatible with the aims of the regional Strategic Economic Plan prepared by the Thames Valley Berkshire Local Economic Partnership, which seeks to increase technological innovation in the area. The Strategic Economic Plan notes AWE's interest in exploring potential commercial applications, and anticipates that dialogue with AWE will take place to explore the long term potential for developing a Science Park facility at Aldermaston or Burghfield. AWE is well placed to co-operate on innovative new work through association with the Universities of Reading, Oxford, and Surrey, which are located relatively close by. In due course it would be possible to establish a series of new business entities reflecting AWE's areas of expertise, for example high energy physics, materials science, and manufacturing and production, offering services such as research, consultancy, and product development.

The former nuclear research site at Harwell and the former Chemical and Biological Defence Establishment at Porton Down, responsible for government research on chemical and biological weapons, provide models for the future trajectory of AWE. Both sites have been successfully converted to commercially viable enterprises undertaking a diverse range of work, with a core remaining within the government sector to manage legacy issues and undertake research and maintain expertise required by government.

Achieving such a transformation would not, of course, be without risk and would require support from government in the form of changes to defence and economic policies and funding and advice from a new national Defence Diversification Agency. It would also require participation of trade unions and staff at AWE and constructive engagement from AWE Management Ltd (the commercial consortium which runs AWE), the Ministry of Defence, and local authorities.

The main conclusion of the study is that, given adequate preparation and financial resources, detrimental consequences for workers at AWE and local communities could be largely avoided if a future government closes the Trident programme. However, this is dependent upon a willingness to engage with the issues, and on starting work early to plan and prepare for a transition away from nuclear weapons-related work. To deliver the transition a partnership approach is needed involving the employer, AWE personnel and their trade unions, central government, and local authorities.

The reality is that, at present none of these parties are engaged. All are assuming that the Trident programme will continue indefinitely and that AWE will continue to have a role in the development and manufacturing of nuclear weapons. This report therefore aims to start the process of engagement and begin the preparation for an alternative future.

# INTRODUCTION

Much of the recent debate over the UK's Trident nuclear weapons programme has focused on the replacement of the Vanguard class submarines and construction of a 'Successor' submarine. However, the Successor submarine decision is not the only critical decision which the government faces if it is to succeed in keeping the Trident system operational into the middle of this century. Decisions on the UK's Trident nuclear warhead – whether to replace it, and if so, what with – are on the horizon and are likely to become pressing by the end of the current decade. Although much work has been done to pave the way towards development of a new UK Trident warhead – and very large sums of money have already been spent to this end – the government faces considerable uncertainty and some tough challenges before a final decision can be made.

The Atomic Weapons Establishment (AWE) will play a crucial role in these decisions. As the UK's only nuclear weapons laboratory, AWE occupies a central, and critical, place in the UK's military nuclear programmes. AWE is responsible not only for the design, construction, maintenance, and decommissioning of the UK's nuclear weapons, but also for undertaking research and advising the Ministry of Defence (MoD) on warhead science and development.

Public awareness about the UK's arsenal of nuclear warheads and AWE's role in managing this arsenal is limited, and so too is political oversight and scrutiny of the warhead programme. As a result, large sums of money can be spent at AWE with little accountability and controversial work on modernising the UK's warhead stockpile is able to proceed in relative secrecy. One of the purposes of this study is to add to the general understanding about AWE's work – and to show that AWE could be transformed to undertake work of value to the civil sector in the event of a decision to cancel the Trident programme.

The first part of this study reviews the role of AWE in the UK's nuclear weapons programme, describes the programme which is underway to refurbish and upgrade AWE in preparation for developing a new warhead, and summarises the information which is currently available on research work conducted towards the development of a successor UK Trident warhead. It concludes by identifying some of the factors which will shape the government's decision on how to address the future of the Trident warhead and a possible successor.

The second purpose of this study is to take a forward look at what might happen to AWE in the event of a decision to cancel the Trident programme. Although this may seem a remote possibility in the current political context, the policy of successive governments has been committed to achieving the goal of a world without nuclear weapons. This aim is also the policy of the current US administration. Assuming this objective is to be met, then it follows without question that at some point in the future nuclear weapons production and maintenance at AWE must cease. The second part of the study examines the consequences for AWE of a decision to cancel the Trident replacement programme, and sets out a blueprint showing how the Establishment could successfully diversify its work into the civilian sector.

# PART 1: AWE: PAST AND PRESENT

The Atomic Weapons Establishment has its roots in the United Kingdom's decision to develop nuclear weapons in the aftermath of World War II. The Atomic Weapons Research Establishment (AWRE) was set up on 1 April 1950 by the Ministry of Supply at the former RAF Aldermaston airfield with the task of designing and developing an atomic weapon for the UK. AWRE's first Director was William Penney, who had previously worked on the Manhattan Project, and other British scientists involved in the Manhattan Project also contributed their expertise[1].

After a programme of atmospheric tests in the 1950s, when AWRE built and tested first fission (atomic) and then fission-fusion (thermonuclear or 'hydrogen') weapons, Harold Wilson's Labour government imposed a moratorium on underground testing and encouraged AWRE to diversify its work into other areas of science and technology. A hiatus in weapon testing followed until 1974, when the moratorium was lifted. By the end of this period AWRE scientists were working on the Chevaline warhead programme: a source of controversy because of its very substantial cost overruns and its secrecy[2]. AWRE received further unwelcome attention in 1978 when it was discovered that staff working at the Establishment had been contaminated with radioactive materials. Plutonium handling operations were temporarily halted and an investigation by Sir Edward Pochin concluded that improvements were required in safety and health physics arrangements at Aldermaston[3].

The first Chevaline warheads entered service in 1982 and from the early 1980s onwards AWRE was heavily involved in research, design, and later manufacturing work to develop a new UK warhead for the Trident D5 missile system which the government had decided to purchase from the United States (see Figure 1). According to the Ministry of Defence the UK Trident warhead is a "UK designed weapon"[4]. However, it is generally believed to be very similar to the US W76 warhead design and the US government is known to have provided the UK with information on the W76 warhead and the Mark 4 re-entry vehicle, in which it is housed, during the design phase of the UK Trident warhead[5]. MoD maintains that the UK warhead is "not necessarily a direct copy or based solely on the W76"[6]. The UK Trident warhead uses W76 components purchased from the USA, including the arming, fuzing, and firing system, the neutron generator, and the gas transfer system[7] and it has to meet the same space and weight constraints as the W76. Design work on the UK Trident warhead was completed in 1987 and production commenced in 1988[8], but was said to have suffered difficulties as a result of a shortage of suitably skilled staff[9].

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1 *'Our History'. Atomic Weapons Establishment website. http://www.awe.co.uk/what-we-do/our-proud-history/ Accessed 23 November 2015.*

2 *'Baylis, John, and Kristan Stoddart: 'The British Nuclear Experience: The Role of Beliefs, Culture, and Identity'. Oxford University Press 2015. Chapter 6.*

3 *Pochin, Sir Edward: 'An investigation into Radiological Health and Safety at the Ministry of Defence (Procurement Executive) Atomic Weapons Establishment Research Establishment, Aldermaston'. 30 October 1978. The National Archives ES14/27.*

4 *Evidence from G. Beaven, Deputy Controller (Nuclear), MoD. House of Commons Defence Committee: 'The Progress of the Trident Programme' Fifth Report 1991-2 (HC 337). HMSO 1992. p.13*

5 *Ritchie, Nick: "A Nuclear Weapons-Free World? Britain, Trident, and the Challenges Ahead'. Palgrave Macmillan, 2012. p96.*

6 *Evidence from G. Beaven, Deputy Controller (Nuclear), MoD. House of Commons Defence Committee 1992, op cit.*

7 *'Trident missiles'. Parliamentary Written Question. Official Report, 3 December 2009, Column 911W. http://www.publications.parliament.uk/pa/cm200910/cmhansrd/cm091203/text/91203w0014.htm#09120373000543 Accessed 11 December 2015.*

8 *House of Commons Defence Committee: 'The Progress of the Trident Programme'. Fifth Report 1988-9 (HC374). HMSO 1989. pxxi.*

9 *Article in 'The Engineer', March 1990, cited in Ramsbotham, Oliver, and Scilla Elworthy: 'The 'Political' Weapon: The Tactical Air-to-Surface Missile'. Oxford Research Group, Current Decisions Report Number 3. July 1990. P21.*

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|---|---|
| 1980: | Government announces decision to procure Trident system from USA. |
| 1983-91: | Trident-related underground tests at the Nevada Test Site in the USA. |
| 1987: | Atomic Weapons Establishment is formed from the amalgamation of the Atomic Weapons Research Establishment and Royal Ordnance Factories involved in the nuclear weapons programme. |
| 1987: | Design work on UK Trident warhead completed. |
| 1988: | Production of UK Trident warhead commences. |
| 1991: | Handover of AWE management to private contractors commences. |
| 1999: | Bulk production of Trident warhead ends |
| 2000: | AWE management and operation contract awarded to AWE Management Ltd. |
| 2005: | Nuclear Warhead Capability Sustainment Programme commences. |
| 2007: | Parliament votes to replace Vanguard class Trident submarines. |
| 2010: | Strategic Defence and Security Review announces planned reductions in numbers of deployed warheads and the total UK warhead stockpile. |
| 2010: | UK - France 'Teutates' Treaty is signed, allowing co-operation on warhead physics research between the two nations. As a result, AWE's 'Project Hydrus' hydrodynamics facility is cancelled. |
| 2011: | Trials involving UK Trident Mk4A warhead modification underway at Sandia National Laboratories in the USA. |
| 2015-16: | UK Trident Mk4A warhead production commences. |
| 2019?: | Decision on replacement of UK Trident warhead. |

*Figure 1. Timeline: AWE and Trident*

In 1987 AWRE was combined with the Royal Ordnance Factory (ROF) Burghfield and ROF Cardiff, both also involved in the manufacturing of nuclear weapons, to form the Atomic Weapons Establishment, bringing the key sites involved in the production of the UK's nuclear weapons together into the same management structure for production of the Trident warhead. An extensive construction programme with over 30 new building projects commenced at Aldermaston, most significant of which were the A90 plutonium components facility and the A91 radioactive liquid effluent treatment plant. However, the programme was delayed by technical problems, delays, and cost overruns. The A91 project was abandoned, with costs of £147 million written off by MoD[10], and A90 entered service in time to manufacture only the last few Trident warheads[11].

AWE's questionable record on safety and project delivery, aligned with broader political trends, resulted in a decision in the final months of Margaret Thatcher's government to privatise the management and operation of the Establishment. The Hunting-BRAE consortium[12] was awarded an initial management contract in 1990, and the site was fully contractorised in 1993 under a government-owned contractor-operated (GOCO) arrangement. A period of consolidation followed, with closure of the AWE Cardiff site and transfer of operations to Aldermaston, and transfer of the AWE Foulness explosives testing site to the Defence Evaluation and Research Agency (DERA) and subsequently QinetiQ.

In 2000 the AWE management and operation contract was awarded to AWE Management Ltd (AWE ML) for a period of ten years, subsequently extended to twenty five years. The AWE ML consortium comprises three commercial partners (Serco Group, Lockheed Martin and Jacobs Engineering, which in 2008 took over a share of AWE ML previously held by British Nuclear Fuels) together with the Ministry of Defence, which holds a special share as a contingency against unforeseen circumstances. Originally established as an equal partnership between the three companies, the joint venture was restructured in March 2016 to allow Lockheed Martin to take a majority holding in the consortium, "reflecting the anticipated relative level of resources and workload involved in future operations". Lockheed Martin now owns 51% of AWE ML with Jacobs and Serco each owning a 24.5% stake[13]. This effectively means that US-owned companies own a stake representing more than 75% in the consortium.

AWE ML operates the AWE sites through a subsidiary company, AWE plc, which is responsible for day-to-day operation of AWE's sites[14]. According to a Serco Group press release, "since 2000, the joint venture's operating margin has varied between 6% and 14%, and in the last two years has been at the bottom of the historic range"[15].

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10 *'AWE'. Parliamentary Written Question. Official Report (Hansard) 21 January 2014, Column 111W. http://www.publications.parliament.uk/pa/cm201314/cmhansrd/cm140121/text/140121w0001.htm#140121w0001.htm_wqn43 Accessed 14 January 2016.*

11 *'UK: Ministry of Defence counts cost of Atomic Weapons Establishment construction project at Aldermaston.' Construction News, 8 August 1991. http://www.constructionnews.co.uk/home/productivity-deal-for-aldermaston-refurb/377759.article Accessed 7 December 2015.*

12 *Hunting BRAE was a partnership between Hunting Engineering Ltd, Brown and Root Ltd, and AEA Technology Ltd.*

13 *'AWE review concluded successfully and updated contract agreed'. Serco Group press release, 31 March 2016. https://www.serco.com/media/pressreleases/awe-review-concluded-successfully-and-updated-contract-agreed Accessed 12 April 2016.*

14 *'Our company'. Atomic Weapons Establishment website. http://www.awe.co.uk/about-us/our-company/ Accessed 7 December 2015.*

15 *'AWE review concluded successfully and updated contract agreed'. Serco Group press release, op cit.*

# AWE IN THE 2000s

*Figure 2: Aerial view of AWE Aldermaston (Google).*

AWE currently operates from three sites located in West Berkshire: Aldermaston (the main research and production site), Blacknest (a centre of expertise for seismic monitoring and arms control verification)[16], and Burghfield (the warhead assembly and disassembly site)[17]. Aldermaston is by far the largest of the three sites, covering an area of approximately 750 acres. AWE Aldermaston can be broadly divided into three areas: the high security nuclear processing and storage area (NPSA), sometimes known as the 'Citadel', in the northwest part of the site; the hydrodynamics research and explosives area to the north and east of the site, and the south and western part of the site which accommodates offices, management and administration functions (see Figures 2 and 3).

Manufacturing work at AWE focused on the production of around 225 Trident nuclear warheads from the late 1980s until probably 1999. The Establishment then began a period of work centred around warhead decommissioning: disassembly of Chevaline warheads, which was completed in February 2002[18], and of the last WE177 tactical nuclear weapons, retired in 1998. Subsequent work focused on maintenance and monitoring of the Trident warhead stockpile, with probably around two to eight warheads returned to AWE from Coulport each year[19] for dismantling, surveillance, and refurbishment. This includes 'assessment and assurance' studies aimed at ensuring that the warhead design remains fit for service into the medium to long term future. AWE is responsible for conducting an annual safety assessment for the UK Trident warhead to determine the condition of the stockpile and monitor any changes which might affect the life and performance of the warhead. Every seven years the state of the stockpile is reviewed to ensure that it has not been affected by factors such as cumulative design changes or environmental and handling impacts.

*Figure 3: Aerial view of AWE Burghfield (Bing).*

16 *AWE Blacknest website. http://www.blacknest.gov.uk/ Accessed 9 December 2015.*

17 *'Our locations'. Atomic Weapons Establishment website. http://www.awe.co.uk/about-us/our-locations/ Accessed 9 December 2015.*

18 *'The year at a glance'. AWE Today Issue No 15. December 2002.*

19 *Based on observations of warhead convoy movements reported annually by Nukewatch UK. 'Annual convoy movements', Nukewatch UK website. http://www.nukewatch.org.uk/?page_id=307 Accessed 9 December 2015.*

20 *A similar perspective drives the Royal Navy's nuclear submarine programme, with industry claiming that a regular 'drumbeat' of submarine production is needed to ensure that specialist skills and capability are not lost and there is no repeat of the problems which beset construction of Astute class submarines following a long pause in submarine building by BAE Systems.*

Over the period 2005 – 2010 AWE devoted much effort to ensuring that it would be able to continue with Trident warhead production if needed, and it is possible that, at various times, the Establishment has been working on the 'trickle production' of Trident warheads since the main batch production run ceased: building perhaps one warhead a year to ensure that the Establishment retains the ability to manufacture warheads and that skills and expertise are not lost[20].

There is evidence that AWE is currently decommissioning excess warheads in the existing Trident stockpile. In 2010, the government announced that it would reduce its overall nuclear weapon stockpile to no more than 180 by the mid 2020s[21]. Although the government has declined to comment on the operational programme for achieving this goal[22], observations of nuclear weapons convoy movements suggest that since 2011 there has been a discrepancy between the numbers of loaded convoys transporting warheads from the Coulport warhead store to AWE and the number of loaded return journeys to Coulport[23]. A balance of two to three warheads per year appears to have been retained at AWE. This is consistent with a programme for decommissioning around three warheads per year between 2011 and 2025 to bring the UK's total warhead stockpile down from around 225 warheads to around 180 warheads.

In addition to work on the UK Trident warhead programme, AWE also undertakes further crucial roles in support of the Ministry of Defence's nuclear programmes. Highly enriched uranium reactor fuel pellets are manufactured for the UK's nuclear powered submarine programme, and the MoD's reserves of special nuclear materials and other strategic materials required for its nuclear programmes – plutonium, uranium, tritium, and beryllium – are also stored in vaults at Aldermaston. AWE is also responsible for Truck Cargo Heavy Duty (TCHD) transport operations – running the convoy which transports warheads between AWE and HM Naval Base Clyde under contract to MoD, and in 2012, in partnership with Lockheed Martin and Babcock as part of the ABL Alliance, entered into a contract to provide support to the Trident Strategic Weapon System at the Royal Naval Armament Deport (RNAD) Coulport[24].

In addition to its work on the Trident nuclear warhead, AWE also plays a leading role in providing a National Nuclear Security capability for the UK government. This programme covers a range of areas aimed at controlling and preventing the spread of nuclear weapons, including nuclear intelligence and counter-terrorism, arms control verification, nuclear forensics and forensic seismology, and the ability to provide an emergency response to a nuclear incident[25].

AWE's Threat Reduction Division plays an international role in supporting arms control measures and disarmament verification and providing nuclear intelligence[26]. Much of this work takes place at AWE's Blacknest site, where research is conducted into techniques for distinguishing the seismic signals generated by underground nuclear explosions.

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20 *A similar perspective drives the Royal Navy's nuclear submarine programme, with industry claiming that a regular 'drumbeat' of submarine production is needed to ensure that specialist skills and capability are not lost and there is no repeat of the problems which beset construction of Astute class submarines following a long pause in submarine building by BAE Systems.*

21 *'Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review'. Cm 7948. Cabinet Office, October 2010. Paragraph 3.11. https://www.gov.uk/government/publications/the-strategic-defence-and-security-review-securing-britain-in-an-age-of-uncertainty Accessed 9 December 2015.*

22 *'Nuclear Weapons: Written Question 222315'. UK Parliament website. http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2015-01-27/222315/ Accessed 9 December 2015.*

23 *'Trident warhead decommissioning continues at a slow pace, says Nukewatch'. Nukewatch UK website, 12 October 2014. http://www.nukewatch.org.uk/?p=481 Accessed 9 December 2015. AWE holds the contract to operate nuclear warhead and special nuclear materials convoys on behalf of the Ministry of Defence.*

24 *'MoD signs Trident support contact'. Ministry of Defence announcement, 27 July 2012. https://www.gov.uk/government/news/mod-signs-trident-support-contract Accessed 12 April 2016.*

25 *'Building Capability for the Future'. AWE Annual Review 2012, p47. http://www.awe.co.uk/app/uploads/2014/07/AWE-Annual-Report-2012-FINAL.pdf Accessed 16 December 2015.*

26 *Tom Milne and Henrietta Wilson: 'Verifying nuclear disarmament: A role for AWE Aldermaston'. British Pugwash Group, 1999.*

# THE NUCLEAR WARHEAD CAPABILITY SUSTAINMENT PROGRAMME

In order to ensure that AWE retains the capability to develop, manufacture, and maintain nuclear weapons into the mid twenty first century a major investment programme is underway at the Establishment. At its peak the infrastructure construction work "will make AWE one of the largest construction sites in the UK", according to AWE's in-house newspaper[27].

In 2002 a study by the MoD's Chief Scientific Advisor recommended an "urgent and substantial increase to the UK's warhead capability"[28]. This was endorsed by a Cabinet subcommittee in January 2004 and in July 2005 the then Defence Secretary John Reid announced that MoD intended to "take forward a programme of investment in sustaining key skills and facilities at the Atomic Weapons Establishment. This will include the provision of necessary extra supporting infrastructure"[29].

The programme, known as the Nuclear Warhead Capability Sustainment Programme (NWCSP)[30] has the following published objectives[31]:

1. To deliver and sustain the capability to underwrite the UK stockpile now and in the future including transition to Mk4A [see below] and to be have the capability required for a future warhead if required.
2. To develop and deliver essential science, technology and production capabilities and critical skills to enable Atomic Weapons Establishment to operate, maintain and certify the safety and performance of the Trident Holbrook warhead.
3. To develop and deliver the UK stockpile to the Mk4A warhead (production, skills, science) approved design.
4. To deliver facilities, skills, production and science capabilities required to maintain the current warheads and support a possible future warhead.
5. To deliver the new hydrodynamics facility.

Retention and development of key skills at AWE is an important feature of the NWCSP, given concerns that the AWE workforce is ageing and that expertise necessary for the development of nuclear weapons may be gradually lost. Over recent years AWE has undertaken a concerted recruitment campaign through its apprentice scheme and partnerships with various universities. However, the most visible and high profile element of the NWCSP is an infrastructure development programme which is currently one of the largest construction schemes in the country. The construction element of the NWCSP consists of a series of new build projects intended to replace ageing facilities at AWE.

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*27* *'Major projects get into gear'. AWE Today, issue 37, August 2006.*

*28* *Response to Freedom of Information Request 23-12-2008-121334-002. Ministry of Defence, 30 September 2010.*

*29* *'Atomic Weapons Establishment' House of Commons written ministerial statement, 19th July 2005, Official Report, Column: 59WS http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo050719/wmstext/50719m03.htm#50719m03.html_sbhd0 Accessed 14 December 2015.*

*30* *Sometimes also referred to within government as the Nuclear Weapons Capability Sustainment Programme.*

*31* *'MoD Government Major Projects Portfolio Data September 2014' Spreadsheet, Ministry of Defence, 25 June 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/437752/MoD_Government_Major_Projects_Portfolio_data__September_2014.xlsx Accessed 14 December 2015.*

A full list of new build projects as at the time of writing is shown in Table 1[32]. Notable among these are the following major schemes:

- Project Orion, a high power laser facility which can be used to heat and compress materials to millions of degrees Celsius in nanoseconds to mimic the conditions in a nuclear detonation[33]. Orion began operations in 2013 (Figure 4).
- Project Mensa, a warhead assembly / disassembly facility at AWE Burghfield – the single most expensive project within the NWCSP to have so far received approval.
- Project Pegasus, a facility for manufacturing uranium components, which is intended to replace the ageing A45 uranium handling facility.
- An unnamed plutonium facility, scheduled for construction in the late 2020s, which will presumably replace the existing A90 complex.

| Project | Site | Projected in-service period | Approved cost (£million) |
|---|---|---|---|
| *Current new build projects that have been through the Ministry of Defence approval process* | | | |
| IT server buildings (two projects) | Aldermaston | 2008-10 | 32* |
| New office accommodation - Gemini | Aldermaston | 2008-10 | 78* |
| Modular accommodation (five buildings) | Aldermaston | 2008-10 | 27* |
| Car park / landscaping | Aldermaston Burghfield | 2008-10 | 3* |
| Orion research laser | Aldermaston | 2011-15 | 183* |
| Small components manufacturing interim - Leo | Burghfield | 2011-15 | 16* |
| Building for high performance computer - Orchard | Aldermaston | 2011-15 | - |
| High explosives fabrication - Circinus | Aldermaston | 2014-15 | 231* |
| Conventional Manufacturing - Phoenix | Burghfield | 2014-15 | 57 |
| Hydrodynamics trials - Technology Development Centre | Aldermaston | 2014-15 | 40 |
| Warhead assembly/disassembly - Mensa | Burghfield | 2016-20 | 734 |
| Uranium components - Pegasus | Aldermaston | 2016-20 | 634 |
| *Projects currently planned for but which have yet to go through the formal Ministry of Defence approvals process* | | | |
| Salts Processing - Octans | Aldermaston | 2020-25 | - |
| Initiator system manufacture - Taurus | Aldermaston? | 2020-25 | - |
| Large Scale formulations - Scorpius | Aldermaston? | 2025-30 | - |
| Small Scale formulations - Cepheus | Aldermaston | 2025-30 | - |
| New Plutonium Facility - not yet named | Aldermaston | 2025-30 | - |
| New Depleted Uranium Facility | Aldermaston | 2025-30 | - |
| Assembly for Trials - Columba | Aldermaston | 2025-30 | - |
| High Explosive Climatic Trials | Aldermaston | 2025-30 | - |
| Non-Metallics and materials R&D - Libra | Aldermaston | 2025-30 | - |
| Chemical processing - Astra | Aldermaston | 2025-30 | - |
| *** Outturn costs** | | | |

*Table 1: Published projects within the Nuclear Warhead Capability Sustainment Programme*[34]

32 *The programme is a flexible programme and projects have been added to it and removed from it over the course of the NWCSP.*

33 *G Brumfiel, 'Welcome to the Atomic Weapons Establishment'. Nature Vol 464, pp156-157, 2010 http://www.nature.com/news/2010/100310/full/464156a.html (Accessed 13 May 2013).*

34 *Table compiled using information from: 'AWE'. Parliamentary Written Question. Official Report (Hansard) 22 November 2011, Columns 271-2W. http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm111122/text/111122w0002.htm#111122114002932 Accessed 14 December 2014.*
*'AWE'. Parliamentary Written Question. Official Report (Hansard) 2 July 2014, Columns 676-8W. http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm140702/text/140702w0003htm#140702w0003.htm_wqn16 Accessed 14 December 2015.*

*Figure 4: The Orion laser facility at AWE Aldermaston (Aldermaston Women's Peace Camp).*

As well as new build projects, the NWCSP also includes a number of 'rekit' projects aimed at refurbishing and re-equipping facilities that have not yet reached the end of their life. These include the following projects[35]:

- Depleted Uranium Upgrade.
- Beryllium Facility.
- Plutonium Capability Programme (A90).
- Enriched Uranium Facility (A45).
- Explosive storage and processing facility.
- Salts Sustainment.
- Facility for assembly/disassembly of warhead.

It should be noted that these projects may in themselves be significant enterprises: the costs of the A90 rekit project, for example, amount to £272 million[36].

35 *'AWE'. Written Question 200409. UK Parliament website. http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2014-06-12/200409 Accessed 14 December 2015*

36 *'AWE Aldermaston'. Parliamentary Written Question. Official Report (Hansard) 27 January 2011, Column 476W. http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm110127/text/110127w0004.htm#11012780001242 Accessed 14 December 2015.*

AWE has also invested heavily in computing capacity through the NWCSP. High performance computing has played a central role in AWE's research programme, using experimental data and sophisticated modelling techniques to predict how warhead components will behave during a nuclear explosion. The past decade has seen a meteoric increase in computing power at the Establishment[37]. A major step forward was taken in 2001 when AWE purchased Blue Oak, an IBM SP Power 3 computer, and in 2006 a Cray XT3 computer known at Larch was installed, adding more than twenty times the computational power of Blue Oak to AWE's capability. At the time of its opening Larch was said to be the most powerful computer in the UK and among the top five most powerful computers in Europe. In 2010 AWE installed three Bullx B510 systems, one of which, 'Blackthorn', was the third largest in the UK when it began operating. Blackthorn was designed to process very large calculations as part of a single project which might take days or even weeks to complete, while the other two Bullx computers, comprising the 'Willow' complex, were intended to undertake smaller concurrent calculations. AWE's next supercomputing milestone was passed in November 2012 when AWE selected three SGI ICE X computers which began operating in early 2014, two of which comprise the 'Spruce' cluster. Barely 18 months old, Spruce received an upgrade in late 2015 known as Project Rosewood. Rosewood consists of the installation of two SGI ICE XA computers and the upgrade is expected to bring Spruce's computing capacity to over 2.0 petaflops (one petaflop equates to $10^{15}$ - one thousand trillion - calculations per second) – around 20,000 times greater than a commercially available desktop computer operating at around 100 gigaflops.

AWE's increasing supercomputer capacity, in parallel with a rapidly growing expansion in computer performance, has enabled AWE to make advances in warhead science by refining mathematical models of nuclear warheads and warhead components and improving their resolution. AWE now has "some of the most advanced and powerful supercomputing facilities in the world", according to the Establishment's website[38]. Each computer upgrade over the past decade has represented roughly an order of magnitude increase in computing speed, allowing AWE to dramatically cut the time it takes to perform complex computations, undertake more complex modelling projects, and process an increased workload.

Over the 25 period of the current AWE contract a total of around £20 billion will be spent at AWE (Table 2). Figures from 2005-06 onwards represent spending on the NWCSP. It can be seen that from 2010-11 onwards the rough costs of the programme hover at around £1 billion per annum, of which approximately 40% is capital expenditure. Tables 1 and 2 suggest that MoD sees the NWCSP as a rolling programme, with an ongoing schedule of construction projects at AWE emerging as required into the indefinite future to ensure that AWE has the capability to fulfil its role. Revenue expenditure is also significant, as one of the aims of the NWCSP is to ensure that AWE has adequate personnel numbers and skills over the long term. Work in collaboration with a number of universities is important in achieving this goal[39].

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37 *'Supercomputing upgrade at Atomic Weapons Establishment'. Nuclear Information Service. 2 August 2015. http://www.nuclearinfo.org/article/development-awe-aldermaston/supercomputing-upgrade-atomic-weapons-establishment Accessed 10 December 2015.*

38 *'High performance computing'. Atomic Weapons Establishment website. http://www.awe.co.uk/what-we-do/science-engineering-technology/high-performance-computing/ Accessed 10 December 2015.*

39 *'Atoms for Peace? The Atomic Weapons Establishment and UK universities'. Nuclear Information Service and Medact, 11 February 2014. http://nuclearinfo.org/sites/default/files/Atoms%20For%20Peace%20Full%20Report.pdf Accessed 16 December 2014.*

| Year | Capital spend (£m) | Total AWE spending (£m) |
|---|---|---|
| 2000-01 | 21 | 311 |
| 2001-02 | 43 | 291 |
| 2002-03 | 45 | 278 |
| 2003-04 | 62 | 300 |
| 2004-05 | 92 | 363 |
| 2005-06 | 172 | 493 |
| 2006-07 | 312 | 687 |
| 2007-08 | 409 | 894 |
| 2008-09 | 395 | 800 |
| 2009-10 | 420 | 870 |
| 2010-11 | 409 | 944 |
| 2011-12 | 349 | 941 |
| 2012-13 | 466 | 972 |
| 2013-14 | 473 | 985 |
| 2014-15 | 534 | 1,067 |
| 2015-16 | 483 | 1,018 |
| 2016-17 | 419 | 962 |
| 2017-18 | 426 | 988 |
| 2018-19 | 402 | 1,078 |
| 2019-20 | 374 | 1,068 |
| 2020-21 | 383 | 1,002 |
| 2021-22 | 392 | 1,027 |
| 2022-23 | Not held | 1,092 |
| 2023-24 | Not held | 1,031 |
| 2024-25 | Not held | 1,020 |
| **Total** | **7,081** | **20,482** |

*Table 2: Ministry of Defence spending on the Atomic Weapons Establishment, 2000-01 to 2024-25*

Figures from 2000-01 to 2012-13 represent outturn spend (provisional figures for 2011-12 and 2012-13)[1 2 3 4]. Figures for 2013-14 to 2017-18 are planned expenditure agreed between MoD and AWE. Figures for 2018-19 to 2024-25 are indicative figures from MoD Planning Round 2012-13[5].

Footnotes to table:

1 *'Nuclear Deterrent'. Parliamentary Written Question. Official Report (Hansard) 10 Oct 2005 , Column 16W. http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo051010/text/51010w05.htm Accessed 14 December 2015.*

2 *'Nuclear Weapons'. Parliamentary Written Question. Official Report (Hansard) 11 December 2007, Column 399W. http://www.publications.parliament.uk/pa/cm200708/cmhansrd/cm071211/text/71211w0012.htm Accessed 14 December 2015.*

3 *Atomic Weapons Establishment: Finance'. Parliamentary Written Question. Official Report (Hansard) 20 Oct 2010, Column 744W http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm101020/text/101020w0001.htm Accessed 14 December 2015.*

4 *AWE'. Parliamentary Written Question. Official Report (Hansard) 19 June 2012, columns 931-2W http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm120619/text/120619w0003.htm#12062019002766 Accessed 14 December 2015.*

5 *Response to Request for Information 22-05-2012-101127-001. Ministry of Defence, 24 August 2012.*

Because of its high costs and ambitious scope, the NWCSP has been subject to a number of reviews which have aimed to cut spending. These include a programme review undertaken in 2006, the 2010 Trident Value For Money Review, an audit of the AWE Management and Operation contract requested in 2013 by the Chief of Defence Materiel, and a number of reviews by HM Treasury. The principal casualty of these reviews was Project Hydrus, a proposal to construct a new hydrodynamics research facility at AWE Aldermaston. Concerns over cost increases, late delivery, and risks associated with the project - believed to have had a forecast cost of around £1 billion - resulted in its cancellation in November 2010. Instead, future hydrodynamics work will take place using the new EPURE radiographic facility at Valduc in France (see below), Aldermaston's new Technology Development Centre, and existing hydrodynamics equipment at Aldermaston. Project Hydrus had been granted planning permission shortly before it was axed, and cancellation of the project resulted in a sum of £117.7 million being written off by MoD[40].

In March 2015 the Sunday Herald newspaper reported that two key projects at AWE, Project Pegasus (uranium components facility) and Project Mensa (assembly / disassembly facility at Burghfield) were running behind schedule and over budget[41]. The Sunday Times subsequently reported that MoD was considering scrapping its contract with AWE Management Ltd because of the consortium's poor performance in delivering the NWCSP construction programme[42]. However, in March 2016 MoD announced that it had secured an "improved" contract with AWE ML for management and operation of the AWE sites which would deliver improved value for money and drive MoD's commercial partners to perform better. The updated contract allows greater risk sharing between the MOD and AWE ML, with penalties if targets are not met and incentives for improved performance[43]. In an associated initiative the November 2015 Strategic Defence and Security Review announced that MoD would "intensify efforts, with our industrial partners, to improve performance" in the nuclear weapons programme and that a new team would be established within MoD "to act as the single sponsor for all aspects of the defence nuclear enterprise, from procurement to disposal, with responsibility for submarines, nuclear warheads, skills, related infrastructure and day-to-day nuclear policy"[44]. It is anticipated that a new delivery body for the Atomic Weapons Establishment will be 'stood up' in 2016[45], but at the time of writing further details are unavailable.

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*40* *'AWE Aldermaston: Written Question 19414'. UK Parliament website. http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2015-12-09/19414/ Accessed 18 December 2015.*

*41* *Edwards, Rob: 'Pegasus grounded: vital Trident bomb project 'on hold' after problems'. Sunday Herald, 8 March 2015. http://www.heraldscotland.com/news/home-news/pegasus-grounded-vital-trident-bomb-project-on-hold-after-problems.120130054 Accessed 14 December 2015.*

*42* *Collingridge, John: 'Nuclear contract may be scrapped'. Sunday Times, 15 March 2015. http://www.thesundaytimes.co.uk/sto/business/Companies/article1531071.ece Accessed 14 December 2015.*

*43* *'MoD drives efficiencies in improved contract for nuclear sites'. Ministry of Defence news story, 31 March 2016. https://www.gov.uk/government/news/mod-drives-efficiencies-in-improved-contract-for-nuclear-sites Accessed 12 April 2016.*

*44* *'National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom'. Cm 9161 . Cabinet Office, November 2015. Para 4.75. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/478933/52309_Cm_9161_NSS_SD_Review_web_only.pdf Accessed 11 December 2015.*

*45* *'Director General Nuclear Candidate Pack'. Ministry of Defence, March 2016. Page 8. http://www.heidrick.com/~/media/ESEJobPostingFiles/DGNuclear/Candidate%20Pack Accessed 11 May 2016.*

As well as undertaking a new build programme, AWE is also implementing a programme to decommission redundant buildings which have reached the end of their life. These include the main A1 plutonium processing facility which opened in the 1950s. Work commenced on decommissioning A1 in 2004 and is due to finish in 2030 at an anticipated cost of between £130 million and £150 million[46]. Decommissioning of the former tritium research facility and Herald research reactor at Aldermaston was completed in the mid 2000s and resulted in dramatic reductions in radioactive discharges to the environment[47]. As well as addressing the environmental impacts of AWE's radioactive legacy, the decommissioning programme also serves a critical role in freeing up land for the construction of new build facilities.

46 *'AWE Aldermaston'. Parliamentary Written Answer. Official Report (Hansard). 20 January 2014, Column 37W. http://www.publications.parliament.uk/pa/cm201314/cmhansrd/cm140120/text/140120w0002.htm#140120w0002.htm_wqn19 Accessed 16 December 2015.*

47 *'Herald consigned to nuclear history'. AWE Today. Issue 34, February 2006.*

# WARHEAD RESEARCH AT AWE

As well as manufacturing and maintaining warheads, AWE is also responsible for guaranteeing their reliability (ensuring that they explode with the full destructive power they are designed to release) and their safety (ensuring that they will not explode unless signalled to do so), and for ensuring that the UK retains the capability to develop a new warhead if necessary. These areas are closely linked and require an active research programme on warhead science and engineering. In practice much of the information gained from 'stockpile stewardship' experiments undertaken to investigate warhead safety and reliability will also be of value in the design of new warhead types.

The UK Trident warhead was designed and built using information derived from underground nuclear testing in the 1980s. However, in 1992 President George H.W. Bush announced a moratorium on nuclear testing at the Nevada Test Site, where UK weapons tests had taken place, and in 1998 the UK ratified the Comprehensive Nuclear-Test-Ban Treaty (CTBT), giving a commitment not to undertake any further nuclear weapon tests. AWE's current nuclear weapons programme is still heavily reliant on the historic database of information derived from underground testing, but is increasingly being supplemented by a much more theoretical approach centred on modelling the behaviour of warhead materials and components at extreme temperatures and pressures. Knowledge and expertise in these areas are maintained through AWE's own experimental programmes which are augmented by close co-operation and peer review arrangements with US nuclear weapons laboratories – principally Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories. Such co-operation takes place under the auspices of the 1958 US-UK Mutual Defence Agreement, which has enabled long term Anglo-American co-operation on nuclear weapons[48]. The USA has unique warhead physics research facilities which have no equivalent in the UK, including the 'Z machine' at Sandia National Laboratories and a range of facilities at the Nevada National Security Site, where sub-critical nuclear test explosions can also be conducted. Other US facilities, such as the National Ignition Facility superlaser at the Lawrence Livermore National Laboratory in the USA and the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility at the Los Alamos National Laboratory operate under different energy regimes to corresponding equipment at Aldermaston, allowing complementary experiments to be conducted by the two nations. An active programme of exchange visits takes place between AWE and the USA's nuclear weapons complex. More than 1,500 visits by AWE staff were made to US nuclear facilities at 48 different sites between 2007 and 2009[49].

48 *Nuclear Information Service: 'Reform Not Renewal: The US-UK Mutual Defence Agreement, How it Works, and Why it Needs to be Reformed'. June 2014. p.13 http://nuclearinfo.org/sites/default/files/Reform%20Not%20Renewal%20-%20Full%20Report.pdf Accessed 13 December 2015.*

49 *'Nuclear Weapons'. Parliamentary Written Question. Official Report (Hansard), 20 January 2011, Column 909W. http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm110120/text/110120w0001.htm#11012056001705 Accessed 14 December 2015.*

In addition to co-operation with American nuclear weapons laboratories on warhead science, co-operation between AWE and French nuclear scientists has begun to take place through the 'Project Teutates' research programme. The Lancaster House Treaty, signed in 2010, allows Britain and France to collaborate on nuclear warhead research over the next 50 years and enables the two nations to undertake a joint programme of co-operation on nuclear weapon technology at a new hydrodynamics research facility, known as EPURE, at Valduc in France and a joint Technology Development Centre at AWE Aldermaston. The new facilities are intended to be operational from 2015 and represent the beginning of a long term programme of co-operation[50]. The scope of collaboration was extended beyond the terms of the original Lancaster House agreement following an Anglo-French summit at RAF Brize Norton in 2014. Under the new arrangements co-operation and information sharing will now take place over a far wider range of scientific matters than was specified in the 2010 treaty. The declaration issued after the summit announced that France and the UK will conduct joint research at the 'Orion' nuclear test laser at AWE Aldermaston and the Laser Megajoule (LMJ) at the Commissariat à l'Énergie Atomique - Direction des Applications Militaires (CEA-DAM) Cesta site near Bordeaux. French researchers will also be given access to hydrodynamics facilities at Aldermaston. Technical and scientific information underpinning warhead testing will also be shared to allow peer review and joint research by weapons scientists from each country, which may allow AWE's scientists to benefit from recent work in developing France's new Tête Nucléaire Océanique (TNO) nuclear warhead, which is currently entering into service[51].

50 *'Anglo-French nuclear co-operation and the 'Teutates' programme'. Nuclear Information Service, November 2010. http://nuclearinfo.org/article/government-awe-aldermaston-development/anglo-french-nuclear-co-operation-agreement-new Accessed 13 December 2015.*

51 *'UK and France extend warhead research collaboration into new areas'. Nuclear Information Service website, 5 February 2014. http://www.nuclearinfo.org/article/government-development-awe-aldermaston/uk-and-france-extend-warhead-research-collaboration Accessed 14 December 2014.*

# EXPLOSIVES DEVELOPMENT AND PRODUCTION

The manufacture and development of explosives is an important part of AWE's work. High explosives are used not only as part of the nuclear warhead design, but also in a variety of hydrodynamic and shock physics experiments designed to test the properties of warhead components.

AWE's Explosives Technology Facility consists of around 170 buildings to the east side of the Aldermaston site, occupying an area of around 300 acres (40% of the total site area). These include a number of explosive chambers for experimental firings. Some of these buildings, together with buildings on the AWE Burghfield site, will be decommissioned following the opening in 2015 of AWE's new high explosives fabrication facility, Project Circinus (Figure 5). As well as providing AWE with new up to date explosives production and testing facilities, Circinus is intended to improve safety standards and reduce the need to transport explosives within the site.

*Figure 5: Circinus explosives facility under construction at AWE Aldermaston (Bing).*

Circinus is a high hazard explosive production facility which can manufacture both high explosive and inert warhead components[52]. The main process building comprises of 12 blast-proof cells arranged around a central corridor. The cells contain process equipment required for pressing, machining, storage and measurement of explosive components and the central corridor contains work stations for the remote operation of processes within cells. Access to the cells is via blast doors, designed to protect the central corridor from the effects of an explosion within a cell. Adjacent to the process building is a support building containing offices, workshops, and storage areas. AWE is currently investing heavily in explosives facilities. In addition to Project Circinus a number of existing buildings have been refurbished and construction of a new facility for conducting high explosive climatic trials is planned for the period 2025-30. Explosives testing is also carried out on behalf of AWE at off site explosive range facilities operated by Qinetiq.

52 *Information accompanying planning application 07/02438/COMIND to West Berkshire Council for Replacement High Explosives Fabrication Facility.*

AWE's interest in explosives covers research into explosives characteristics and the modelling of explosives behaviour, the development and formulation of new explosives for future applications, and the manufacture and production of explosive components. An important area of work is the programme of inspection intended to assure that warhead explosives remain stable and safe throughout their life. Both the performance and the safety of the warhead are affected by the ageing of high explosive. There is uncertainty about the medium to long term effects that ageing may have on the explosive type used in the UK Trident warhead, and so an ongoing programme of surveillance and replacement is necessary.

A key aim of AWE's explosives research is to develop formulations with an enhanced explosive performance and with more predictable and controllable properties – and particularly reduced sensitivity to shocks. The high explosive used in the UK Trident warhead to compress fissile components and commence a nuclear reaction is a formulation known as EDC37[53]. This is different to the explosive used in the US W76 Trident warhead, which uses a type of explosive known as PBX9501. Explosive in the US warhead will be replaced during the W76-1 warhead refurbishment programme and it is likely that the Mk4A modification programme for the UK Trident warhead will likewise require the remanufacturing and replacement of high explosive components. One of the objectives of any future programme to develop a new US 'interoperable warhead' will be to improve its safety characteristics, including use of an insensitive high explosive to initiate the nuclear explosion. Although the UK's EDC37 explosive is less sensitive to shocks than PBX9501, it is not categorised as an insensitive high explosive[54].

AWE re-established an explosives formulations team in around 2006 to develop new PBX formulations for future applications[55]. Re-establishment of the team ensured that AWE retained the ability to remanufacture explosive components for the UK Trident warhead, and also enables the development of a new insensitive high explosive for use in any successor warhead. The production of reduced sensitivity high explosive materials is said to be "driving research at AWE and academic outreach partners"[56].

AWE also develops and produces electronic explosive devices, which are designed to produce an explosive output by converting electrical energy into intense heat or light, and act as explosive detonators. Protection of these devices against hazards from electrostatic discharges is an active and important area of research which would contribute to development of a new warhead.

53 *Ainslie, John: 'The Future of the British Bomb'. WMD Awareness Programme, October 2006. www.swordofdamocles.org/pdf/future.pdf Accessed 19 April 2016.*

54 *Gustavsen, R. L.; Sheffield, S. A.; Alcon, R. R.; Winter, R. E.; Taylor, P.; and Salisbury, D. A.: 'Double Shock Initiation of the Explosive EDC-37'. Paper presented at the American Physical Society, Shock Compression of Condensed Matter Meeting, 24-29 June 2001, Renaissance Waverly Hotel, Atlanta, Georgia. Bulletin of the American Physical Society, Vol. 46, No. 4, abstract #H1.053. Abstract online at http://adsabs.harvard.edu/abs/2001APS..SHK.H1053G Accessed 12 May 2016.*

55 *'Overview'. Discovery 25. Atomic Weapons Establishment, September 2014. P2. www.awe.co.uk/app/uploads/2015/01/Discovery-25.pdf Accessed 7 January 2016.*

56 *'Explosives Materials Development'. Discovery 25. Atomic Weapons Establishment, September 2014. P6. www.awe.co.uk/app/uploads/2015/01/Discovery-25.pdf Accessed 7 January 2016.*

# THE UK TRIDENT MARK 4A WARHEAD MODIFICATION PROGRAMME

Although the government has never formally announced it, AWE is currently engaged on a secretive programme to modify and upgrade all UK Trident warheads. The Mk4A modification programme aims to upgrade the capability of the warhead and increase its operational life[57]. The original US W76-0/Mk4 warhead on which the UK Trident warhead is modelled was designed for deployment on the relatively inaccurate Trident C4 missile against a limited range of targets. Following a 1992 study into future warheads for the Trident missile system, the US government eventually decided to undertake a programme to upgrade the warhead to a newer Mk4A version (Figure 6). This would increase the war-fighting effectiveness of the weapon, making it more accurate and extending the range of targets it is able to destroy to include hardened targets. The modification programme is intended to extend the service life of the W76 warhead by 30 years[58].

*Figure 6: US Mark 4A re-entry vehicle containing W76-1 warhead (Sandia National Laboratories).*

The UK has embarked upon a parallel programme to upgrade and extend the life of its Trident warheads. The UK Trident Mk4A warhead modification project is taking place under the auspices of the NWCSP, which has development and delivery of the UK stockpile to the Mk4A warhead as one of its objectives. It is possible that the resulting increase in capability of the modified warhead contributed to the government's conclusion that it will be able to meet its 'minimum deterrent' criteria with a lower number of warheads than previously, enabling the 2010 decision to reduce the size of the UK's nuclear warhead stockpile.

The UK warhead modification project is believed to be similar to the US Mk4A / W76-1 upgrade. A key feature of the programme is the development of a new arming, fuzing, and firing system, which activates the warhead, triggers the firing system, and controls the height and conditions under which it detonates. The government has conceded that "the Mk4A Arming, Fuzing and Firing System is a non-nuclear component being introduced into the UK Trident warhead to replace similar component [sic] which is becoming obsolete"[59], but the scope of the programme is likely to be considerably wider than this. The modification arrangements probably also include replacing the warhead's gas transfer system, which injects tritium gas into the warhead as it detonates, with a new design, Acorn II, which is part of the US W76-1 upgrade. The new gas transfer system is likely to improve the performance of the warhead and increase its yield, and thus its destructive capability.

57 *Ainslie, John: 'United Kingdom'. In 'Assuring Destruction Forever: 2015 Edition'. Reaching Critical Will of the Women's International League for Peace and Freedom, 2015. p72-3. http://www.reachingcriticalwill.org/images/documents/Publications/modernization/assuring-destruction-forever-2015.pdf Accessed 9 December 2015.*

58 *'Fiscal Year 2017 Stockpile Stewardship Management Plan – Biennial Plan Summary. Report to Congress March 2016'. National Nuclear Security Administration, United States Department of Energy, p8. http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/FY17SSMP%20Final_033116.pdf Accessed 13 April 2016.*

59 *Response to Freedom of Information Request FOI2015/07375. Ministry of Defence, 13 October 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470321/20151013-FOI_2015_07375.pdf Accessed 9 December 2015.*

The Mk4A modification programme is also likely to include refurbishment of the secondary and radiation case of the warhead to address corrosion concerns and extend the life of the weapon[60], and the replacement of high explosive warhead components with new remanufactured explosives (see above).

The programme involves close collaboration with the US nuclear weapons laboratories through a joint US/UK Joint Re-entry System Working Group, and key components for the modified warhead are purchased from the USA[61]. A senior staff engineer at Lockheed Martin in California is responsible for planning, coordinating, and executing the development and production of "UK Trident Mk4A Reentry Systems as part of the UK Trident Weapon System Life Extension program"[62]. In March 2011 Sandia National Laboratories announced that they had conducted "the first W76-1 United Kingdom trials test" at their Weapons Evaluation and Test Laboratory (WETL), providing qualification data critical to the UK implementation of the W76-1"[63].

No timetable has been published for the development and entry into service of the modified warhead. However, "Safety Case for Mk4A processing" is listed as one of the successes for the Burghfield site in AWE's Annual Review of Safety 2014[64], suggesting that this milestone was completed at some point during the year. A letter to the Senior Responsible Owner of the MoD's Nuclear Warhead Capability Sustainment Programme states that the duties of the postholder include "Commencement of Mk4A production in accordance with the Trident Manufacture Plan"[65]. The letter is dated July 2014 and states that the postholder's tenure will end in the summer of 2018, so the modified warhead is evidently scheduled to begin entering service at some period within this window. It is believed that production has commenced and Mk4A warheads are at the time of writing being transported to the Clyde submarine base to allow their deployment.

The costs of the Mk4A modification programme have not yet been disclosed, despite a number of requests from Parliamentarians for more information on this point. At different times the government has claimed that the costs of the Mk4A modification programme should not be published because their release would be likely to prejudice national security and defence in the UK[66], and because they cannot be distinguished from other AWE management and operation costs[67].

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60 *Ainslie, John: 'United Kingdom' in Reaching Critical Will 2015, op cit.*

61 *'Trident Missiles'. Parliamentary Written Question. Official Report, 3 December 2009, Column 911W. http://www.publications.parliament.uk/pa/cm200910/cmhansrd/cm091203/text/91203w0014.htm#09120373000543 Accessed 9 December 2015.*

62 *Linkedin profile for Senior Staff Systems Engineer at Lockheed Martin Space Systems Company. https://www.linkedin.com/in/paul-tom-672b09b Accessed 9 December 2015. Cited in Ainslie, John: 'United Kingdom' in Reaching Critical Will 2015, op cit.*

63 *'Labs Accomplishments'. Sandia National Laboratories, March 2011. p3. http://www.sandia.gov/LabNews/labs-accomplish/2011/lab_accomp-2011.pdf Accessed 9 December 2015. Cited in Kristensen, Hans M: 'British Submarines to Receive Upgraded US Nuclear Warhead'. Federation of American Scientists, 1 April 2011. http://fas.org/blogs/security/2011/04/britishw76-1/ Accessed 9 December 2015.*

64 *Atomic Weapons Establishment: 'Environment, Safety, and Health. Annual Review of Safety 2014'. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/484491/20151001_Whitham_FOI_2015-03576__AWE_Annual_Review_of_Safety_2014-Redacted_Copy.pdf Accessed 22 December 2015.*

65 *'Appointment as Senior Responsible Owner for the Nuclear Warhead Capability Sustainment Programme'. Letter from Jon Thompson to Paul Hollingshead, 2 July 2014. Ministry of Defence reference D/PUS/5/1 (451). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/471199/Nuclear_Warhead_Capability_Sustainment_Programme_SRO_appointment_Letter_-_P.Hollingshead.pdf Accessed 9 December 2015.*

66 *'Trident missiles'. Parliamentary Written Question. 8 Dec 2009 : Column 214W. http://www.publications.parliament.uk/pa/cm200910/cmhansrd/cm091208/text/91208w0008.htm#09120870002511 Accessed 9 December 2015.*

67 *'Nuclear Weapons: Finance'. Parliamentary Written Question. Official Report, 11 November 2010, Column 450W. http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm101111/text/101111w0003.htm#10111178000722 Accessed 9 December 2015.*

# A REPLACEMENT TRIDENT WARHEAD

A decision will in due course be made on whether to replace the UK Trident warhead, and this decision will be heavily informed by research undertaken by AWE. The 2015 Strategic Defence and Security Review stated that "work continues to determine the optimum life of the UK's existing nuclear warhead stockpile and the range of replacement options. The government's view is that a replacement warhead is not required until at least the late 2030s, possibly later", although a decision on replacement may be required in this Parliament or early in the next[68]. Assuming, however, that the UK Trident Mk4A warhead modification programme will extend the life of the current warhead by a similar length of time - 30 years - to the corresponding US W76-1 upgrade programme, the government's assessment of the timeline for replacement appears to be highly cautious.

Much work has already been undertaken at AWE to pave the way towards the decision on a replacement warhead and its possible design. In the late 1970s several underground nuclear tests were conducted to develop a family of 'packageable' warheads for use in delivery systems designed to replace Chevaline and WE177[69]. Further work on design of a variable yield WE177 replacement warhead - by then known as the Future Theatre Nuclear Weapon (FTNW), to be delivered by a stand-off missile known as the Tactical Air to Surface Missile (TASM) - took place at the end of the 1980s[70]. A decision not to proceed with the programme was made in the mid 1990s[71], but much experimental data had by then been gathered, and sufficient information to design a workable warhead appears to have been obtained[72]. AWE is drawing on this earlier work, and data from Trident underground tests, in evaluating warhead replacement options.

In 2007 the Herald newspaper reported that AWE was undertaking a secret programme to design a "revamped British nuclear warhead"[73]. The warhead was known as the High Surety Warhead (HSW) and was said to be a British version of the Reliable Replacement Warhead (RRW), at the time under development in the USA[74]. As part of the HSW programme aerodynamic, aerothermal, and trajectory modelling studies were carried out and an architectural over-review was conducted[75]. Franklin Miller, formerly Senior Director for Defense Policy and Arms Control at the National Security Council for President George W. Bush has confirmed that the UK was exploring options for developing its own version of the RRW, saying: "They [the UK] will need a Reliable Replacement Warhead of their own. In fact, they're working on one. It has a different name. It's got a different acronym. But they are working on the same kind of a thing for their W76 variant"[76].

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68 *'National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom'. Cm 9161 . Cabinet Office, November 2015. Para 4.72. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/478933/52309_Cm_9161_NSS_SD_Review_web_only.pdf Accessed 11 December 2015.*

69 *Burnell, Brian: 'WE.177. Retirement'. Website 'Nuclear weapons: A guide to British nuclear weapons projects'. http://www.nuclear-weapons.info/vw.htm Accessed 13 December 2015.*

70 *Ainslie, John: 'UK nuclear tests at the Nevada Test Site 1974 – 1991. Unpublished paper, 2011.*

71 *Comment from David Omand. Transcript of 'Cabinets and the Bomb workshop (Session Two)'. British Academy, 27 March 2007. http://www.britac.ac.uk/pubs/review/perspectives/0703cabinetsandbomb-2.cfm Accessed 13 December 2015.*

72 *The 2013 Trident Alternatives Review refers to a cruise missile warhead option which "uses a design based on work done in the early-90s for a cruise-missile 'Future Theatre Nuclear Weapon'". Trident Alternatives Review. Cabinet Office, 16 July 2013. Para 2.19 https://www.gov.uk/government/uploads/system/uploads/attachment_data file/212745/20130716_Trident_Alternatives_Study.pdf Accessed 13 December 2015.*

73 *Bruce, Ian: 'Britain in top-secret work on new atomic warhead'. The Herald, 4 September 2007 http://www.heraldscotland.com/britain-in-top-secret-work-on-new-atomic-warhead-1.864537 Accessed 13 December 2015.*

74 *The RRW programme was cancelled by President Obama in 2009.*

75 *Response to Request for Information 2013/00028. Ministry of Defence, 7 January 2015*

76 *Interview with Frank Miller by Jessica Yeats. Centre for Strategic and International Studies, 28 January 2008. Washington, DC. Audio file previously available at http://csis.org/program/us-uk-nuclear-cooperation-after-50-years (no longer online).*

Data from the HSW programme was exchanged with the US government in support of their RRW programme[77]. The UK's interest in the RRW programme, and work on developing a High Surety Warhead which is apparently closely related to the RRW, indicates that the UK government and AWE are keen that their own research work should closely follow and harmonise with research programmes underway in the USA, and that British warhead design should closely match American warhead design.

MoD has stated that the HSW programme was an "academic study" intended to "show that AWE had the skills and knowledge to produce a replacement warhead to Trident if the Government made such a decision in the future. There was no intention that the study should in itself form any part of any future replacement or refurbished warhead in service"[78]. The High Surety Warhead programme was able to 'prepare the ground' in developing a new warhead by undertaking research and modelling work before any formal replacement decision was made.

According to MoD, approval to commence studies to inform the policy decision on refurbishment or replacement of the UK Trident warhead was formally given in September 2008. The studies are being undertaken under the auspices of the Re-entry Systems Options (RES(O)) project, and are expected to have been completed sometime in the life of the current Parliament[79]. Among other work, the studies will "draw upon existing technical evidence from previous programmes (Trident, FTNW, etc)" and current "technical readiness activities". The work is proceeding at AWE with input from the US nuclear weapons laboratories.

The total spent on studies to inform the decision on whether to refurbish or replace the existing warhead as of March 2015 comprises £80 million on technology studies to support refurbishment of the current system and explore options for a potential future warhead; and £5.5 million on studies to support the decision on whether to refurbish or replace the existing warhead[80].

The UK faces a number of risks and dilemmas in deciding whether, when, and how to develop a successor warhead to the current UK Trident warhead. Unlike the UK's previous warhead designs, it will not be possible to perform an underground test to validate the reliability of a new warhead, and modelling techniques based on data from hydrodynamic and laser testing have not yet reached the stage where they can be fully trusted. On the other hand, the risks to keeping the current warhead in service increase with the warhead's age. A particular concern is the possibility that an unexpected technical problem may suddenly arise, given that certain warhead materials, including special nuclear materials, are relatively novel and that limited information is available about their ageing and corrosion characteristics and life expectancy. The UK is unlikely to be able to develop a new warhead inside the time period within which AWE can guarantee the performance and safety of the current design.

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77 *Taylor, Matthew, and Richard Norton-Taylor: 'US using British atomic weapons factory for its nuclear programme'. Guardian, 9 February 2009: http://www.guardian.co.uk/world/2009/feb/09/us-uk-atomic-weapons-nuclear-power Accessed 14 December 2015.*

78 *Response to Request for Information 2013/00028. Ministry of Defence, op cit.*

79 *Response to Request for Information 15-12-2010-104012-001. Ministry of Defence, 21 June 2011.*

80 *'Trident: Written Question 19392'. UK Parliament website. www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2015-12-09/19392/ Accessed 28 December 2015.*

Any programme for development of a replacement for the UK Trident warhead would require close co-operation with the USA. The new design would have to be compatible with non-nuclear components purchased from the US, and also with any successor missile to the current Trident D5 missile. The design and certification programmes for the UK Trident warhead and the Mark 4A modification saw close collaboration between the US and the UK, and relied upon unique experimental facilities at the USA's nuclear weapons laboratories. However, the US has not yet come to a clear decision on whether or not to develop a new interoperable warhead, and the risks to a UK programme which proceeded in advance of the US timetable would be considerable.

If the UK does decide to develop a successor warhead, it is likely that it will be as similar as possible to the current UK Trident warhead's design baseline so as to maintain its reliability. Toxic and corrosion-susceptible components will be replaced by more durable, inert materials and efforts will be made to develop a less sensitive explosive for the warhead. Because of concerns about nuclear terrorism and the possible theft of a nuclear weapon, a new warhead can be expected to include improved disablement mechanisms to prevent unauthorised use, and possibly contain a lower quantity of highly enriched uranium which could be removed from a stolen weapon for illicit use. The justification for replacing the warhead will be presented to the public as being for safety and security reasons, rather than maintaining the reliability of the weapon.

# VERIFICATION AND ARMS CONTROL

As well as its role in manufacturing and developing nuclear weapons, AWE also plays a leading role in providing the government's national nuclear security capability, working alongside a number of other government agencies and university departments. The Establishment's Threat Reduction Division conducts research into arms control verification, including collaborative international work with Norway[81] and the United States[82]. AWE Blacknest undertakes seismic research and monitoring work, and manages the Eskdalemuir seismic monitoring array in Dumfries and Galloway which detects seismological signals. AWE's radionuclide and seismic analysis both make valuable contributions to the Comprehensive Nuclear-Test-Ban Treaty Organisation's (CTBTO) international work in detecting underground nuclear explosions[83]. AWE's Threat Reduction Division also works alongside the security agencies to counter radiological and nuclear terrorism and interpret nuclear intelligence, and provides an emergency response function for nuclear weapons accidents and terrorist threats (Figure 7). In May 2012 a new nuclear forensics laboratory was opened at AWE to allow the investigation of criminal acts involving nuclear materials[84].

*Figure 7: AWE personnel undertake radiation monitoring during a field exercise (AWE).*

81 *'UK / Norway Initiative on nuclear warhead dismantlement verification'. Ministry of Defence website, 31 March 2010. https://www.gov.uk/government/publications/uk-norway-initiative-on-nuclear-warhead-dismantlement-verification--2 Accessed 28 December 2015.*

82 *'Joint U.S.-U.K. Report on Technical Co-operation for Arms Control. National Nuclear Security Administration, Office of Nonproliferation and Arms Control, Ministry of Defence, and Atomic Weapons Establishment. 12 May 2015. http://nnsa.energy.gov/sites/default/files/Joint_USUK_Report_FINAL.PDF Accessed 28 December 2015.*

83 *'The GBL Laboratory' (p36) and 'Seismology' (p46). Discovery 26. Atomic Weapons Establishment, October 2015. http://www.awe.co.uk/app/uploads/2016/04/OFL-Discovery-26_V9-FINAL.pdf Accessed 11 May 2016.*

84 *'Nuclear Forensics'. Discovery 26. Atomic Weapons Establishment, October 2015, op cit.*

# AWE'S REGULATORY PERFORMANCE

AWE's safety and environmental performance has been somewhat chequered over recent years, and on several occasions the Establishment has been the subject of enforcement action by government regulators.

In August 2010 a fire in an explosives handling facility at AWE Aldermaston resulted in injury to a member of AWE staff, evacuation of homes adjacent to the site, and contamination of some parts of the site with asbestos. Following the incident AWE plc was prosecuted by the Health and Safety Executive and fined £200,000 at Reading Crown Court for breaching safety laws. The judge found that, had explosives in the building detonated when the emergency services were close by, "the building would have been destroyed and there might have been multiple casualties", and that AWE had failed to take precautions which "would have undoubtedly reduced the risk of ignition without significant difficulty or expense"[85]. Since the 2010 fire a number of low-level incidents have occurred at AWE as a result of alarms being activated by smoke from faulty drive systems for ventilation fans.

In August 2012 corrosion was discovered in steel columns supporting the structure of building A45, the main uranium processing building at AWE Aldermaston. Following structural surveys, the Office for Nuclear Regulation (ONR) concluded that routine operations in the facility, including production work, "could no longer be justified". Radioactive materials were removed from affected areas of the building and work was limited to operations deemed necessary in the interests of safety, including repair work. An ONR investigation found "clear evidence" that AWE was in breach of the conditions of its nuclear site operating licence by failing to adequately inspect and maintain a nuclear structure, and that as a result "people were exposed to risk"[86]. The regulator served a formal Improvement Notice on AWE requiring the company to complete a programme of remedial actions, including inspections of similarly designed buildings across the AWE estate, which were eventually completed to ONR's satisfaction in early 2015.

In February 2014 AWE failed to meet a legally binding deadline imposed by the Nuclear Installations Inspectorate (now the Office for Nuclear Regulation) requiring the company to reduce in volume and encapsulate 1,000 drums of radioactive waste which have accumulated at Aldermaston. An ONR investigation concluded that AWE had "contravened the Health and Safety at Work Act 1974 by failing to demonstrate that its long-term strategy for managing Higher Active radioactive Waste reduces the future risk to the public and employees so far as reasonably practicable throughout the anticipated storage life of the waste at Aldermaston"[87]. AWE has been served with an Improvement Notice by ONR which sets a deadline of 30 September 2016 for the company to recommend options on how it will manage the waste in future.

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85 *'Nuclear weapons factory operators fined £200,000 for safety breaches'. Nuclear Information Service, 28 May, 2013. http://nuclearinfo.org/article/awe-aldermaston/nuclear-weapons-factory-operators-fined-%C2%A3200000-safety-breaches Accessed 28 December 2015.*

86 *'Safety watchdog: Atomic Weapons Establishment 'exposed people to risk''. Nuclear Information Service. 8 February 2013. http://nuclearinfo.org/article/safety-awe-aldermaston/safety-watchdog-atomic-weapons-establishment-exposed-people-risk Accessed 28 December 2015.*

87 *'Improvement Notice served on AWE'. Office for Nuclear Regulation news release, 13 July 2015. http://news.onr.org.uk/2015/07/improvement-notice-served-on-awe-2/ Accessed 9 April 2016.*

In early 2014 AWE also informed the Office for Nuclear Regulation of two cases where fire detection systems in buildings holding radioactive materials were not functioning properly[88]. Following the discovery, AWE was required to undertake a site-wide investigation and remediation programme to ensure that all fire alarms were operating properly.

AWE has also been the subject of enforcement action following failures in its environmental performance. In August 2013 AWE plc was served with a formal warning letter and enforcement notice by the Environment Agency after increases in levels of tritium were found in the Aldermaston Stream[89]. A site inspection by the Environment Agency in July 2014 revealed that insufficient numbers of competent personnel were in post to allow AWE to comply with its environmental permits. The company was formally notified that it had breached a condition of its environmental permit, and that this was an offence under environmental law[90].

As a result of a failure to improve safety performance, AWE Aldermaston is currently receiving "an enhanced level of regulatory attention" from the Office for Nuclear Regulation. This is the third year running that Aldermaston has received enhanced attention from ONR – one of just eight UK nuclear licensed sites requiring 'special measures' of this nature[91]. ONR's Annual Report for 2014/15 indicated that safety performance at Aldermaston had not improved and cited ageing plant, delays in building new facilities, and delays in undertaking safety reviews as key concerns[92]. Although AWE Burghfield was assessed as requiring a 'routine' level of regulatory attention, performance at Burghfield was judged to have declined over the year. ONR expressed concern that "deteriorating programme performance has resulted in delays to new build assembly/disassembly facilities which has led to the need for extended use of current ageing facilities".

The quantities of radioactive materials held at the Aldermaston and Burghfield sites are sufficiently large for the sites to be covered by the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR). Under the terms of these regulations AWE is required to prepare a hazard identification and risk evaluation for each site, and West Berkshire Council is required to prepare an off-site emergency plan to direct the response to a radiation emergency[93]. Households in the vicinity of each site are provided with a public information brochure with guidance on self-protection in the event of a radiation emergency[94]. A multi-agency table-top exercise to rehearse the off-site emergency arrangements is conducted every three years, supplemented by more frequent, smaller scale on-site exercises.

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88 *'Investigation into faulty fire detection systems underway at Atomic Weapons Establishment'. Nuclear Information Service. 11 June 2014. http://nuclearinfo.org/article/awe-aldermaston/investigation-faulty-fire-detection-systems-underway-atomic-weapons Accessed 28 December 2014.*

89 *'Environment Agency warns Atomic Weapons Establishment following radioactive effluent investigation'. Nuclear Information Service. 12 October 2013. http://nuclearinfo.org/article/awe-aldermaston/environment-agency-warns-atomic-weapons-establishment-following-radioactive Accessed 28 December 2015.*

90 *'Environment Agency raps Atomic Weapons Establishment over radioactive waste management staff shortages'. Nuclear Information Service. 2 October 2014. http://nuclearinfo.org/article/awe-aldermaston-awe-burghfield/environment-agency-raps-atomic-weapons-establishment-over Accessed 28 December 2015.*

91 *'Nuclear weapons factory to stay under 'special measures' for third year running as watchdog reports decline in MoD nuclear safety performance'. Nuclear Information Service. 7 July 2015. http://nuclearinfo.org/article/safety-awe-aldermaston-safety/nuclear-weapons-factory-stay-under-special-measures-third-year Accessed 28 December 2015.*

92 *'Office for Nuclear Regulation Annual Report and Accounts 2014/5'. Office for Nuclear Regulation. HC164. 29 June 2015. Table 1 and p36-7. http://www.onr.org.uk/documents/2015/annual-report-2014-15.pdf Accessed 28 December 2015.*

93 *'Atomic Weapons Establishments Off-Site Emergency Response Plan'. West Berkshire Council. November 2011. www.westberks.gov.uk/CHttpHandler.ashx?id=29769&p=0 Accessed 5 January 2016. Following the August 2010 fire at AWE Aldermaston the plan was extended to cover a broad range of emergencies which might have off-site consequences, rather than focusing solely on radiation emergencies.*

94 *'REPPIR. What to do in the event of an emergency at AWE'. Atomic Weapons Establishment. May 2013. http://info.westberks.gov.uk/CHttpHandler.ashx?id=39234&p=0 Accessed 5 January 2016.*

# CONCLUSIONS

AWE has been undertaking research work over many years which has generated information contributing to both stewardship of the current UK Trident warhead stockpile and development of a successor warhead. A certain momentum has developed, with joint work undertaken over the past decade with US nuclear weapons laboratories on the Mk4A modification programme and other tentative warhead designs, and more recently commencement of the Teutates warhead science collaboration with France. Very large sums of money have been sunk into regenerating the infrastructure at AWE sites. This momentum, together with the unknowns relating to the life expectancy of the current warhead and the possibility of an unpredicted critical failure in the warhead design, can be expected to generate pressure in favour of a decision to 'replace' the warhead, most likely with a refurbished and upgraded variant of the current UK Trident warhead.

Broader factors will underpin this decision. The linkage between the US nuclear weapons laboratories and AWE is seen as a crucial element of the US-UK nuclear 'special relationship'. Development of a successor warhead would provide AWE with information to 'trade' in dialogue with the US laboratories, and at the same time enable AWE to protect and retain its own technical expertise in warhead science. Should the US government decide to develop a new warhead to replace its own W76 warhead – perhaps after some gentle coaxing from Whitehall – this would align with the UK government's unwavering philosophy of steadfast alignment with the US nuclear programme at both the technical and political levels.

Other factors act against replacing the current warhead. Costs remain a formidable barrier, and any further shocks to the UK economy could be expected to dent nuclear ambitions. In recent years there has been more discussion about a ban on nuclear weapons for humanitarian reasons. So far the supporters are located mainly in the southern hemisphere and in developing nations, but if the humanitarian initiative gains more ground internationally, it may also have an impact on the policies of the United Kingdom.

The current government is expected to make an 'in principle' decision on a new warhead in the second part of its term of office, while the next government (2020-25), if it decides to go ahead with a warhead replacement programme, will have to deal with the detail of the programme and provide the resources to implement it. On the other hand, the 2020-25 government will also have the opportunity to cancel or delay any programme approved by the previous government.

The government's current position on a new UK Trident warhead appears to be to keep options open as far as possible, whilst taking it for granted that national policy on nuclear weapons will remain unchanged over the long term and that a new warhead will eventually be required. This would equate to 'business as usual' at AWE. However, circumstances may conspire against this course of events, and the future for AWE in the event of a decision to cancel the Trident replacement programme is examined in Part 2 of this report.

# RECOMMENDATIONS FROM PART 1 OF THE REPORT

Major programmes of infrastructure development and warhead research and development are evidently well underway at AWE, and as a result large sums of public money are being spent at the Establishment. To date Parliament has shown little interest in scrutinising the work of AWE to establish whether it is delivering programmes effectively and providing value for money, despite evidence that all may not be well at the Establishment.

We recommend the following actions:

1. The House of Commons Defence Committee should undertake an inquiry into work at AWE, covering delivery of the Nuclear Warhead Capability Sustainment Programme, the Mk4A warhead modernisation programme and research underpinning development of a new UK Trident warhead, and performance of the AWE management and operation contract. This should be undertaken as part of a broader series of annual reviews of delivery of the Trident programme, as conducted by the Committee in the late 1980s and early 1990s during implementation of the first stage of the Trident programme.

2. The National Audit Office should be invited to review delivery of the Nuclear Warhead Capability Sustainment Programme and report on progress annually in its Defence Major Projects Report.

3. The Ministry of Defence should publish the costs, timetable, and justification for introduction into service of the Mk4A warhead modification.

4. At the appropriate decision point Parliament should debate whether to replace the UK Trident warhead, given the questions over its necessity, cost, proliferation implications, and impact on the UK's nuclear disarmament obligations.

# PART 2 : AWE: FUTURE POSSIBILITIES

Part 1 of this study outlines AWE's current role, which is largely centred on the research, surveillance, and production work necessary to keep the UK Trident warhead in service and if necessary develop a successor warhead. It is often assumed that AWE will continue to undertake such a role indefinitely, on the assumption that the UK government will continue to maintain its nuclear weapons programme for the foreseeable future. However, this will not necessarily be the case. Domestic politics, economic circumstances, and the international situation may combine to result in a change in this state of affairs. It is beyond the scope of this study to list all the circumstances which may curtail warhead-related work at AWE, but such circumstances might include:

- Significant progress in international multilateral disarmament negotiations, and / or negotiation of an international treaty banning nuclear weapons.
- Election of a future government which is committed to rapid nuclear disarmament regardless of progress in international negotiations.
- A vote in favour of Scottish independence raising insuperable difficulties for the remainder of the UK in continuing with a viable nuclear weapons programme.
- A series of economic shocks which meant that the UK could no longer afford to run a nuclear weapons programme.
- A major accident involving a UK nuclear weapon.

These scenarios may not represent the most probable course of events, but each of them is a plausible possibility over the next five to ten years. Looking to the future, the 2015 Strategic Defence and Security Review clearly states that the UK is "committed to the long-term goal of a world without nuclear weapons"[95] and this has been a long standing policy of successive governments, regardless of political persuasion. If this is the case, AWE's role in the manufacturing of nuclear weapons must eventually come to an end at some point in time.

A threat to the future of UK's nuclear weapons programme will naturally lead to worries about the impacts that this may have on employment and the economy in areas where there is a concentration of jobs which depend upon the programme, such as the West Berkshire / North Hampshire area where AWE is situated. Part 2 of this study identifies a number of potential scenarios for the future of AWE and sets out a blueprint to show how the local employment and economic benefits deriving from AWE could be preserved by transforming AWE into a series of enterprises specialising in technological innovation in the civil sector. Although this transformation would not be without risks in terms of the disruption and uncertainty involved, we consider there are marked opportunities for AWE to diversify and extend its work into civilian markets.

95 *'National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom'. Cm 9161 . Cabinet Office, November 2015. Para 4.79. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/478933/52309_Cm_9161_NSS_SD_Review_web_only.pdf Accessed 11 December 2015.*

Margaret Beckett, Secretary of State for Foreign and Commonwealth Affairs in the 2005-10 Labour government, proposed in 2007 to the international community that the United Kingdom should become a "disarmament laboratory" to help build impetus for global nuclear disarmament[96]. Transformation of the Atomic Weapons Establishment away from work on nuclear weapons and into a commercially focused centre for civil sector innovation and technology would be a major contribution to this goal. This section of the study aims to begin the process of undertaking such a transformation.

96 *Beckett, Margaret: 'A World Free of Nuclear Weapons?' Speech at the Carnegie International Nonproliferation Conference. Carnegie Endowment for International Peace, Washington DC, 25 June 2007.*

# AWE'S CONTRIBUTION TO THE LOCAL ECONOMY

As one of the largest industrial manufacturing and research sites in the United Kingdom, AWE makes a considerable contribution to the local economy and is a major local employer. AWE claims that the company contributes in excess of £475 million to the local economy every year as an employer and through its supply chain[97]. 4920 personnel currently work at AWE with 890 contractors also engaged on the Establishment's sites[98], following a build up in staff numbers over the past decade to meet the requirements of the NWCSP which saw an increase in headcount of over 700 staff over the period 2005-7 and a slower build up in staff numbers to a peak in contract year 2010-11. These jobs are, by and large, well paid: the average annual cost to AWE for a professional employee is around £120,000 per person[99] (although the actual average salary paid will be less than this). In addition to AWE personnel around 500 Ministry of Defence Police officers are employed on duties at AWE. A broad breakdown of the skills profile of AWE personnel and a rough estimate of the number of staff in each discipline is shown in Table 3.

In addition to AWE's human resources, the Establishment also has a number of scientific and research assets, some of which are unique within the UK. These include the Orion laser, AWE's supercomputing resources, and an Apprentice Academy for training apprentices in a range of engineering disciplines.

However, AWE's contribution to the local economy comes at a price. As a major employer located away from a major urban centre, AWE has a disproportionate economic impact in its immediate vicinity. Employment and income in the area are dependent upon AWE's operation. As West Berkshire Council's Economic Development Strategy states, "The biggest challenge we, or any other local authority, is ever likely to face is the potential of one of our large employers relocating all or part of its business out of the area, for whatever reason"[100].

Although defence industries are sometimes said to represent a major part of the UK manufacturing base, they actually account for a small proportion of national employment, and, as is the case with AWE, most jobs in the manufacture of arms are located in areas with relatively low unemployment[101]. Analysis by PricewaterhouseCoopers indicates that, over the period 1997-2015, UK employment showed annual average growth rates of 1.6% in the transport and communication sector; 2.8% in business services, and 2.0% in the education and health sector[102].

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97 *'Delivering Excellence, Shaping the Future.' Atomic Weapons Establishment, 2011. P20.*

98 *'AWE: Staff: Written question - 24292'. UK Parliament website. http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2016-01-26/24292/ Accessed 3 February 2016. Contractors working at AWE but employed by sub-contractor companies are not included in these figures.*

99 *'AWE Proposal for TP1 for the Implementation of the Nuclear Warhead Capability Sustainment Programme. Volume 1 Annex I. Manpower and Staffing Plan'. Atomic Weapons Establishment, April 2007. P9. Provided in response to Response to Request for Information 22-09-2011-133321-007, Ministry of Defence, 6 June 2013.*

100 *'West Berkshire – "Open for Business". A Local Economic Development Strategy for West Berkshire 2013 – 2018' West Berkshire Council. Paragraph 3.5.6, page 25. info.westberks.gov.uk/CHttpHandler.ashx?id=35208&p=0 Accessed 1 February 2016.*

101 *Schofield, Steven: 'Making Arms, Wasting Skills: Alternatives to Militarism and Arms Production'. Campaign Against Arms Trade, April 2008. https://www.caat.org.uk/resources/publications/economics/making-arms-2008.pdf Accessed 1 February 2016.*

102 *'UK Economic Outlook'. PricewaterhouseCoopers, March 2016. Chapter 4. http://www.pwc.co.uk/assets/pdf/ukeo/uk-economic-outlook-full-report-march-2016.pdf Accessed 11 May 2015.*

| Discipline | Estimated number of staff | Subtotal by sector |
|---|---|---|
| **Science:** | | 1060 |
| Chemistry | 240 | |
| Computer Science | 100 | |
| Material Science | 150 | |
| Nuclear | 100 | |
| Physics | 470 | |
| **Engineering and Manufacturing:** | | 2415 |
| Apprentice | 100 | |
| Building Services | 230 | |
| Chemical | 140 | |
| Civil | 100 | |
| Decommissioning / Waste Management | 100 | |
| Electrical / Electronic | 295 | |
| Frontline Workers | 320 | |
| Manufacturing | 220 | |
| Mechanical | 295 | |
| Metallurgy | 45 | |
| Project Management | 330 | |
| Systems Engineer | 240 | |
| **Business Services:** | | 795 |
| Administration | 210 | |
| Business Management | 320 | |
| Commercial | 70 | |
| Finance / Procurement | 95 | |
| General Support | 25 | |
| Human Resources | 75 | |
| **Technical Support:** | | 650 |
| Assurance | 430 | |
| Lab Support / Technicians | 70 | |
| IT / Telecoms | 150 | |
| **Total:** | 4920 | 4920 |

*Table 3. Skills profile by discipline of AWE personnel. Figures estimated by Nuclear Information Service on the basis of historical data.*

In contrast, employment fell by 0.4% per year in the public administration, defence, and security sector and by 2.6% in the manufacturing sector. The education, health, and business services sectors are predicted to continue to dominate the UK's employment growth over the next ten years, while the number of jobs in manufacturing, defence, and public administration are expected to fall further.

A paper prepared for the BASIC Trident Commission concluded that not only is alternative public spending to the Trident programme able to create and support jobs, skills and provide wider economic benefits, but that "often, there are alternative and more cost effective methods of creating UK jobs". The central issue is which option from a choice of alternative public spending projects will make the greatest contribution to national output and job creation[103]. There is compelling evidence to demonstrate that spending on personal consumption, health care, education, mass transit, and construction for home weather-proofing and infrastructure repair all create more jobs relative to the same expenditure on defence[104]. In some cases – for example, the social care and mass transit sectors – the jobs created are less well paid and less skilled than in the defence sector, but in others – notably the education sector – average pay exceeds that from military related activities.

At the end of the Second World War, with over 3.5 million British armed forces personnel to be demobilised and 3.25 million workers in arms manufacture needing to find alternative employment, many feared a return to the mass unemployment that blighted the 1930. These fears proved groundless, and after a short adjustment period a rapid recovery in output and employment took place as savings accumulated during the war were available to spend on civil goods, stimulating demand that more than compensated for the loss of military work and allowing a relatively smooth transition to full employment by 1947[105]. Disarmament can be viewed as an investment process with short-term costs offset by long-term benefits as resources released from the military-industrial sector are reallocated to the production of civil goods and services[106]. In this context, then, it makes sense to investigate how AWE's personnel and assets might have an even greater local economic impact than at present if they were devoted to new, non-defence related areas of activity.

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*103 Hartley, Keith: 'Defence-Industrial Issues: Employment, Skills, Technology, and Regional Issues. Discussion Paper 2 of the BASIC Trident Commission, March 2012. http://www.basicint.org/sites/default/files/trident_commission_defence-industrial_issues_keith_hartley_0.pdf Accessed 11 May 2016.*

*104 Pollin, Robert, and Heidi Garrett-Peltier: 'The US Employment Effects of Military and Domestic Spending Priorities'. Department of Economics and Political Economy Research Institute, University of Massachusetts, Amherst. October 2007. www.comw.org/pda/fulltext/Pollin-Garrett-Peltier.pdf Accessed 1 February 2016.*

*105 Schofield, Steven: 'Oceans of Work: Arms Conversion Revisited'. British American Security Information Council, J anuary 2007. http://www.basicint.org/sites/default/files/oceans_0.pdf Accessed 28 January 2016.*

*106 Hartley, Keith: 'Defence-Industrial Issues: Employment, Skills, Technology, and Regional Issues', 2012, op cit.*

# FUTURE OPTIONS FOR AWE

As AWE is a government-owned establishment conducting a government-contracted work programme, its future will depend upon government policies. Depending on how political, economic, and international factors play out, AWE's future could take one of a number of possible paths forward over the medium to long term future (see Figure 8).

**Path 1: Business as usual**

Under this scenario work continues on maintaining and keeping the UK Trident warhead in service, with the development and production of a new warhead if necessary. This represents the default scenario for AWE, with minimal change to its current role and operating arrangements. AWE's contribution to the local and regional economy might be expected to remain much as at present. It is likely that personnel numbers at the Establishment would show a gradual trend downwards over time as a result of pressure from MoD to reduce costs, the drive from the contracting consortium to sustain and increase profits, and opportunities generated by technological and management improvements. Looking towards the long term, however, this scenario is incompatible with the future goal of a world without nuclear weapons.

**Path 2: 'AWE lite'**

An alternative case could see a decision made to reduce, but not cease, work on nuclear weapons at AWE and diversify into other areas. This situation might arise, for example, from a decision not to develop a successor warhead to the current UK Trident warhead, to relax reliability standards for the warhead, or to move to a 'virtual' nuclear capability[107] under which the UK retains the ability to produce nuclear weapons but refrains from doing so. To a certain degree, AWE has already started moving down this path, having set a target in its 2010 Enterprise Strategy to derive 15% of its income from non-warhead related work by 2015[108]. Under such circumstances work is likely to shift into areas which are closely related to AWE's core mission, such as the civil nuclear sector and government-funded military and security programmes, rather than broader areas of innovation. This option would allow the continued production of highly enriched uranium submarine reactor fuel at Aldermaston, required for the Royal Navy's SSNs (submarines which are nuclear powered but not nuclear armed) as well as for SSBNs (submarines which are nuclear armed and nuclear powered).

**Path 3: A post-nuclear AWE**

A decision by the government to permanently renounce nuclear weapons would, in the longer term, necessitate more fundamental changes at AWE. If the economic and employment benefits from AWE are to be conserved then action would be necessary to safely close down the UK's military nuclear programmes - both the Trident weapons programme and probably, in due course, the naval nuclear propulsion programme - in a way which allows the international community to verify that the UK has indeed disarmed its nuclear weapons and placed its fissile materials beyond further military use, and at the same time build up sustainable new economic opportunities based around the assets and skills at AWE.

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107 *Paloczi-Horvath, George: 'Virtual Nuclear Capabilities and Deterrence in a World Without Nuclear Weapons'. Research Report No. 3. VERTIC, October 1988. http://www.vertic.org/media/Archived_Publications/Research_Reports/Research_Report_3_Paloczi-Horvath.pdf Accessed 6 January 2016.*

108 *'We Are AWE'. Atomic Weapons Establishment, May 2010. P19.*

The extent to which the new AWE would be able to diversify from its traditional nuclear and military-related work into civil sector work would depend on the level of assistance provided by government, the commercial appetite of AWE personnel, the degree to which it proved necessary to retrain personnel with highly specialised skills which have limited civilian applications, the external economic climate, and the timescale scheduled for the transition.

As this path represents a challenging scenario for AWE, with the prospect of disruption and uncertainty which might reasonably lead to local concerns about jobs and economic benefits, a detailed blueprint for how such a transition might be achieved is set out below.

**Path 4: Wind down**

As a result of a decision to renounce nuclear weapons, the government could decide to wind down activities at AWE, perhaps with a view to permanently closing the Establishment. Outright closure would represent a decision not only to abandon nuclear weapons, but also to abandon AWE as an establishment and abdicate any duty of care towards its workforce. However, this is unlikely to be an attractive option to the government given the unique and costly research assets on the site, the skills of the AWE workforce, and AWE's national importance as a reserve of scientific talent. More likely would be a gradual wind down of the site, with transfer of fissile materials to secure storage elsewhere and the possibility of eventually relocating certain scientific capabilities, such as arms control verification and nuclear forensic laboratories, to new locations. Regardless of any decision to close AWE, it would take many years to decommission radioactive handling facilities on the site and transfer fissile material away from the site for safe long-term storage, and employment on these activities would remain secure over the medium term.

**Business as usual:**

- Core business: Trident warhead programme.
- No change from current direction.
- Government and defence sector clients.
- Single operating entity.
- Government owned.
- Entirely government funded.
- Economic / employment impact unchanged.
- No material progress towards the goal of a world without nuclear weapons.

**'AWE lite':**

- Core business: Trident warhead programme, supplemented by other defence and nuclear sector work.
- Minimal change from current direction.
- Government and defence sector clients.
- Single operating entity.
- Government owned.
- Largely government funded: some commercial work.
- Economic / employment impact unchanged.
- No material progress towards the goal of a world without nuclear weapons.

**Post-nuclear AWE:**

- Core business: Legacy management, nuclear threat reduction, and technology sector work.
- Radical change from current direction.
- Diverse range of government and civil sector clients.
- Multiple operating entities as 'spin off' enterprises.
- Government owned entities and commercially owned entities.
- Government funded entities and entities with commercial income.
- Economic / employment impact may be positive (best case) or negative (worst case).
- Demonstrable progress towards a world without nuclear weapons.

**Wind down:**

- Core business: Legacy management.
- Radical change from current direction.
- Government client (site management only).
- Single operating entity.
- Government owned.
- Entirely government funded.
- Negative economic / employment impact.
- Demonstrable progress towards a world without nuclear weapons.

*Figure 8: Comparison of future options for AWE.*

**Overview and local economic context**

This section of the study outlines how, in the event of a government decision to cease work on the Trident nuclear warhead programme, the AWE site could make the transition from a nuclear weapons factory and remain a significant local employer. We argue that AWE's best bet for a future in which work has ceased on the Trident nuclear weapons programme is as an enterprise – or more likely, a number of separate enterprises – which are able to meet demand for technologically-based knowledge, services, and products, and thus able to prosper in the market conditions in which the UK and the south of England compete. A shortage of highly-skilled workers is often a significant bottleneck constraining economic development - more so than financial investment - and an injection of highly skilled workers with expertise appropriate for a growing technology sector will help stimulate the regional economy.

An obvious option for the future of AWE and its workers in the event of an end to the Trident programme would be a move into the defence and civil nuclear energy sectors. It could be argued that these areas are closely related to the work that AWE currently undertakes, and thus the transition into these markets would be relatively simpler than a more ambitious move into civil sector markets. However, there are a number of factors to consider in taking this approach:

- It would be possible (though progressively more difficult as time went on) for a future government to resume nuclear weapons production at AWE if expertise in military and nuclear applications is conserved. Assuming the UK wanted to maximise the impact of halting work on Trident on global disarmament initiatives, it would need to verifiably demonstrate to other governments that work on nuclear weapons had irreversibly ceased at AWE sites.

- Cancellation of Trident and change in direction for AWE would be likely to take place as part of a broader transformation of UK defence, foreign, and economic policy and a shift in political culture which would see a move away from investment in military production and conceivably also from a civil nuclear power programme.

- Markets in military production and the nuclear sector are more specialised and limited than broader civil sector markets which are not constrained by security concerns.

- As discussed previously (see 'AWE's contribution to the local economy'), spending on civil sectors of the economy can create more jobs than expenditure on defence. A shift towards civil sector production could help maximise the economic impact of work at the former AWE.

AWE has a formidable array of skills and resources and there is no reason why it should not use these to provide new services and products in the civilian sector, if necessary with support from new commercial sector partners. In the short term developing markets in the civil technology sector might be a more demanding approach than remaining in the military and nuclear energy sectors, but in the longer term it is likely to bring greater rewards.

The extent to which AWE is able to transform itself from a government-dependent nuclear weapons factory to a successful market-driven enterprise will depend upon the local economic context, including the structure of the regional economy and its strengths and weaknesses and plans for the future of the economy. Fortunately, what AWE has to offer to the local economy is very much in harmony with current local economic plans, which place an emphasis on innovation and on strengthening skills in science, technology, engineering, and mathematics (STEM) to develop a 'knowledge-based economy' in the Thames Valley. Also encouragingly, other defence and nuclear related research establishments have successfully undergone similar transitions in the recent past[109].

The main economic development plan for the region in which AWE is located is the Strategic Economic Plan (SEP) published by the Thames Valley Berkshire Local Enterprise Partnership[110]. The plan notes that, as one of the most economically active parts of the United Kingdom, the Thames Valley is currently close to full employment. There is a thriving market for employment in science and according to the plan over 90,000 of the jobs in Thames Valley Berkshire are in the technology sector[111]. However, businesses in the Thames Valley need more people with skills and qualifications in science, technology, engineering, and mathematics according to the SEP. The plan states that "among the businesses that contributed directly to the development of the Strategic Economic Plan, the availability of potential recruits with expertise in science, technology, engineering and mathematics featured among the most frequently aired concerns. The shortage of STEM-related skills is not unique to TVB [Thames Valley Berkshire]"[112]. A common theme running through the SEP's future skills gap analysis is a major shortage of workers skilled in STEM both now, and, based upon the available forecasts, in the future[113]. There is thus ample demand both locally and further afield for the type of skill which AWE's professional staff can offer, and a framework is in place through the SEP to support the development of AWE into new markets in STEM-related sectors and make provision for retraining staff, where necessary, to aid this process.

**Warhead decommissioning**

The first task for AWE following a decision to cease work on the Trident warhead programme would be to safely dismantle and decommission the existing warhead stockpile. It would take some time to complete this task. Warheads would need to be disembarked from the submarines on which they are deployed, placed in interim secure storage at the Royal Naval Arms Depot at Coulport or another secure location, and gradually transported back to AWE for dismantling and decommissioning. Warheads would be dismantled in either the 'Gravel Gerties' (Figure 9) or the new 'Mensa' warhead assembly / disassembly facility at AWE Burghfield, with non-fissile components then destroyed and fissile and hazardous materials transported to AWE Aldermaston for secure storage.

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*109* *See case studies from the USA in 'Trident & Jobs: The case for a Scottish Defence Diversification Agency'. Scottish Trades Union Congress and Scottish Campaign for Nuclear Disarmament. 22 April 2015. Section 4, p6. http://www.stuc.org.uk/files/Congress%202015/DefenceDiversificationReport2014%20v2.pdf Accessed 1 February 2016.*

*110* *'Strategic Economic Plan, 2015-16 – 2020-21'. Thames Valley Berkshire Local Economic Partnership. Five volumes available online at http://thamesvalleyberkshire.co.uk/strategic_economic_plan#ourplan Accessed 13 January 2015.*

*111* *'Strategic Economic Plan: Ministerial Summary'. Thames Valley Berkshire Local Economic Partnership. P1. http://thamesvalleyberkshire.co.uk/Portals/0/FileStore/StrategicEconomicPlan/TVB%20SEP%20-%20Ministerial%20Summary.pdf Accessed 13 January 2016.*

*112* *'Strategic Economic Plan: Evidence Base'. Thames Valley Berkshire Local Economic Partnership. P118. http://thamesvalleyberkshire.co.uk/Portals/0/FileStore/StrategicEconomicPlan/TVB%20SEP%20-%20Evidence%20Base.pdf Accessed 13 January 2016.*

*113* *'Strategic Economic Plan: Evidence Base'. Thames Valley Berkshire Local Economic Partnership. P126. http://thamesvalleyberkshire.co.uk/Portals/0/FileStore/StrategicEconomicPlan/TVB%20SEP%20-%20Evidence%20Base.pdf Accessed 13 January 2016.*

*Figure 9: Aerial view of the 'Gravel Gertie' warhead assembly / disassembly complex at AWE Burghfield (Google).*

According to the 2010 Strategic Defence and Security Review, the UK has "not more than 225" Trident warheads, and this number will be reduced to "not more than 180 by the mid 2020s"[114]. To reach this target, decommissioning has been taking place at a slow rate since 2010 and assuming progress has been made at a linear rate, the UK stockpile stands at around 210 warheads at the time of writing. Dismantling of the WE177 and Chevaline arsenals apparently took place at a rate of around 20 – 30 warheads per year, meaning that the Trident stockpile could be completely dismantled in between seven to eleven years, and possibly as rapidly as four years[115]. According to information provided in a written Parliamentary answer by the Ministry of Defence, the costs of dismantlement of the UK's warhead stockpile at AWE sites would be expected to cost £146 million at 2006-7 prices[116].

**AWE's radioactive legacy**

Following decommissioning of the existing warhead stockpile the programme to cease nuclear warhead production at the Atomic Weapons Establishment and diversify work into the commercial sector would, as an early step, require each of the two main AWE sites at Aldermaston and Burghfield to be divided into two parts: a secure government-controlled 'legacy site' with holdings of radioactive wastes and radioactively-contaminated buildings awaiting decommissioning, and a larger 'innovation campus' where commercial work is undertaken (see below).

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*114 'Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review'. Cm 7948. Cabinet Office, October 2010. Paragraph 3.11. https://www.gov.uk/government/publications/the-strategic-defence-and-security-review-securing-britain-in-an-age-of-uncertainty Accessed 9 December 2015.*

*115 'Disarming Trident'. Scottish CND, June 2012. Page 9. http://www.banthebomb.org/images/stories/pdfs/disarmingtrident.pdf Accessed 20 January 2016.*

*116 'Nuclear Liabilities'. Parliamentary Written Question. Official Report, 24 July 2006, Column 778W. http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo060724/text/60724w0015.htm Accessed 12 April 2016.*

Because of AWE's long history of work involving nuclear materials, nuclear processing buildings on the site are contaminated with radioactivity. Many of the buildings themselves are purpose-built for specific tasks relating to warhead manufacturing, and conversion to other uses would not be feasible. These buildings will require therefore decommissioning, decontamination, and demolition before the areas in which they are situated can be safely put to other uses. This is a long-term process: decommissioning and dismantling of the former A1 main processing facility is programmed to take 26 years.

Assuming that the main processing buildings at AWE Aldermaston (A45 and its successor, and A90) have a role to play in recasting shape-sensitive warhead components and blending down uranium components into lower activity forms, they will be required to remain in service until the end of the warhead decommissioning phase. Even if work to decommission these buildings is able to commence immediately after work on warhead decommissioning has ended, it is likely that the earliest date by which the task could have been completed and the buildings demolished would be some time in the 2050s[117]. The costs associated with decommissioning, care and maintenance of redundant facilities at AWE sites (including the conditioning, retrieval and storage of contaminated materials; research and development; and the procurement of capital facilities to handle the various waste streams) was estimated by MoD as £3,395 million at 2006-7 prices[118].

Fissile materials from dismantled warheads and other radioactive wastes will also require secure storage before being placed under a long term management regime. Current government policy for the long term management of intermediate level radioactive wastes requires storage of such wastes in a yet to be constructed national waste repository. The Ministry of Defence is currently planning on the assumption that the national waste repository will commence receipt of AWE's intermediate level waste materials in 2070, assuming no slippage in the programme to construct the repository[119].

It is apparent that, even if a decision to cease work on Trident warheads was made immediately, dismantling of the warheads, decommissioning of legacy nuclear processing buildings, and managing the resulting radioactive wastes would represent a large programme extending over many years. There are currently 209 contractors and 78 AWE personnel working on decommissioning projects, including demolition, at the Atomic Weapons Establishment, and it is likely that this number could be significantly increased if the decommissioning programme was expanded and accelerated[120]. AWE's expertise in nuclear decommissioning and the management of large scale decommissioning projects represents marketable knowledge which can be employed commercially elsewhere in the nuclear sector in the UK and globally. Decommissioning work will therefore help guarantee jobs at AWE over the medium term and in the longer term provides opportunities for developing successful spin-off enterprises.

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*117* *Assuming work starts on warhead decommissioning immediately, and takes ten years, and that processing buildings are decommissioned in parallel over a twenty five year period, as was the case with A1.*

*118* *'Nuclear Liabilities'. Parliamentary Written Question. Official Report, 24 July 2006, Column 778W. http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo060724/text/60724w0015.htm Accessed 12 April 2016.*

*119* *'AWE: Radioactive Waste'. Parliamentary Written Answer. Official Report (Hansard). 9 November 2011. Column 364W. http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm111109/text/111109w0002.htm#111109109001645 Accessed 20 January 2016.*

*120* *'AWE: Staff: Written question 24293'. UK Parliament website. http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2016-01-26/24293/ Accessed 3 February 2016.*

The great majority of the buildings and facilities at AWE Aldermaston requiring special efforts to decontaminate and decommission them are located in the high security nuclear processing and storage area (the 'Citadel'). Aldermaston's radioactive waste storage facilities are also located in the Citadel area. At Burghfield the nuclear handling facilities – the Gravel Gerties and Mensa facility - are located within the nuclear licensed site section of the base. These parts of the two sites would therefore require separation from the remainder of the sites and would remain under Ministry of Defence control as secure 'legacy sites' until the radioactive inventory has been removed from the site and the contaminated buildings demolished – a process which would take decades rather than years. Security, monitoring and maintenance, and emergency response functions would need to remain in operation for the legacy sites, guaranteeing employment in these roles for the foreseeable future.

Operation of the legacy part of the AWE site could continue under similar contract arrangements to the current AWE management and operation contract, with personnel engaged on legacy management and decommissioning work continuing in their current roles under their existing terms and conditions of employment.

Figure 10 presents a possible timeline for ending nuclear weapons-related work at AWE Aldermaston and converting the location to a brown-field site suitable for development for alternative uses. Following closure, it has been suggested that the Gravel Gerties at Burghfield should be preserved as a historic monument to the UK's Cold War heritage, and other buildings at the AWE Aldermaston site might also be preserved for a similar purpose.

**2020 - Government decision to renounce nuclear weapons.**

**2025 - AWE broken up into legacy / arms control / commercial entities.**

**2030 - All warheads decommissioned. Decommissioning of warhead assembly / disassembly facilities at Burghfield ('Gravel Gerties' and Mensa facility) commences and transfer of all fissile material from Burghfield to Aldermaston begins. Decommissioning of A90 (Aldermaston) begins.**

**2055 - Burghfield warhead assembly / disassembly facility decommissioning concludes. Burghfield site available for brown-field use. A90 decommissioning concludes.**

**2070 - Consignment of higher active wastes and fissile materials from Aldermaston to national waste repository commences.**

**2080 - Final stocks of fissile materials removed off site.**

**2100? - All wastes removed and Aldermaston NPSA finally decommissioned for brown-field use.**

*Figure 10. Transformation Timeline: How AWE could end work on nuclear weapons*

**The transition from warhead-related work to civilian work**

Once separated from the legacy areas, the remainder of the Aldermaston and Burghfield sites would then be in a position to evolve into innovation campuses – science campuses where AWE's world calibre research and development equipment and the technical skills of AWE's employees were put to use in a range of small and medium sized spin-off enterprises.

Such a model has been successfully adopted at other defence and nuclear laboratories, where government research establishments have been transformed into profitable private sector enterprises. At nearby Harwell, the former Atomic Energy Research Establishment has become the Harwell Science and Innovation Campus[121]. The management of Harwell's nuclear legacy is the responsibility of the Nuclear Decommissioning Authority and the section of the campus which remains a nuclear licensed site section is currently being decommissioned by Research Sites Restoration Ltd. The remainder of the campus has become home to around 200 science/research organisations and private companies, clustered into five core sector specialist disciplines.

The role of the Porton Down laboratory, responsible for the UK government's research on chemical and biological weapons, has evolved in a similar fashion over the years. The former Chemical and Biological Defence Establishment (CBDE) at Porton Down, at one time responsible for the UK's offensive chemical and biological weapons capabilities, changed to take on a role centred around verification and monitoring as the UK signed the Chemical Weapons convention in 1993. The laboratory eventually became the headquarters of the Defence Science and Technology Laboratory (Dstl)[122]. As well as housing Dstl, Porton Down is the site of a small science park and the site of Public Health England's research laboratory, which is currently relocating to a new location in Harlow, Essex.

The Atomic Weapons Establishment should be able to make a similar transition to Harwell and Porton Down following the closure of the Trident warhead programme (see Figure 11). Major scientific assets such as the Orion laser, ASP accelerator, and the Aldermaston supercomputer suite should be transferred to the management of the Science and Technology Facilities Council (STFC) for broader academic or commercial use[123]. The Orion laser could be assigned to research in the inertial confinement fusion field, perhaps to work as part of an international programme, with funding for its pure research work reassigned to the STFC from current defence budgets. AWE's Apprentice Academy, too, should be able to operate as a stand-alone enterprise training future staff for employment on the new Aldermaston science campus or elsewhere locally. The Academy could play a key role in helping to retrain AWE staff whose skills are so specialised that they are not easily transferable to the civilian sector.

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*121* *Harwell Campus website. http://harwellcampus.com/ Accessed 20 January 2016.*

*122* *Dstl was formed following the privatisation of the Defence Evaluation and Research Agency (DERA) in 2001, representing 25% of DERA which was retained by the Ministry of Defence to provide science and technology services in areas that are inappropriate for the private sector to deliver. Its headquarters are at Porton Down, where chemical and biological weapons expertise is located, with other sites at Alverstoke, Portsdown West, and Fort Halstead (soon to close).*

*123* *At the time of writing around 15% of the operating time of the Orion laser facility is already scheduled to be available to UK university researchers for high energy density collaborative investigations in areas of interest to AWE. See 'First academics granted access to Orion'. AWE website: http://www.awe.co.uk/what-we-do/science-engineering-technology/orion-laser-facility/academic-access/first-academics-granted-access-to-orion/ Accessed 2 February 2016.*

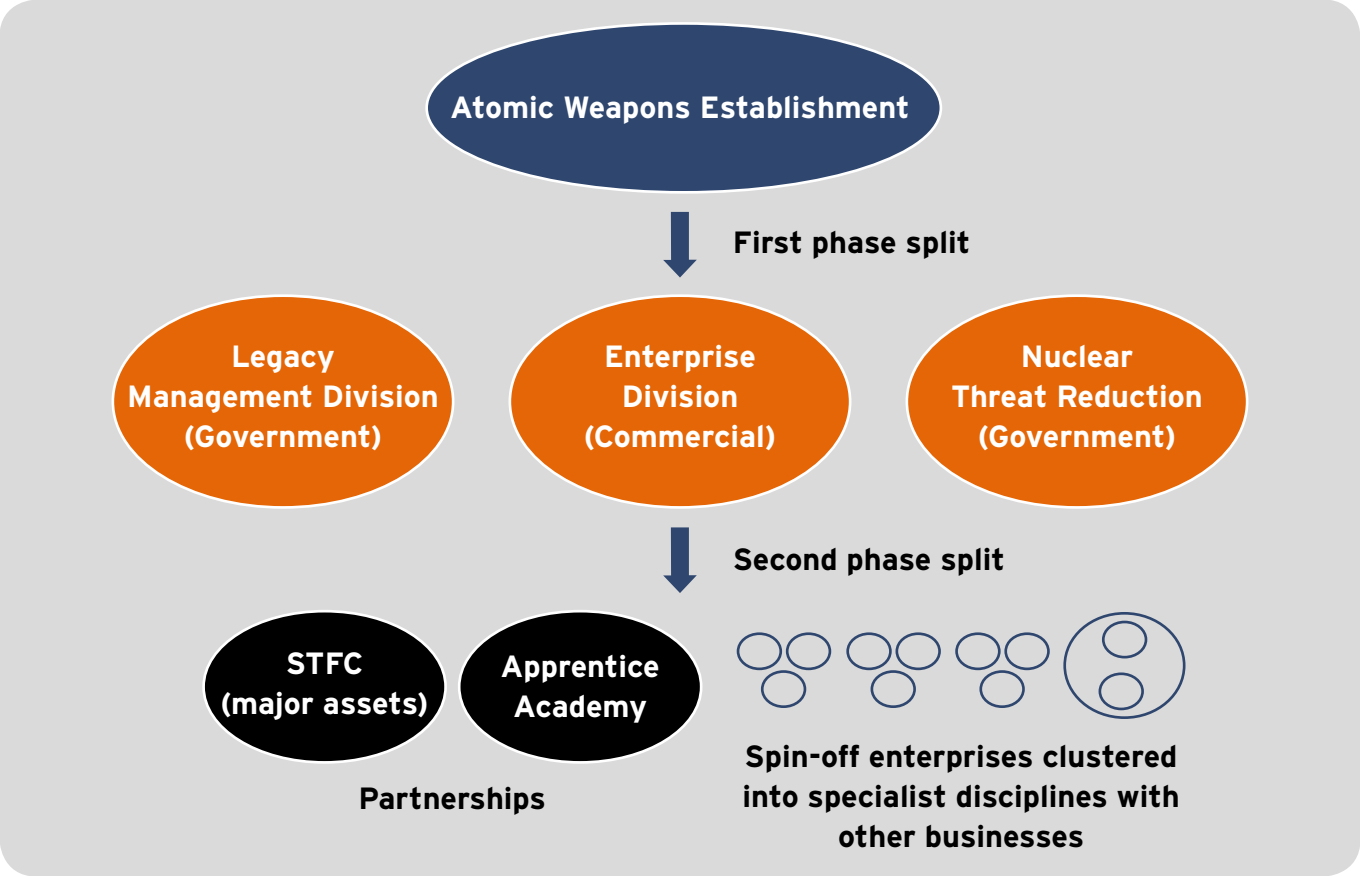


*Figure 11: Diagram showing how a post-Trident AWE could be broken up into different divisions.*

The remainder of the Establishment could then be set up as an 'enterprise division' – a commercially focused company aimed at putting AWE's expertise and the skills of its employees to work in civil sector markets. This could be along similar lines to AEA Technology plc – the privatised offshoot of the UK Atomic Energy Authority (UKAEA) which was set up in 1996 to exploit UKAEA's research expertise as an energy and environmental consultancy business. In due course a series of new spin-off enterprises can be divested from the enterprise division as separate business entities reflecting AWE's areas of expertise: for example, high energy physics, materials science, manufacturing and production, and national security, offering services such as research, consultancy, and product development. As an example, the new small scale components manufacturing facility and conventional manufacturing facility at AWE Burghfield are equipped with the latest precision manufacturing technology, which could be adapted to a number of commercial uses. Perhaps most productively, AWE's expertise in manufacturing could be utilised in the form of a 'Catapult' Centre at Burghfield, where scientists and engineers work with business clients on late stage research and development projects involving high value manufacturing[124].

The following factors will be important if such a transition is to succeed:

- Start-up finance and business development support from central government. This could be through regional development funding or dedicated support from a new national Defence Diversification Agency established to limit the economic impacts of a decision to close the Trident programme[125].

124 *'About Us'. Innovate UK Catapult Centres web page. https://www.catapult.org.uk/about-us-text Accessed 20 January 2016.*

125 *Corbyn, Jeremy: 'Defence diversification'. August 2015. https://d3n8a8pro7vhmx.cloudfront.net/jeremyforlabour/pages/111/attachments/original/1439209889/DefenceDiversification.pdf?1439209889 Accessed 20 January 2016.*

- Constructive engagement from AWE Management Ltd. The current contract between AWE ML and MoD is for the management and operation of the Atomic Weapons Establishment, not the commercial transformation of the Establishment. The contractor would have to implement the organisational changes needed to break AWE up into legacy management and enterprise divisions, transfer major assets to the STFC, and set up clusters and spin-offs from the enterprise division which are so structured as to enable them to succeed in the marketplace. It is likely that the terms of the current contract would have to be amended to allow the contractor to continue the job of managing and decommissioning AWE's legacies, and also undertake the new task of 'enabling' work needed to set up a new enterprise division.

- Participation of staff and trade unions in the planning and development of spin-offs. Staff working at AWE are best placed to assess how their skills can best be used commercially, and to decide how spin-off companies can be best structured and managed to enter the marketplace successfully. Such an approach, with input from trade unions and local authorities as well as staff and management, would help in identifying the most viable commercial opportunities for AWE spin-offs to take up.

The M4 corridor dominates Britain's technology economy with six of the top ten local authorities with the highest concentrations of technology sector jobs clustered around the motorway, including Wokingham Borough, within which AWE Burghfield is located[126]. AWE is located within reasonable distance of the Universities of Reading, Oxford, and Surrey, and nationally important scientific establishments in the south of Oxfordshire: the Culham Centre for Fusion Energy and the Harwell Science and Innovation Campus, which includes the Rutherford Appleton Laboratory. AWE also has close links with universitities which are further afield, such as Imperial College and Cranfield University, which have innovation and commercialisation enterprises. A post-Trident AWE would therefore be well placed to collaborate on scientific innovation projects with these institutions. Indeed, a flagship project in the Thames Valley Berkshire Strategic Economic Plan is the creation of a new Thames Valley Science Park in partnership with the University of Reading, which will provide specialist space for start-up and growing technology and knowledge-based companies. The plan notes AWE's interest in exploring potential commercial applications, and it is anticipated that dialogue with AWE will take place to explore the long term potential for a Science Park facility at Aldermaston or Burghfield[127].

AWE's current Technical Outreach programme for academic collaboration with universities and scientific institutes provides a sound foundation through which AWE spin-offs could collaborate with universities on technology development and other new innovative projects. The Technical Outreach programme also gives an indication of the specialist areas into which offshoots from a post-Trident AWE could move. Disciplines that AWE has funded at Strategic Alliance universities over the past two years are[128]:

- Physics, including numerical modelling, uncertainty analysis, computational fluid dynamics, shock physics and hydrodynamics, plasma physics and solid mechanics.

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126 *Vasagar, Jeevan: 'UK technology job creation outpaced other sectors for four years'. Financial Times, 20 October 2013. http://www.ft.com/cms/s/2/1e04f794-327b-11e3-91d2-00144feab7de.html Accessed 11 May 2016.*

127 *'Strategic Economic Plan: Implementation Plan'. Thames Valley Berkshire Local Economic Partnership. P25, p27. http://thamesvalleyberkshire.co.uk/Portals/0/FileStore/StrategicEconomicPlan/TVB%20SEP%20-%20Implementation%20Plan.pdf Accessed 13 January 2016.*

128 *'AWE: Research'. Parliamentary Written Answer from Peter Luff MP (substantive response from Gerald Howarth MP). Official Report (Hansard), 3 September 2012, c44W. http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm120903/text/120903w0002.htm#120903w0002.htm_wqn19 Accessed 2 February 2016.*

- Materials science, ranging from chemical synthesis of polymers and adhesives through to properties of energetics (explosives), metallurgy, computational chemistry and nuclear materials.
- High performance computing focusing on the development of computer algorithms and future energy efficient computing platforms.
- Engineering and manufacturing, which includes developing sensor technologies, electronic components and integrated circuits both for experimental and project use, and systems engineering and production. In particular, AWE has specialist expertise in miniaturisation and nanotechnology and 3D printing.
- Nuclear detection techniques and nuclear forensics.

Research and development work at AWE ranges from long-term fundamental research through to the development of technology, materials, and engineering processes, product design, the prototype development of novel systems, and the environmental testing of engineered products. Much of AWE's work is at the frontiers of science and technology and requires precision engineering of the highest order. AWE therefore has unrivalled specialist equipment and facilities for research and production including:

- Remote control and CNC machining facilities.
- Equipment for advanced metal working, specialising in work with hazardous and toxic materials.
- Production suites for microcircuits.
- High powered lasers.
- High voltage flash X-ray machines.

In the mid-1960s Harold Wilson's Labour government encouraged AWRE to diversify its work into other areas of science and technology. Over this period some 14 – 16 per cent of total expenditure at AWRE was attributable to civil work[129], and the Establishment was involved in the development of non-nuclear products such as carbon composites for aircraft brakes and rocket nozzles, chemical explosives, and ceramic products for military applications such as radomes for guided missiles. More recently AWE has signed agreements with industrial companies to market spin-off technology from its core business, including a moulding process for manufacturing components made from boron carbide (used in personnel and vehicle armour) and the use of calixarenes (cup shaped molecules) to capture uranium and recover heavy metals from liquids[130].

Not surprisingly, customers for AWE's commercial work have historically been from the defence, government, and civil nuclear sectors, and it can be expected that in the short term much of the work done by a post-Trident AWE would also be in these areas. However, in the longer term there is scope for diversification into a broader range of civilian markets, moving away from predominantly government-funded programmes into commercially viable projects.

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129 *'Atomic Weapons Research Establishment, Aldermaston'. House of Commons Debate, 18 March 1968. Official Report, Volume 761 Columns 8-10. http://hansard.millbanksystems.com/commons/1968/mar/18/atomic-weapons-research-establishment Accessed 2 February 2016.*

130 *'Commercial success for AWE'. AWE Today Issue No. 15. December 2002.*

# QUESTIONS AND RISKS

Although we believe the prospects for a post-Trident AWE are generally positive, we do not wish to downplay the risk of disruption and uncertainty associated with a move away from Trident related work, and so some significant questions remain. Firstly, how well would AWE, a generously and government-funded institution used to providing a monopoly service to a single customer, be able to adapt to the reality of work in a commercial environment? The structure, culture and management style of AWE is geared towards fulfilling MoD contract requirements – very different to competing in the civil sector markets. A new AWE enterprise division could perhaps be helped through this transition by bringing in new commercially experienced personnel from outside, and forming joint partnerships with established private sector players to help set up viable spin-off enterprises.

The private sector partners in the AWE ML consortium – Lockheed Martin, Serco, and Jacobs – are all very familiar and comfortable with the process of winning and delivering government contracts, and might conceivably impede progress in moving to an enterprise focused, post-Trident organisation.

Large multinational companies of this nature, with significant interests in the defence sector, are perhaps not best placed to lead a post-Trident AWE into the marketplace. A government intent on disarming Trident might need to hand over management of AWE to a new contractor, with drastically different terms of reference, in order to set the new organisation off on a sound trajectory for success in new civil sector markets with the longer term aim of breaking the organisation up into smaller, more manageable commercial units.

AWE's current work programme is centred heavily on nuclear and security related applications, raising further issues about the viability of post-Trident commercial work. Some of the advanced technologies and processes used at AWE will be security classified, and it is likely that this will place restrictions on their use for non-military purposes. It might also restrict the range of commercial partners with which AWE spin-off enterprises would be able to work: for example, proliferation concerns might prevent partnership with companies from nations such as China, India, or Israel, and foreign nationals from certain countries may face restrictions on employment with or access to these businesses. In addition, it may be difficult to find or create markets in the civil sector to replace work done by teams working on highly specialised tasks which are particular to the Trident programme, and it may be difficult to find other work which matches their particular skill set. One way forward might be for a post-Trident AWE to undertake a certain amount of nuclear or security focused work as a 'bridge' for an interim period while gradually reducing its reliance on such markets, and at the same time building up a civil sector portfolio.

Advocates of disarmament would argue that, in order to verifiably demonstrate that the UK has dismantled its nuclear weapons programme, a post-Trident AWE should be stripped of the capability to develop nuclear weapons. The more the Establishment is able to retain its focus on defence and nuclear sector work, and the closer its organisational structure remains to the current AWE structure, the easier it would be to re-establish a nuclear weapons programme at the Establishment. The more superficial the changes, the more easy it would be to reverse them. The blueprint we have outlined above envisages AWE being broken up into a series of spin-off enterprises with expertise in different areas, which would probably be difficult to

reassemble into a 'new' AWE with the ability to build nuclear weapons. However, it would take time to reach the stage at which new enterprises are ready to spin off as independent entities, and in the meantime a large part of AWE's expertise will remain together in a coherent whole in an 'enterprise division' – commercially focused, but a single entity. There is thus a trade-off between the speed at which a post-Trident AWE is able to move into new civil markets, the commercial viability of new businesses, and the reversibility of the change away from nuclear weapons production.

Finally, AWE is currently a significant source of local employment for project managers and contractors in the construction sector through the NWCSP new build programme. It is difficult to see how such jobs could be sustained at a post-Trident AWE – although some posts could conceivably be redeployed to decommissioning work. In general, however, employment on construction projects is by necessity temporary in nature, and construction skills are transferable to other building schemes.

# AWE AND DISARMAMENT VERIFICATION

AWE's work on disarmament verification supports international efforts towards nuclear disarmament, and would continue to be important following cancellation of the Trident programme. AWE's Threat Reduction Division consists of 140 staff working on arms control verification, nuclear emergency response arrangements, counter radiological and nuclear terrorism, nuclear forensics, and nuclear intelligence[131]. This includes radionuclide monitoring and seismological support to the CTBTO as part of the international monitoring system set up to detect nuclear weapon tests and verify compliance with the Treaty.

*Figure 12: Disarmament verification exercise underway as part of the UK-Norway Initiative (Norway Mission to the UN).*

There would be great value in preserving AWE's Threat Reduction Division, in a modified and possibly expanded form, as a centre of government expertise in nuclear non-proliferation and disarmament verification. AWE's National Nuclear Security programme should also be developed as part of this initiative so that the wider scientific community, including international partners, can engage with and add to this expertise in a non-classified environment[132]. This would allow knowledge derived from AWE's work on nuclear weapons design and production to be used constructively to work towards the goals of global nuclear disarmament and ensuring the security of nuclear materials worldwide – roles that the UK would be particularly suited to play having closed its own nuclear weapons programme. The revamped Threat Reduction Division would be able to retain some of AWE's technical links on nuclear research with the US and French governments, albeit from an arms control point of view rather than for current purposes. Such work would build on technical co-operation on arms control in support of the Nuclear Non-Proliferation Treaty which has already been taking place between the USA and the UK for more than fifteen years[133]. A joint working group on arms control, non-proliferation, and disarmament should be established with the US government under the auspices of the 1958 US-UK Mutual Defence Agreement, which allows the exchange of classified nuclear information, and joint research with other governments on verification and disarmament, such as the UK-Norway Initiative, should also continue (Figure 12).

131 *'Atomic Weapons Establishment'. Parliamentary Written Question. Official Report, 29 April 2009, Column 1285W. http://www.publications.parliament.uk/pa/cm200809/cmhansrd/cm090429/text/90429w0001.htm#09042951000680 Accessed 2 February 2016.*

132 *See Recommendation 5 in the Royal Society report 'Fuel cycle stewardship in a nuclear renaissance'. Royal Society, October 2011 Available at: http://royalsociety.org/policy/projects/nuclear-non-proliferation/report/ Accessed 2 February 2016.*

133 *'Joint U.S.-U.K. Report on Technical Co-operation for Arms Control'. Office of Non-Proliferation and Arms Control, National Nuclear Security Administration; Ministry of Defence; and Atomic Weapons Establishment. May 2015. https://nnsa.energy.gov/sites/default/files/Joint_USUK_Report_FINAL.PDF Accessed 13 May 2016.*

The British Pugwash Group has proposed the establishment of a British International Non-Proliferation, Arms Reduction and Disarmament Institute (BRINPARDI) as an independent UK-based centre of international excellence on nuclear non-proliferation and disarmament[134]. Once opened, the Institute should work closely with any new government body built around AWE's former Threat Reduction Division, and could even be based upon the new Aldermaston science campus.

There would be considerable international interest in cancellation of the Trident programme and a halt to warhead related work at AWE. Assuming that the government wished to gain the credit and kudos it deserved for taking such a step in support of global nuclear disarmament, it would need to verifiably demonstrate to other governments that work on nuclear weapons had irreversibly ceased at AWE. This would require some kind of international access and inspection regime at the former AWE sites. AWE has already conducted a certain amount of work on disarmament verification, notably the development of information barriers and managed access to sensitive sites, through its involvement in the UK – Norway initiative and similar programmes[135]. However, there would undoubtedly be challenges in arranging inspection visits to AWE sites without compromising proliferation-sensitive and other classified information. A government disarmament verification / Threat Reduction unit, based at Aldermaston and drawing on expertise from former AWE teams, would play a key role in resolving these challenges and helping the international community learn from practical experience how a nuclear production site can be dismantled and nuclear weapons 'disinvented'. The unit could also be responsible for the key task of dealing with security issues relating to former AWE personnel who have been privy to sensitive information, such as tracking their whereabouts and ensuring that they do not share their knowledge.

134 *Watson, Christopher, and John Finney: 'Attachment 2. British International Non-Proliferation, Arms Reduction and Disarmament Institute (BRINPARDI).' Written Evidence from British Pugwash Group to the House of Commons Foreign Affairs Committee on Global Security: UK – US Relations. 11 October 2008. http://www.publications.parliament.uk/pa/cm200910/cmselect/cmfaff/114/114we13.htm Accessed 2 February 2016.*

135 *Ministry of Defence, 'UK / Norway Initiative on nuclear warhead dismantlement verification', op cit.*

# POLICY FRAMEWORK

Efforts to transform AWE, maintain the benefits it brings to the local economy, and preserve the jobs of AWE staff will only succeed with the support of central government. The broader political tide must favour the transformation of AWE from a nuclear weapons factory to an innovation hub and support from government and industry must be forthcoming. This will be necessary not only to provide funding needed to manage the transformation of AWE, but also to help the new organisation develop new markets in the civil sector.

One area where change will be necessary is in defence policy. AWE's expertise is currently grounded in the defence technology sector. If AWE is to move beyond being viewed as a defence science establishment, acting as a source of expertise for the government in this field and majoring on the development of military hardware, then government policy will need to move from offensive intervention into overseas conflicts towards 'sustainable security'[136], and shift from promoting overseas arms sales to developing a robust civil manufacturing sector. Political relationships with the USA and France would also need to change, with emphasis shifting away from being seen principally as military allies. These would represent significant changes in policy, which would not be achieved overnight, but which might be expected to accompany the political circumstances leading to a decision to end the Trident programme.

Labour Party leader Jeremy Corbyn has committed to establish a new national Defence Diversification Agency to use money saved by not replacing Trident nuclear weapons to support communities whose livelihoods depend upon the defence sector and transfer their engineering and scientific skills into more socially productive industries[137]. A Defence Diversification Agency is unlikely to succeed if it is a centralised Whitehall bureaucracy taking a directive approach to economic and industrial planning. Decisions on the future direction of the individual factories, dockyards, and research establishments that depend on the Trident programme for their existence should be taken at the local level and driven primarily by the workforce and communities at each site, in partnership with local government and regional development agencies. The role of the Defence Diversification Agency should be as an enabler, setting out a high-level policy framework for diversification of the defence industrial sector into civil markets and providing funding to back schemes for transforming individual sites as part of devolved broader regional development programmes.

Policies at the local level should play a key role in setting the direction of diversification plans for workplaces such as AWE. As we have seen, proposals by the Thames Valley Berkshire Local Enterprise Partnership to develop science, technology, engineering, and mathematics sectors in the local economy broadly match the skills available at AWE, and diversification of AWE away from nuclear-weapons related work would complement the aims of the local Strategic Economic Plan. However, economic planning arrangements in England require strengthening to make them more effective and representative. Local Enterprise Partnerships are relatively unaccountable and opaque, and are dominated by the private sector and local authorities with very limited involvement for community representatives and none at all for trade unions.

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136 *Sustainable security relies on tackling the root causes of international conflict, rather than relying on military force to control threats. It is based around territorial defence, conflict resolution, diplomacy, and peace-building rather than offensive overseas military intervention. For more information see http://sustainablesecurity.org/what-is-sustainable-security/the-concept/ Accessed 3 February 2016.*

137 *Corbyn, Jeremy: 'Defence diversification', op cit.*

Local and regional level structures and policies for delivering economic development therefore need to be strengthened if proposals for diversifying the role of sites like the AWE are to succeed in taking off. Ultimately the market will determine the success or failure of such proposals, but a sound base in planning and support will help in maximising their chances. In comparison with the costs of the UK's defence budget, or even the fraction of the defence budget which is allocated to Trident nuclear weapons, the costs of local regeneration are relatively moderate. In the event of cancellation of the Trident programme, a portion of the money saved should be allocated to regional development budgets not only to help support employment diversification at Trident related sites, but to assist in broader economic advancement.

In the UK a number of schemes for the diversification of defence related industry have been proposed over recent decades (see Appendix). By and large these schemes have not been implemented – not because they are not viable, but because of a lack of action from government and the directors of the businesses concerned. This lack of action is the result of a political choice to prioritise investment in the defence sector rather than create new business and employment opportunities.

The experience is different in the United States, where successful programmes for avoiding unemployment at military bases closed at the end of the Cold War have been implemented. Under the Base Realignment and Closure programme vulnerable communities receive support with statutory backing. The Office of Economic Adjustment, an agency within the Department of Defense, is responsible for redressing the impact of base closures on manufacturing communities and creating alternative employment locally. Although there have been failures as well as successes, the Office of Economic Adjustment claims that in a majority of cases its intervention has ensured that "communities have been able to absorb the economic loss and show positive economic growth at or above national averages"[138]. Experience from USA shows that adequate advance planning, sufficient resources, and political direction at both the local and national level are necessary if transition schemes are to succeed, and all of these factors have been lacking for the diversification schemes proposed to date in the UK.

At the Atomic Weapons Establishment the prospects for diversification into new markets is good. The workforce is highly skilled; the Establishment is equipped to a very high standard, in some cases with unique national assets; the sites are located in a region with a thriving economy; and plans for future development in the area emphasise the importance of technology. Importantly, the AWE sites and their assets are owned by the government, meaning that the government has the power to decide on their future and the future of their workforce. Although the plants are managed by a private sector contractor, they are run to meet government requirements. A future government committed to cancelling the Trident programme could direct AWE's managers to establish a transformation programme for diversification into civil sector markets, and if necessary intervene to ensure it was implemented effectively.

138 *US Department of Defense Office of Economic Adjustment website. https://www.oea.gov/46-main-navigation/assistance-programs/base-realignment-closure Accessed 8 February 2016.*

# CONCLUSIONS

Peter Luff, former Minister for Defence Equipment, Support, and Technology has described the Atomic Weapons Establishment as 'a centre of scientific and technological excellence, with some of the most advanced research, design and production facilities in the world....a key capability, which is essential for our national security'[139]. AWE requires highly sophisticated scientific and technological capabilities to design and produce nuclear warheads, but these capabilities could also be put to work on innovative new civil sector work aimed at addressing society's pressing needs.

For this reason we believe that a decision by the UK government to renounce its nuclear weapons need not have major jobs implications in relation to AWE. On the contrary, by opening the gates to civilian sector markets AWE could use its potential to generate far greater economic benefits that the closed world of top secret military research can deliver. In the short to medium term, employment at AWE would be guaranteed by the need to dismantle the existing warhead stockpile and over a longer period decommissioning and demolition of radioactively contaminated manufacturing and production areas at Aldermaston and Burghfield – a task likely to extend into the middle of this century – would require a skilled workforce. Meanwhile, exciting opportunities in undertaking novel, cutting-edge work in the civilian sector would open for other AWE staff as the Establishment transforms into an innovation and technology hub. Just a small fraction of the cost of the Trident programme could fund transition programmes for AWE and other Trident related workplaces, and generate new employment opportunities as part of focused regional development programmes.

The main conclusion of this study is that, given adequate preparation and financial resources, detrimental consequences for workers at AWE and local communities could be largely avoided if the government closes the Trident programme. However, this is dependent upon a willingness to engage with the issues, and start work early to plan and prepare for a transition away from nuclear weapons-related work. To deliver the transition a partnership approach is needed involving the employer, AWE personnel and their trade unions, central government, and local authorities.

The reality is that, at present none of these parties are engaged. All are assuming that the Trident programme will continue indefinitely and that AWE will continue to have a role in the development and manufacturing of nuclear weapons. This report aims to start the process of engagement and begin the preparation for an alternative future.

139 *'MOD announces investment in nuclear facilities'. Ministry of Defence press announcement. 15 May 2012. https://www.gov.uk/government/news/mod-announces-investment-in-nuclear-facilities (Accessed 8 February 2016).*

# RECOMMENDATIONS FROM PART 2 OF THE REPORT

Making an early start is crucial. Although there is no immediate likelihood of the Trident nuclear weapons programme being canceled, beginning the process of preparation for this eventuality now will reduce risks and would also support initiatives in the regional Strategic Environmental Plan aimed at engaging AWE in the local civilian research economy.

We recommend the following actions:

1. AWE and the Thames Valley Berkshire LEP should lead a joint study, working with trade unions and local authorities in the vicinity of AWE, to identify scope for using AWE's resources for civilian purposes, and the opportunities for AWE presented by closure of the Trident programme. The study should identify the most viable areas for spin off initiatives; skill areas in which jobs are guaranteed in the long term, and areas where new work will be need to be generated to retain jobs both at AWE and in supply chains.

2. The government should undertake a national study to identify the number and locations of jobs which are dependent on the Trident programme, the broad skill portfolio available at each location, and outline possibilities for diversification into civil sector work at each location.

3. The government should make a clear statement accepting responsibility for the future of the workforce at AWE and other workplaces heavily dependent on the Trident nuclear weapons programme, and promising to maintain local economic and employment opportunities in the event that the Trident programme is cancelled. Local authorities and trade unions with an interest in AWE should endorse and support the statement.

4. The government should begin work to set up a new Defence Diversification Agency to address issues relating to economic and employment impacts of contraction within the defence sector. If the government will not do this, opposition parties should work with trade unions and local authorities to set up a shadow Defence Diversification Agency which can commence work ready to transform into a formal Agency upon a change of government.

# AFTERWORD

## JONATHON PORRITT

As we've seen from this illuminating account, the Atomic Weapons Establishment has been at the heart of the UK nuclear weapons programme for decades. And therefore, by default, at the heart of the UK's entire defence establishment. As regards its future, it's no exaggeration to say that this will now be shaped by decisions taken in the UK Parliament and elsewhere over the course of the next five years.

That Parliament has only a partial influence on decisions taken vis-à-vis the AWE's strategy and priorities. One of the most disturbing aspects of this Report is the degree to which the AWE (and the whole nuclear weapons programme in the UK) is exempted from even rudimentary scrutiny by Parliament. AWE's current programme, for instance, is focused on a limited decommissioning programme (to help meet a commitment under the Strategic Defence and Security Review to reduce the size of the UK's warhead stockpile), but also on a much bigger modification programme to upgrade the UK's Trident warheads. As yet, Parliament has not yet even been notified of this part of AWE's work.

Extraordinarily, a significant element in this programme is to ensure that the UK will still be able to 'sit at the top table' (through its notionally 'independent' nuclear weapons capability) well into the second half of the century. Say what you like about chronic short-termism at the heart of the UK's political systems: when it comes to matters nuclear (both military and civilian), the establishment displays a commitment to long-term planning and investment that is the envy of every other Government Department.

And all this prioritised investment continues in the tragically anachronistic belief that the best way of protecting our national security is by hanging on – at literally any cost – to the once reassuring notion of an independent nuclear deterrent. For many in our political and defence establishment, this has now become 'an article of faith', placing it entirely outside of any rational, science-based analysis of what we really need to be doing to protect our security as a nation.

But that may, at long last, be changing. Whatever people may feel about the election of Jeremy Corbyn as Leader of the Labour Party, this has galvanised (and legitimised) the debate about our nuclear deterrent in a way that seemed all but impossible before then, with the UK's three major parties all seemingly 'as one' on the question of Trident renewal.

As a direct consequence of that debate – and the now serious possibility that the Trident programme may be further postponed, modified or even cancelled – the future of the AWE itself is now a matter of live debate. With the jobs of nearly 5,000 highly-qualified people at stake,

I was delighted when I heard that the Nuclear Information Service (of which I'm proud to be a Patron) had decided to examine in detail the prospects for AWE in the event of the Trident programme being cancelled.

The Report's authors have argued convincingly that the closure of AWE (even in what would be seen by many as terminally threatening conditions for the continued existence of the organisation) is highly unlikely:

"Even if such a decision is made by a future Government, the dismantling of the existing warhead stockpile is expected to take at least four years, guaranteeing work over the short to medium term. Decommissioning of radioactively contaminated facilities is likely to last into the 2040s/50s, with a need to hold radioactive waste securely at the site until at least 2070. Work at AWE on disarmament verification and nuclear forensics might be expected to continue regardless of the future of the Trident programme."

The comparison between what happened at the former nuclear research site at Harwell, and at the chemical and biological facilities at Porton Down, is particularly instructive. Both sites have been successfully converted to commercially viable enterprises, undertaking a diverse range of work with a small core remaining in the Government sector.

AWE's position would be even stronger in that regard. With a nuclear weapons legacy stretching back over 65 years, there are now literally innumerable swords (many defunct, but many still in active service) that have still to be beaten into ploughshares.

For that reason, I wholly commend the way in which NIS pays tribute to the extraordinary skills and expertise of AWE's core staff and supporting consultants. This is an international asset that the UK would be well-advised to value and nurture, even if (or, as I would argue, once) we, as a nation, have decided once and for all to put our national security first by getting rid of our Trident submarines and their warheads.

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: DEFENCE DIVERSIFICATION AND TRIDENT

In January 1976 workers at Lucas Aerospace published an Alternative Plan for the future of their corporation in the face of large scale job losses. This plan was to become famous as a pioneering project showing how workplaces involved in manufacturing and production for the defence sector could transform their structure and ethos and diversify into the civil industrial sector. The Lucas plan was based on the knowledge, skills, and experience of the workers themselves and included market analysis, proposals for the training needed to move into new markets, and plans to bring people with complementary skills together into multi-functional work teams[140]. Although the Lucas management declined to act on the plan's proposals, it inspired trade unions and academics to further investigate how the defence sector could be diversified and transformed.

A number of subsequent studies have investigated the potential for generating employment alternatives at defence-related sites in the event of an end to the Trident programme. In 1987 the 'Oceans of Work' study investigated the possibilities for undertaking non-military work at the Barrow shipyard where the Royal Navy's nuclear powered submarines are manufactured[141]. The proposal, put forward with support from some of the trade union representatives from the shipyard identified how the shipbuilding and engineering skills of the workforce could be used on civil research, development, and production projects and particularly an offshore renewable energy programme, including wave and wind power systems. Twenty years later 'Oceans of Work Revisited', a follow-up study, charted how the decision by shipyard managers to consolidate specialism in nuclear submarine production, rather than diversify into alternative markets, had led to a 75% drop in employment at the yard (from 12,000 in 1987 to 3,000 in 2006)[142]. 'Oceans of Work Revisited' concluded that Barrow could still successfully move away from military-related work, although this would depend upon the UK moving towards a 'non-offensive' defence strategy and a co-ordinated government programme for developing and investing in alternative energy.

A study by the Nuclear Education Trust published in 2012 also investigated the economic and industrial implications for Barrow resulting from options other than a like-for-like replacement of Trident[143]. The study concluded that a review of the Trident programme might lead to a step-down in employment at Barrow but need not lead to closure of the shipyard, and that work on the Astute submarine programme would provide employment until 2023. Regeneration and diversification of employment at Barrow is possible, but this may come at a cost of £100 million or more.

In Scotland HM Naval Base Clyde, where Trident submarines are berthed and warheads stored, is another important location where jobs are dependent on the Trident programme.

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*140 Smith, Adrian: 'The Lucas Plan: what can it tell us about democratising technology today?' The Guardian, 22 January 2014. http://www.theguardian.com/science/political-science/2014/jan/22/remembering-the-lucas-plan-what-can-it-tell-us-about-democratising-technology-today Accessed 20 January 2016.*

*141 Barrow Alternative Employment Committee: 'Oceans of Work - The Case for Non-Military Research, Development and Production at the VSEL Shipyard, Barrow'. BAEC, 1987.*

*142 Schofield, Steven: 'Oceans of Work: Arms Conversion Revisited', 2007, op cit.*

*143 'Trident Alternatives Review and the future of Barrow'. Nuclear Education Trust, December 2012. http://www.nuclearedu cationtrust.org/trident-alternatives-review-and-future-barrow Accessed 28 January 2016.*

A 2007 study by the Scottish TUC and Scottish CND into the economic and employment consequences for Scotland of a decision not to renew Trident found that this would result in no more than 1,800 jobs being lost, and that this reduction would not take place until after 2022[144]. The study also found that Scotland would be significantly worse off if Trident is continued than otherwise because of opportunities lost elsewhere as a result of spending on Trident. It concluded that the non-replacement of Trident represents a major opportunity for productive investment in the Scottish economy, specifically to develop technologies for energy efficiency, energy conservation and renewables, which would require similar manufacturing and research skills to those currently used for Trident maintenance. The report argued for the creation of a Scottish Arms Conversion Agency to sustain employment of former Faslane employees by allocating funds to diversify the economy and investing in the productive economy, focusing on energy, to create new engineering jobs. A follow-up report in 2015 revisited the study in the light of the Government's austerity programme, which has squeezed defence budgets and spending elsewhere in the public sector, and presented a number of case studies from the United States which showed that with early planning, adequate resources, workforce involvement and the political will, local communities can prosper after the closure of large military installations[145].

The possibility for converting employment in the military equipment sector to work on renewable energy and energy efficiency is frequently raised and is an area with considerable potential. The skills used in both sectors are reasonably similar: for example, a US study[146] has examined the crossover potential between a naval shipyard, manufacture of the F-22 fighter and C130J transport aircraft, and expeditionary fighting vehicles with work on a range of 'green' technologies. The report concluded that nearly every position had an equivalent position that an arms industry worker could be retrained to fill.

Studies such as those cited above have shown that, even at relatively isolated locations which are heavily dependent on Trident, opportunities exist for sustaining the local economy and preserving jobs if the UK's nuclear weapons programme is closed. Unlike sites such as Barrow and Faslane, AWE is located in an area where there is a thriving, diverse, and integrated regional economy where employment opportunities are high, especially for skilled industrial and technical workers, and so the impacts of an end to the Trident programme may be expected to be lower than in more remote areas.

144 *'Cancelling Trident: The Economic and Employment Consequences for Scotland'. Scottish Campaign for Nuclear Disarmament and Scottish Trades Union Congress. 11 March 2007. http://www.stuc.org.uk/files/STUC%20-%20CND%20Trident%20Report%202007/STUC-CND%20Trident%20Report.pdf Accessed 1 February 2016.*

145 *'Trident & Jobs: The case for a Scottish Defence Diversification Agency'. Scottish Trades Union Congress and Scottish Campaign for Nuclear Disarmament. 22 April 2015. http://www.stuc.org.uk/files/Congress%202015/DefenceDiversificationReport2014%20v2.pdf Accessed 1 February 2016.*

146 *Pemberton, Miriam: 'Military vs. Climate Security: Mapping the Shift from the Bush Years to the Obama Era'. Institute for Policy Studies, August 2009. http://www.ushrnetwork.org/sites/ushrnetwork.org/files/military_vs_climate_security.pdf Accessed 17 April 2016.*

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Comments on this study are invited and should be Peter Burt, Research Manager at Nuclear Information Service by email to peter@nuclearinfo.org

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