STATUS OF UK'S NUCLEAR FORCES

Nuclear weapons

Stocks

In its Strategic Defence and Security Review, published in September 2010, the UK government announced that it had a total stockpile of “not more than 225” Trident nuclear warheads and that this would be reduced to “not more than 180” by the mid 2020s.1

The UK Trident warhead shares some common features with the American W76 design, but it is not identical. At least three of the key components in the UK warhead are purchased from the United States, but the high explosive is British.2 In 1978 and 1979 the UK conducted a series of nuclear tests to develop its own small high-yield warhead design.3 This could be the basis of its Trident warhead. On the other hand, the UK received information on the W76 design from the United States in August 1980.4 The W76 is thought to have a yield of around 100 kilotons. An analysis of British nuclear tests between 1982 and 1991 suggests that the yield of the UK warhead is between 80 and 110 kilotons.5

For most of the Cold War, the UK deployed sub-strategic nuclear weapons. In 1993 the government abandoned its plan to build a new air-launched weapon, which would have continued this capability. The free-fall WE-177 nuclear bombs were reaching the end of their life. In order to retain some ability to launch a limited nuclear strike, the Ministry of Defence (MoD) allocated the sub-strategic role to its sole remaining nuclear force, Trident. In March 1998, George Robertson, Defence Minister, said that the UK “has some flexibility in the choice of yield for the warheads on its Trident missiles.”6 The White Paper on Trident replacement in December 2006 referred to “the continuing availability of a lower yield from our warhead.”7 The number of lower-yield warheads is not known, but these are likely to constitute only a small proportion of the total stockpile.

Deployed

The number of armed Trident submarines fluctuates because of the submarine refit cycle. Each submarine carries out a series of trials for around one year after completing a major refit. During this post-refit period, only two Vanguard class submarines are armed with Trident missiles. At other times, there are three armed submarines.

In 2010 each armed submarine carried a maximum of 48 warheads. The MoD is reducing this “over the next few years” to a maximum of 40 per submarine.8 This was implemented on one submarine by June 2011.9

Currently the UK maintains some warheads in an operational state in addition to those on submarines. In 2010 there were “fewer than 160” operationally available warheads. This is 16 more than the maximum number that could be carried on three armed submarines. Over the next few years the total number of operationally available warheads will be reduced to “no more than 120,” which is the same as the new maximum number for three armed submarines.10

Storage

Warheads that are not deployed on submarines are stored in the Re-entry Body Magazine at the Royal Naval Armaments Depot Coulport. Storage capacity at the warhead assembly site, the Atomic Weapons Establishment (AWE) Burghfield, is limited to work-in-progress and warheads awaiting dispatch.

Dismantlement

The decommissioning of WE-177 nuclear bombs was completed by March 1998.11 Disassembly of the Chevaline warhead, which was replaced by Trident, was completed by February 2002.12 AWE may still retain the plutonium pits from some of these warheads.

Delivery systems

The UK’s only nuclear delivery system is the Trident D5 missile. The US Strategic Systems Program (SSP) supplies all the components of the D5 system including missiles, launcher, fire control, guidance, and navigation.

The UK has tested a Trident D5 missile over a range of 5,000 nautical miles.13 When equipped with the Mk4 Re-entry Body, each missile can carry a total of 12 objects. Some of these are nuclear warheads and the remainder are decoys.

Until 2010 each of the two or three armed Vanguard class submarines carried between 12 and 14 operational D5 missiles. This will be reduced to eight missiles per submarine over the next few years.14
Fissile materials

When the UK government decided to acquire the Trident system, it calculated that it would need significant additional stocks of plutonium and highly enriched uranium (HEU).15 Plutonium was produced in the UK.16 HEU was procured from the United States.17 An analysis of published movements of plutonium through AWE suggests that Calder Hall and Chapel cross power stations produced over 1 tonne of weapon-grade plutonium for the Trident programme between 1985 and 1995.18 The stockpile of military plutonium rose to 3.5 tonnes by 1995, when the UK ceased production of fissile materials. In 1999 the MoD placed 0.3 tonnes of weapon-grade plutonium under international safeguards, leaving 3.2 tonnes which are not subject to these safeguards safeguards.19 The UK would appear to hold a substantial reserve of military plutonium, which is not subject to international safeguards, in addition to the material in warheads.20

In 2006 the UK government published a report on the historical accounting of HEU.21 This report is short on detail.22 It says that the total amount of HEU which the UK had acquired by 2002 was 26.36 tonnes. 4.72 tonnes of this had been removed, leaving a balance of 21.64 tonnes.23 The UK produced between 4 and 5 tonnes of HEU at Capenhurst between 1954 and 1962.24 This implies that the UK procured an additional 21-22 tonnes of HEU from the US between 1964 and 2002.25 The report does not say what form this material takes. Large quantities of HEU were acquired for the naval nuclear propulsion programme. Some of the stock will be in the form of fuel on submarines. A significant amount may be in used fuel cores which have been removed from submarines and stored at Sellafield.26 The size of the stocks held for future warheads and new fuel cores is not known.

The UK’s nuclear-powered submarine programme creates an ongoing demand for weapons-grade HEU.27 This may be met by placing new orders with the United States. The UK government is considering options for the acquisition of HEU for its Trident replacement programme.

Infrastructure

Nuclear warheads are developed and manufactured at the AWE sites of Aldermaston and Burghfield in Berkshire. The work at Aldermaston includes the production of plutonium, HEU, and Beryllium components and research into warhead design. Warheads are assembled and disassembled at Burghfield.

Vanguard class submarines operate from Faslane and nuclear warheads are stored at Coulport. Both sites are parts of HM Clyde Naval Base in Scotland.

Submarines are built at Barrow in Furness. The fuel cores for naval reactors are manufactured by Rolls Royce in Derby. There is normally one Vanguard class submarine in refit at Devonport dockyard. Rolls Royce operates a prototype submarine reactor at HMS Vulcan, Dounreay. It is planning to close down this reactor in 2015 but to keep on the workforce until 2030.28

The nuclear firing chain is a “substantial element” of the overall infrastructure which supports Trident.29 It includes Command, Control, Communications, and Computers (C4). There are three key facilities: the Nuclear Operations and Targeting Centre, underneath the MoD Main Building in Whitehall, London; Commander Task Force (CTF) 345, at the Permanent Joint Headquarters, Northwood, Middlesex; and Corsham Computer Centre, a deep underground bunker in Wiltshire that processes the UK’s fire control and targeting software. Launch instructions would be issued over all available frequencies from the Defence Communications hub, which is also at Corsham. The primary means of maintaining radio contact with submarines is over Very Low Frequency using two transmitters at Skelton and Anthorn in Cumbria.

The Strategic Weapons System Integrated Project Team (SWS IPT) at Abbey Wood in Bristol provides logistical support for the Trident programme.

Modernization

In December 2006 President Bush wrote to Prime Minister Blair, agreeing to support the British nuclear weapon programme. Bush referred to “the steps outlined in your letter to maintain and modernize the U.K.’s capability in this area for the longer term”.30

Warheads

Warhead Modification Program (Mk4A)

The US Departments of Energy and Defence have a joint program to upgrade their W76-0/Mk4 warheads to a new W76-1/Mk4A specification. In 2007 there was a UK project called the “Mk4A refurbishment programme”.31 Annual reports from the Defence Nuclear Environmental and Safety Board in 2006–2008 referred to a “Warhead Modification” program.32 The 2006 report described this as “the planned modification of the nuclear warhead (principally the Mk4A AF&F upgrade)”.33 The AF&F is the Arming, Fusing, and Firing system. The annual report from the Nuclear Weapons Regulator for 2004/5 also mentioned the “introduction of replacement AF&F”.34

Defence Ministers Lewis Moodie and John Reid failed to disclose the existence of the Mk4A upgrade project when questioned by Members of Parliament in 2002 and 2006.35 The MoD mentioned “some relatively minor upgrading and refurbishment” of the Trident
warhead in a memorandum to the House of Commons Defence Committee in 2006. In reply to a follow-up question Des Browne, Defence Minister, said on 18 December 2006: “We occasionally replace components of our nuclear warheads, if and when they become obsolete, but we have no plans to upgrade or refurbish our Trident warhead stockpile in the next five years.”

In 2007 AWE failed to censor an advert that was circulated to recruitment agencies. The advert was for a Warhead Electrical Engineer who would “support the approval program for the introduction of the Mk4A AF&F System into UK Trident”. The Guardian newspaper reported this on 14 March 2007. Only then did Browne acknowledge that the MoD was replacing the AF&F on the Trident warhead. On 4 December 2009 his successor, Bob Ainsworth, admitted for the first time that the AF&F on the British Trident warhead was purchased from the United States.

The replacement of the AF&F is not a minor upgrade. The US Departments of Energy and Defense designed the original W76-0/Mk4 warhead for the relatively inaccurate C4 missile. It did not intend to use the C4/Mk4 combination against hardened targets. The original AF&F was designed for airburst detonation. The US Navy subsequently deployed the W76-0/Mk4 warhead on the D5 missile, which is far more accurate than C4. In April 1992 the US Departments of Energy and Defense began a study into future warheads for Trident. One outcome of this study was the development of a new AF&F that would enable upgraded (Mk4A) warheads on D5 missiles to be effective against hardened targets.

The 1994 draft military characteristics for Mk4A included “near surface burst,” which was not an option for Mk4. This upgrade would improve the warhead’s effectiveness against hardened targets. The 1994 report indicated that the D5/Mk4A combination would be effective against a range of targets, the hardest of which would be SS-11 missile silos.

In 1997 Rear Admiral P Nanos, the Director of Strategic Systems Programs, wrote that the Mk4 was never given a fuse that made it capable of placing the burst at the right height to hold other than urban industrial targets at risk. With the accuracy of the D5 and Mk4, just by changing the fuse in the Mk4 reentry body, you get a significant improvement. The Mk4, with a modified fuse and Trident II accuracy, can meet the original D5 hard target requirement.

The US plan was to incorporate features from the Mk5 AF&F in the upgraded Mk4A. The Mk5 had been designed for attacking one of the hardest targets, SS-18 missile silos, with the higher-yield W88 warhead. The Mk4 AF&F is considerably smaller than the Mk5. Sandia National Laboratory in New Mexico, USA freed up space on the Mk4A by developing a single complex battery which replaces two batteries on the Mk5. Because it is newer, the electronics on the Mk4A are substantially more powerful than on the Mk5. The Mk4A has a new radar fuse and a sophisticated control system.

In 2007 Browne said that the Mk4A AF&F would be introduced “over the next decade” on UK warheads. The annual report from defence nuclear safety report in 2008 said that there were delays in the warhead modification project and that these were “symptomatic of the proximity of the UK introduction program to the completion of US development and production.” The first W76-1 warheads were delivered to the US Navy in 2009. So the upgraded Mk4A warhead is likely to enter service with the Royal Navy over the next few years.

In March 2011 Sandia National Laboratory announced that it had conducted “the first W76-1 United Kingdom trials test” at their Weapons Evaluation and Test Laboratory (WETL) and that this had “provided qualification data critical to the UK implementation of the W76-1.” One of the centrifuges in WETL simulates the ballistic trajectory of the W76/Mk4 submarine-launched reentry-vehicle.

One purpose of the American W76-1 programme is to extend the life of the warhead to match the revised life of the D5 missile, which is to remain in service until 2040. AWE has also been focusing on stretching the life of the UK Trident warhead. In 2001 a major objective of the UK nuclear weapons programme was to keep the warhead in service “over a period much longer than its originally intended service life.” This implies that the replacement date would be around 2032. In 2010 the government said that the current warhead would remain operational into the 2030s. Keeping the warhead in service for an additional seven years is likely to require a more extensive modification programme.

Details of the US W76-1 Life Extension project suggest components which AWE may refurbish or replace during their upgrade of the British warhead (see Table 1).

The US supplies the Gas Transfer System (GTS) for the UK Trident warhead. This GTS is a warhead component that stores tritium and injects it into the plutonium pit. In the early 2000s the US Department of Energy replaced the original W76 GTS, Heather, with a new model, Acorn. In 2004 AWE was introducing a replacement GTS, presumably Acorn, into British warheads. Los Alamos National Laboratory has designed an improved version, Acorn II, and this is part of the US W76-1 Life Extension program. Acorn II is likely to be part of the UK warhead modification programme.

The new GTS designs are more capable than earlier models. A review of US research and development in this area pointed out: “The tritium GTS can be the easiest way to improve the performance margin of an existing weapon without extensive rebuilding of the weapon.
or its nuclear components. Changes to the tritium GTS can sometimes compensate for the potential loss of performance margin due to aging or other phenomena.62

The high explosive will be replaced in the US warhead Life Extension programme and it can be assumed that AWE has similar plans. The proven 30-year life of PBX9501 high explosive is a key factor in establishing the projected life of the refurbished American W76-1 warhead. The UK warhead does not use PBX9501, but a British equivalent, EDC37. AWE has carried out a series of trials to extend the life of EDC37.63 However, it may not have been able to match the long life of the US explosive.

**Successor warhead**

The 1998 Strategic Defence Review said that the UK should not abandon its capability to design and build a successor to Trident.65 In 2002 the Chief Scientific Adviser carried out a review of the UK’s nuclear weapon infrastructure. This resulted in the Nuclear Warhead Capability Sustainment Programme (NWSCP).66 NWSCP had two aims: “maintain a minimum capability to design and produce a successor nuclear warhead should this prove necessary” and “maintain its existing warhead portfolio in a safe, secure and dependable state for an extended fixed period”.67 Clive Marsh, Chief Scientist at AWE, said that most of their research and development work focused on design capabilities, including the potential to develop a successor, as distinct from supporting the current warhead.68

The first stage in the revival of AWE was that AWE Management Limited (AWEML), which had taken over the establishment in 2000, changed the management and operational systems.69 This led, in 2003, to the MoD extending AWEML’s contract from 10 years to 25 years.70 In July 2005 the government announced the start of a large investment programme, under NWSCP, to rebuild facilities and recruit new staff.

The December 2006 White Paper said that a future parliament would have to decide “whether and how we may need to refurbish or replace the warhead”.71 However, refurbishment is probably only being considered as a short-term option. To sustain a nuclear force until the 2060s, the MoD is looking at replacement, with remanufacture of the current design a second choice. On 29 June 2007 David Gould, the senior official responsible for defence procurement, told an Industry Day meeting that their plan was “to replace the entire Vanguard Class submarine system. Including the warhead and missile.”72

In May 2011 the government said that a decision “on a replacement warhead” would be required in future.73 This decision, which had been scheduled for 2010–2015, was postponed to 2015–2020.74

The MoD has been keen to distinguish between having the capability to develop a successor warhead and taking the decision to develop such a weapon. For example, in November 2007 Defence Minister Des Browne told Parliament that there was “no programme to develop a new UK nuclear warhead”, but he acknowledged that there was ongoing work “to inform future decisions”.75

Browne added that some of this work was being undertaken with the US and that this “includes reference to the proposed US Reliable Replacement Warhead (RRW)”.76 In 2008 Frank Miller, who played a central role in US-UK nuclear relations, said: “They [the 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 thing for their W76 variant”.77 Jeffrey Lewis of Arms Control Wonk reported that the UK design was called the “High Surety Warhead”.78

There are a number of signs which indicate that AWE is not just sustaining generic capabilities for warhead development, but that it is developing designs as options for a successor warhead. The MoD set up a Warhead Pre-Concepts Working Group.79 There is also a UK Re-entry System (Options) program.80 AWE is the Coordinating Design Organisation for “potential successor warhead candidates”.81 There is a directorate within AWE responsible for work on the Successor, separate from other directorates which deal with Trident and Capability.82

### Table 1: US and UK modernization

<table>
<thead>
<tr>
<th>Component</th>
<th>US W76-1 Life Extension</th>
<th>UK Warhead Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arming, Fusing and Firing System (AF&amp;F)</td>
<td>New Mk4A (MC4700)</td>
<td>New US Mk4A (MC4700)</td>
</tr>
<tr>
<td>Gas Transfer System</td>
<td>New Acorn II</td>
<td>Probably new US Acorn II</td>
</tr>
<tr>
<td>High Explosive</td>
<td>Remanufacture PBX9501</td>
<td>Remanufacture EDC37</td>
</tr>
<tr>
<td>Canned Sub-Assembly</td>
<td>Refurbish</td>
<td>Not known</td>
</tr>
<tr>
<td>Interstage special material</td>
<td>Remanufacture Fogbank</td>
<td>Not known</td>
</tr>
<tr>
<td>Plutonium pit</td>
<td>Requalify each pit</td>
<td>Not known</td>
</tr>
<tr>
<td>Pit tube</td>
<td>Replace</td>
<td>Not known</td>
</tr>
<tr>
<td>Cabling</td>
<td>Replace</td>
<td>Not known</td>
</tr>
<tr>
<td>Detonators</td>
<td>Replace</td>
<td>Not known</td>
</tr>
<tr>
<td>Purge valve</td>
<td>Replace</td>
<td>Not known</td>
</tr>
</tbody>
</table>
AWE recently carried out a cost-benefit analysis of its Technology Division. One of the criteria in this analysis was support for future options. For each component in a successor warhead, the survey asked: Do we need a new design? Can we buy off the shelf? Can we work with a partner?83

Owen Price, a senior official at AWE, said the Establishment has been increasing the range of tasks that it can carry out, in order to improve its ability to design and build a new warhead.84 He highlighted systems engineering and warhead integration as two critical capabilities AWE will need to develop for a successor warhead programme.85 In 2006 AWE was recruiting engineers who would transfer warhead-to-weapon integration capability from the US to the UK.86

Three areas where AWE is working on new designs are AF&F, Gas Transfer Systems, and Neutron Generators.

The UK is developing an AF&F for a successor warhead. This is in addition to the Mk4A AF&F upgrade for the current warhead. The new initiative is a joint AWE, US Air Force, and US Navy project. The goal is “the development of a joint arming, fusing, and firing system for application to the Air Force Mk12A, the Navy Mk5 and a UK re-entry system.”87 This is related to UK successor warhead designs of a specific size.88 A joint working group of US Navy, US Air Force, and British engineers leads the work.89 Their plan is to use the same components, and possibly the same system, on the three weapons.

AWE is producing Demonstrators to test new AF&F concepts in laboratory conditions and in a relevant environment.90 They are developing electronics,91 circuit boards,92 High Integrity Software and Hardware,93 firing sets,94 and capacitors95 for AF&Fs. The engineers designing these components are expected to spend some of their time working in the US.96 Likewise, their American counterparts at Sandia National Laboratory have been told they will be collaborating with AWE.97

AWE is designing new Gas Transfer Systems (GTS). This includes developing “designs of hydrogen storage and delivery systems for possible future warheads”.98 The establishment has recruited staff to design new GTS and to test the new models in the UK and US.99 Specialists at Aldermaston are developing new pressure vessels and joining technologies.100 AWE is working with two American laboratories, Sandia and Los Alamos, to design “long-life GTS”.101 The laboratories have shared their advanced designs for GTS valves.

AWE recruited engineers and scientists, between 2006 and 2011, to develop new neutron generators and their components.102 In 2008 the Establishment was developing “novel neutron tube” designs for neutron generators in collaboration with the US.103

AWE’s research into AF&F, GTS, and Neutron Generators is unusual, because current practice is to buy these components from the US. Price says that warhead components that are currently procured from the US might, for the successor warhead, be designed and manufactured in the UK.104

One focus of recent warhead research is surety, which encompasses safety, security, and use control. The term “High Surety Warhead” has been associated with AWE’s new warhead and with the US Department of Defense’s proposal to merge the W88 and W78 warhead designs.105 The Enhanced Nuclear Safety Product Realisation Team at AWE is developing new surety concepts. Engineers are producing demonstrators of new components and testing them in laboratory and relevant environments.106 New strong-link safety systems are being developed.107 In 2009 Sandia National Laboratory was working with AWE on improved Magnetic and Electrical strong-link designs for future systems.108 Furthermore, Kansas City Plant is supporting UK work on new surety components.109

AWE is working closely with the Los Alamos and Lawrence Livermore National Laboratories on enhanced surety.110 This includes joint research into Multi-Point Safe warhead designs.111 Current warheads are designed so that they will not produce a yield if the explosive accidentally detonates at one point. A multi-point safe design should not produce any yield if the explosive detonates simultaneously at several points. Multi-Point Safety is a design objective set by the Defence Nuclear Safety Regulator in the UK, but AWE cannot meet this target by modifying the current design.112 This implies that its work on Multi-Point Safety is for a successor warhead. The US Department of Energy plans to develop its knowledge of a Multi-Point Safe design by 2016 and to understand the performance of this design in a realistic environment by 2018.113 AWE’s timescale is likely to be similar, or longer. One option for the UK warhead replacement will be a Multi-Point Safe design. But this may not be the most likely option. One Point Safe alternatives would be simpler and easier to certify.

AWE has recruited scientists to review alternative materials for use in future warheads. The current UK Trident warhead includes Beryllium.114 A future UK warhead might, like the proposed US Reliable Replacement Warhead design, introduce a replacement for Beryllium. AWE has been considering the use of Insensitive High Explosives (IHE) in nuclear warheads since 1977.115 It is likely that a future AWE design would incorporate IHE.

**Delivery systems**

**Modernization of the D5 missile system**

The US Strategic Systems Program (SSP) is extending the life of the D5 Trident weapon system. They are updating all the Trident subsystems: launcher, navigation, fire control, guidance, missile, and re-entry.116 All of these modernization measures apply to the system deployed on British submarines. In December 2006, US
President Bush wrote to Prime Minister Blair, saying, “We will work to ensure that the necessary components of the overall system are made available to the United Kingdom to support life-extended D5 missiles.”

The US Navy is ordering 24 new D5LE missiles each year. In addition, it is upgrading existing missiles. The D5 Life Extension (D5LE) missile is due to enter service in the Royal Navy towards the end of this decade.

A key part of the D5LE program is the development, by Charles Stark Draper Laboratory, of a new guidance system, Mk6LE. Draper is replacing the gyroscope, accelerometer, and stellar camera in the guidance module. The new system will use software rather than hardware for some functions. As a result, Mk6LE will be more flexible and easier to upgrade than the current Mk6 unit. The new guidance system will be able to “support new missions.” It will “allow for mission adaptability.”

Draper has, over several decades, improved the performance of missile guidance systems. The effect has been to make each new generation of ballistic missiles more accurate than the last. Its development of the Mk6LE is a continuation of this trend. The combination of new hardware and software in this advanced guidance system will improve the capability of the D5 missile.

In addition to replacing the guidance system, the US Navy is also building new flight electronics for the modernized D5LE missile. The new system will replace obsolete parts with modern components.

The Fire Control System (FCS) is a computerized network on the submarine which controls the launch of Trident missiles. SSP initially supplied the Mk98 Mod 3 FCS for British submarines. It replaced this with the Mod 5 in 2002/03. This upgrade was part of the SLBM Retargeting System, which was designed to increase the flexibility and speed of retargeting.

SSP has recently produced Mod 7, the next upgrade of the FCS. The first two Vanguard class submarines had been fitted with Mod 7 by April 2011. General Dynamics Advanced Information Systems (GDAIS) is designing a further modification, Mod 9. This will operate on British submarines in conjunction with the upgraded, Mk6LE, missile guidance system.

In addition, SSP is developing a new Shipboard Data System for the Trident FCS. This is due to enter service in 2012.

In September 2009, SSP commissioned work to develop the FCS system for the UK Successor submarine and the US Ohio replacement submarine.

The Trident navigation system provides information on the exact position of the submarine and is critical for missile accuracy. SSP is upgrading the navigation system in two phases. In the first stage, it will modernize some components while retaining the core system, Electro Static Gyro Navigation (ESGN). By 2014 it will update the Global Positioning System (GPS) and Navigation Sonar, and replace the Local Area Network (LAN). This initial navigation upgrade will be carried out on British as well as American Trident submarines. SSP will develop a new navigation trainer for Faslane naval base.

The second stage of the upgrade will replace ESGN with a new Inertial Navigation System (INS). SSP plans to achieve Initial Operating Capability of INS on US submarines in FY2020. It also plans to install INS on the UK Successor submarine.

The US Navy and Royal Navy are jointly developing a new Submarine Communications Buoy for very low frequency (VLF) communications with submarines. VLF is the primary method of issuing launch instructions to submerged Trident submarines.

Successor submarine

The UK government’s plan to replace the Vanguard class submarine was published in December 2006 and endorsed by Parliament in March 2007. Officials then drew up two families of options for the successor submarine. “Adapt Astute” would be an Astute class submarine, powered by a PWR2 reactor, with an added ballistic missile compartment. “Derived Submarine” would be a new design, powered by a new PWR3 reactor. It would “not only deliver a safer, but also a more capable submarine than the PWR2 Adapt Astute.”

This second option was described as “a new design developed from Astute technologies with updates where appropriate to achieve performance or improved availability, reliability and maintainability.”

On 18 May 2011, Defence Secretary Liam Fox told Parliament that the Government had selected the PWR3 (Derived Submarine) option for the successor submarine. Dr Fox said that the new submarine “will be powered by a nuclear propulsion system known as Pressurised Water Reactor 3, which will incorporate the latest safety technologies and ensure our future nuclear-armed submarines have the performance required to deliver our minimum credible deterrent out until the 2060s.”

The PWR3 reactor will be based on a modern American design. It will have a passive cooling system that can operate without coolant pumps. The new reactor will be quieter and more efficient. The US Navy developed reactors with passive cooling systems to reduce the noise made by nuclear submarines.

When the UK government decided to replace Polaris with Trident, one of the factors it considered was the vulnerability of the ballistic missile submarine (SSBN) to future anti-submarine warfare technology. Submarine design has progressed to make vessels progressively quieter. The US Navy is developing new stealth technology for the Ohio Replacement, on the assumption that the submarines will remain in service until the 2080s. They are working with the Royal Navy in a joint research program, from FY2010 to FY2014, to re-
duce the electromagnetic signatures of the Successor and Ohio Replacement submarines. The UK government’s choice of PWR3 for the successor submarine and the research into reduced electromagnetic signatures are signs that it plans to make the new submarine more difficult to detect than current vessels.

The US Navy is designing a Common Missile Compartment (CMC) for the British successor and US Ohio Replacement submarines. Initial research costs were paid by the UK, which will contribute 12.5% to the overall cost. The British CMC unit was initially designed for 12 missile tubes. In September 2010 the UK government announced that the new vessel would carry eight missiles. As a result, “work is ongoing with the US to look at how best to include our requirement for eight operational missiles into this design.”

The US government has decided that the D5 missile will be “the initial baseline mission payload” for the Ohio Replacement. It is designing the CMC around the specifications of D5.

Replacement submarine-launched ballistic missile

The intention is that the UK successor submarine will remain in service until the 2060s and the US Ohio replacement will be operational until the 2080s. The Life Extension programme for D5 will only sustain this missile until the early 2040s. D5 will not be available for most of the intended lives of the new submarines. The UK government has acknowledged that “investment in a replacement ballistic missile would eventually be needed.” Rear Admiral Benedict, head of the US Strategic Systems Program, has revealed that the Pentagon is considering sharing some of the development effort for a new ICBM and a new SLBM. He said “This is not a decision we can postpone through 2020–2030—this is a near-term decision that will affect sustainment and recapitalization.”

Infrastructure

Laboratories/production facilities

In November 2005 the MoD told the House of Commons Defence Committee about its plan to upgrade facilities at AWE. The MoD explained, “This additional investment at AWE is required to sustain the existing warhead stockpile in-service irrespective of decisions on any successor warhead.” However, an earlier document suggests that some of the new facilities are specifically for a successor warhead. In 2002 AWE was considering whether to build a new warhead assembly/disassembly facility at Aldermaston rather than Burghfield. One reason it did not locate the building at Aldermaston was that “there might not be sufficient room at Aldermaston to accommodate facilities for a successor programme as well as Trident.” If the MoD had not authorized substantial new investment in AWE then its warhead options for the successor system would have been limited.

The Nuclear Warhead Capability Sustainment Programme (NWCS) included “some 100 facility schemes focused at AWE over the next 20 years.” The work covers both research and production capabilities, with a combination of new build and refurbishment projects.

The government amended the AWE modernization program following the 2010 Value for Money Review. Some projects were cancelled, others modified and the future of several elements remains in doubt.

Research and test facilities

Laser (Orion)

AWE has a High Energy Density Physics programme, which provides information on the performance of materials in extreme conditions. AWE uses this data to build computer simulations of nuclear explosions. One of the goals the program is to give British scientists access to American research efforts. AWE has completed the construction of a new laser, Orion, which is many times more powerful than the earlier Helen laser. Orion was being commissioned during 2011. High Energy Density Physics research at Aldermaston is “typically in support of secondary physics”. Orion will be able to simulate, for a fraction of a second, the intense heat and extreme pressures that are experienced during the fusion stage of a thermonuclear explosion.

Hydrodynamics (Teutates)

The construction of new hydrodynamic facilities was part of the initial plan for the redevelopment of Aldermaston. AWE planned to have a new Hydrus facility in operation by 2015. It was to “surpass equivalent facilities elsewhere.” AWE played a leading role in developing the radiographic machines used in hydrodynamic tests. It was developing an Inverted Voltage Adder (IVA) machine for the first axis of Hydrus and carried out experiments at the American RITS-6 facility to develop the technology for this machine.

In November 2010 this plan was radically changed when agreement was reached with France on the Teutates project. Britain will support the construction of a new test facility in France. The French will move their current Airix x-ray machine to this new Anglo-French hydrodynamic facility, Epyrë, at Valduc. Epyrë will be operational for the French program in 2014 and for the
British programme in 2016. Teutates is a key part of a new Anglo-French Defence and Security Treaty.

Construction of the proposed Hydrus test facility in Aldermaston has been cancelled. But Britain will build a Technology Development Centre (TDC) at AWE by 2014. TDC will develop a second x-ray machine for Epure by 2019 and a third by 2022. A second firing point will also be established by 2022.

Airix has a similar performance to the first axis at the American DAHRT facility at LANL. It is significantly less powerful than the IVA machine that AWE were planning to build for Hydrus. Aldermaston's research into the latter is likely to form the basis for the second axis at Epure.

The proposed Hydrus facility had been due to play an important role in the US Dynamic Plutonium Experiment (DPE) program. According to documents from the US Department of Energy, "The Hydrus facility is deemed essential to aiding in DPE decisions in the 2015-2017 time frames." The capability sought by the US National Nuclear Security Administration (NNSA) will probably only become available at Teutates in 2019 at the earliest.

Although France and Britain will share the same research facility they will not share the detailed results from the experiments.

**Material Sciences Laboratory**

AWE plans to build a new Combined Non-Metalurgy and Material Science laboratory (Octans) at Burghfield. The Establishment has recruited new staff to work on material science. Its remits include the development of replacement materials for use in nuclear warheads.  

**Computing**

AWE has purchased supercomputers that have been amongst the most powerful deployed anywhere in the UK at the time. It acquired Blue Oak (2.8 teraflops) in 2002, then Redwood (34 teraflops) in 2006 and Blackthorn (145 teraflops) in 2010. It plans to build a 4,500 square foot computing complex, Project Orchard.  

**Manufacturing and production**

**Enriched uranium facility**

AWE is building a new Enriched Uranium Facility (EUF), Project Pegasus, which is due to be in service by 2016. The building will service "enriched uranium components" of current warheads and "undertake the specialised chemical and metallurgical operations needed to manufacture enriched uranium components for successor warheads to Trident, should they be built."

EUF has a similar role to the proposed new US Uranium Processing Facility (UPF) at Y-12. The main tasks of the American plant are to manufacture, assemble, and dismantle the Canned Sub Assembly and radiation case of warheads. The Canned Sub Assembly includes the secondary or fusion stage of a thermonuclear weapon and the radiation case is the special metal case that encloses the primary and secondary. The "enriched uranium components" which will be produced and handled by the EUF at Aldermaston are probably the radiation case and HEU part of the Canned Sub Assembly.

EUF will carry out the initial stage of the fabrication of fuel rods for naval nuclear reactors. It will also store enriched uranium and conduct surveillance and research into enriched uranium warhead components.

AWE is also spending £2 million refurbishing the current HEU facility, building A45.

**Warhead assembly/disassembly**

AWE has been given planning permission to build a new facility, Project Mensa, to assemble and disassemble nuclear warheads at Burghfield. Construction was due to start in 2010. The building will have Assembly Cells, where the high explosive and radioactive components of warheads are combined, and a Main Process Building. Mensa will "maintain the existing assembly/disassembly capability and fulfill the requirements of the warhead maintenance programme." It will be only slightly smaller than the current facility. It would appear to be designed to support a warhead stockpile of a similar size to that held by Britain in the 1980s and 1990s.

**Plutonium fabrication**

AWE will carry out a £278 million programme of refurbishment and modernization of building A90, which manufactures the plutonium pits for British nuclear warheads. A90 is a replica of building PF-4 in Los Alamos, which is the current American pit production facility.

**High explosives fabrication**

West Berkshire Council granted planning permission for a new High Explosives Fabrication Facility (HEFF), Project Circinus, at Aldermaston. This will process the high explosive for nuclear warheads. HEFF is located in the middle of the Western part of AWE Aldermaston, as far as possible from other facilities on the site, particularly those handling radioactive material.

**Conventional Manufacturing Rationalisation**

In 2008 West Berkshire Council granted AWE permission to build a Conventional Manufacturing Rationalisation (CMR) facility at Burghfield. This would replace several buildings at Aldermaston. The start to construction work was delayed and in April 2011 the Council renewed their permission, subject to advice from the Health and Safety Executive. AWE will use the building for the manufacture of non-nuclear components of nuclear warheads.

**Timescale and costs**

In November 2011 the government published details of £1,938 million capital expenditure at AWE, however this figure does not include all the proposed projects. The planned in-service dates and costs are:
• 2007/10—New office block for 1,200 staff (Gemini) (£78 m); IT servers (£32 m); office buildings (£27 m).
• 2010/15—High Explosives Fabrication (Circinus) (£231 m); Small Components Interim (Leo) (£16 m); High Performance Computing (Orchard); Laser (Orion) (£183 m); Technology Development Centre (Tueltas).
• 2016/20—Enriched Uranium Facility (Pegasus) (£634 m); Warhead Assembly & Disassembly (Mensa) (£734 m); Non Metallurgy and Material Science Laboratory (Octans).

The future of several projects is uncertain, following the Strategic Defence and Security Review. These include high explosives climatic trials, chemical processing (Astra), high explosives assembly for trials, and small components (Libra). 186

Other infrastructure
The 2006 White Paper said that the government expected to spend £2–3 billion, at 2006 prices, on infrastructure over the life of the successor submarine.187 The 2010 defence review indicated that the government “agreed to defer and potentially to remove over £1 billion of future spending on infrastructure over the next 10 years.”188 The postponement was for a period of ten years. 189 The submarine infrastructure facilities at Faslane, Coulport, Devonport, and Barrow each have a projected lifespan of 40 years. The MoD plans to extend the life of these facilities to keep them operational until 2040. 190 Its plans for the remaining projected life of the successor submarine, until the 2060s, are not clear.

In February 2010 Derby City Council approved a planning application from Rolls Royce to build a new manufacturing facility at Raynesway with 15,230 square meters of floor space.191 By 2017 the new facility will replace current buildings which are used for the manufacture of fuel cores for nuclear submarines.192 The Raynesway site also conducts research into naval reactors and propulsion systems. It is at the centre of the development of the PWR3 reactor for the successor submarine.

There were initial proposals to modernize the Nuclear Command and Control system or “Nuclear Firing Chain”. In November 2010 the Defence Minister announced that these plans had been postponed for ten years and might be cancelled.193

Timelines
Nuclear warhead
• Upgrade of current warhead to Mk4A: 2012–17?
• Stockpile reduction to 180 warheads: mid 2020s
• New warhead: decision 2015–20, in service 2030s

Missile
• D5 life extension: in service with the Royal Navy around the end of this decade
• New missile: in service 2040

Missile support systems
• Mk98 Mod 7 Fire Control System: 2011
• Shipboard Data System: 2012
• Upgrade of ESGN navigation system: 2014

Successor submarine
• Start of concept phase: 2007
• Initial Gate decision: May 2011
• Design and order for long lead items: 2011–16
• Main Gate decision: 2016
• First of class in service date: 2028
• Decommissioning: 2060s

Infrastructure
• AWE modernization 2005: 2020
• New manufacturing facility for submarine reactor fuel: 2017
• Shiplift (Faslane), Explosives Handling Jetty (Coulport) & Dry Dock (Devonport): plan to extend life to 2040
• Command and control upgrade: work postponed until after 2020.

A timeline in the December 2006 White Paper showed that the successor submarine would be withdrawn from service between 2050 and 2055. 194 This date has since been pushed back for two reasons. Firstly, the Coalition Government postponed the in-service date from 2024 to 2028. Secondly, it decided to adopt the PWR3-based submarine design. Had it opted for PWR2 then the new submarine would have had a projected life of 25 years with a possible extension to 30 years. PWR3 will be able to remain in service for longer;195 The May 2011 Initial Gate report says the submarines will be operational “until the 2060s”.196 The US Navy extended the life of its Ohio-class submarines to 40 years.197 It is possible that the new British submarines, with an American-designed PWR3 reactor, could remain operational until as late as 2070.

ECONOMICS AND POLITICAL ECONOMY
Annual expenditure on the UK nuclear weapons programme, including AWE, was between £1.1 and £1.2 billion in each year between 1998/9 and 2004/5.198 It increased to £1.7 billion in 2007/8 and 2008/9.199 In 2007, annual expenditure, including work on a replacement system, was projected to rise to £2 billion in 2009/10 and £2.1 billion in 2010/11. 200 Procurement costs alone were expected to amount to 3% of defence expenditure over the main period they were incurred.200 The current government has not published more recent estimates of annual costs.

Cost projections
In December 2006 the Labour government published outline estimates of the costs of modernizing
UK nuclear forces. In 2008 the National Audit Office argued that more detailed and robust figures should be produced when the project reached its Initial Gate. The Initial Gate decision was taken in May 2011. At this time the Coalition government published a short report but it did not include comprehensive and detailed cost projections. Capital costs published in December 2006 were:

- Submarines (four boats): £11-14 billion
- Warhead refurbishment/replacement: £2-3 billion
- Infrastructure: £2-3 billion
- Sub-total: £20-25 billion

The 2006 report also gave the following costs:

- D5 Missile Life Extension: £250 million
- Replacement missile: £1.5 billion
- Annual in-service costs: £1.5 billion
- Total cost: £20-25 billion

All of the above figures were based on 2006/7 prices. In May 2011 the MoD said that the submarine element would still be within the £11-14 billion range, at 2006/7 prices. It also gave a new figure for the submarines at outturn prices, including inflation in the year the costs would be incurred, of £25 billion. The MoD has not published the method used to produce this figure, but it suggests that the cost will be near the top of their earlier range, i.e. £14 billion at 2006/7 prices.

The figures published for the Trident replacement program do not include the costs of upgrading AWE. In November 2011, Peter Luff, Junior Defence Minister, indicated that the total cost of a list of AWE modernization projects would be £1938 at 2010/11 prices. The list did not include a new laboratory, the Technology Development Centre, and several other projects. The total amount of new money being spent on AWE, in addition to normal running costs, is significantly higher than this. Between 2005/6 and 2007/8, the government spent £1.1 billion on the construction of new facilities and the recruitment of additional staff, under the Nuclear Warhead Capability Sustainment Programme. This work continued beyond 2007/8, but the government has not released equivalent figures for later years. It has only published the overall costs of AWE. From these overall figures, it is possible to deduce that an extra £1.6 billion was spent in the years 2008/9-2010/11 and that a further £2 billion has been allocated for 2011/12-2013/14, over and above normal operating costs. The additional work includes the Mk4A warhead refurbishment programme as well as the construction and refurbishment of facilities.

Extending the life of the current Vanguard class submarines, in order to postpone the in-service date for the replacement, introduced extra costs. Parliament was told that an additional £1.3 billion would be required because of the need for three Long Overhaul Periods. However, this may have been exaggerated. One or more of these refits were probably already scheduled. It is unlikely that a postponement of four years would require three additional submarine refits.

**Comparative costs**

The £2 billion annual cost of Trident could instead pay for the construction of 100 new schools every year. In 2004 the Labour government launched a major Building Schools for the Future programme, which replaced secondary schools across England. This project was scrapped by Michael Gove, the education minister, in July 2010. The average capital cost of building a new school in 2007 was around £20 million.

Instead of funding Trident, the government could reverse its plans to cut welfare benefits for the disabled. The Welfare Reform Bill will introduce means testing for young disabled people and for those who have had cancer for more than one year. These measures are designed to save £1.6 billion, less than the annual cost of Trident.

**The impact of austerity measures**

Public expenditure in the UK is due to be cut by 5.3% between 2011/12 and 2016/17. The government’s aim is to reduce public spending from 46.6% of GDP to 39% of GDP. This is expected to result in the loss of 710,000 public sector jobs. The impact is likely to be greatest in the poorer areas of the UK. In January 2012 unemployment reached 2.68 million (8.4%), which is the highest it has been for 17 years.

One of the greatest changes is a 25% reduction in the amount that will be spent on pensions for public service workers. Workers in the public sector will be faced with working longer for a smaller pension. The age at which people will be entitled to a state pension has been raised. The greatest increase in the age limit applies to women.

In 2010 Liam Fox, the Defence Minister, acknowledged that there was a £38 billion black hole in the defence budget for the period 2010-2020. This projected shortfall rose to £42 billion if the costs of Trident replacement were included. The MoD is planning to cut its budget by £4.4 billion between 2011/12 and 2014/15. Most of the savings are scheduled for the later years in this period.

The regular army will be cut from 100,000 to 84,000. One of the two new Queen Elizabeth class aircraft carriers will be mothballed immediately after it is built. Nimrod maritime reconnaissance aircraft were scrapped after a £3.6 billion upgrade.

The number of MoD civil servants will be reduced by 40%. One of the sites which will be most affected is
the Defence Equipment and Support headquarters at Abbey Wood in Bristol. One quarter of the 8,000 staff members are expected to lose their jobs. One of Abbey Wood’s biggest projects is Trident replacement.

In January 2012 the Telegraph reported that the MoD was planning a further £2 billion cuts. An MoD source said that most of the savings would come from a “ruthless approach” to renegotiating existing contracts with the private sector. This second round of cuts was also expected to result in further reductions in civil service numbers.

Professor Malcolm Chalmers of the Royal United Services Institute has identified the Trident replacement programme as one of three projects that pose substantial financial risk to the MoD. He argues that it could wreck the government’s plan to bring the deficit in the defence budget under control.

In September 2010 the government announced that it had been able to make savings of £1.2 billion, at out-turn prices, in the Trident replacement programme from a Value for Money Review. It is not possible to assess how likely it is that these savings can be achieved, because the MoD’s explanation is incomplete. The projected cost of the Common Missile Compartment has been reduced by £250 million. In addition the MoD hopes to save £900 million across the whole nuclear-powered submarine program as a result of the Submarine Enterprise Performance Programme, through rationalizing facilities and improved contracting. Only part of this should be attributed to the Trident replacement project. The MoD has a poor record in controlling the cost of major projects, including the Astute class submarine, so this reduction may be an aspiration rather than a reasonable expectation.

The government claimed that the review would “reduce costs by £3.2 billion”. However, £2 billion of this figure is not true savings, but deferrals. It has postponed planned expenditure of £1 billion on infrastructure and £500 million on a replacement warhead to after 2020. The remaining £500 million deferral is not explained.

In May 2011 the government announced that it had chosen a submarine design with a new PWR3 reactor, rather than one based on the existing PWR2 reactor. This is likely to undermine their attempts to reduce costs, at least in the period prior to 2030. The capital costs of the PWR3-based design will be higher than the PWR2 option. The MoD said that selecting PWR3 would increase the cost by £50 million per boat over a 25-year life. The in-service costs for PWR3 will be lower, so the increase in the initial capital cost of the PWR3 option is probably more than £50 million per boat. The savings claimed in the Value for Money Review will be at least partly offset by the additional costs of the PWR3 option.

The Alternatives review, which is being led by Nick Harvey, was set up to placate the Liberal Democrat wing of the Coalition. It was initially thought that there was little chance that the government would seriously consider any radical proposals which it produced. However, the ongoing economic crisis may force a rethink. Options in Harvey’s review, such as reducing the submarine order from four to three or taking Trident off patrol, are likely to receive a more sympathetic hearing in Whitehall. While supporters of Trident within the MoD are unwilling to budge on either issue, the calls for change from other elements of the military and from the Treasury may start to have an impact.

The Value for Money Review introduced a delay of four years to the in-service date, to save money. This brought the UK programme close to the timescale of its US counterpart. On 26 January 2012 the US government announced that there would be a two year delay in the in-service date for their Ohio replacement. If the MoD sticks to its current timeline then it will find that costs will rise, because it will be out of step with American efforts. They may decide to push back the successor submarine in-service date by two years, which would reduce short-term costs. This might require a rethink of the policy of continuous patrols.

Private companies

The key UK-based companies in the Trident programme include BAE Systems, Babcock Marine, Rolls Royce, and Serco. BAE Systems operates the submarine construction yard at Barrow in Furness. Babcock Marine runs Devonport dockyard, which refits nuclear submarines, and support facilities at the Clyde Naval Base. Rolls Royce designs, manufactures, and supports the nuclear reactors on British submarines. Serco have a one-third share in AWEML. BAE Systems, Babcock Marine, and Rolls Royce are the three main contractors for the successor submarine. They are also the three Tier 1 suppliers in the wider Submarine Enterprise Performance Program (SEPP).

US-based companies involved in the UK Trident program include Lockheed Martin, Jacob’s Engineering, General Dynamics, and Electric Boat. Lockheed Martin is the lead contractor for the Trident missile system. The company also has a one-third share in AWE Management Limited (AWEML), which operates the UK nuclear warhead development and manufacturing facilities. Lockheed Martin UK maintains components of the Trident missile system at the Clyde Naval Base. AWEML, Lockheed Martin UK, and Babcock Marine are partners in a new joint venture that will be responsible for nuclear warhead and Strategic Weapon System activities at the Clyde Naval Base. Lockheed Martin manages Sandia National Laboratory, in the US, which has designed and produced “non-nuclear” components of the UK Trident warhead.

Jacob’s Engineering has a one-third share in AWEML. General Dynamics produces support systems for Trident, including the Fire Control System. Electric Boat assisted BAE Systems with the Astute programme and will give it support with the successor submarine.
In 2006 the UK government claimed that its plan to replace Trident was consistent with the nuclear Non-Proliferation Treaty (NPT) because “the NPT recognizes the UK’s status (along with the US, France, Russia and China) as a nuclear weapon state.” It also argued that the Treaty does not set a timetable for nuclear disarmament and does not specifically prohibit the updating of nuclear capabilities.

This implies that the UK government thinks it can continue indefinitely to retain and modernize its nuclear forces. Its current plan is not to keep nuclear weapons for a short period of a few years, pending unilateral progress on disarmament, but to introduce a new system that can remain in service until the 2060s.

The former president of the International Court of Justice (ICJ), H.E. Judge Mohammed Bedjaoui, pointed out that when the Court said, in its 1996 Advisory Opinion, that nuclear weapon states have an obligation to bring to a conclusion negotiations on nuclear disarmament under article VI of the NPT, this “is nothing more nor less than actually to bring about concrete nuclear disarmament.”

He added that the nuclear weapon states should “not betray the legitimate trust which the non-nuclear states could reasonably have invested in the hope that the promised negotiations would lead swiftly to an agreement on nuclear disarmament.”

The UK government’s plan to retain nuclear weapons for the long term is not consistent with negotiating in good faith to achieve disarmament.

Bedjaoui says that the ICJ’s failure to reach a conclusion in Point 2(E) of their Advisory Opinion, on the threat or use of nuclear weapons in an extreme circumstance of self defence, was influenced by suggestions that nations might develop low-yield, “clean” and “reduced-effect” nuclear weapons. He said: “The Court was unable to expunge completely and soundly this pseudo-scientific chiaroscuro which, thus distilled, finally managed to seep into some interstices of its reasoning.”

In 2010 Bedjaoui was asked for his view on the legality of a nuclear weapon system that deploys over 100 warheads, each with a yield of 100 kilotons (like the UK Trident force). He concluded:

Even in an extreme circumstance of self-defence, in which the very survival of a State would be at stake, the use of a 100 kt nuclear warhead (regardless of whether it was targeted to land accurately on or above a military target) would always fail the tests of controllability, discrimination, civilian immunity, and neutral rights and would thus be unlawful....

The modernization, updating or renewal of such a nuclear weapon system would also be a material breach of the NPT obligations, particularly the unequivocal undertaking by the nuclear-weapon states to ‘accompany the total elimination of their nuclear arsenals leading to nuclear disarmament’ and the fundamental Article VI obligation to negotiate in good faith on cessation of the arms race and on nuclear disarmament, with the understanding that these negotiations must be pursued in good faith and brought to conclusion in a timely manner.

Trident was not designed to launch one warhead against one target. The system is designed around a scenario when all of the missiles on a submarine are launched almost simultaneously. In the earlier Polaris system the UK submarine on patrol had to be able to launch its missiles at intervals of 20 seconds. This suggests that a UK Trident submarine, armed with eight missiles, would be able to launch all of its missiles in less than three minutes.

In 1998 the Scottish Campaign for Nuclear Disarmament estimated that a UK attack with 48 100-kiloton warheads on command bunkers in and around Moscow would result in 3 million fatalities in the short term. There would also be widespread long-term environmental damage, because the warheads would be detonated on the surface and not in the air.

The change announced in 2010, from 48 to 40 warheads per submarine, would reduce these figures. On the other hand, the UK always has two nuclear-armed submarines and often three. An attack with all of the warheads on three submarines, against similar targets, could result in 7 million short-term fatalities. The number of casualties would be higher if the warheads were deliberately targeted to maximize civilian damage.

In the light of Bedjaoui’s view of the illegality of an attack with a single 100-kiloton warhead, an attack involving many such warheads would be a breach of international law.

In November 2006 Phillipe Sands QC and Helen Law gave advice on the legality of the maintenance and replacement of the UK Trident system. They said:

If the position of the UK is that a nuclear deterrent remains necessary whilst there is the unascertainable risk of a future threat developing, this amounts to a de facto acceptance that the UK will never fully disarm. In our opinion, this can only negate the good faith with which the UK is required to negotiate to achieve nuclear disarmament under Article VI of the NPT.

The Mk4A warhead modification program and the upgrade of all elements of the Trident system are likely to enhance the targeting capability of Trident. Sands and Law argue that upgrades of this nature would be likely to increase the circumstances in which the UK’s nuclear weapons would be used and that this would be contrary to the UK’s obligation to pursue a diminishing role for nuclear weapons, as set out at the 2000 NPT Review Conference and reaffirmed at the 2010 NPT Review Conference.

Lord Murray, formerly the senior government law officer in Scotland, has questioned whether the upgrad-
The Warhead Modification Programme: The UK's Modernization Programme

The UK government has disclosed some of its plans for modernization, but there have been important limits to its transparency. It has tried to keep the Mk4A warhead modification program out of the limelight. The upgrading of AWE is presented as if it were disconnected from the development of a successor warhead. Blair's government argued that it was only planning to replace the submarine platform. It tried to censor an official's speech when it revealed that they would replace the warhead and missile as well.244

Each decision point has been presented as only a small step on the way. The government told MPs in March 2007 that parliament was only endorsing the concept phase of the programme for a successor submarine. When the next package of work was approved, in May 2011, MPs were told that the important Main Gate decision was still five years away. In July 2005 the government published the cost of the three years of its plan to modernize AWE. The full extent and cost of the programme have never been revealed.

Blair's government presented its case for modernization in the December 2006 White Paper and used this document to persuade parliament to back their proposal. The White Paper gave the misleading impression that status was not an important consideration. It said: “We maintain our nuclear forces as a means of deterring acts of aggression against our vital interests and not for reasons of status.”245 The status argument has been deliberately played down in official publications because of its implications for proliferation. The former UK Disarmament Ambassador, David Brough-t, described it as “pernicious” the notion that nuclear weapons give Britain a seat at the top table.246

Tony Blair contradicted the White Paper in his memoirs. He wrote: “I could see clearly the force of the commonsense and practical arguments against Trident, yet in the final analysis I thought giving it up too big a downgrading of our status as a nation, and in an uncertain world, too big a risk for our defence.”247 John McTernan, a former special adviser to the Blair government, put the case more bluntly: “If we didn’t have Trident we’d be Belgium. Some people would find that a comfortable place to be. I wouldn’t. If Britain is going to be a major power, Britain should have the kinds of weapons a major power has.”248 In 2011 Admiral Lord Boyd-Carpenter, a former Chief of the Defence Staff, wrote that unilateral disarmament would undermine the UK’s ability to remain a strong player on the world stage.249

Dr. Nick Ritchie has suggested that possession of nuclear weapons is tied up with aspects of Britain's identity as a nation, including how the country sees itself as a responsible, interventionist major power.250 One aspect of this identity is the special relationship which Britain feels it has with the US.251 Another is the sense that Britain should be above France and Germany in the pecking order of European states.

Bernard Jenkins MP argues that the UK should retain nuclear weapons to keep its place at the top table in nuclear disarmament negotiations.252 However the UK’s ability to play an active role in these talks is crippled by its dependence on US support for its nuclear programme. Britain’s role is not to question its key ally, but to support it. Frank Miller said that the main benefit that the US derives from assisting AWE is that the UK stands alongside the US in the dock when they are accused by other nations during discussions on disarmament.253

The 2006 White Paper said that no state had the intent and capability to threaten British vital interests with nuclear weapons. The 2010 National Security Strategy placed nuclear threats to the UK in the lower, second tier, of risks. In a situation where there is no identifiable threat, and where the status argument can only be whispered, UK governments have sought to justify their modernization programmes on the grounds that nuclear weapons are an insurance policy in an uncertain world.

In a key speech on Trident, Blair said that “the one certain thing about our world today is its uncertainty.”254 Supporters of British nuclear weapons have marshaled positive changes in world politics to justify Trident. Lord Robertson says that the fall of the Berlin Wall and the Arab Spring show how events cannot be foreseen, and that in such an unpredictable world Britain must have nuclear weapons.255

General Sir Hugh Beach challenges this reliance on uncertainty, arguing that “in no other area of military provision is the justification of a general insurance against the unforeseen accepted.”256 He describes the government’s rationale as “just-in-case” posited on a most unlikely concatenation of circumstances.257 Ritchie points out that we can’t predict the future, but
we can “outline robust parameters and undertake a
detailed analysis” of the specific threats presented in
Blair’s White Paper.256

The first scenario in the White Paper is a re-emerging
threat from Russia or China. Professor Michael Clarke
says that we were lucky to have survived the Cold War
without nuclear destruction.257 Ritchie points out that
we should reassess the real risks that we ran of nuclear
war by miscalculation and argues that British nuclear
weapons were only a peripheral concern for the Soviet
Union.258

The second scenario is of an emerging nuclear state.
The White Paper says that the UK should not allow
itself to be subject to nuclear blackmail from such a
state. Beach counters this by giving examples of how
nuclear threats have been ineffective.259 Ritchie points
out that a British threat to use nuclear weapons in this
situation would probably not be credible.260

The third scenario is state-sponsored nuclear terror-
ism. But intelligence agencies are not foolproof, as
witnessed in Iraq. Assigning blame would always be a
matter of disputable judgment and threatening nucle-
ar attack in such a situation particularly problematic.

UK government decisions about nuclear weapons,
since the 1960s, have focused on the argument that
“now is not the time” to disarm. Sir Michael Quinlan,
former permanent secretary at the MoD, said that each
set of decision-makers, over several decades, produced
“a set of rationales to clothe that gut decision.”261 Blair
wrote in his biography, “Imagine standing up in the
House of Commons and saying I’ve decided to scrap it.
We’re not going to say that, are we?”262

The White Paper rejected the argument that if Brit-
ain disarmed, then others would follow their example.
It said, “There is no evidence or likelihood that oth-
ers would follow the UK down a unilateralist route.”263

Lord Robertson said that there was no reciprocal re-
response from other countries to the reduction in de-
ployed UK warhead numbers which he announced in
1998—“there was no benign chain reaction.”264 He then
criticized China for increasing its nuclear arsenal and
Russia for modernizing its nuclear forces.

On the other hand, Professor Michael Clarke says
that British disarmament could have a significant posi-
tive effect on others. He argues that if Britain were to
scrap Trident this would be the most significant nu-
clear decision the world has ever seen.265 Professor
William Walker points out that such a move would be
unique because of Britain’s role in the early develop-
ment of nuclear weapons and its position as one of the
three custodians of the NPT.266 Walker adds that if Brit-
in disarm this would be far more dramatic than the
examples of disarmament we have seen so far. These
have been in the peculiar situations of the disintegra-
tion of the Soviet Union and the end of apartheid in
South Africa. Clarke adds that, even if others don’t fol-
low and we end up in an unstable scenario with more
nuclear-armed states, Britain would still be better off
by not being one of them.

A major criticism of British nuclear weapons policy is
that it sets a bad example for others. If Britain requires
nuclear weapons as an insurance policy in an uncertain
world, then every other nation in the world can say the
same. In response, the government falls back on Brit-
in’s position as a nuclear weapon state in the NPT.267
But this ignores the basic bargain of the Treaty—that
the nuclear weapon states are obliged to genuinely seek
to achieve disarmament.

Prime Minister Cameron describes the Trident force
as an “independent nuclear deterrent”.268 Beach points
out that most aspects of the system use American
equipment and it is hard to imagine Britain launching
a nuclear attack if the United States was opposed to
such action.269

Dependence on American support is a significant
driver for Britain’s modernization efforts. The Royal
Navy is determined to buy the latest American equip-
ment, so it is not left with the costs and problems of
sustaining an obsolete system. One of the main goals
of AWE’s research programme is to retain Britain’s unique
access to the closely guarded secrets of the US nuclear
laboratories. In return for this assistance, the United
States expects that the UK would join any nuclear co-
alition of the willing.270 The US-UK nuclear exchange
is based on the Mutual Defence Agreement, which is due
for renewal in 2014.

John Woodcock, the Member of Parliament for the
submarine town of Barrow, has been at the forefront of
arguing for the successor submarine, because it creates
jobs in his constituency. Similar arguments have been
presented by Jackie Baillie, the Member of the Scottish
Parliament for the area around Faslane. But, while the
Clyde Naval Base supports thousands of jobs, the gov-
ernment has acknowledged that only 464 civilian posts
at the site are directly related to Trident.271 The Scottish
Trade Unions Congress continues to oppose nuclear
weapons and has called for a programme of diversifica-
tion to enable these workers to be redeployed on other
projects, such as the construction of marine energy fa-
cilities.

The government uses safety and surety as arguments
to support the modernization of British nuclear forces.
For example, Liam Fox pointed out that the PWR3 re-
actor on the successor submarine would incorporate “the
latest safety technologies”. However these improve-
ments would not be made if the UK was planning to
dismantle its nuclear arsenal in the near future. The
reduced risk of an accident is outweighed by the in-
creased risk of the deliberate use of nuclear weapons if
there is no progress in tackling the conjoined issues of
proliferation and disarmament.

The Liberal Democrat party raised nuclear weapons
as a significant issue in the 2010 general election. They
challenged the view of the Conservative and Labour
parties, that Britain should build a new system with Submarine Launched Ballistic Missiles, and said that the UK should look for a cheaper alternative. Their range of options included having no nuclear weapons at all, although this was played down in their campaign. The election resulted in a Conservative / Liberal Democrat government. The coalition is based on a joint agreement. With regard to Trident, the agreement says the parties "will maintain Britain's nuclear deterrent, and have agreed that the renewal of Trident should be scrutinised to ensure value for money. Liberal Democrats will continue to make the case for alternatives."272

In May 2011 the government announced that Armed Forces Minister Nick Harvey, a Liberal Democrat MP, would lead a study into alternatives. This study will consider whether British nuclear forces must be submarine-based, if they are submarine-based whether they could deploy cruise rather than ballistic missiles, and if there has to be one submarine on patrol at all times.273 Speaking to the Liberal Democrat conference in September 2011, Mr. Harvey said that the study was looking at dual-use submarines, which could be deployed in a nuclear or conventional role.274 This could involve either Astute-class submarines or the proposed new successor submarine.275

The alternatives study has revived the issue of whether the UK has to keep one nuclear-armed submarine at sea at all times. The government position is that the UK has to have an assured second-strike capability, and that this is best be provided by Continuous At Sea Deterrence (CASD). An unlikely critic of this approach was Sir Michael Quinlan, for over thirty years the primary advocate of British nuclear deterrence. Shortly before his death he wrote:

The case for having a boat at sea used to centre, in my long-ago DUS(P) days, on the argument that in the Cold War setting we must maintain this ultimate level of insurance against the admittedly-remote hypothesis of super-power bolt from the blue. That hypothesis has surely evaporated. Can we not now assume, for any realistic scenario, that we would have some warning.276

Supporters of CASD say that if there was no submarine at sea, then decision-making in a crisis would be more difficult. Deploying a nuclear submarine might heighten tension at a crucial time. Quinlan said he was skeptical of this argument and he didn’t think it was worth the extra cost, of having four submarines rather than three. He also suggested that, in a crisis, the UK might want to deliberately deploy a submarine as a means of sending a signal to the opponent.

Harvey’s report on alternatives will be completed in late 2012, fifty years after the Cuban missile crisis. This coincidence of timing will provide an opportunity to highlight the real risks from flawed theories of deterrence operating in the real world of human fallibility and error. It may also help to focus minds on whether Britain needs today, and for the next 50 years, to keep one submarine on patrol at all times, waiting for a bolt-from-the-blue strike from a Soviet Union which long ago ceased to exist. Ending this posture would not only be a significant step in itself, but it could also be a way to unravel the UK’s plan to modernize its nuclear forces, because this plan is based on the requirement to keep a submarine at sea at all times.277

Philip Hammond, the current Defence Minister, has said that Harvey’s report will remain a closely guarded secret.278 But, in order to comply with the 2000 and 2010 NPT Review Conferences, the UK should be more transparent about this investigation and about all aspects of its modernization programme.

The Trident force operates from Faslane in Scotland. In March 2007 a majority of the MPs at Westminster who represented Scottish constituencies opposed the government’s plan to modernize British nuclear forces. In June 2007 the Scottish Parliament passed a motion which called on the UK government not to go ahead with this plan. The Scottish National Party (SNP), which is strongly opposed to Trident, has formed the Scottish government since May 2007. In May 2011 it won a majority in the Scottish Parliament.

The Scottish government will hold a referendum on Scottish independence in Autumn 2014. First Minister Alex Salmond has stressed that one of the main advantages of independence is that it would mean an end to nuclear weapons in Scotland.279 Officials in the MoD have admitted that it would not be feasible to move the nuclear weapons depot from Coulport to another site.280 A detailed review by Scottish CND of the alternatives found that none of the sites in England and Wales that were considered for Polaris in 1963 are viable today and that locating the UK nuclear force in the US or France would be very difficult because of the Non-Proliferation Treaty.281 A senior official in the MoD told the Telegraph that Scotland voting “yes” in the referendum would be a “unbelievable nightmare” for Trident.282

Some commentators have suggested that an independent Scotland would be forced to do a deal and that Trident would stay in Faslane.283 First Minister Salmond was asked in the Scottish Parliament whether this was a possibility. He replied: “It is inconceivable that an independent nation of 5.25 million people would tolerate the continued presence of weapons of mass destruction on its soil.”284 Opposition to nuclear weapons has consistently been stronger in Scotland than in England since the deployment of US Polaris submarines to the Holy Loch in 1961. Civic Scotland, including the churches and trade unions, has a long tradition of supporting nuclear disarmament. As Admiral Lord West, former First Sea Lord, has suggested, Scottish independence would be likely to lead to unilateral nuclear disarmament.285

Opinion polls suggest that the majority of Scots may not vote for independence in 2014. However, the
growing movement in this direction must raise serious question within the MoD of the viability of its plan to base nuclear weapons at Faslane until 2060. The perfect storm of the Scottish question and the economic crisis means that the UK nuclear weapons programme is more fragile today than at any time in its 50 year history, since the first British atomic test in October 1952.

NOTES

1. Strategic Defence and Security Review 2010, para 3.1. These figures were repeated by Liam Fox, Hansard, 28 June 2011.
2. The UK has purchased three W76 components—the Arming, Fuzing and Firing System, Gas Transfer System and Neutron Generator—from the US. Hansard, 4 December 2009. The UK Trident warhead contains EC37, a British explosive, rather than the American equivalent, PBX9501.
9. "The program for implementing the SDSR warhead reductions has commenced: at least one of the Vanguard Class ballistic missile submarine (SSBN) now carried a maximum of 40 nuclear warheads." Liam Fox, Hansard, 29 June 2011 Col 51WS.
13. Rear Admiral Stephen Johnson, head of the Strategic Systems Program, said that HMS Victorious had fired a D5 missile over a range of 5,000 miles from Florida to off the coast of Africa on 24 May 2009, in testimony to the Senate Armed Services Committee on 3 June 2009.
15. "The point has been reached where it is certain that the United Kingdom will need to procure significant quantities of highly enriched uranium, weapons grade plutonium and tritium from the US Department of Energy, at various rates from about 1985 for some ten years, in order to implement our future nuclear deterrent proposals". Letter from Margaret Thatcher to Ronald Reagan, 10 September 1981, TNA DEFE 25-435 e48-1.
16. In 1981 it was assumed that HEU would be purchased from the US because this was cheaper than building a new "Destiny" enrichment facility in the UK. Special Nuclear Materials—Background Note (for MISC 7), November 1981 TNA DEFE 24-2123. In 1987 the Defence Committee was told that final enrichment of HEU was carried out in the US. Progress of the Trident Programme, House of Commons Defence Committee report, HC 422, 1987/88 page 22.
20. For most of the period from 1969 to 1985 the UK military plutonium stockpile was around 2 tonnes. If each of the current warheads contains 4 kg of plutonium then the total amount in the current stockpile (less than 225 weapons) is less than 1 tonne, leaving 2.2 tonnes as a reserve. Much of this will have been in the form of pits for WE-177 and Chevaline warheads.
22. There are major gaps in its history of the British programme. The complex relationship with the US is mentioned in just one sentence. There is no reference to a known barter transaction with the US in 1964-9 and no explanation of how the UK obtained HEU for the Trident programme.
24. In February 1957 the plan was to produce 4940 kg of HEU at Capenhurst between 1958/9 and 1961/2. Cost estimates for plutonium and uranium 235 for the years 1958-65, Note by the Technical Policy Branch, Risley, February 1957, TNA AB16-3878 e12. There was a requirement for 3463 kg of HEU for Green Grass and Red Snow warheads between 1957/8 and 1961/2, TNA AB43- 92 e46, 4 May 1964. In 1996 the Stockholm International Peace Research Institute (SIPRI) estimated that Capenhurst had produced 3.8–4.9 tonnes of HEU, almost all of this between 1959 and 1961: http://nuclearweaponarchive.org/UK/UKFacility.html.
25. The official account of the HEU stockpile says that the two sources of HEU for the UK military programme were the Capenhurst plant (until 1962) and the United States. Historical accounting for UK defence Highly Enriched Uranium, op. cit. 7.5 tonnes were obtained from the US between 1964 and 1969 in exchange for plutonium. Plutonium and Aldermaston: a historical account, op. cit. This implies that the UK procured the remaining 14–15 tonnes of HEU from the US between 1970 and 2002.
27. British and American nuclear submarine reactors require HEU which is enriched to at least military grade.
30. Letter from George W Bush to Tony Blair, 7 December 2006.
33. Defence Nuclear Environment and Safety Board 2006 Assurance report. This says that the Safety Justification Plan for the warhead modification was due to be submitted in early 2007.
35. In 2006 Angus Robertson MP asked what discussions the MoD had held with the US on the Mk4A Reentry Body. Defence Minister John Reid replied, "officials from the Ministry of Defence regularly discuss a range of nuclear matters with their US counterparts under the auspices of the 1958 Mutual Defence Agreement," Hansard, 2 May 2006, Column 1353W. In 2002 Lewis Moody MP gave a similar reply to a question from Lynne Jones MP about W76-1, Hansard 6 February 2002, Column 997W.
37. Vacancy for a Warhead Electrical Engineer as advertised on planetrrecruit.com and beechwoodrecruit.com in 2007. In the description of this position on the Aldermaston website the words “Mk4A AF&F” were omitted. A similar position was advertised on the Aldermaston website in June 2009. This included the abbreviation "AF&F" but not "Mk4A.
40. A key Measure of Effectiveness for C4/Mk4, when it was original-
ly developed, was a target with a vulnerability number (VNTK) of 27Po. A target of this type would be destroyed by blast overpressure of around 50 psi, which is far less than required to destroy a hardened target. C4 achieved sufficient accuracy to be effective against 27Po. This measure of Effectiveness for C4/Mk4 was used again in 1994. Joint DoD/DoE Trident Mk4/Mk5 Reentry Body Alternate Warhead Phase 2 Feasibility Study Report, January 1994. P. 9-14.

4. MC2912, the AF&F in the Mk4 RV, has three fusing systems: Airburst Radar with 3 range options (prime), contact fuze (backup) and G-started timer (prime or backup). Survey of Weapon Developments and Technology, Sandia National Laboratory, February 1998, p. 485.


8. A near-surface burst detonates the warhead before it reaches the ground, but at a height where the fireball will touch the surface.


16. High Energy Density Physics, National Nuclear Security Administration, April 2001, Appendix G—United Kingdom Statement on High Energy Density Physics. One of the two goals of the Nuclear Warhead Capability Sustainment Programme is to keep the existing warhead in service over an “extended fixed period”. MoD Screening Decision Form (MoD Form No 1923) for the Nuclear Warhead Capability Sustainment Programme, 2007.

17. AWEML’s management contract was extended to 2025. AWE’s annual report said “The contract now covers the expected life cycle of the Trident system”. Annual report 2002, AWE. The 2006 White Paper said that the existing warhead was expected to remain in service until some point in the 2020s: Future of the United Kingdom’s Strategic Nuclear Deterrent, December 2006.

18. Trident Value for Money Review, Note by the Ministry of Defence, obtained under the Freedom of Information Act by Greenpeace.


22. The Acorn GTS was originally due to enter service in 1998, as part of Alteration 371 to the W76-0 warhead, but its completion was delayed by a few years. LANL Reflections, December 2002.

23. “Processing of the replacement tritium reservoir” at Coulport was an issue in the Nuclear Weapons Regulator Annual Report 2004-05, DNSB/06/05.


25. In 2000 AWE were conducting trials to extend the life of EDC37 from 10 years to 14 years.

26. Between 1978 and 1980 the MOD used the term “successor warhead” for the replacement for Chevaline, i.e. Trident. They are reapplying same phrase today for the future warhead.

27. It would be premature to abandon a minimum capability to design and produce a successor to Trident should this prove necessary”. Strategic Defence Review, 1998.

28. Discussion on Key Elements and Enablers of the UK Version of a Responsive Infrastructure, Heather Pragnell, A collection of papers from the 2007 PONI conference. Center for Strategic and International Studies, 2008, p. 73. NW CSP was based on proposals which were endorsed by the Defence Management Board (nuclear) in November 2002 and by Cabinet committee in January 2004. The description of these proposals was redacted in MoD Screening Decision Form (MoD Form No 1923) for the Nuclear Warhead Capability Sustainment Programme, 2007.

29. MoD Screening Decision Form (MoD Form No 1923) for the Nuclear Warhead Capability Sustainment Programme, 2007.

30. “Our research and 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 into this capability area”. Clive Marsh, Chief Scientist AWE, http://www.youtube.com/watch?v=GTQsCFkvl4.

31. Discussion on Key Elements and Enablers, p. 73.


33. The Future of the United Kingdom’s Nuclear Deterrent, December 2006, Cm 6994, p. 31.


37. Hansard, 19 November 2007, Column 483W.

38. Written answer by Des Browne to question from Nick Harvey, Hansard, 19 November 2007, Column 483W.


42. “Re-entry Systems (Options): Options are now being considered by SWPT and AWE for the maintenance of nuclear warhead capability for current and future SSBNs. When variability of ISD for any successor warhead is factored in, a quite complex picture emerges in which continuing research and development of warhead technologies and features is a central theme. DNSR has
good visibility of and engagement with the ReS(O) programme.” Defence Nuclear Environment and Safety Board 2009 Assurance report.


82. “At AWE, this portfolio of experience is spread across the Trident, Capability and Successor Directorates”. “How Much Science Is Enough?” op. cit., p. 53.

83. On the basis of this approach, the analysis identified the warhead capabilities at AWE which were most important. The conclusion of Cox and Farr’s paper was that cuts at AWE should focus on discrete areas. Across the board reductions would be less efficient. “How Much Science Is Enough?” op. cit., p. 57–60.

84. AWE’s capacity to carry out certain tasks was at a low ebb in the late 1990s. In some areas they retained the ability to specify work, but not to carry it out themselves. Owen Price, “Must Life Extension Compromise Responsiveness?” A collection of papers from the 2005 PONI conference series, Center for Strategic and International Studies, 2006, p. 113f.

85. Owen Price, op. cit., p. 120. A key aim of the Technology Division at AWE is to improve systems engineering and warhead integration skills—“How Much Science is Enough?” op. cit., p. 51.

86. The Senior Systems Engineer was to “lead a team of AWE engineers on long-term overseas secondment for the purposes of AWE systems integration capability development” and “to support the development of a warhead-to-weapon system integration.” The Deputy Team Leader for Weapon Integration was to “implement a strategy to transfer systems integration capability from the overseas team to the core UK programme.” The Senior Systems Engineer was to be based at the “suppliers facility,” which is probably the Systems Engineering facility at Sandia National Laboratory. Jobs advertised at awe.co.uk, accessed in June 2006.


88. One task in the AF&F project, to be carried out in FY2011, was to “document enveloping requirements to support Navy, Air Force and UK applications,” US Navy Research, Development, Test & Evaluation budget FY2012, BA7 PE 001221N Strategic Sub & Wpn Supt, February 2011. The UK successor warhead will probably be designed to fit into the US Mk5 Re-entry Vehicle.


94. Vacancies for Firing Unit Mechanical Designer and Electronics Engineer, accessed 25 April 2011.


96. “Liaise with overseas colleagues … longer-term secondment overseas may be required to support collaborative activities” Vacancy for Senior Digital Electronics Research and Development Engineer, accessed 25 April 2011.

97. SNL vacancy for Weapons Systems Engineer, accessed 10 July 2011. The scope of this post includes “support arming, fusing, and firing (AF&F) architecture development.” The employee is expected to “participate in advanced architecture studies in collaboration with the Department of Defence and the United Kingdom Atomic Weapons Establishment”.


100. AWE vacancies for Pressure Vessel Engineer—Gas Transfer (12 November 2007), Joining Engineer—Gas Transfer (12 November 2007), Senior Pressure Vessel Engineer—Gas Transfer (12 November 2007).


104. Owen Price, op. cit.


109. “KCP supports the Enhanced Surety subprogram of the Engineering Campaign through participation in specific component maturation efforts in support of Enhanced Collaboration with the United Kingdom” NNSA FY2012 budget, Weapons Activities, Engineering, Enhanced Surety. In November 2011 AWE was advertising for a manager who would “act as the UK Point of Contact for a specific US collaboration”. This post would be accountable to the Team Leader Surety Integration and Technology Division. Post for Major Task Manager advertised on the AWE careers website, 13 November 2011.

110. “Development and certification of Multi-Point Safety options for the next insertion opportunity will continue … with some continued effort through the enhanced collaborations with the United Kingdom” NNSA budget FY 2012, p. 98. "Los Alamos National Laboratory and Lawrence Livermore National Laboratory will continue to develop multi-point safety options working in collaboration with the United Kingdom”: NNSA Budget FY2010, p. 105. In 2009 “parametric material studies” were carried out on Multi-Point Safety at LANL and LLNL through collaboration with the United Kingdom to bracket technologies: NNSA Budget FY 2011, p. 102.

111. “In principle increased nuclear safety can be achieved by designing a WH [warhead] to be Multi-Point Safe (MPS). Whilst theoretically possible, physical or technical impracticality has prevented MRS being achieved in current WH designs. It shall be a design objective for nuclear WHs to be MRS.” JSP 538 Regulation of the Nuclear Weapons Programme, MOD, March 2005, Annex F Nuclear Weapon Safety Principles and Safety Criteria, p. 10.


113. Beryllium components of the Trident warhead are manufactured in Bay 2 of building A90 in Aldermaston.

114. A “very secure high explosive” was considered for a replacement for WE177, UK Nuclear Weapons Programme, 30 May 1977, TNA PREM 16-182 E80. A study was recommended into the “potential military and political value of TATB if large weapons could be used” for a replacement for WE177, WE177 studies, 30 August 1977, TNA DEFE 70-783 e1.


117. 36 missiles were ordered prior to FY2010 and 24 in each year from FY2010 to FY2012. FY2012 budget Weapons Procurement, Navy/BA-1 Ballistic Missiles, 1250 Trident II modifications, February 2011.

118. The Future of the United Kingdom’s Nuclear Deterrent, Cm 6994, MOD/FCO, December 2006.
http://www.draper.com/profile_boost_guidance.html

A solid-state Interferometric Fiber Optic Gyroscope (IFOG) will replace the current mechanical gyros, an Alternate Pendulous Inertial Gyroscopic Assembly (Alt PIGA) that will replace the current PIGA accelerometer. Charles Stark Draper Laboratory and the E2V Corporation have designed a new stellar camera. www.akama.com/company/The_Charles_Stark_Draper_Laboratory_Inc_a2746333485.html; A simulation-based Integration Approach for the First Trident Mk6 Life Extension Guidance System, presentation to the AIAA Missile Sciences Conference, Monterey, 18-20 November 2008.

Explorations, Winter 2004 and Spring 2006, Draper Laboratory.

Explorations, Spring 2006, Draper Laboratory.

Explorations, Spring 2006, Draper Laboratory.


"Since the development of MKI, Draper has significantly improved the reliability and accuracy of the follow-on systems, continuing today with the development of the MARK 6 MOD 1 system." Mk6 Mod 1 is an alternative name for Mk6LE; see www.draper.com/Documents/Flier_Strategic.pdf.

http://www.archive.org/stream/departmentofdefense072004unit//departmentsofdefe072004unit_djvu.txt. Both the new flight electronics and the Mk6LE guidance unit use new radiation-hardened computer parts.

Written answer by Adam Ingram to question from Angus Robertson, Hansard, 18 June 2004.


Solicitation Noo0309-07-G-004X7Y9, Mk6 LE 344 update 26 August 2009, www.fbodaily.com; Mk98 Mod 9 is part of the SSP Shipboard Integration (SSI) increment 4.

Justification and approval for use of other than full and open competition, contract Noo0309-08-C-041, SSP, www.fbodaily.com. The Shipboard Data System is SSI Increment 2.


Class justification and approval for use of other than full and open competition, SSP, 17 September 2009, www.fbodaily.com.


Draft request for proposal (DRFP) Noo0309-10-R-0018, SSP, 24 June 2009, www.fbodaily.com; the second navigation upgrade is SSI increment 8.

FY2012 budget, Navy RDT&E, BA 5 Development & Demonstration, PE 0604593N SNN-688 and Trident Modernization.

Safety regulator’s advice on the selection of the propulsion plant in support of the future deterrent review note, DNSR/22/12/2, 4 November 2000; Defence Board reports on its Successor Submarine Project. The section quoted had been redacted but was accidentally released on the House of Commons website.


The United Kingdom’s Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011.

Successor Submarine Project—Update, DER Capability, 24 November 2009, Defence Board report (09)/62 Successor Submarine Project.


Rear Admiral Andrew Mathews Director General Submarines, "Showing the US the way?" 17 January 2008.

Natural circulation was first introduced in the S5G reactor on USS Narwhal. As a result this was the quietest submarine in the US Navy. A derivative of S5G is installed on US Ohio Class (Trident) submarines.

FY2012 budget, Navy RDT&E BA 4 Advanced Component Development and Prototypes, PE 0603560N, Advanced submarine system development.


"We will also reduce the number of operational missiles on the Vanguard class submarines to no more than eight," Hansard 19 October 2010 Col 801; “We can reduce the number of operational launch tubes on those new submarines from 12 to eight”—statement by Prime Minister David Cameron, Hansard 19 October 2010, Col 801.

The United Kingdom’s Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011.


The United Kingdom’s Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011.


The future of the UK’s Strategic Nuclear Deterrent: Written evidence from the Ministry of Defence, HC 835 2005/06 EV 5

Recommendation for the AWE Burghfield Site, AWE, 3 December 2002. This also said, “There is insufficient space at Aldermaston alone to accommodate the new operational facilities in the Company’s Major Investment Schemes and those that would be required for any Successor Programme.” A list of requirements for the Aldermaston site in this report included “future facilities for a successor system”.

[The MoD press statement] dissociates the funding from any decision on the future of Trident—this is required irrespective of decisions on a successor warhead. However, in the absence of this funding, it might be reasonable to assume that intellectual and infrastructure capabilities future options would have been more limited or less credible.” Owen Price, op. cit., p. 16.

MoD Screening Decision Form (MoD Form No 1923) for the Nuclear Warhead Capability Sustainment Programme, 2007.

Nick Bennet—DG Strat Tech, “Future Nuclear Deterrent Industry Day, Nuclear Warheads Capabilities Infrastructure Capabilities future options would have been more limited or less credible.”


Dr Daryl Lanberg, Chief Scientist AWE, “Warhead assurance under CTBT constraints,” PONI Fall Conference, 21 September 2010.


Demonstration of the Self-Magnetic-Pinch Diode as an X-ray Source for Flash Core-Punch Radiography, SNL, 2007. Similar experiments were continuing in 2009. Fiscal Year 2009 Program Implementation Plan, Directed Stockpile Work, Research and Development Program. NNSA, Revision 3, 26 August 2009, p. 37. RITS-6 is a testbed for pulsed power.


170. Reply by Bob Ainsworth to question from Norman Baker, Hansard 26 June 2008 Col 449W. The AWE Site Development Strategy Plan 2003 said that material science research would be consolidated at a small number of facilities at Aldermaston and Burghfield.

171. The remits of AWE vacancie includes—develop new organic materials (Organic materials chemist), investigate novel materials (Inorganic materials chemist), strengthen capabilities in new product development (head of material science research), understand the synthesis of new materials (theoretical chemist), develop new replacement materials (NMR spectoscopist), and research alternative materials and processes (graduate student).

172. Dr Daryl Landeg, “Warhead assurance under CTBT constraints,” PONI 2010 Fall Conference, 21 September 2010. A teraflop is a trillion calculations per second.

173. Reply by Bob Ainsworth to question from Norman Baker, Hansard 26 June 2008 Col 449W; reply by Des Browne to question from Nick Harvey, Hansard 7 January 2008 Col 29W; and AWE Site Development Context Plan (SDCP08) 2005-15, April 2008.


178. Reply by Peter Luff to question from Caroline Lucas, Hansard, 27 January 2011, Column 476W.


180. Project Mensa: High Level Nuclear Design Philosophy. Design and Access statement Project Mensa, AWE, Submitted to West Berkshire Council as part of the planning application for Project Mensa.

181. The floor space for Mensa is 26,573 sq m and this will replace a current facility of 30,000 sq m.

182. Reply by Peter Luff to question from Caroline Lucas, Hansard, 27 January 2011, Column 476W.

183. Reply by Peter Luff to question from Caroline Lucas, Hansard, 27 January 2011, Column 476W.

184. Reply by Peter Luff to question from Caroline Lucas, Hansard, 22 November 2010, Column 272W.

185. Reply by Peter Luff to question from Caroline Lucas, Hansard, 22 November 2010, Column 272W.

186. The Future of the United Kingdom’s Nuclear Deterrent, December 2006, Cm 6994.


188. Reply by Liam Fox Hansard 3 November 2010 Col 855W.

189. Nuclear submarine infrastructure—sufficient to minimise future costs, DES-MI LoD-Infra-01/03, 7 July 2010, obtained under the Freedom of Information Act by Greenpeace.

190. http://www.derby.gov.uk/DR/dodnlyres/FDFoocoCB-355B-461E-9C03-2E34C8CC77BF0/10090366CommitteeReport.pdf. This planning application had originally been approved in November 2008 and was resubmitted with minor changes.

191. The current fuel manufacture plant is scheduled for decommissioning in 2017; A review by the Health and Safety Executive’s Nuclear Installation Inspectorate of the strategy of Rolls Royce Marine Power Operations Ltd for the decommissioning of its nuclear sites, HSE, 2002.

192. Reply by Liam Fox Hansard 3 November 2010 Col 855W.


194. PWRJ has a “longer in-service life”; The United Kingdom’s Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011, para 3.1.

195. Ibid., para 3.1.


197. Written answer by Bob Ainsworth, Hansard, 3 June 2008.


201. Ibid.


204. The Future of the United Kingdom’s Nuclear Deterrent, Cm 6994, MOD/FDCO, December 2006.

205. The December 2006 White Paper said the annual in-service costs would be equivalent to 5-6% of the Defence Budget. The MoD said that this would be £45 billion in a Memorandum from MoD to the Defence Committee, 19 February 2007, published in The Future of the UK’s Strategic Nuclear Deterrent: the White Paper, 9th report from the House of Commons Defence Committee 2006/7, 27 February 2007.

206. The outturn figure was used to illustrate that less than 15% of the total expenditure would be incurred before the Main Gate decision. The United Kingdom’s Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011.

207. Reply by Peter Luff to question from Caroline Lucas, Hansard 22 November 2011, Column 272W.


209. Total AWE costs for 2005/6 to 2007/8 were £2024: Written Answer by Liam Fox, Hansard, 15 November 2010, Column 95W. As £1.1 billion was additional funding, the routine costs of AWE in 2005/6-2007/8 were around £300 million per year. Total AWE costs from 2008/9 to 2010/11 were projected to be £258 million: Written Answer by Liam Fox, Hansard, 3 June 2010, Column 78W. Total AWE costs from 2010/11 to 2012/13 were projected to be £1 billion per year: Written Answer by Liam Fox, Hansard, 26 October 2010, Column 204W.

210. When asked how much the government was spending on the Mk4A refurbishment project, Dr Fox replied, “The AWE costs associated with the Mk4A modification form part of the Nuclear Warhead Capability Sustainment Programme, which cannot be distinguished from the AWE management and operation costs,” Hansard, 11 November 2010, Column 450W.

211. Written Answer by Liam Fox, Hansard, 22 October 2010, Column 88W.


214. Economic and fiscal outlook, Office for Budget Responsibility, Cm 8218, Presented to Parliament by the Economic Secretary to the Treasury by Command of Her Majesty, November 2011, Column 272W.


221. "It’s £42 billion if you include the deterrent": Ibid.
228. Ibid.
229. Ibid.
230. “Overall the PWR3 Derived Submarine will not only deliver a safer, but also a more capable submarine than the PWR2s Adapt Astute. The dominant sacrifices between the options are therefore in cost and in schedule risk.” Safety regulators’ advice on the selection of the propulsion plan in support of the future deterrent review note, Andrew McFarlane, Head of the Defence Nuclear Safety Regulator, November 2009, Defence Board report (09/62), obtained by Scottish CND under the Freedom of Information Act.
231. PWR3 has “lower through-life maintenance costs”: The United Kingdom’s Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report, May 2011, para 3.1.
232. Ibid., para 4.2
235. Ibid., p. 72–73.
236. Ibid., p. 63.
238. Naval Staff Requirement (NSR) 7959, 1972 TNA DEFE24-1081 e31 NSR 7959 set out the requirement for an upgrade to Polaris and was the foundation for the Chevaline system.
241. Note by Lord Murray for a Scottish Government Summit on a Future Without Nuclear Weapons, 22 October 2007. Lord Murray is a former Lord Advocate, the senior Government law officer in Scotland, and also a former Judge on the High Court of Justiciary and Court of Session.
242. Speech by David Gould, Chief Operating Officer, Defence Equipment and Support, to the Future Deterrent Industry Day at Abbey Wood, Bristol on 29 June 2007. The phrase “including the warhead and missile” was redacted from the speech when it was first released to the Scottish Campaign for Nuclear Disarmament. It was only disclosed following a review under the Freedom of Information Act. The MoD argued that Gould had been mistaken.
rent there would be other valid uses to which the submarines could be put and you wouldn’t be tearing up that vast amount of expenditure. You would just be putting assets to different uses.” Nick Harvey, quoted in Joel Shenton, “Dual-use nuclear subs a ‘game-changer.’” Defence Management, 21 September 2011, www.defencemanagement.com/news_story.asp?id=17502.

275. “Whether it’s the dual use of an Astute or an adapted Astute submarine or if that’s too expensive – which it might prove to be – dual use of the planned successor in similar ways to what the Americans have done, it’s a game-changer.” Nick Harvey, quoted in Joel Shenton, op. cit.


277. One of the assumptions in the 2010 Value for Money Review was that the force would be required to sustain “continuous at sea deterrent patrols”: “Trident Value for Money Review,” Note by the Ministry of Defence, obtained under the Freedom of Information Act by Greenpeace.

278. “In looking at alternative systems and posture, the review draws upon highly classified technical, intelligence and policy information covering extremely sensitive national security issues. There are, therefore, no plans to publish either the report or the information it draws upon” Philip Hammond, reply to question from Jeremy Corbyn, Hansard, 21 November 2011, column 34W.

279. Alex Salmond told the SNP conference in October 2011 that giving Scotland more powers, short of full independence, would not be enough: “All good, all necessary, but not good enough. Trident missiles would still be on the Clyde, we could still be forced to spill blood in illegal wars, such as Iraq, and we would still be excluded from the councils of Europe and the world.” SNP conference report, BBC, 22 October 2011.

280. “Berths would not be a problem—there are docks on the south coast that could be used without too much fuss. But there simply isn’t anywhere else where we can do what we do at Coulport, and without that, there is no deterrent.” James Kirkup, “Nuclear subs will stay in Scotland, Royal Navy chiefs decide,” The Telegraph, 26 January 2012, www.telegraph.co.uk/news/uknews/defence/9043092/Nuclearsubs-will-stay-in-Scotland-Royal-Navy-chiefs-decide.html.

281. If the UK nuclear force was based in the US or France then the UK would have to build new unique facilities rather than using those of the host country, because the weapons would have to remain under UK control at all times. John Ainslie, Trident—Nowhere to Go, Scottish CND, January 2012.


285. Admiral West speaking on Radio 4 as quoted in the Daily Record, 30 December 2011.