NUCLEAR WARHEAD ACTIVITIES AT AWE ALDERMASTON

Dr. Nick Ritchie, July 2009

This report examines current and potential future nuclear warhead activities at the Atomic Weapons Establishment (AWE) Aldermaston and AWE Burghfield. Given the very close collaboration between the British and American nuclear weapon programmes the report examines aspects of US nuclear weapon developments that have a direct bearing on current and potential future activities at AWE.

1. TRIDENT

1.1 The UK Trident system

Britain's single remaining nuclear weapon system comprises three core components: four Vanguard-class nuclear powered ballistic missile submarines (SSBNs); 50 US-designed and built Trident II (D5) submarine-launched ballistic missiles (SLBMs) drawn from a common pool of Trident missiles based in the US; and 160 operational nuclear warheads. Collectively, and sometimes misleadingly, the composite system is usually referred to as Trident.

The first Vanguard-class SSBN, HMS Vanguard, was commissioned into the Royal Navy in 1993 and entered operational duty in 1994. HMS Victorious entered operational duty in 1996, HMS Vigilant in 1998 and HMS Vengeance in 2001. At least one of these submarines is at sea at all times at several days' notice-to-fire in an operational posture labelled 'continuous-at-sea deterrence' (CASD).

Each submarine can carry up to 16 Trident missiles and each missile is capable of delivering up to 12 independently-targetable warheads providing a maximum potential capacity of 192 warheads per submarine. The government states that each submarine will carry no more than 48 warheads, giving an average loading of perhaps 12-14 missiles carrying 3-4 warheads each. The warheads are thought to have an explosive yield of 100 kilotons (kt). A 'sub-strategic' version with a yield of around 10kt is also available.[5] In comparison, the bomb that destroyed Hiroshima in August 1945 had an explosive yield of approximately 14kt.

The Trident system also includes a substantial UK-wide infrastructure covering submarine operation and maintenance facilities, nuclear reactor development, warhead production, and nuclear targeting and system management.

1.1.1 Submarine operation and maintenance

The Vanguard SSBN fleet is stationed at the Faslane submarine base at Her Majesty's Naval Base (HMNB) Clyde. HMNB Clyde is also home to the Royal Naval Armaments Depot (RNAD) Coulport where warheads and missiles are stored for loading and unloading on to the submarines. The Vanguard submarines also undergo a major Long Overhaul Period (Refuelling) (LOP(R) mid-way through their planned service life at HMNB Devonport in Plymouth.

1.1.2 Nuclear reactor development

The nuclear power plants and fuel for the UK's nuclear-powered submarines, including the Vanguard fleet, are designed and manufactured at Rolls Royce's Raynesway plant in Derbyshire. They are trialled at the submarine nuclear reactor testing site at HMS Vulcan in Dounreay.

1.1.3 Warhead production

The UK's nuclear warheads are design and built at the Atomic Weapons Establishment (AWE) sites at Aldermaston and Burghfield. Both sites are near Reading in Berkshire. AWE Aldermaston constitutes the UK's centre for nuclear weapons research, design and component fabrication. AWE Burghfield is a smaller site for nuclear weapon assembly and disassembly. Trident warheads are assembled at AWE Burghfield and transported by road to RNAD Coulport. They are loaded on to Trident missiles aboard the Vanguard submarines at Coulport's Explosive Handling Jetty. Warheads may be returned to AWE Burghfield and AWE Aldermaston for disassembly, testing of component parts, reassembly and redeployment, or for decommissioning. References to 'AWE' include AWE Aldermaston and AWE Burghfield.[1]

1.1.4 Nuclear targeting and system management

Targeting operations for the Trident system take place at MoD's Nuclear Operations and Targeting Centre in London. The overall Trident system and the cooperative nuclear weapons relationship with the United States is managed by MoD's Chief Strategic Systems Executive office in Bristol and Corsham. UK SSBN operations and patrols are controlled and coordinated with US SSBN patrols through MoD's Northwood Headquarters in Middlesex.[2]

1.2 The US Trident system

The United States also operates Trident II (D5) system aboard a fleet of 14 Ohio-class SSBNs that can each carry up to 24 missiles. The first Ohio-class SSBN entered service in 1981 and the last in 1997. The first Ohio SSBNs carried the older Trident I (C4) SLBM. The C4 missile entered service in 1979 and was retired in October 2005.[3] The Trident II (D5) missile entered service in 1990 and is still on low rate production in the United States with a total order of 540 to be purchased by 2013.[4]

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1 There is also a much smaller AWE site near Aldermaston called AWE Blacknest where seismic monitoring and research takes place to detect nuclear tests by other countries. A fourth site, AWE Cardiff, to manufacture non-nuclear components for warheads was decommissioned in the 1990s.

2 John Ainslie, "The Future of the British Bomb" (Scottish CND: Glasgow, October 2005), p. 59.

3 Robert Norris and Hans Kristensen, "U.S. Nuclear Forces, 2006", *Bulletin of the Atomic Scientists*, January/February 2006, p. 69.

4 Robert Norris and Hans Kristensen, "U.S. Nuclear Forces, 2005", *Bulletin of the Atomic Scientists*, January/February 2005, p. 74.

US Trident missiles can be equipped with up to 12 100kt W76 warheads or 455kt W88 warheads. The US is thought to deploy approximately 800 W76 and 400 W88 warheads with approximately 2,400 W76 warheads in its reserve stockpile.[5] The W76 warhead entered service in November 1978. Production ended in 1987.[6] W88 production began in 1988 but was prematurely terminated in 1989 after the closure of the Rocky Flats plutonium pit production facility on safety grounds.

2. US ASSISTANCE WITH THE UK NUCLEAR WEAPONS PROGRAMME

Britain remains highly dependent on the US for nuclear weapon systems and support. Nuclear weapons cooperation is a deep and abiding component of the wider 'special relationship' between the two countries.[7] Linton Brooks, former head of the National Nuclear Security Administration responsible for the US nuclear weapons production complex, stated in 2008 that "during the past 50 years extensive cooperation with the UK has become an accepted practice within the U.S. nuclear weapons community. The details and intensity of that cooperation varied, but it is inconceivable to most nuclear professionals that cooperation could end altogether".[8]

Nuclear dependence upon the United States was cemented in the 1958 Mutual Defence Agreement (MDA) and the 1963 Polaris Sales Agreement (PSA). The 1958 MDA, formally known as the Agreement for Co-operation on the use of Atomic Energy for Mutual Defence Purposes, has a number of appendices, amendments and Memoranda of Understanding, many of which are still classified.[9] It is known, however, that the agreement provides for extensive cooperation on nuclear warhead and reactor technologies, in particular the exchange of classified information concerning nuclear weapons to improve "design, development and fabrication capability".[10] The agreement also provides for the transfer of nuclear warhead-related materials. The agreement was renewed in 2004 for a further 10 years.[11]

Every 18 months a review, or 'stock take', of US-UK nuclear cooperation is conducted involving senior officials from the US and UK. More frequent interaction between the US and UK nuclear weapons laboratories and defence bureaucracies

5 Robert Norris and Hans Kristensen, "U.S. Nuclear Forces, 2009", *Bulletin of the Atomic Scientists*, March/April 2009, p. 62.

6 Ainslie, "The Future of the British Bomb", p. 93.

7 John Dumbrell, *A Special Relationship: Anglo-American Relations in he Cold War and After*, (Macmillan: Basingstoke, 2001); John Simpson, *The Independent Nuclear State: The United States, Britain, and the Military Atom* (MacMillan: London, 1983).

8 Linton Brooks, "The Future of the 1958 Mutual Defense Agreement", in Mackby, J and Cornish, P. *U.S.-UK Nuclear Cooperation after 50 Years* (CSIS Press: Washington, D.C., 2008), p. 154.

9 Mark Bromley and Nicola Butler, "Secrecy and Dependence: The UK Trident System in the 21st Century" (BASIC: London, November 2001). Available at <http://www.basicint.org/pubs/Research/2001UKtrident1.htm>.

10 Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America for Co-operation on the Uses of Atomic Energy for Mutual Defence Purposes', signed in Washington, July 3, 1958.

11 See Nigel Chamberlain, Nicola Butler and Dave Andrews "US-UK Nuclear Weapons Collaboration under the Mutual Defence Agreement: Shining a Torch on the Darker Recesses of the 'Special Relationship'", BASIC Special Report 2004.3 (BASIC: London, June 2004).

takes place via a range of Joint Working Groups (JOWOGs). These deal with specific areas of physics, engineering or material science. The government reported in February 2009 that there had been a total of 1,868 meetings in the US and UK under the auspices of the MDA since 2001 involving 17 JOWOGs on:

- Radiation Simulation and Kinetic Effects
- Energetic Materials
- Nuclear Materials
- Warhead Electrical Components and Technologies
- Non-Nuclear Materials
- Nuclear Counter-Terrorism Technology
- Facilities
- Nuclear Weapons Engineering
- Nuclear Warhead Physics
- Computational Technology
- Aircraft, Missile and Space System Hardening
- Laboratory Plasma Physics
- Manufacturing Practices
- Nuclear Warhead Accident Response
- Nuclear Weapon Code Development
- Nuclear Weapon Environment and Damage Effects
- Methodologies for Nuclear Weapon Safety Assurance[12]

The 1963 Polaris Sales Agreement allows the UK to acquire, support and operate the US Trident missile system. Originally signed to allow the UK to acquire the Polaris SLBM system in the 1960s, it was amended in 1980 to facilitate purchase of the Trident I (C4) missile and again in 1982 to authorise purchase of the more advanced Trident II (D5) in place of the C4. In return the UK agreed to formally assign its nuclear forces to the defence of NATO except in an extreme national emergency under the terms of the 1962 Nassau Agreement reached between President John F. Kennedy and Prime Minister Harold Macmillan to facilitate negotiation of the PSA.[13] Under the Polaris Sales Agreement, as amended for Trident, the UK is involved in a number of other working groups, including a Joint Steering Task Group, supported by the Trident Joint Re-Entry Systems Working Group and the Joint Systems Performance and Assessment Group.[14]

3. UK DEPENDENCE ON US SUPPORT

The UK is entirely dependent upon the United States for supply and refurbishment of its Trident missiles. The missile themselves are produced and serviced in the United States by Lockheed Martin. The UK does not actually own any individual missiles, but purchased the rights to 58 missiles from a common a pool held at the US Strategic Weapons facility at the Kings Bay Submarine Base, Georgia. British Trident

12 *Official Report*, House of Commons, February 27, 2009, column 1150.

13 For details see Peter Hennessy, *Cabinets and the Bomb* (Oxford University Press: Oxford, 2007).

14 *Official Report*, House of Commons, January 12 1998, column 140.

submarines also conduct their missile test firings at the US Eastern Test Range, off the coast of Florida.

The UK is also dependent upon the United States for the software used for targeting and firing its Trident missiles. Ainslie reports that "targeting data on British Trident submarines is processed in the Fire Control System by software produced in America. This data is created in the Nuclear Operations and Targeting Centre in London. The centre relies on US software".[15] Ainslie also reports that both UK and US Trident submarines use the Mk 98 Fire Control System produced by General Dynamics Defense System (GDDS) to carry out the calculations to prepare and launch the Trident missiles.[16]

UK nuclear targeting is also integrated into US nuclear targeting plans through the UK Liaison Cell at US Strategic Command (STRATCOM) in Omaha, Nebraska.[17] STRATCOM develops and coordinates US nuclear targeting plans. This used to involve periodic revision of a Single Integrated Operational Plan (SIOP) covering all US nuclear forces. It now involves an 'adaptive planning' system comprising a family of nuclear war plans for different scenarios together with the ability to rapidly create new nuclear targeting plans for unexpected contingencies.[18]

The UK Trident force is formally declared to NATO. Ainslie argues that it is likely that detailed target planning for NATO use of strategic nuclear forces, including the UK Trident system, is also conducted at STRATCOM.[19] The purpose of the UK presence at STRATCOM is therefore to coordinate and 'deconflict' NATO and US nuclear targeting plans as they affect UK nuclear forces and avoid possible duplication and fratricide in nuclear war plans.[20] It is unclear whether NATO or the UK still maintain standing nuclear war plans.[21]

3.1 Support for the UK Trident warhead

3.1.1 How a nuclear warhead works

It is helpful at this stage to briefly describe the key components of a Trident nuclear warhead. The Trident warhead is two-stage thermonuclear weapon. When the weapon is fired conventional high explosives surrounding the 'primary' first stage uniformly compress a hollow sphere of plutonium. This increases its density to form a supercritical mass that undergoes an uncontrolled nuclear chain reaction. A source of neutrons is used to start the chain reaction at the right moment resulting in a nuclear fission explosion. A single stage nuclear fission weapon can produce an explosive

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15 Ainslie, "The Future of the British Bomb", p. 12.

16 *Ibid.*, p. 67.

17 *Ibid.*, and Interview with Frank Miller by Jessica Yeats, CSIS, January 28, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

18 Nick Ritchie, *US Nuclear Weapons Policy after the Cold War* (Routledge: Abingdon, 2009), pp. 25, 65.

19 Ainslie, "The Future of the British Bomb", p.66.

20 *Ibid.*, p. 52.

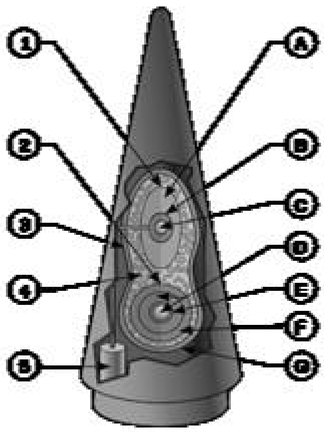
21 On NATO see *Ibid.*, p. 52. On the UK see Michael Quinlan, "The British Experience", in Henry Sokolski (ed), *Getting MAD: mutual assured destruction, its origins and practice*, Strategic Studies Institute (Army War College, Carlisle, PA), November 2004, p. 265.

yield of tens of kilotons. The fission explosion is boosted by the injection of tritium gas.

In a thermonuclear weapon the x-ray energy released by the detonation of the primary is transmitted through the interstage material to initiate detonation of the 'secondary'. The explosion of the secondary involves the fusion under extremely high pressure and temperature of tritium and a lithium-deuterium compound encased in a uranium shell. The uranium shell further fuels the fusion and fission reactions. The explosion occurs in a fraction of second and can produce an explosive yield of hundreds to thousands of kilotons. The effects of a such an enormous explosion are outlined in the Appendix.

The primary and secondary are often referred to as the warhead 'physics package' or 'nuclear explosive package'. The physics package, plus all the other components of the warhead, are assembled within an aeroshell, or re-entry body, designed to house the warhead and provide thermal protection from the harsh atmospheric re-entry environment. The re-entry body for the W76 warhead is known as the Mk 4.

Table 1: Diagram of a W88 US Trident warhead



1. The 'primary'
   - A. High explosive
   - B. Plutonium-239 pit
   - C. Tritium and Deuterium booster gas
2. The 'secondary'
   - D. Lithium-6 Deuteride
   - E. Uranium-235 'sparkplug'
   - F. Uranium-235 (heat shield, tamper and fission fuel)
   - G. Uranium-238 case
3. Radiation case
4. Interstage channel filler
5. Tritium gas canister

3.1.2 The UK Trident warhead

The warheads for the UK Trident system were designed and built at AWE Aldermaston and Burghfield. AWE began exploring a warhead for the Trident missile in the mid-1970s with the main development period running from 1980 to 1987.[22] Production of plutonium pits for Trident warheads began in January 1988 with the first warhead delivered in 1992.[23] Warhead production continues at a trickle rate.[24] Detailed monitoring of the transportation of UK nuclear warheads by the Nuclear

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[22] House of Commons Defence Committee, "Progress of the Trident Programme", HC 374 (HMSO: London, June 1989), p. 1.

[23] *Ibid.*, p. xxvi; House of Commons Defence Committee, "Progress of the Trident Programme", HC 337 (HMSO: London, March 1992), p. 29.

[24] "Progress of the Trident Programme", HC 337, March 1992, p. 29 and "A New Beginning: Annual Report 2000", AWE Aldermaston, p. 11.

Information Service suggests that one Trident warhead was assembled at Burghfield in 2008.[25]

The warheads undergo regular maintenance at AWE Aldermaston and RNAD Coulport when components with a shorter lifespan are replaced.[26] Each year a handful of warheads are returned to AWE for surveillance tests to ensure the continued safety, security and reliability of the warhead stockpile. According to AWE, this involves "dismantling the warhead, inspecting the condition of the components and, in some cases, replacing certain parts before re-assembly and recertification."[27]

Aldermaston may have designed and built the UK Trident warhead but it appears to have received substantial assistance from the US through provision of key warhead component parts and design assistance. In fact, the UK warhead is believed to be closely based on US W76 Trident warhead. The House of Commons Defence Committee noted in 1988 that "most of the expenditure on development and production of the [UK Trident] warheads is incurred in the United States. This includes the costs of attributable nuclear tests, and the purchase of elements of the re-entry body and certain warhead related components within it" but that "the nuclear components of the warheads are being developed and constructed in the UK".[28]

The British American Security Information Council (BASIC) also reported in 2001 that "documents released under the US Freedom of Information Act indicate that in the early 1980s, when the UK was designing its Trident warhead, the Joint Atomic Information Exchange Group established communication channels to allow the US to pass to the UK 'atomic information on the MK-4 Re-entry Body and W76 Warhead for the Trident Missile Systems'."[29]

The US is thought to have supplied the Mk4 re-entry bodies for the UK warheads, as well as the Arming Fusing and Firing system, neutron generator, and probably the tritium gas transfer system.[30] US assistance was probably required to ensure that the UK warhead would match the size, weight, centre of gravity and other characteristic requirements for the US-supplied Mk4 re-entry body. In addition, the British Trident warhead was tested three times at the US Nevada Test Site during its development.[31]

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25 "UK Nuclear Warhead Production Down to one a Year", Nuclear Information Service-Update, April 15, 2009. Available at <http://nuclearinfo.org/view/publications_%2526_media/NIS_updates/a2004 >.

26 Claire Taylor and Tim Youngs, "The Future of the British Nuclear Deterrent", Research Paper 06/53 (House of Commons Library: London, November 2006), p. 16.

27 "A New Beginning: Annual Report 2000", AWE Aldermaston, p. 14.

28 House of Commons Defence Committee, "Progress of the Trident Programme", HC 422 (HMSO: London, May 1988), p. xix.

29 Mark Bromley and Nicola Butler, "Secrecy and Dependence: The UK Trident System in the 21st Century", BASIC: London, November 2001. Available at <http://www.basicint.org/pubs/Research/2001UKtrident1.htm>. Citing "Annual Historical Summary (U)", Joint Atomic Information Exchange Group, HQ, Defense Nuclear Agency, 1 October 1982 – 30 September 1983. Document released under the Freedom of Information Act.

30 John Ainslie, "What Next for Aldermaston?" (Scottish CND: Glasgow, 2006).

31 House of Commons Defence Committee, "Progress of the Trident Programme", HC 549 (HMSO: London, June 1993), p. 9; Interview with John Harvey, Director of Policy and Planning, US National Nuclear Security Administration, by Jessica Yeats, CSIS, January 23, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

Nevertheless, MoD officials have insisted that "the warhead for the Trident fleet in the UK is a UK designed weapon, it is not necessarily a direct copy or based solely on the W76"[32] and that the UK retains the design authority on its Trident warhead.[33]

4. THE US NUCLEAR STOCKPILE STEWARDSHIP PROGRAMME

The United States produced its last W76 Trident warhead in 1987 and its last W88 Trident warhead in 1988. In 1992 President George H. W. Bush imposed a temporary ban on nuclear testing. President Bill Clinton extended the US testing moratorium and pursued negotiation of a global Comprehensive Test Ban Treaty to ban all explosive nuclear tests. The treaty was opened for signature in 1996. The United States signed the treaty but the Clinton administration failed to secure sufficient votes when it submitted the treaty to the Senate for ratification in 1999. The UK ratified the CTBT in 1998.

In order to maintain the long-term safety, security and reliability of the US nuclear arsenal in an era of zero testing the Clinton administration established a science-based Stockpile Stewardship Program (SSP).[34] A detailed plan for SSP was set out in the US Department of Energy's 1995 report "The Stockpile Stewardship and Management Program: Maintaining Confidence in the Safety and Reliability of the Enduring U.S. Nuclear Weapon Stockpile".

The programme was designed to sustain a consolidated Cold War legacy nuclear arsenal well into the future. It would use data from past nuclear tests, small-scale laboratory experiments, large scale experimental facilities, and detailed examination of warheads and their constituent parts to development of a comprehensive understanding of the functioning of all aspects of nuclear weapons under extreme conditions and the behaviour of the materials involved as they aged. This knowledge would be used to develop and improve powerful computer codes that simulate aspects of weapons performance and enhance understanding and prediction of defects in warheads.[35]

The primary objective of the SSP was to maintain the capability to identify problems in nuclear warheads, repair any problems and certify the repairs, or replace complete warheads or their component parts that could not be repaired, all without explosive nuclear testing.[36] It would also allow the nuclear weapons complex to maintain a

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32 "Progress of the Trident Programme", HC 337, March 1992, p. 13.

33 House of Commons Defence Committee, "The Future of the UK's Strategic Nuclear Deterrent: the Strategic Context", HC 986 (HMSO: London, June 2006), p. 21.

34 William J. Clinton, "The President's Radio Address", July 3, 1993, *Weekly Compilation of Presidential Documents, vol. 29, no. 27, pp. 1229-1296* (Government Printing Office, Washington, D.C.).

35 Jonathan Medalia, "The Reliable Replacement Warhead Program: Background and Current Developments", *CRS Report for* Congress (Congressional Research Service, Washington, D.C., 2007), p. 7.

36 Siegfried Hecker, "Testimony by Dr. Siegfried S. Hecker, Director, Los Alamos National Laboratory", Hearing before the Senate Committee on Armed Services, March 19, 1997 (Government Printing Office, Washington, D.C.), pp. 206-207; Tom Collina & Ray Kidder, "Shopping Spree Softens Test-Ban Sorrows", *Bulletin of the Atomic Scientists,* vol. 50 no. 4 (July/August 1994).

cutting edge technological capability and, crucially, to train and retain a highly capable nuclear weapons workforce.[37]

The programme was to be implemented through the construction of a host of sophisticated and expensive facilities including:

- The high-energy laser National Ignition Facility designed to create very brief, contained thermonuclear reactions.
- The Dual Axis Radiographic Hydrotest Facility (DARHT) to allow nuclear scientists to 'see' inside the explosion of the first stage of a thermonuclear weapon and a more sophisticated Advanced Hydrotest Facility.
- The Jupiter Facility for testing weapon effects.
- The Atlas pulsed-power facility for simulating weapon environments.
- A Contained Firing Facility.
- An Accelerated Strategic Computing Initiative to build the most powerful computers in the world at the national laboratories to simulate nuclear explosions.[38]

Progress would be monitored through a new annual certification process for validating the safety and security of the nuclear arsenal and a dual revalidation process that required a detailed technical analysis of each type of warhead in the US arsenal over a two to three year period.[39]

4.1 The Life Extension Programme for the W76 warhead

A central part of the SSP was the modification and refurbishment of several types of nuclear warhead through extensive modernisation and life extension programmes (LEPs), including the W76 Trident warhead.[40] Concerns about the ageing of warhead components, the non-availability of replacement components used in original designs, and a desire to modernise nuclear safety features were judged to require a

37 Charles Curtis, "Prepared Statement by Charles B. Curtis, Under Secretary of Energy", Hearing before the Senate Committee on Armed Services 'Department of Defense Authorization for Appropriations for Fiscal Year 1995 and the Future Years Defense Program', May 3, 1994 (Government Printing Office, Washington, D.C.), p. 265; Victor Reis, "Testimony by Dr. Victor Reis, Assistant Secretary for Defense Programs, Department of Energy", Hearing before the Senate Committee on Armed Services, May 16, 1995, (Government Printing Office, Washington, D.C.), p. 213.

38 "The Stockpile Stewardship and Management Program: Maintaining Confidence in the Safety, Reliability of the Enduring U.S. Nuclear Weapon Stockpile" (U.S. Department of Energy: Washington, D.C., 2005); Collina and Kidder, "Shopping Spree Softens Test-Ban Sorrows".

39 For full details of these processes see William Cohen, "Joint Prepared Statement By William S. Cohen and Gen. Henry H. Shelton", Hearing before the Senate Committee on Armed Services, October 6, 1999 (Government Printing Office, Washington, D.C.), p. 18; Harold Smith, "Testimony by Dr. Harold P. Smith", Hearing before the Senate Committee on Armed Services, March 13, 1996 (Government Printing Office, Washington, D.C.), p. 196; and Victor Reis, "Testimony of Dr. Victor Reis, Assistant Secretary of Energy for Defense Programs", October 29, 1997 (Government Printing Office, Washington, D.C.), p. 36.

40 "Stockpile Stewardship Program: 30-Day Review" (U.S. Department of Energy: Washington, D.C., 1999), pp. 2-1.

refurbishment of the W76 warhead and its Mk4 re-entry body in order to extend the life of the warhead by some 30 years.[41]

LEP studies from October 1998 to December 1999 identified design options, production and certification plans, and cost estimates.[42] Approval for a 'Block 1'life-extension of approximately 800 warheads was granted in March 2000 with a first production unit initially scheduled for 2008 and full completion by 2012. The Block 1 LEP process involved:

- Refurbishment of the high explosive, detonators, organic materials and cables.
- A new tritium Gas Transfer System.
- Replacement of the MC2912 Arming, Fusing, and Firing System (AF&F) with the MC 4700 designed by Sandia National Laboratory.
- Modernisation of nuclear detonation safety features.
- A replacement of the neutron generator designed by the Sandia National Laboratory.[43]

A review of US nuclear weapons policy by the Bush administration in 2001 resulted in plans to fully refurbish up to 2,000 of the roughly 3,200 W76 warheads in the stockpile in a 'Block 2' phase of refurbishment from 2012 to 2022.[44]

The refurbished warhead is known as W76-1 and the refurbished re-entry body as the Mk 4A.[45] The first test flight of the W76-1/Mk 4A on a Trident missile took place in December 2002 with a series of further tests resulting in a first production unit in 2007.[46] Delivery of the first production unit has, however, been delayed by problems in re-manufacturing a material known as Fogbank used in the interstage that channels energy from the warhead primary to the secondary. That problem now appears to have been overcome.[47]

The W76 LEP has involved significant changes to the both the W76 warhead and the Mk4 re-entry body although it has remained as close to the original design as possible for the nuclear explosive package.[48] Barry Hannah, Chairman of the W76 LEP Project

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41 Jonathan Medalia, "Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program", *CRS Report for Congress* (Congressional Research Service, Washington, D.C., December 2007), p. 25.

42 See "W76-0/Mk 4 / W76-1/Mk 4a" available at <http://www.globalsecurity.org/wmd/systems/w76.htm>.

43 See "W76-0/Mk 4 / W76-1/Mk 4a" available at <http://www.globalsecurity.org/wmd/systems/w76.htm>.

44 Everett Beckner, "Testimony of Dr. Everett Beckner, Deputy Administrator for Defense Programs, National Nuclear Security Administration", Hearing before the Senate Committee on Armed Services, April 10, 2002 (Government Printing Office, Washington, D.C.).

45 Hans Kristensen, "Administration Increases Submarine Nuclear Warhead Production Plan", FAS Blog, Federation of American Scientists, August 30, 2007. Available at <http://www.fas.org/blog/ssp/2007/08/us_tripples_submarine_warhead.php >.

46 *Ibid*.

47 "Nuclear Weapons: NNSA and DOD Need to More Effectively Manage the Stockpile Life Extension Program", GAO-09-385 (Government Accounting Office, Washington, D.C., March 2009).

48 Jonathan Medalia "Comprehensive Nuclear-Test-Ban Treaty: Updated "Safeguards" and Net Assessments" *CRS Report for Congress* (Congressional Research Service, Washington, D.C., 2009), p. 12, citing Information provided by Dr. Barry Hannah, SES, Branch Head, Reentry Systems, Strategic Systems Program, U.S. Navy, personal interview with the author, February 17, 2009. Dr. Hannah retired at the end of February 2009.

Officers Group (POG) stated that "I am confident that the W76-1 will extend the life of the W76... The W76-0 has aged well, and we have learned some lessons from its ageing process that we have applied to the W76-1."[49]

4.2 The Reliable Replacement Warhead programme

In the mid-1990s the US began to explore potential new warhead designs to replace the W76 under a joint SLBM Warhead Protection Program (SWPP) coordinated among the US Navy Strategic Systems Program Office, the Department of Energy, and the nuclear weapons laboratories.[50] Two candidate replacement nuclear designs were identified that involved "a design which re-uses plutonium pits ('Pit Re-Use Project'), for which Lawrence Livermore National Laboratory has nuclear explosive package (NEP) design responsibility, and a LANL 'high-margin' NEP design incorporating a new pit ('Replacement Warhead Project')."[51] The replacement warhead design would "reflect no new weapon requirements but the desirable replacement characteristics include decreased sensitivity to ageing, increased design margins, increased ability for surveillance by above-ground testing, and the ability to be certified without an underground test".[52]

Development of these designs ran parallel to the W76 warhead life extension programme.[53] But by the early 2000s the US nuclear weapons laboratories and others began to argue that it may not be possible to maintain current warheads beyond the planned 20-30 year LEPs currently underway.[54] Minor but inevitable variations between original and replacement warhead components might accumulate with successive refurbishments and "may pose an unacceptable risk to maintaining high confidence" in the safety and effectiveness of LEP warheads.[55] Furthermore, as time passes it would become much more difficult to maintain warheads that were built with technology, materials, skills and processes that were already anachronistic and less readily available.[56] One life extension process to extend warhead life by 20-30 year

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49 *Ibid.*

50 US Department of Energy's 1996 'Green Book' on "Stockpile Stewardship and Management Plan", p. V-9. Reprinted in "End Run: Simulating Nuclear Explosions under the Comprehensive Test Ban Treaty" (National Resources Defense Council: Washington, D.C., 1997. Available at <http://www.nrdc.org/nuclear/endrun/erintro.asp>.

51 "End Run: Simulating Nuclear Explosions under the Comprehensive Test Ban Treaty" (National Resources Defense Council: Washington, D.C., 1997. Available at <http://www.nrdc.org/nuclear/endrun/erintro.asp>.

52 "Nuclear Weapon Systems Sustainment Programs," Office of the Secretary of Defense (US Department of Defense: Washington, D.C., May 1997), p. 18.

53 Bruce Tarter, Director, Lawrence Livermore National Laboratory, "The National Nuclear Security Administration's Budget Request for FY2002", Hearing of the Committee on Armed Services, April 25, 2001 (Government Printing Office: Washington, D.C.), p. 7.

54 See, for example, "Interim report of the Feasibility and Implementation of the Reliable Replacement Warhead Program", U.S. Department of Defense and U.S. Department of Energy, Washington, D.C., 2006, p. 3.

55 D'Agostino, *testimony of Thomas P. D'Agostino,* 28 March 2007; Jonathan Medalia, "Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program" (Congressional Research Service: Washington, D.C, July 2007), p. 1.

56 Medalia, "The Reliable Replacement Warhead Program", p. 9.

was permissible, but a second or third life extension process beyond that was deemed too risky.

Congress responded to these concerns by funding research into a 'reliable replacement warhead' (RRW) programme in 2004 to "improve the reliability, longevity and certifiability of existing weapons and their components".[57] Two years later, Congress passed legislation that required the Bush administration to produce a detailed plan to significantly reduce the size of the nuclear weapons production complex whilst ensuring the long term safety, security and reliability of a smaller future nuclear stockpile.[58]

The response was set out in a 2006 report describing steps that would be taken to further consolidate the nuclear weapons production complex by 2030.[59] The plan was tied to the full development of a new Reliable Replacement Warhead (RRW) to replace existing LEP warheads by 2030. The George W. Bush administration argued that further consolidation of the production complex could only be accomplished if Cold War-era warheads were phased out of the stockpile and replaced with RRWs because the warhead LEP approach was unsustainable over the long term. The Complex-2030 and RRW plans were endorsed at the highest level in a joint statement by the Secretaries of Energy, Defense and State on "National Security and Nuclear Weapons: Maintaining Deterrence in the 21st Century" issued in July 2007.[60]

RRWs were conceived as completely re-engineered and remanufactured warheads based on existing tested designs that would incorporate less exacting design requirements and enhanced safety features. They would also be easier to monitor and maintain than the existing arsenal of Cold War-era warheads that had tight performance margins designed to minimise weight and size and maximise yield giving very little room for error as weapons age.[61] The new RRW concept reflected the studies undertaken under the SLBM Warhead Protection Program in the 1990s. This stands in contrast to the LEP approach designed to maintain existing warheads by reproducing and replacing defective parts and upgrading others, whilst minimising changes to the nuclear explosive package.[62]

The first planned RRW, labelled WR-1, would replace some, and perhaps eventually all, of the W76 warheads for the US Trident II (D5) SLBM fleet.[63] The RRW

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57 Medalia, "The Reliable Replacement Warhead Program", p. 1.

58 See, for example, Rep. David Hobson, D. "Energy and Water Development Appropriations Act, 2005", *Congressional Record (House of Representatives)*, June 25, 2004, p. H5084 and Medalia, 'The Reliable Replacement Warhead Program', p. 21; Medalia, 'Nuclear Weapons Complex Reconfiguration', p. 27.

59 "Complex 2030: An Infrastructure Planning Scenario for a Nuclear Weapons Complex Able to Meet the Threats of the 21st Century" (Department of Energy, Washington, D.C., 2006).

60 "National Security and Nuclear Weapons: Maintaining Deterrence in the 21st Century", July 2007, A Statement by the Secretary of Energy, Secretary of Defense and Secretary of State, Washington, D.C.

61 Medalia, "The Reliable Replacement Warhead Program", p. 11.

62 Medalia, "The Reliable Replacement Warhead Program", p. 2.

63 "Interim report of the Feasibility and Implementation of the Reliable Replacement Warhead Program", Submitted to the Congressional Defense Committees in response to section 3111 of the National Defense Authorization Act for Fiscal Year 2006, Public Law 109-163, by the Secretaries of Defense and Energy in consultation with the Nuclear Weapons Council, p. 3.

programme is therefore of *direct relevance* to the UK warhead programme because history suggests that AWE Aldermaston will follow the US lead on the long-term future of the W76 warhead, a theme that is explored further below.

A design competition for the WR-1 was subsequently launched in March 2005 between the US nuclear weapons laboratories.[64] The first production unit was planned for deployment by 2012-2014 with full production by 2022.[65] A final WR-1 design by the Lawrence Livermore and Sandia National Laboratories was approved in March 2007 to allow NNSA to conduct detailed design and cost studies.[66]

The Livermore/Sandia design is thought to be based on a previously tested but not deployed warhead. The design increased the explosive yield of the primary in order to increase the margin for driving the explosion of the secondary while controlling uncertainties. The design and planned certification process involved a number of hydrodynamic tests and use of a number of experimental nuclear weapon facilities.[67] The US National Academy of Sciences state that in order to certify an RRW-type warhead, the design laboratories will have to make the case that the new design is 'close enough' to successful tested designs and that "any gaps between the knowledge of physics and engineering and the archival underground nuclear test base are bridged by experiments".[68] Experimental nuclear weapon facilities developed under the SSP are therefore essential to the design and certification of a new RRW warhead.[69]

4.3 A 'hybrid' LEP/RRW compromise

Nevertheless, the rationales presented by the administration for major expenditure on a suite of new facilities for a consolidated nuclear weapons complex and the RRW programme were greeted with scepticism by influential members of Congress. They remained unconvinced that the administration had conducted a thorough review of the long-term direction of the nuclear complex and size and purpose of the overall nuclear stockpile as requested.[70] Funding for the RRW and Complex-2030 plans was stripped by Congress in 2007 and 2008 and in March 2009 the Obama administration formally terminated the RRW programme in its current iteration.[71]

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64 Medalia, "The Reliable Replacement Warhead Program", p. 16.

65 "Report on the Plan for Transformation of the National Nuclear Security Administration Nuclear Weapons Complex", p. 11; Medalia, "The Reliable Replacement Warhead Program", p. 18.

66 "Reliable Replacement Warhead: Executive Summary", JASON Program Office, JSR-07-336E (The MITRE Corporation: McLean, VA, 2007), p. 3.

67 *Evaluation of Quantification of Margins and Uncertainties Methodology for Assessing and Certifying the Reliability of the Nuclear Stockpile* (National Academy of Sciences: Washington, D.C., 2008), p. 45.

68 *Ibid.*, p. 46.

69 The US Department of Energy also stated in the context of the replacement warhead design developed under the SLBM Warhead Protection Program in the 1990s that "New experimental and computational capabilities are required to certify these designs without further nuclear testing". US Department of Energy's 1996 'Green Book' in "End Run", National Resources Defense Council.

70 Medalia, "The Reliable Replacement Warhead Program and the Life Extension Program", p. 3.

71 "America's Strategic Posture", Final Report of the Congressional Commission on the Strategic Posture of the United States (United States Institute of Peace Press: Washington, D.C., 2009), p. 41.

It is now likely that a compromise package will be agreed by Congress and the Obama administration that allows for significant refurbishment of nuclear weapons complex facilities and a hybrid LEP/RRW programme. Bruce Goodwin and Glenn Mara, both US nuclear weapon scientists from the Lawrence Livermore National Laboratory, argued in 2008 that the US should pursue what they label an 'extensive reuse' LEP (erLEP). This would involve a life extension process for existing nuclear warheads that re-uses a number of warhead components in storage, either separated from weapons or integral to weapons slated for disassembly, including complete primaries and secondaries. They argue that micro-sensors could be embedded into erLEP warheads to continuously monitor a warhead's health. Advanced security technologies similar to the system proposed for RRW could be incorporated into erLEPs. They argue that their erLEP concept sits on a continuum between the current LEP process to replicate weapons exactly as they entered the stockpile with no changes to the primary and secondary through to new high-margin, high-surety RRW designs that have never been tested.[72]

In 2009 the bipartisan Congressional Commission on the Strategic Posture of the United States stated that "The two basic approaches to refurbishment and modernization are, in fact, not stark alternatives. Rather, they are options along a spectrum. That spectrum is defined at its two ends by the pure remanufacturing of existing warheads with existing components at one end and complete redesign and new production of all system components at the other. In between are various options to utilize existing components and design solutions while mixing in new components and solutions as needed. Different warheads may lend themselves to different solutions along this spectrum."[73] The Commission recommended that the possibility of developing alternative plutonium pits and secondaries for W76 warheads should be left open during the second phase of the W76 LEP, potentially permitting an LEP/RRW hybrid life extension programme for some of America's W76 warheads.[74]

5. THE UK WARHEAD ASSURANCE PROGRAMME

The United States has invested heavily in a suite of facilities to ensure the long-term safety, security and reliability of its nuclear arsenal without explosive nuclear testing as part of its Stockpile Stewardship Program. The UK has pursued a comparable programme, albeit on a much smaller scale, labelled the Warhead Assurance Programme designed to "ensure the safety, effectiveness and durability of the UK nuclear warhead stockpile."[75] As then Defence Secretary John Hutton stated in March 2009: "There are a number of similarities in approach between the Atomic Weapons Establishment and their counterparts in the United States national laboratories. These include the management of research, the assessment of technology readiness, and the

[72] Bruce Goodwin and Glenn Mara, "Stewarding a Reduced Stockpile", AAAS Technical Issues Workshop, Washington, D.C., April 24, 2008. See also Jeffrey Lewis, "After the Reliable Replacement Warhead: What's Next for the U.S. Nuclear Arsenal?", *Arms Control Today*, December 2008.

[73] "America's Strategic Posture", Final Report of the Congressional Commission on the Strategic Posture of the United States (United States Institute of Peace Press: Washington, D.C., 2009), p. 42.

[74] *Ibid.*, pp. 42, 45.

[75] Defence Secretary Des Browne, *Official Report*, House of Commons, July 13, 2006, column 1944W.

fundamentals of science-based stockpile stewardship in the absence of underground nuclear tests."[76]

In 2002 Keith O'Nions, Robin Pitman and Clive Marsh, all senior MoD or AWE officials, elaborated further on the UK Warhead Assurance Programme in *Nature* magazine. The article stated that "a new scientific methodology is being developed, without further nuclear tests, aimed at underwriting the safety and performance of the ageing Trident stockpile with continued high confidence."[77] It went on to state that confidence in the safety and performance of the nuclear stockpile must rest on 'high-fidelity' computer models combined with experimental data on the performance of warheads and their materials, historical nuclear test data, and information from the examination of individual warheads.[78] The purpose is to develop highly accurate computer models that can be used to predict the physical processes of the many materials used in the warhead which occur when a weapon is detonated and validate those models against as wide a range of experimental data as possible, as well as against the database of previous nuclear tests.[79]

The UK and US stockpile stewardship programmes therefore follow a similar approach with a central focus on high energy laser experiments, hydrodynamic experiments and advanced computer models to simulate nuclear explosions in order to understand how the properties of warheads and warhead materials behave under a wide range of physical conditions, how these properties change with age and how to extend the life of existing warheads with high confidence.

5.1 AWE recapitalisation

The UK Warhead Assurance Programme is also referred to as the Nuclear Weapons Capability Sustainment Programme. In the early 2000s a government review of AWE concluded that additional investment was required in order to maintain the country's nuclear weapons capability.[80] In response in July 2005 then Defence Secretary John Reid announced a new programme of investment in manpower and replacement of many of the major science, manufacturing and assembly facilities at Aldermaston and Burghfield. This amounted to an additional £1billion investment for a Nuclear Weapons Capability Sustainment Programme over three years from 2006-07 to ensure that AWE could continue to support the Trident warhead and build a replacement if needed.[81]

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[76] *Official Report*, House of Commons, March 2, 2009, column 1370W.

[77] Keith O'Nions, Robin Pitman and Clive Marsh "Science of Nuclear Warheads", Nature, Vol. 415, February 21, 2002.

[78] *Ibid*.

[79] Caroline Handley (a scientist in the Design Physics Department at AWE) "Nuclear Weapon Design and Certification in the CTBT Era" in *A Collection of Papers from the 2007 PONI Conference Series*, Project on Nuclear Issues (Center for Strategic and International Studies: Washington, D.C., 2008), p. 31.

[80] Heather Pragnell, "Discussion on Key Elements and Enablers of the UK Version of a 'Responsive Infrastructure" in *A Collection of Papers from the 2007 PONI Conference Series*, Project on Nuclear Issues (Center for Strategic and International Studies: Washington, D.C., 2008), p. 72.

[81] *Official Report*, House of Commons, March 11, 2005, Column 1257W.

A Site Development Context Plan (SDCP) was subsequently published by AWE in November 2005 that identified the core components of the recapitalisation programme. The plan reiterates that "AWE's core mission is to build and maintain the warheads for the submarine-launched Trident ballistic missile system that today forms the United Kingdom's sole nuclear deterrent. AWE is also required to maintain a capability to design a successor warhead to Trident should it ever be required in the future."[82]

A memorandum from MoD to the House of Commons Defence Committee in 2006 outlined the three broad areas of investment as:

1. Upgrading a range of research facilities to underpin the science that enables AWE to underwrite the safety and performance of the warhead.
2. Refurbishment of some of the key infrastructure on the sites
3. Investment in sustaining core skills within the Establishment.[83]

Under 'Science Facilities' MoD stated that the main areas for investment were high performance computer simulation, hydrodynamics and high energy density physics, in particular "the replacement of major facilities for hydrodynamics experiments; and the development of a new high energy laser facility (Project Orion)."[84] AWE has since:

- Ordered a new Larch computer (sometimes referred to as 'Redwood') in 2006 capable of 40 teraflops to replace the Blue Oak computer installed in 2002 that has a power of just under 3 teraflops.[85]
- Begun construction in 2006 of the new Orion Laser that will be 1,000 times more powerful than the current Helen laser. It will allow AWE scientists to study the processes of nuclear fusion and construct predictive models for nuclear explosions.[86]
- Begun development of a replacement hydrodynamics testing facility, known as the Core Punch Facility, that will have the capacity to make measurements an order of magnitude more precise than the existing hydrodynamic facility.[87]

MoD also noted new developments under the heading 'Manufacturing, Assembly and Disassembly Facilities', stating that AWE will "replace or refurbish some of the basic assembly and disassembly facilities at Aldermaston and Burghfield. These will include new facilities for handling high explosives and highly enriched uranium, modernisation of the assembly/disassembly facilities at Burghfield, and facilities for non-nuclear components in the warhead".[88] Current plans beyond the Orion laser, Core Punch Facility and supercomputer capabilities include:

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82 "AWE Aldermaston and Burghfield Site Development Context Plan (SDCP) 2005 – 2015: Update (SDCP08)", AWE Aldermaston, 2008.

83 "Memorandum from Ministry of Defence", House of Commons Defence Committee, "The Future of the UK's Strategic Nuclear Deterrent: the Manufacturing and Skills Base", HC 59 (HMSO: London, December 2006), p. Ev. 86.

84 "Memorandum submitted by the Ministry of Defence, Annex C (Investment at the Atomic Weapons Establishment)", January 19, 2006, paras 7-8.

85 Stephen Jones, "Recent Developments at the Atomic Weapons Establishment", Standard Note SN/IA/05024 (House of Commons Library: London, March 2009), p. 7.

86 Jones, "Recent Developments at the Atomic Weapons Establishment", p. 7.

87 Jones, "Recent Developments at the Atomic Weapons Establishment", p. 8.

88 "Memorandum submitted by the Ministry of Defence", paras 7-8.

- A new warhead assembly/disassembly facility at AWE Burghfield.
- A new Conventional Manufacturing Facility.
- A new Uranium Handling Facility to store, cast, machine and recycle enriched uranium for Trident warheads and submarine reactor fuel.
- A Materials Test Facility to research how individual materials within a warhead behave and interact.
- An Explosives Handling Facility.
- A new Systems Engineering Facility.[89]

Under "Investment in Skills" MoD stated that AWE has "started a programme of recruitment and it is planned to increase the current workforce by around 350 staff per annum until 2007/08, of whom some 70% will be Non-Industrial staff and 30% Industrial staff."[90] Between 2004 and 2008 staffing levels increased by over 1,000 from 3,510 to 4,620.[91] This includes expertise in the areas of "chemistry, computer science, materials science, nuclear physics, chemical engineering, decommissioning and waste management, civil engineering, manufacturing, metallurgy, electrical and electronic engineering, mechanical engineering, assurance, laboratory support and IT/telecommunications"[92]

Greenpeace argue that "Of particular interest are plans to increase the number of scientists with expertise in hydrodynamics testing from 70 to 95 over the next three years. The only real use for hydrodynamic expertise, according to Greg Mello, the Director of the Los Alamos Study Group, is for designing a new nuclear weapon."[93]

5.2 US-UK SSP collaboration

The US and UK have collaborated on many aspects of their stockpile stewardship programmes. As early as 1995 MoD stated that the UK's stockpile stewardship programme would be "undertaken in continuing co-operation with the United States, which will contribute to the safe stewardship of Trident throughout its service life as well as sustaining capabilities to meet future requirements".[94]

In 2009 then Defence Secretary John Hutton stated that **"**Research, including trials, and experiments, is conducted on a regular basis, by the Atomic Weapons Establishment as part of its responsibility for maintaining the safety, security, and effectiveness of the UK nuclear stockpile in the absence of live testing. Some of this research is undertaken in collaboration with the United States under the auspices of the 1958 Mutual Defence Agreement".[95]

89 *Official Report,* House of Commons, June 28, 2008, Column 447W; "Memorandum from Greenpeace UK", House of Commons Defence Committee, "The Future of the UK's Strategic Nuclear Deterrent: the Manufacturing and Skills Base", HC 59 (HMSO: London, December 2006), p. Ev. 78; *Official Report*, House of Commons, June 28, 2008, Column 447W.

90 "Memorandum submitted by the Ministry of Defence", paras 7-8.

91 *Official Report*, House of Commons, April 3, 2008, column 1209W.

92 *Official Report*, House of Commons, November 7, 2006, column 1449W.

93 *Britain's New Bomb Programme Exposed*, Greenpeace report, October 2006, p.4.

94 House of Commons Defence Committee, "Progress of the Trident Programme", HC 350 (HMSO: London, July 1995), p.24.

95 *Official Report*, House of Commons, March 23, 2009, column 17W.

In addition the US and UK have conducted joint hydrodynamic experiments under the auspices of the MDA.[96] O'Nions *et al* state that "In addition to future [hydrodynamic] tests planned at AWE, complementary experiments are being carried out in collaboration with the US weapons laboratories, including some at their U1A facility in Nevada".[97]

The two countries have also conducted joint 'sub-critical' nuclear tests using fissile material in tests that do not produce a nuclear explosion. O'Nions, Pitman and Anderson, for example, state that the UK has conducted a number of sub-critical nuclear experiments at the US Nevada Test Site in 2002 and 2006 "that provided data of direct benefit to both the U.S. and UK warhead certification efforts".[98] The permissibility of sub-critical tests under the terms of the 1996 Comprehensive Test Ban Treaty is controversial but both the UK and US government insist they are permitted because they do not establish conditions for an exponentially growing fission chain reaction.[99]

US nuclear weapon laboratories have similarly used AWE experimental facilities to conduct tests that Congress had prohibited in the United States. Stanley Orman, former Deputy Director of AWE, stated in 2008 that "we also devised a technique…of imploding a non-fissile plutonium isotope. Now because it was plutonium the laws in the States would not allow you to implode this even though it was non-fissile, because it was plutonium. So again the American scientists would come across and use our laboratories because they couldn't use theirs."[100] US nuclear weapons labs will also have access to the Orion Laser at Aldermaston under the MDA.[101]

In fact an important rationale for additional government investment in AWE expertise and advanced experimental facilities is to ensure that AWE can continue to make a valuable contribution to US nuclear weapon programmes, including a credible peer-review capability, and ensure benefits from the relationship are two-way. Under-investment in experimental facilities and high-fidelity computer modelling capability and atrophying expertise would risk undermining AWE's vital relationship with the US by appearing to have little to offer the US nuclear weapons laboratories in exchange for their invaluable support.[102] As Linton Brooks, former head of the US National Nuclear Security Administration, argues: "The major revitalisation conducted in recent years at the Atomic Weapons Establishment, Aldermaston, will

96 *Official Report*, House of Commons, February 27, 2009, column 1151W.

97 O'Nions *et al*., "Science of Nuclear Warheads", p. 856.

98 Keith O'Nions, Roy Anderson and Robin Pitman, "Reflections on the Strength of the 1958 Agreement", in Mackby, J. and Cornish, P. *U.S.-UK Nuclear Cooperation After 50 Years* (CSIS Press: Washington, D.C., 2008), p. 182.

99 See Suzanne Jones and Frank von Hippel, "Transparency Measures for Subcritical Experiments under the CTBT", *Science & Global Security*, vol. 6, 1997. pp.291-310.

100 Interview with Stan Orman by Tara Callahan, CSIS, January 24, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

101 Stephen Jones, "Recent Developments at the Atomic Weapons Establishment", Standard Note SN/IA/05024 (House of Commons Library: London, March 2009), p. 7.

102 See, for example, interview with Everet Beckner, former deputy Administrator for Defense Programs, National Nuclear Security Administration, by Cassandra Smith, CSIS, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

improve British technical capability and thus the technical value of ongoing exchanges".[103]

5.2.1 Management of AWE

The extent of US-UK collaboration is also demonstrated by the fact that the management company that runs AWE is two-thirds owned by American corporations that have been deeply involved in the US nuclear weapons programme. AWE is a Government-Owned Contractor-Operated (GOCO) facility. It has been contractorised since 1993. Following a competition held by MoD, the contract for a second term was awarded on April 1, 2000 to AWE Management Limited (AWEML) for a period of ten years. AWEML is a consortium comprising British Nuclear Fuels Limited (BNFL), the UK-based company Serco and US-based Lockheed Martin. In January 2003 the contract was extended to 25 years.

In June 2007, after consultation between the then Department of Trade and Industry and MoD, a decision was made to sell BNFL's one-third stake in AWEML. That stake was bought by the US company Jacobs Engineering Group with the UK government's blessing. The contract confirming the deal was finally signed by BNFL and Jacobs in December 2008.[104] Both Lockheed Martin and Jacob's Engineering Group are major contractors in the US nuclear weapons complex. MoD retains a special 'golden share' in AWE Plc, the company owned by AWEML to manage operations on a day-to-day basis, which would allow intervention in the management of AWE or the transfer of responsibility to another contractor if that became necessary.[105] The government states that "The Government have not transferred or sold any of its stake in the Atomic Weapons Establishment itself, which remains entirely owned by the MoD and in which UK sovereignty remains protected".[106]

6. TRIDENT REPLACEMENT

In December 2006 the Labour Government presented its decision to replace the current Vanguard-class submarines nuclear weapon system when it reaches the end of its service life in a White Paper on *The Future of the United Kingdom's Nuclear Deterrent*.[107] In March 2007 Parliament voted in favour of this decision.

The government stated that the Vanguard submarines that carry the Trident missiles have a service life of 25 years. In order to maintain the current 'continuous-at-sea deterrence' posture with one submarine at sea on operational patrol at all times, a new submarine will be required by the time the oldest Vanguard submarine retires in 2024. The government argued in its 2006 White Paper that it will take approximately 17 years to design, build and test a new submarine, hence a decision on whether or not to proceed was required in 2007. In October 2007 MoD's Defence Equipment and

103 Brooks, "The Future of the 1958 Mutual Defense Agreement", p. 155.
104 *Official Report*, House of Commons, February 12, 2009, column 2284W.
105 *Official Report*, House of Commons, January 12, 2009, column 1WS.
106 *Official Report*, House of Commons, February 12, 2009, column 2284W.
107 Ministry of Defence (MOD) and Foreign & Commonwealth Office (FCO) *The Future of the United Kingdom's Nuclear Deterrent*, Command 6994 (HMSO: London, December 2006).

Support (DES) department formally established a Future Submarines Integrated Project Team (FSM-IPT) to develop a concept design for a new submarine over two years.[108]

6.1 Collaboration with the US on a new Trident submarine

The future of the British nuclear weapons programme is intimately linked to the United States. The UK will look to the US for political and technical support in replacing its Vanguard SSBNs and modernising the Trident system.[109] The US Navy is 4-5 years behind the UK in planning a replacement for its Ohio-class Trident submarines having opted to extend the life of its submarines by 15-20 years in. The UK plans to introduce its first successor submarine in 2024 but the US only provisionally plans to introduce a new submarine in 2028/29.[110]

The UK has already begun working with the United States on possible new submarine designs and in February 2008 it set up a programme office in the US to facilitate liaison on the design process in the US for an Ohio-class successor SSBN.[111] MoD reported in December 2007 that since March 2007 UK and US experts in the Joint Steering Task Group that oversees the Polaris Sales Agreement had already met three times during which concept studies for a new successor submarine were discussed.[112]

In December 2008 it was reported that US General Dynamics Electric Boat Corporation had been awarded a contract to perform studies and design of a Common Missile Compartment (CMC) for both the UK Vanguard-class and the US Ohio-class successor submarines paid for the by UK but run through the US Naval Sea Systems Command in Washington.[113] MoD is also contracting out additional aspects of its own concept studies to US companies.[114]

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108 "Birth of Son of Trident, at Yard", *North-West Evening Mail*, October 11, 2007; "Future Submarines Integrated Project Team Office Officially Opens", News Release, BAE Systems, October 12, 2007.

109 It was reported in July 2005 that Defence Secretary John Reid had authorized officials to begin negotiations with Washington on the nature of Britain's post-Vanguard nuclear force. David Cracknell, "Talks start with U.S. on Trident's 15bn successor", *The Sunday Times*, July 17, 2005.

110 Elaine Grossman, "Strategic Arms Funds Tilt Conventional in 2009", *Global Security Newswire*, November 7, 2008. Available at <http://www.nti.org/d_newswire/issues/2008/11/7/2E8D226C-261C-4209-8B38-147F3CD8012B.html>; "Sub officials: missiles will decide design of strategic deterrent", *Inside the Navy*, February 23, 2009.

111 Uncorrected transcript of oral evidence to the Committee of Public Accounts hearing on *The United Kingdom's Future Nuclear Deterrent Capability*, November 19, 2008, p. 19.

112 Defence Secretary Des Browne, House of Commons, *Official Report*, December 3, 2007, Column 843W.

113 "CMC Contract to Define Future SSBN Launchers for UK, USA", *Defense Industry Daily*, December 26, 2008.

114 "UK WTS Training Implementation Plan Future Hull", Defense Contract Management Agency, solicitation number N00030-07-G-0044NJ57, May 28, 2008.

6.2 Maintaining the capability to build a new warhead

The Labour government has consistently stated since its 1998 Strategic Defence Review that the UK must not only maintain "a robust capability at the Atomic Weapons Establishment to underwrite the safety and reliability of our nuclear warheads" but that it must also maintain "a minimum capability to design and produce a successor to Trident should this prove necessary".[115]

It has therefore always been Labour's policy to ensure that AWE can not only ensure the safety and reliability of the current Trident system, including sustaining a basic capability to remanufacture key components of the Trident warhead, but also retain the ability to design and manufacture a new warhead to replace the current Trident warhead if required.[116] Defence Minister Adam Ingram, for example, reiterated in June 2003, "We maintain a research capability to ensure the safety of our existing stockpile and to support the policy set out in the Strategic Defence Review of maintaining a minimum capability to design and produce a successor to Trident should this prove necessary."[117]

Dr Clive Marsh, AWE's Chief Scientist, stated in an AWE promotional video in 2007 that "Our research & development work splits into two main but inter-related areas. The first is the requirement to maintain the current Trident stockpile. The second is to develop our overall warhead design and assurance capabilities, including the ability to provide a new warhead lest our government should ever need it as a successor to Trident. Most of our research is conducted in this capability area."[118]

The UK will face a decision on whether to refurbish its Trident warheads through a full LEP comparable to the W76-1 process in the US or develop its own version of an RRW or perhaps a hybrid based on the erLEP concept outlined above. In its 2006 White Paper on Trident replacement the government stated that a decision on whether to refurbish or replace the current UK Trident warhead is likely to be needed during the next parliament (2010-2015).[119] The White Paper stated that "The current warhead design is likely to last into the 2020s, although we do not yet have sufficient information to judge precisely how long we can retain it in-service. Decisions on whether and how we may need to refurbish or replace this warhead are likely to be necessary in the next Parliament. In order to inform these decisions, we will undertake a detailed review of the optimum life of the existing warhead stockpile and analyse the range of replacement options that might be available. This will include a number of activities to be undertaken with the United States under the 1958 UK-US Agreement for Cooperation on the Uses of Atomic Energy for Mutual Defence Purposes."[120]

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115 Ministry of Defence, *The Strategic Defence Review*, Command 3999 (HMSO: London, July 1998), "Supporting Essay 5: Deterrence, Arms Control and Proliferation" (HMSO: London), paragraph 14.

116 "Memorandum submitted by the Ministry of Defence", paras 9-10.

117 *Official Report*, House of Commons, June 11, 2003, column 919W.

118 The clip is available on YouTube at <http://www.youtube.com/watch?v=gT8qCFkbIv4&feature=PlayList&p=03EA85851D947C18&playnext=1&playnext_from=PL&index=44>.

119 MoD & FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 7.

120 MoD & FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 31.

In November 2007 the government stated that studies on the potential need for a new warhead were now being undertaken by a Warhead Pre-Concept Working Group at AWE.[121] Some of this research is being undertaken with the US. Then Defence Secretary John Hutton announced that following an exchange of letters between Prime Minister Tony Blair and President George W. Bush in December 2006 "additional research is currently being undertaken, some in collaboration with the US, on how we may need to refurbish or replace our current warheads to help inform decisions, likely to be made in the next parliament."[122]

6.3 Collaboration with the US on a refurbished Trident warhead?

The UK has been involved in the US W76 LEP, although to what extent is unclear. According to the AWE's 1998 Annual Report, AWE participated significantly, as an independent contributor, in the United States Dual Revalidation Programme, which reviewed the status of the US W76 Trident warhead as the first stage of the LEP process.[123]

It has also been revealed that an April 1998 US "Stockpile Stewardship Plan: Second Annual Update" report from the US Department of Energy that set out the work plan for the W76 LEP between 1999 and 2001 included an engineering, design and evaluation schedule for the UK Trident warhead.[124]

Furthermore, Steven Henry, Deputy Assistant to the Secretary of Defense (Nuclear Matters) under George W. Bush, stated in an audio interview for the US Center for Strategic and International Studies in 2008 that in the mid 1990s, when the US began developing Life Extension Programs (LEP) for various warheads: "As part of that exchange we also did exchanges with the UK to find out what kind of information did they know through their surveillance program and what kind of concerns did they have with their own unique weapons systems that would help us learn and to make decisions as to what kind of components would we replace and at what time would we replace those components. So we entered into a cooperation with the UK looking at Life Extension itself for the different warheads. We entered into a program of sharing information for the Enhanced Surveillance program and we also looked at more innovative ways of being able to do production so that we could gain efficiencies."[125]

One clear instance where the UK has benefitted directly from the W76 LEP is through the design and production in the US of a new Arming, Fusing and Firing system (AF&F) for the Mk4A re-entry body. The Mk4A AF&F is being installed on UK warheads and AWE has been recruiting a number of new staff to work on AF&F. A recruitment notice for one of these posts referred to work on introducing the Mk4A

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[121] Defence Secretary Des Browne, *Official Report*, House of Commons, November 28, 2007, Column 452W.

[122] *Official Report*, House of Commons, March 23, 2009, column 17W.

[123] Bromley and Butler, "Secrecy and Dependence", citing "Hunting-BRAE Annual Report", 1998, p. 41. Available at <http://www.basicint.org/pubs/Research/2001UKtrident1.htm>.

[124] Tara Callahan and Mark Jansen, "UK Independence or Dependence", in Mackby, J and Cornish, P. *U.S.-UK Nuclear Cooperation After 50 Years* (CSIS Press: Washington, D.C., 2008), p. 31.

[125] Interview with Steve Henry by Michael Gerson, CSIS, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

AF&F into UK warheads.[126] Then Defence Secretary Des Browne confirmed that this upgrade is taking place and would be introduced over the next decade.[127]

6.4 Collaboration with the US on a re-engineered Trident warhead?

It has been suggested that the UK is also exploring options for a new RRW-type warhead that could be developed without nuclear testing, a so-called High Surety Warhead.[128] The government has denied any direct involvement in the US RRW programme[129] and insists that it is not developing a new warhead at Aldermaston.[130] Nevertheless, in 2006 David Overskei, chair of the US Secretary of Energy's Advisory Board reportedly said that "as far as I know they [the British] are not involved with the RRW…but they are keenly, keenly interested".[131]

In 2004 the Mutual Defence Agreement was extended for a further 10 years and amended to facilitate US-UK cooperation on nuclear warhead research related to the RRW concept. In 2008 John Harvey, policy and planning director at the US National Nuclear Security Administration, stated in an audio interview for the US Center for Strategic and International Studies (CSIS), that "we have recently, I can't tell you when, taken steps to amend the MDA, not only to extend it but to amend it to allow for a broader extent of cooperation than in the past, and this has to do with the RRW effort."[132] He added that the MDA had been amended to give the UK access to information on US technologies to secure warheads against possible unauthorised use, for example by a terrorist group that managed to steal or otherwise gain access to a US nuclear weapon. This technology had not previously been explicitly declared as an area of cooperative research under the MDA. Harvey said that it "is such an integral part of our RRW efforts we will need to have the Brits involved in that if we are going to have them involved in RRW".[133] Harvey also stated that UK scientists "are observers on some of the working activities that are chaired by the Navy for the Reliable Replacement Warhead."[134]

This is supported by the most recent US nuclear weapons budget for FY2010 that shows AWE is continuing to collaborate with US nuclear weapons laboratories on a programme of "Enhanced Surety" for nuclear warheads.[135] This is research into ways of making warheads safer and introducing new technologies to prevent unauthorised use "for consideration in scheduled stockpile refurbishments, life extension programs

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126 Recruitment notice for a Warhead Electrical Engineer for AWE as publicised by Beechwood Recruitment Agency, February 2, 2007, reference CA829v27.

127 *Official Report*, House of Commons, March 28, 2007, column 1524W.

128 Ian Bruce, "Britain in top-secret work on new atomic warhead", *The Herald*, September 4, 2007.

129 *Official Report*, House of Commons, February 27, 2009, column 1150W.

130 *Official Report*, House of Commons, March 21, 2006, column 364W.

131 Cited in Geoff Brumfiel, "The next nuke", *Nature*, vol. 442, no. 6, July 2006.

132 Interview with John Harvey by Jessica Yeats, CSIS, January 23, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

133 Interview with John Harvey.

134 Interview with John Harvey.

135 "FY2010 Congressional Budget Request", National Nuclear Security Administration (U.S. Department of Energy: Washington, D.C., May 2009), volume 1, p. 101.

(LEP), and future stockpile strategies".[136] Warhead research of this type was previously associated with the RRW programme. It constituted one of the concept's core rationales and formed a critical part of the RRW design competition. One specific area of future joint research collaboration between Los Alamos National Laboratory, Lawrence Livermore National Laboratory and AWE Aldermaston is the design of a Multi-Point Safe warhead.[137] Current UK Trident warheads are designed to be one-point safe, meaning that an accident leading to detonation of the high explosive trigger at one single point will not cause the warhead to go critical.[138] Re-designing the current UK Trident warhead to make it Multi-Point Safe could be difficult, suggesting that this collaborative UK-US research is for a potential future warhead design.

A number of other interviews in the CSIS series suggest that the UK has worked closely with the US on the RRW programme. Frank Miller, a civil servant who was Senior Director for Defense Policy and Arms Control at the National Security Council under George W. Bush and previously held senior positions in the Department of Defense with responsibility for nuclear weapons policy under Reagan, Bush senior and Clinton, stated in 2008 that "They [UK] will need a Reliable Replacement Warhead of their own. In fact they are 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".[139]

It was also reported that data from the 2006 UK sub-critical Krakatau test conducted at the US Nevada Test Site would be used in the US RRW study. The *Times* stated that "Jacob Perea, project manager at Los Alamos, told *The Times* that data from Krakatau, a British-US test, was being used to help the US to work out how to build its new generation of weapons. Although he said that the project was American, he added: 'It would be pretty surprising if they (the British) weren't watching this pretty closely'."[140]

Speculation that a new warhead was in development was fuelled by revelations in July 2008 that a senior defence official (David Gould, chief operating officer at the MoD's Defence Equipment and Support) told the arms industry that the government plans to spend £3billion replacing the current warhead arsenal even though the government insists it has made no formal decision on whether the warhead can be maintained as they are or whether a new warhead will be built. He reportedly stated that "the intention is to replace the entire Vanguard class submarine system. Including the warhead and missile".[141] Further fuel is added by a report in September 2006 that AWE advertised for 31 warhead-related vacancies, including one that involved

136 *Ibid.*, p. 100.

137 *Ibid.*, p. 105.

138 See "JSP 538 – Regulation of the Nuclear Weapons Programme", NIS Technical Briefing Note (Nuclear Information Service: Reading, August 2008), p. 4.

139 Interview with Frank Miller by Jessica Yeats, CSIS, January 28, 2008. Audio files available at <http://csis.org/program/us-uk-nuclear-cooperation-after-50-years>.

140 Tim Reid, "In the Wilderness, a Computer Readies a New Nuclear Arsenal", *The Times*, April 7, 2006.

141 Matthew Taylor, "Britain plans to spend £3bn on new nuclear warheads", *The Guardian*, July 25, 2008; MoD presentation on the future strategic deterrent, released under the Freedom of Information Act (FOIA). The phrase "including the missile and warhead" was redacted and only disclosed following an internal review requested under the FOIA.

"managing a team of Requirement Engineers that will be a focal engineering requirement for future weapon systems."[142]

7. QUESTIONING THE NECESSITY OF SCIENCE-BASED STOCKPILE STEWARDSHIP

Some critics question the government's insistence that the new facilities under construction at Aldermaston are essential to ensure the safety and reliability of the existing Trident warhead stockpile. They argue that such facilities are of limited use in that regard, but are crucial for the development of new warhead designs.[143]

A number of reports in the UK and US have argued that both an RRW programme to re-engineer nuclear warheads and a science-based LEP stockpile stewardship process based on computer modelling, and high-energy laser and hydrodynamic testing are unnecessary. Instead, existing warheads can be maintained through an engineering-based inspection and remanufacture programme.

In the UK Greenpeace argued in 2006 that an engineering-based 'curatorship' approach would involve "detaching and checking each of the thousands of individual parts that make up a nuclear weapon and its subsystems. If there are any problems or signs of deterioration the part is simply replaced by an identical part. Stocks of identical parts are created through remanufacturing parts according to their original specifications. As long as the basic weapon design, particularly the plutonium pit in the warhead itself, is not changed then this method will continue to work."[144]

Greenpeace cite a 1994 report on "Science-Based Stockpile Stewardship" by a member of the JASON group of US nuclear weapons scientists stating "I suggest that it is better to describe the future task as curatorship [i.e. engineering-based inspection and remanufacture] than as stewardship, and emphasize the distinction between these two concepts. In stewardship the human resources required to design and develop weapons are maintained, with skills honed on classified and unclassified experiments conducted at facilities such as the National Ignition Facility (NIF) and in hydronuclear tests. In curatorship these facilities are not built... only those skills required to remanufacture weapons according to their original specifications are preserved. The purpose of this note is to argue that curatorship is preferable to stewardship. The chief nuclear danger in the present world is that of proliferation, and stewardship will exacerbate this danger, while curatorship will mitigate it while preserving our existing nuclear forces.[145]

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142 "Memorandum from Aldermaston Women's Peace Campaign", House of Commons Defence Committee, "the Future of the UK's Strategic Nuclear Deterrent: the Manufacturing and Skills Base", HC 59 (HMSO: London, December 2006), p. Ev. 94.

143 Jones, "Recent Developments at the Atomic Weapons Establishment", p. 9.

144 Greenpeace, *Britain's New Bomb Programme Exposed*, p.5.

145 Greenpeace, *Britain's New Bomb Programme Exposed*, pp.6-7, citing Drell, S. et al., "Science Based Stockpile Stewardship", JASON report JSR-94-345 (The MITRE Corporation: McLean, USA, 1994), p. 81.

The concept of 'curatorship' was further explored in an April 2009 report by the US Nuclear Weapons Complex Consolidation Policy Network. It argues that "Under Stockpile Stewardship, NNSA is performing extensive 'Life-Extension Programs' (LEPs) for each type of warhead in the stockpile. In practice, 'life extension' has become a misnomer for a nearly complete rebuild and upgrade of a warhead system that is nowhere near the end of its life."

It recommends "a more conservative approach to maintaining the existing nuclear weapons stockpile, based on ensuring that today's safe and reliable warheads are changed as little as possible and only in response to documented findings that corrective action is needed to fix a component or condition that could degrade performance or safety. The key to this approach is our conclusion that there is no need for the United States to design any new nuclear weapons or to make performance or safety-enhancing modifications to existing ones. This technical approach is more consistent with U.S. initiatives in nuclear non-proliferation and nuclear threat reduction."

The report continues, "Our methodology is called 'Curatorship.' Just as a museum curator maintains artistic treasures and occasionally restores them to their original condition, so too would NNSA [National Nuclear Security Administration] and the Department of Defense (DoD) maintain nuclear weapons to their original design and condition, with occasional restorations. NNSA's role in maintaining nuclear weapons would focus on scrupulous surveillance and examination of warheads to determine if any component has changed in any manner that might degrade the safety or performance of the warhead. If so, it would then restore that part as closely as possible to its original condition."[146]

They recommend that the US "de-emphasize nuclear weapons science and technology and cease its quest for more and more detailed simulations of exploding thermonuclear weapons. The existing codes are sufficient, in conjunction with limited use of hydrotesting, for the analyses needed to maintain the stockpile as it is. Improved codes have little use except for designing new types of nuclear weapons or verifying the impact of major changes to existing ones...This empirical approach to stockpile surveillance and maintenance is far superior and should be prioritized over endless 'nuclear weapons science.' A simple way of putting it is that we recommend an 'engineering' rather than a 'science-based' approach to stockpile maintenance."[147]

One of the main concerns driving the RRW concept in the United States was that age-related defects in the warhead primary resulting from chemical changes in the plutonium pit as it ages would undermine confidence in the reliability of the warhead. This argument was fundamentally dismissed following peer reviewed studies by the JASON group of work done at US nuclear weapons laboratories on plutonium ageing that confirmed that the minimum expected lifetime of plutonium pits in US nuclear weapons is 85 years.[148] Civiak *et al* also report that "There is even less concern that HEU or other materials in warhead secondaries might degrade over time and have to

[146] Robert Civiak *et al*., "Transforming the U.S. Strategic Posture and Weapons Complex", Nuclear Weapons Complex Consolidation Policy Network, April 2009, p. 10.

[147] *Ibid*., p. 84.

[148] R.J. Hemley, *et al.*, "Pit Lifetime," JASON Program Office, JSR-06-335 (The MITRE Corporation: McLean, USA, November 2006).

be replaced because of ageing than there is for plutonium pits and other primary components".[149] This undermines arguments that the core 'physics package' of current nuclear warheads needs to be remanufactured to address age-related defects and supports the case for the feasibility of an engineering-based curatorship approach.

The core argument underpinning these independent analyses is that maintaining the long-term health of the current warhead stockpile based on the warheads' current characteristics does not require many of the facets of a science-based stockpile stewardship programme, whose capabilities can be used to advance the state of the art of nuclear weapons science and significantly enhance current warheads by changing some of their original characteristics through an LEP process or develop new or 're-engineered' warheads based on existing tested designs through an RRW process.

For example, in the UK analysis by Scottish CND submitted to the House of Commons Defence Committee in 2006 provides an analysis of which AWE facilities are likely to be required for extending the life of the Trident warhead or a new warhead design:[150]

Facility	*Dismantle Trident 2020–25 with no replacement*	*Trident Life Extension*	*Design and build replacement warhead*
High Powered Computing	No need to increase capability	Some investment	Substantial investment
Hydrodynamics	New facilities not essential	Limited programme of experiments to extend pit life	Substantial programme of experiments for new pit
Orion Laser	Not required	Limited programme of experiments	Substantial programme of experiments
New Uranium Production Facility	Not required; use A90	Limited production related to the surveillance programme	Substantial production if secondary or radiation case replaced
A90 Plutonium Production Facility	Plutonium and Uranium work	Limited production related to the surveillance programme	Upgrade of A90 required for substantial production of new pit
Tritium Extraction Facility	Not required	New facility	New facility
Warhead Assembly and Disassembly Facility	Scaled down new facility	New facility	New facility
Explosive facilities	Limited requirement	New facility	New facility
Material science facilities	Not essential	New facility	New facility

Nevertheless, it remains government policy that AWE retain the capability to develop a new warhead if required and that this requires a science-based stockpile stewardship approach. The government also insists that there is little to differentiate between facilities and processes to maintain the current Trident system and those required to

149 Civiak *et al.*, "Transforming the U.S. Strategic Posture and Weapons Complex", p. 98.
150 "Memorandum from Scottish CND", House of Commons Defence Committee, "The Future of the UK's Strategic Nuclear Deterrent: the Manufacturing and Skills Base", HC 59 (HMSO: London, December 2006), p. Ev. 101.

design and produce a possible successor warhead. In reply to a question by Jeremy Corbyn, MP, then defence secretary John Reid stated in 2005 that "My hon. Friend posits something that envisages a qualitative and quantifiable watershed between the maintenance of facilities, whereby they are updated and rendered continually safe so that our existing nuclear deterrent is made more effective, and a new weapon...The reality is that the preparations necessary to maintain a nuclear deterrent in a safe condition, which is constantly updated to meet new threats in terms of accuracy and new technology, are an integral part of what might become—I do not say will become—one possible avenue for one of the many alternatives that we might have to consider if are going to update, replace or modernise our nuclear deterrent."[151]

8. CONCLUSION

A number of conclusions can be drawn from this report that can be usefully divided into known and suspected activities and policies relating to nuclear warhead activities at AWE Aldermaston and Burghfield.

8.1 What is known

The historical record shows that the UK nuclear weapons programme, including work on the UK Trident nuclear warhead at AWE Aldermaston, has been heavily dependent upon the United States since the late 1950s through provision of nuclear weapon systems, materiel, design assistance and operational support.

We know that this extends to the current Trident system where dependencies are reflected in provision of the Trident missile, assistance with the development and production of the UK Trident warhead, including the Mk4 re-entry body, operational targeting, and in-service support for the weapon system.

We know that the UK has embarked on a long process of replacing the current Trident system beginning with the procurement of a new fleet of ballistic missile submarines to carry the Trident missile. US-UK cooperation on nuclear weapon systems is already shaping the UK programme, for example through cooperation with the US on a new Common Missile Compartment for both countries' next generation SSBNs.

We know that both the US nuclear weapons laboratories and AWE Aldermaston have developed extensive science-based stockpile stewardship / warhead assurance programmes focussing on high-energy laser experiments, hydrodynamic experiments, powerful computing capabilities to simulate nuclear explosions, archived nuclear test data and surveillance of individual warheads in the operational stockpile.

We know that the US nuclear weapons laboratories and AWE Aldermaston have conducted joint stockpile stewardship experiments and used each other's facilities stockpile stewardship activities.

[151] *Official Report*, House of Commons, May 18, 2005, column 250.

We know that the US nuclear weapons laboratories have undertaken a major life extension programme to refurbish a significant quantity of its W76 Trident warhead stockpile and Mk 4 re-entry body, resulting in the W76-1/Mk 4A.

We know that the AWE Aldermaston has participated in aspects of the W76 LEP and has benefitted from some of its outputs, notably the new Arming-Fusing and Firing system.

We know that the US nuclear weapons laboratories have developed a new Reliable Replacement Warhead design based on tested weapon designs to replace some, or all, of the W76 stockpile but that eh programme was terminated before detailed design and costs studies were undertaken.

We know that the policy of the current Labour government since 1997 has been to maintain the skills and capabilities at AWE not only to ensure the safety, security and reliability of the current Trident warhead stockpile, but also to design and build a new warhead should if required.

We know that the UK government has stated that a decision on whether to refurbish or replace the current warhead will be required in the next parliament; that it has established a programme at AWE to explore these options; and that it is working with the United States on these options under the auspices of the 1958 Mutual Defence Agreement.

8.2 What is suspected

Evidence suggests that the UK will remain dependent upon the United States for the long-term viability of its nuclear arsenal and that US support through the many nuclear and missile working groups under the auspices of the Mutual Defence Agreement and Polaris Sales Agreement will continue. As Linton Brooks argues: "future cooperation will be even more collaborative and in even greater depth than in the past".[152]

Evidence suggests that the AWE Aldermaston has been involved in RRW design studies at US nuclear weapons laboratories and that it is currently involved in 'enhanced surety' studies to develop warhead use-control technologies integral to the RRW concept, even though the government has explicitly stated on several occasions that it is not currently developing a new warhead.

Evidence suggests that the development of new science-based stockpile stewardship facilities does not prove that AWE is currently developing or intends to develop new nuclear weapons, only that it is maintaining the potential to do so in line with government policy; despite the case presented by critics of this approach that an engineering-based curatorship approach is all that is required to maintain and safe, secure and reliable nuclear arsenal.

[152] Brooks, "The Future of the 1958 Mutual Defense Agreement", p. 155.

Evidence suggests that a new iteration of the RRW concept will emerge in the US, probably a hybrid LEP/RRW 'erLEP' concept, and that this will probably be focused on replacing some, or all, of the W76 warhead stockpile.

8.3 Summary conclusion

This assessment leads to a robust conclusion that is it extremely likely the UK government and AWE Aldermaston will follow the US lead on the future development of the W76 LEP and potential replacement warhead or 'erLEP' for the W76. The UK's Trident warheads are younger than their American W76 counterparts. The last US W76 was produced in 1987. The first UK Trident warhead was produced in 1992 and production continues at a trickle rate, which means that the average age of the stockpile is lower than would otherwise be the case.[153] The UK government can therefore afford to wait and see how the US RRW concept evolves and the implications of the US W76 stockpile.

This conclusion is supported by statement from US officials. John Harvey, for example, stated in 2008 that "They [UK] are involved in our studies examining the Reliable Replacement Warhead approach and so if we move along that path they will have to make a decision about whether they want to move along that path and that will be very interesting and they have several years in which to make that decision in which we do and so their decision will lag ours but it will be informed by ours."[154]

Glenn Mara, Principal Associate Director for Weapons Programs and the Los Alamos National Laboratory, also stated that "If the US decides to stay with the legacy stockpile…it is much more difficult for the UK to embark on a transformed stockpile, i.e. to go it alone, because there are so many inter-dependencies, just on the evolution of your nuclear deterrent stockpile…in a large part I would expect the UK in many regards to follow the US".[155]

The future at AWE Aldermaston is therefore likely to involve considerable activity to extensively refurbish the current Trident warhead stockpile through a life extension programme using upgraded US warhead components but little change to nuclear explosive package; and/or develop and produce a hybrid re-engineered warhead based on a previously tested UK warhead design and possibly involving fabrication of new primaries and secondaries. This would essentially constitute a 'new' weapon, although the definition of 'new' in this context has been contested in the RRW debate in the US.

153 *Ibid.*
154 Interview with John Harvey.
155 Interview with Glenn Mara by Tom Tierney, LANL, 2008. Audio files available at <http://csis .org/program/us-uk-nuclear-cooperation-after-50-years>.

APPENDIX: THE EFFECTS OF A NUCLEAR DETONATION

The size of the explosive yield of a nuclear weapon, particularly a thermonuclear fusion nuclear weapon, mean that such devices can only be considered indiscriminate weapons of mass destruction in the literal, as opposed to politicised, sense of the term. Use of one or two 100kt UK Trident warheads can be expected to kill hundreds of thousands of people if used against cities or military facilities near major conurbations. The explosive yields of the two atomic bombs detonated above Hiroshima and Nagasaki in August 1945 were 14kt and 20kt respectively and between them killed an estimated 200,000 people.

The effects of a nuclear detonation may extend over a large area and take a number of forms. Douglas Holdstock and Liz Waterston state that the 'lethal area' for a 100kt warhead, defined as the area within which the number of survivors is equal to the number of blast fatalities, if circular has a radius of 2.4km. The heat flash from a 100kt 'airburst' detonation "would cause lethal burns out of doors over about 75km^2. Flash blindness would occur over many kilometres". Radiation doses would affect people over a much wider area. They go on to state that "a single nuclear explosion over a medium-sized city would overwhelm the health services of even a developed country, and an attack with multiple weapons would disrupt the whole country's economic and social structure". This would interrupt the availability of food and potable water, provision of basic health and social services and lead to many more deaths through the indirect effects of a nuclear attack.[156]

A report by Scottish CND in 1999 estimated that a single 100kt Trident nuclear warhead would kill 98 per cent of people within 1.6km of ground zero and injure 2 per cent, kill 55 percent within 1.6-2.9km and injure 40 per cent, and kill 8 per cent within 2.9-5.3km and injure 45 per cent. It estimates that if a single Trident warhead was detonated over Moscow, for example, it would cause around 200,000 fatalities.[157] A map of these effects from the Scottish CND report is reproduced below.

Quite apart from the destruction wrought by the initial blast, heat flash and radiation, the incendiary effects of a single 100kt nuclear blast would also be devastating. In Hiroshima, a tremendous fire storm developed within 20 minutes after detonation. A fire storm burns in upon itself ferociously with gale force winds blowing in towards the centre of the fire.[158] For large warheads (those at or above 100kt), the thermal effects of the explosion extend much further than the blast effects. William Bell and Cham Dallas observe that "casualties resulting from fires, and burns in a nuclear attack would be of major impact for civil defense and emergency health care… The entire US has specialized facilities to treat roughly 1,500 burn victims, which is far

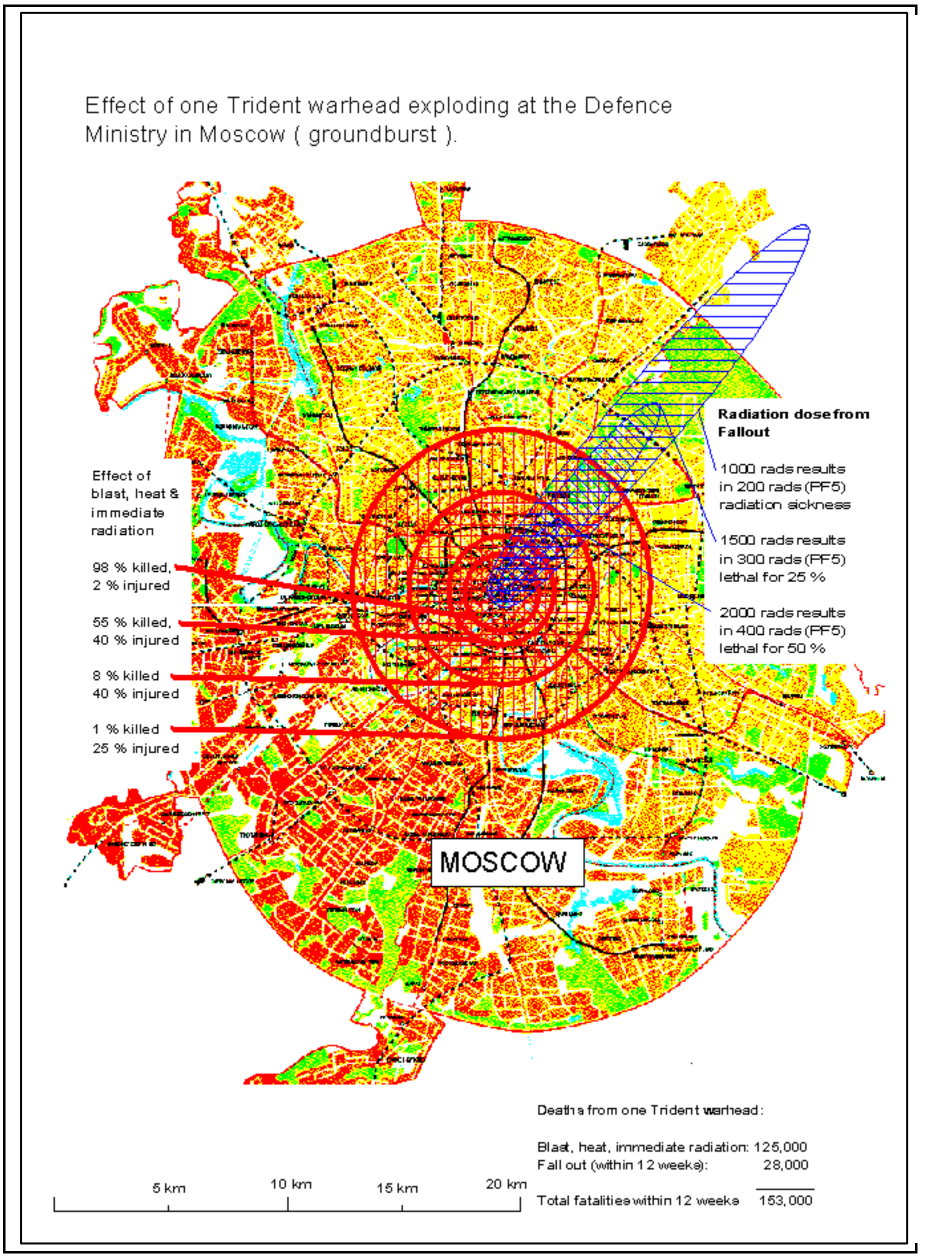
[156] Douglas Holdstock and Liz Waterston, "Nuclear Weapons, a Continuing Threat to Health", *The Lancet*, 355(9214), April 29, 2000, pp. 1544-1547.

[157] John Ainslie, *Trident: Britain's Weapons of Mass Destruction* (Scottish CND: Glasgow, 1999). Available at <http://www.banthebomb.org/archives/wmd/ch4mosc.htm>.

[158] "Effects of Nuclear Explosions", chapter 3 in *FM 8-9: NATO Handbook on the Medical Aspects of NBC Defensive Operations AMedP-6*, Department of the U.S. Army, Navy and Air Force, February 1996.

less than the burn casualties produced by one single small nuclear explosion…most of these beds are already occupied."[159]

New research also suggests that the use of 100 Hiroshima-sized nuclear weapons in a regional conflict would devastate the earth's ozone layer. It finds "losses in excess of 20% globally, 25–45% at mid-latitudes, and 50–70% at northern high latitudes persisting for 5 years, with substantial losses continuing for 5 additional years" from the heating of the stratosphere by smoke plumes released by nuclear-induced firestorms. This, the authors of the research argue, presents an "unprecedented hazard to the biosphere worldwide".[160]



[159] William Bell and Cham Dallas, "Vulnerability of populations and the urban health care systems to nuclear weapon attack – examples from four American cities", *International Journal of Health Geographics*, 6(5), 2007.

[160] Michael Mills *et al*, "Massive Global Ozone loss Predicted Following Regional Nuclear Conflict", *Proceedings of the National Academy of Sciences*, 105(4), April 8, 2008.