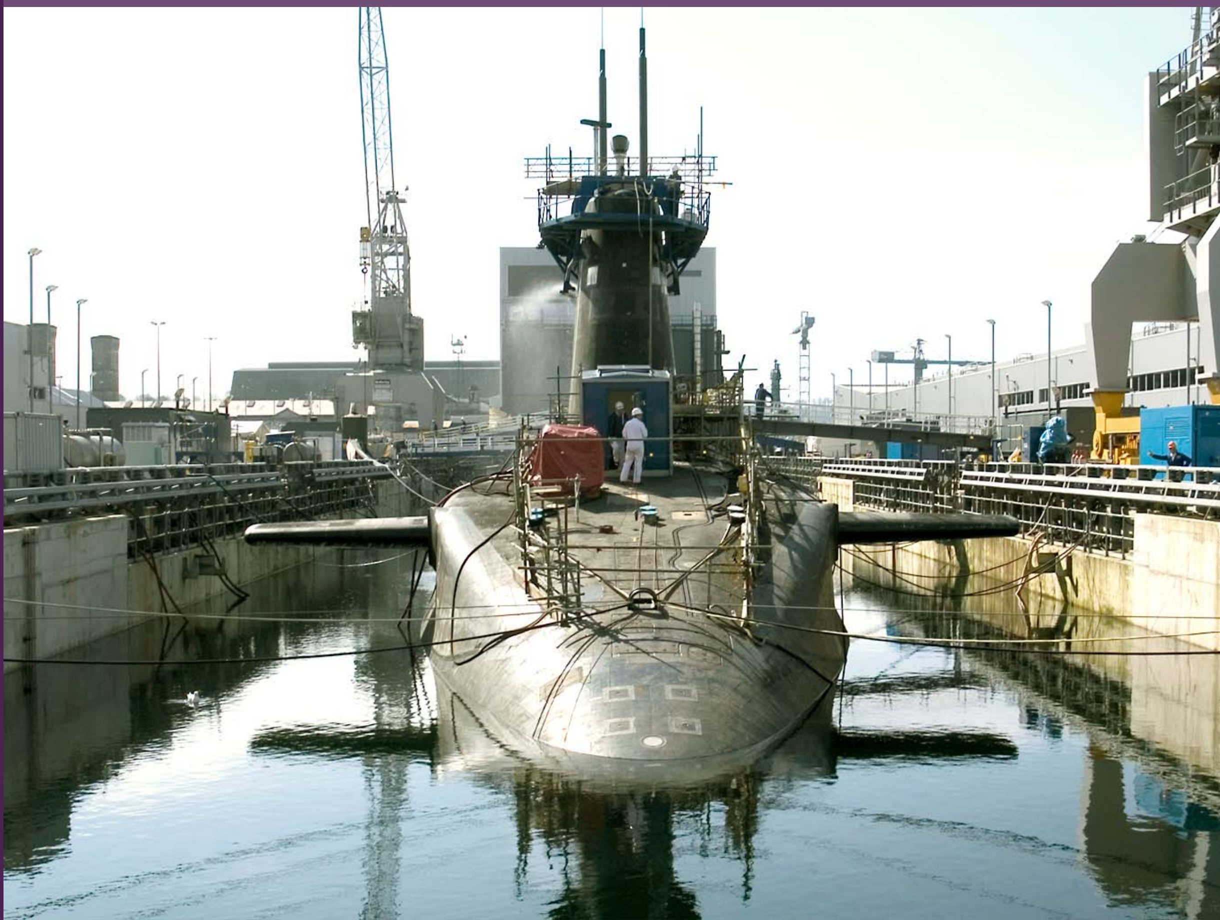
CONTINUITY / CHANGE:

RETHINKING OPTIONS FOR TRIDENT REPLACEMENT

DR. NICK RITCHIE



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About this report

This report is part of a series of publications under the Bradford Disarmament Research Centre's programme on *Nuclear-Armed Britain: A Critical Examination of Trident Modernisation, Implications and Accountability*. To find out more please visit **www.brad.ac.uk/acad/bdrc/nuclear/trident/trident.html.**

Briefing 1: *Trident: The Deal Isn't Done – Serious Questions Remain Unanswered,* at **www.brad.ac.uk/acad/bdrc/nuclear/trident/briefing1.html**

Briefing 2: *Trident: What is it For? – Challenging the Relevance of British Nuclear Weapons,* at **www.brad.ac.uk/acad/bdrc/nuclear/trident/briefing2.html.**

Briefing 3: *Trident and British Identity: Letting go of British Nuclear Weapons*, at **www.brad.ac.uk/acad/bdrc/nuclear/trident/briefing3.html.**

Briefing 4: *A Regime on the Edge? How Replacing Trident Undermines the Nuclear Non-Proliferation Treaty,* at **www.brad.ac.uk/acad/bdrc/nuclear/trident/briefing4.html.**

Briefing 5: *Stepping Down the Nuclear Ladder: Options for Trident on a Path to Zero,* at **www.brad.ac.uk/acad/bdrc/nuclear/trident/briefing5.html.**

About the author

Dr. Nick Ritchie is a Research Fellow at the Department of Peace Studies, University of Bradford. He is lead researcher on the *Nuclear-Armed Britain* programme. He previously worked for six years as a researcher at the Oxford Research Group on global security issues, in particular nuclear proliferation, arms control and disarmament. His PhD thesis examined the evolution of US nuclear weapons policy from 1990-2004. Recent publications include "Relinquishing Nuclear Weapons: Identities, Networks and the British Bomb", *International Affairs*, 86: 2, March 2010, and "Deterrence Dogma? Challenging the Relevance of British Nuclear Weapons", *International Affairs*, 85:1, January 2009.

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Cover photo: HMS Vanguard in refit at HMNB Devonport

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Acronyms

ALCM	Air-Launched Cruise Missile
ASW	Anti-Submarine Warfare
AWE	Atomic Weapons Establishment
CADMID	Concept Assessment Demonstration Manufacture In-Service Disposal
CASD	Continuous-at-sea Deterrence
CMC	Common Missile Compartment
DASO	Demonstration and Shake-down Operation
DCA	Dual Capable Aircraft
ECM	Enhanced Cruise Missile
FPM	Flexible Payload Module
HMNB	Her Majesty's Naval Base
JASSM	Joint Air to Surface Standoff Missile
MAC	Multiple all-up-round Canister
MDA	Mutual Defence Agreement
MIRV	Multiple Independently-targetable Re-entry Vehicle
NPR	Nuclear Posture Review
NPT	Non-Proliferation Treaty
PNI	Presidential Nuclear Initiative
RATTLRS	Revolutionary Approach to Time Critical Long Range Strike
RNAD	Royal Naval Armaments Depot
RRW	Reliable Replacement Warhead
SDR	Strategic Defence Review
SLBM	Submarine-Launched Ballistic Missile
SLCM	Submarine/Sea-Launched Cruise Missile
SOF	Special Operations Forces
SSBN	Ship Submersible Ballistic Nuclear (Nuclear powered ballistic missile submarine)
SSGN	Ship Submersible Guided Nuclear (Nuclear powered guided missile submarine)
SSN	Ship Submersible Nuclear (Nuclear powered attack submarine)
SWS	Strategic Weapon System
TASM	Tactical Air-to-Surface Missile
TLAM	Tomahawk Land Attack Missile
TWS	Tactical Weapon System
UAV	Unmanned Aerial Vehicle
UUV	Unmanned Underwater Vehicle
VLT	Vertical Launch Tube
VPT	Virginia Payload Tube

Introduction

Debate on the future nuclear capability of the United Kingdom has resurged since 2006 when the Labour government presented a White Paper on *The Future of the United Kingdom's Nuclear Deterrent* setting out its case for replacing the current Trident system with a like-for-like capability that would last well into the 2050s.

Advocates of the current Trident replacement process insist that there are only two real choices: a like-for-like replacement of the current system or unilateral nuclear disarmament. The latter remains politically unacceptable leaving only like-for-like replacement.

Since the publication of 2006 White Paper two things have happened: 1) arguments that the international community must make significant progress towards a world free of nuclear weapons have gathered considerable momentum and have been taken forward by the Obama administration; 2) the UK has moved into a deep recession that will place severe constraints on public spending for the next two parliaments at a time when the Ministry of Defence budget is also facing a multi-billion pound black hole in its procurement programme.

In this context the Nuclear-Armed Britain programme at the University of Bradford published a briefing paper on *Stepping Down the Nuclear Ladder: Options for Trident on a Path to Zero* in May 2009 setting out opportunities and obstacles for a number of options between a like-for-like replacement of the current Trident system and unilateral nuclear disarmament.[1] This was followed by a workshop at the University of Bradford in September 2009 to explore these options through a set of working papers.[2] The purpose was to open space for debate and challenge orthodox understandings about what is and is not possible for UK nuclear weapons policy.

This report explores these options, opportunities and obstacles in detail. **Part I** examines the current political context in terms of the progress of the Trident replacement programme to date, renewed international momentum to work towards a world free of nuclear weapons, and constraints on public spending together with a detailed look at cost of the like-for-like replacement programme.

Part II examines in detail options for the Trident replacement programme including:

1) A 'Trident lite' replacement programme that adheres to current understandings of 'minimum deterrence'.
2) A 'reduced readiness' downsized Trident replacement programme that ends 'continuous-at-sea deterrence' and scales down the requirements for 'minimum deterrence'.

[1] Nick Ritchie, "Stepping Down the Nuclear Ladder: Options for Trident on a Path to Zero", Bradford Disarmament Research Centre, University of Bradford, May 2009. Available at <http://bit.ly/trident_options>.
[2] Available at <www.brad.ac.uk/acad/bdrc/nuclear/trident/trident.html>.

3) A flexible, dual-use 'hybrid' submarine programme for conventional and nuclear missions that also ends 'continuous-at-sea deterrence' and scales down 'minimum deterrence' requirements.
4) A nuclear-armed cruise missile capability aboard current or new attack submarines.

The report examines precedents from US nuclear weapons policy to support the option of a dual-use 'reduced readiness' UK nuclear posture. The report ends by exploring the potential flexibility and cost of the options examined based on data provided by successive governments in Command Papers, Parliamentary answers and evidence before Parliamentary hearings.

The report calculates that a like-for-like replacement will cost between £57 and £81 billion for capital and operating costs over 25 years (Table 7). It also provides illustrative costing for three options (Tables 10-13):

1) Nuclear-armed TLAMs on the planned fleet of *Astute* SSNs	£28 billion
2) A new nuclear cruise missile for four new 'Block II' *Astute* SSNs	£54 billion
3) A smaller Trident nuclear arsenal for three new hybrid SSGN/SSBNs	£53-74 billion

If the significant and ongoing capital investment in the Atomic Weapons Establishment (AWE) Aldermaston through to 2013 is not covered by annual operating costs then a further £10 billion must be added to these totals.

The report shows that there is a genuine opportunity for the new coalition government to demonstrate international leadership with the UK's nuclear arsenal without recourse to unilateral nuclear disarmament that remains politically unacceptable at the present time. This includes opportunities to reduce the procurement and operational costs of the Trident replacement programme at a time of serious and sustained reductions in public expenditure and reinforce the renewed global momentum towards a world free of nuclear weapons.

Part 1: Context

The Trident system

Trident is the United Kingdom's only remaining nuclear weapon system. It comprises 160 operational nuclear warheads carried by Trident II (D5) submarine-launched ballistic missiles (SLBMs) aboard four *Vanguard*-class nuclear-powered ballistic missile submarines (SSBNs).

The submarine

The submarines were built in the 1980s and 1990s by Vickers Shipbuilding and Engineering Limited (now owned by BAE Systems) at the Barrow-in-Furness shipyard with US design assistance. HMS Vanguard entered operational service in 1994, HMS Victorious in 1996, HMS Vigilant in 1998, and HMS Vengeance in 2001. The submarines have a crew of approximately 135 and are based at Her Majesty's Navy Base (HMNB) Clyde at Faslane in Scotland. They can remain at sea for 3-4 months. The submarines are powered by a Rolls Royce Pressurised Water Reactor-2 (PWR2) nuclear reactor.

The missile

Each submarine can carry 16 Trident II (D5) submarine-launched ballistic missiles (SLBMs). The missiles were designed and built in the United States by Lockheed-Martin. They have a range of approximately 4,600 miles at full payload and 6,900 miles with a reduced number of warheads.[3] They are accurate to within 90 metres. The UK purchased 58 missiles as part of a larger collective pool maintained at the United States Strategic Weapons Facility Atlantic, King's Bay, Georgia – home to many of America's *Ohio*-class submarines that also deploy Trident missiles. It has 50 left after test-firings. The missile was first deployed by the US Navy in 1990.

Each Trident missile has the capacity to deliver twelve nuclear warheads that can be independently targeted, giving each *Vanguard*-class submarine the capability to deploy 192 warheads across 16 missiles. The Thatcher government limited the total capability 512 warheads, equivalent to eight warheads for 16 missiles on four submarines, and that it would not deploy more than 128 warheads per boat.[4] Current policy restricts warheads deployments to no more than 48 per submarine, suggesting around 3-4 warheads on 12-16 missiles per submarine. Trident missiles are not serviced in the UK but are returned to Kings Bay for periodic refurbishing.

[3] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 337 (London: HMSO, March 1992), p. xviii.

[4] *Statement on the Defence Estimates 1988,* House of Commons Defence Committee, HC 495 (London: HMSO, June 1988), para 3.7.

The warhead

The warheads carried by the Trident missiles are manufactured and designed in the UK by the Atomic Weapons Establishment (AWE) Aldermaston. The design was completed in 1987. Production began in 1988 and the first warhead was delivered in 1992 after 8-9 years of trials and assessments.[5] The UK warhead is closely based on the 100 kiloton (kt) American W76 warhead design used for US Trident missiles. By comparison, the bomb that destroyed Hiroshima was approximately 14kt. The UK has modified some of its warheads to provide what is termed a "sub-strategic" capability with a yield of perhaps 10 kilotons. In 2006 the UK reduced its stockpile of operational warheads to 160. The total stockpile stands at 225.[6]

Support infrastructure

The Trident programme is supported by a dispersed infrastructure. HMNB Clyde is home to the Faslane submarine base and the Royal Naval Armaments Depot (RNAD) Coulport. The *Vanguard* submarine fleet is based at Faslane together with the smaller *Swiftsure* nuclear-powered attack submarines (SSNs) that only deploy conventional weapons. The new *Astute*-class SSNs currently under construction at the Barrow shipyard will also be stationed at Faslane. Warheads and missiles are stored at Coulport for loading and unloading on to the submarines.

The Atomic Weapons Establishment at Aldermaston and Burghfield is the centre for nuclear warhead design, testing, production and maintenance. It is a Government Owned Contractor Operated (GOCO) enterprise operated by a consortium of SERCO, BNFL and Lockheed Martin. Burghfield is responsible for the final assembly of warheads, their in-service maintenance and their eventual decommissioning. After assembly warheads are transported to Coulport by road.

The *Vanguard* submarines undergo a major 3-4-year refitting and reactor refuelling at HMNB Devonport in Plymouth mid-way through their service life. The nuclear power plants and nuclear fuel assemblies that power the *Vanguard* submarines are designed and manufactured at Rolls Royce's Raynesway plant in Derbyshire.

Deterrence doctrine

British nuclear weapons policy is described as one of 'minimum deterrence' based on much lower levels of nuclear weapons than those of the United States and Russia.[7] It is based on the ability to inflict massive devastation upon an opponent with minimum nuclear force. Since the end of the Cold War the UK has steadily reduced its operationally deployed nuclear arsenal from

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[5] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 374 (London: HMSO, June 1989), p. xxi.
[6] "U.K. Offers Nuke Numbers", *Global Security Newswire*, May 26, 2010. Available at <http://gsn.nti.org/gsn/nw_20100526_8311.php>. Accessed June 2, 1010.
[7] Britain is one of eight states that are known to possess nuclear weapons. The others are: USA (5,200 operational warheads of which 2,700 are deployed and 500 are non-strategic; plus a further 4,200 retired and awaiting dismantlement); Russia (4,850 operational or active warheads; a further 8,150 whose status is unclear); France (300); China (240); Israel (80-100); Pakistan (70-90); India (60-80); North Korea (suspected of possessing 3-6 nuclear weapons). Robert Norris and Hans Kristensen, "Nuclear Notebook: Worldwide Deployments of Nuclear Weapons 2009", *Bulletin of the Atomic Scientists*, November/December 2009, pp. 86-98.

approximately 400 nuclear warheads to 160 and has reduced to one nuclear weapon system in Trident.

Prevailing conceptions of minimum deterrence require one of the four *Vanguard* submarines to be at sea on operational patrol in the Atlantic at all times and fully armed with up to 48 nuclear warheads. This posture is known as 'continuous-at-sea deterrence' (CASD). The warheads are not pre-targeted and the alert status of the submarine on operational patrol if described as at "several days 'notice to fire'", although this could be reduced considerably in a crisis.[8] During the Cold War the submarine on patrol was on Quick Reaction Alert ready to fire within 15 minutes of an order.[9] It also requires a nuclear capability of global range that is invulnerable to a surprise pre-emptive attack.

The 2006 White Paper assigned a number of roles to British nuclear forces

- Deterrence against aggression towards British/NATO vital interests or nuclear coercion/blackmail by major powers with large nuclear arsenals.
- Deterrence against nuclear coercion or blackmail by regional 'rogue' states.
- Deterrence against state-sponsored acts of nuclear terrorism.
- Provide an independent centre of nuclear decision-making in NATO to support Euro-Atlantic collective security.
- A general 'residual' deterrent to preserve peace and stability in an uncertain world.[10]

The Government states that it would only use nuclear weapons in "extreme circumstances of self-defence" but it does not rule out using nuclear weapons first in a crisis.[11]

[8] *Strategic Defence Review*, Ministry of Defence, CM 3999 (London: HMSO, July 1998), Chapter four: Deterrence and Disarmament, para. 68.
[9] *Strategic Nuclear Weapons Policy*, House of Commons Defence Committee, HC 674-iv (London: HMSO, October 1980), p. 90.
[10] Ministry of Defence (MoD) and Foreign & Commonwealth Office (FCO), *The Future of the United Kingdom's Nuclear Deterrent,* Cm 6994 (London: HMSO, December 2006), pp. 5, 18, 19.
[11] *The Future of the UK's Strategic Nuclear Deterrent: The Strategic Context: The Government's Response to the Committee's Eighth Report of 2005-06*, House of Commons Defence Committee, HC 1558 (London: HMSO, July 2007), p. 3.

Figure 1: The effects of using Trident

The bomb dropped on Hiroshima in August 1945 had a yield of 14 kilotons – an explosive power equivalent to 14,000 tons of TNT. 130,000 people died immediately or within 3 months and a further 70,000 in the following five years. Over 80% of those living within 1km of the site of the explosion died and over 50 % of those living within 1.5kms. There were also a wide range of health problems found in survivors.

British Trident warheads are around 100kt, roughly 7 times the Hiroshima bomb. A nuclear explosion has three immediate effects: blast, thermal radiation (heat) and nuclear radiation. Nuclear explosions also have a delayed effect through radioactive debris and fallout with long radioactive lifetimes and the risk of radiation-induced genetic mutation that may affect the next generation of people living the targeted area.

The blast, heat flash, radiation and incendiary firestorm effects of one or two 100kt standard UK Trident warheads could kill hundreds of thousands.[12] The two bombs dropped on Hiroshima and Nagasaki were 14kt and 20kt respectively and between them killed around 200,000 people. Douglas Holdstock and Liz Waterston state that "a single nuclear explosion over a medium-sized city would overwhelm the health services of even a developed country, and an attack with multiple weapons would disrupt the whole country's economic and social structure".[13] The incendiary effects of a single 100kt nuclear blast would also be devastating. In Hiroshima, a tremendous fire storm developed within 20 minutes after detonation.[14]

CND estimate that if a UK Trident submarine fired all 48 warheads against targets in and around Moscow the total number of people who would die within 12 weeks in Moscow and the surrounding areas would be around 3 million, including around 750,000 children. Several million people would be injured: "The overall effect of an attack on this scale is particularly numbing. Anyone trying to flee would be likely to find themselves travelling through contaminated areas. The pollution of water supplies, destruction of homes and general devastation would result in secondary problems with disease. Radiation reduces the body's ability to fight off illness. There would also be both short term and long term problems with food supplies, because of the contamination of agricultural land and disruption of transport. The figures above do not include those deaths which would arise indirectly from disease or other longer term fatalities."

The environmental consequences of a limited regional nuclear war would also be devastating. In January 2009 Alan Robock and Brian Toon, the foremost experts on the climatic impact of nuclear war, warned that a limited nuclear exchange could create urban firestorms that would loft millions of tons of thick, black smoke above cloud level that would remain in the stratosphere and have profoundly disruptive effects, including blocking sunlight, heating the upper atmosphere, reducing average surface temperatures, and causing massive destruction of protective stratospheric ozone.[15]

[12] *FM 8-9: NATO Handbook on the Medical Aspects of NBC Defensive Operations AMedP-6*, Department of the U.S. Army, Navy and Air Force, February 1996, chapter 3, "Effects of Nuclear Explosions".
[13] Douglas Holdstock and Liz Waterston, 'Nuclear Weapons, a continuing threat to health', *The Lancet*, vol. 355, issue 9214, April 29, 2000, pp. 1544-1547.
[14] *FM 8-9: NATO Handbook on the Medical Aspects of NBC Defensive Operations AMedP-6*, chapter 3.
[15] See Steven Starr, "The climatic consequences of nuclear war", *The Bulletin of the Atomic Scientists*, March 12, 2010. Available at <http://www.thebulletin.org/web-edition/op-eds/the-climatic-consequences-of-nuclear-war>. Accessed April 30, 2010.

The 'Successor' programme

In December 2006 the British government released a White Paper announcing its intention to begin the process of replacing its current Trident nuclear weapons system, thereby enabling it to retain nuclear weapons well into the 2050s.[16] The decision to begin this process was endorsed by parliament in March 2007. Three years on and the programme is well underway.

Procurement process

A decision was said to be needed in 2007 because the *Vanguard* submarines carrying the Trident missiles are aging and need to be replaced if Britain is to continue to deploy the Trident missile over the long-term. The first *Vanguard* submarine is due to retire in 2024 after a five-year life extension programme. The government estimated that will take around 17 years to design, manufacture and commission a replacement submarine leading to the requirement for a decision in 2007 (see the timeline in Appendix I).[17]

In October 2007 MoD's Defence Equipment and Support (DES) department formally established a Future Submarines Integrated Project Team (FSM-IPT) to develop a concept design over two years for a new submarine, dubbed 'Successor', to carry the Trident missile. The team is based in Barrow at BAE Systems' Submarine Solutions site and manned by 128 people from MoD, BAE Systems, Rolls Royce and Babcock Marine and works with the FSM IPT office in MoD's Abbey Wood offices in Bristol.[18]

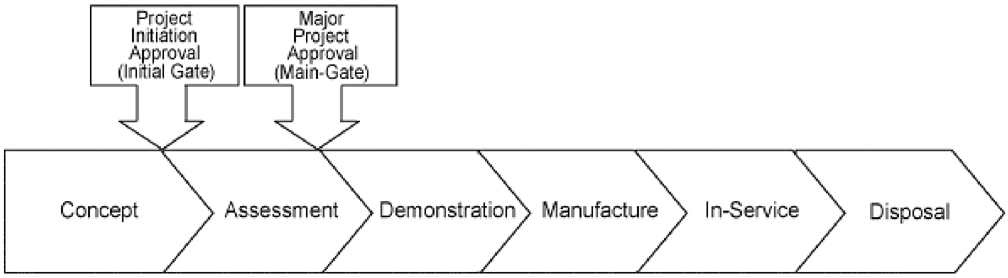
The procurement of the new submarines is being managed by MoD as part of a wider programme to manage the future provision Britain's nuclear arsenal. Responsibility for delivering the overall 'future deterrent capability' rests with the Director General Equipment in MoD's Defence Equipment Support (DES). The Director General Equipment chairs the Strategic Deterrent Programme Board and is accountable to the Defence Management Board for the integration and delivery of Britain's nuclear force. He allocates the budget for the future submarine programme through the FSM-IPT as well as the UK's contribution to the Trident II (D5) missile life extension programme in the United States and the ongoing programme of investment in facilities and skills at the Atomic Weapons Establishment in Aldermaston (see below).[19]

The Ministry of Defence procures new weapon systems according to a procurement cycle of Concept, Assessment, Demonstration, Manufacture, In-service and Disposal (CADMID).[20] On March 14, 2007 Parliament voted to authorise the initial 'Concept' phase to begin the process of

[16] Ministry of Defence (MoD) and Foreign & Commonwealth Office (FCO), *The Future of the United Kingdom's Nuclear Deterrent*, Command 6994, The Stationary Office: London, December 2006.
[17] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 10.
[18] "Birth of Son of Trident, at Yard", *North-West Evening Mail*, October 11, 2007; "Future Submarines Integrated Project Team Office Officially Opens", News Release, BAE Systems, October 12, 2007.
[19] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, HC 1115 (London: HMSO, November 2008), p. 23.
[20] *UK Defence Statistics*, Ministry of Defence, London, 2007, chapter 1, table 1.17.

procuring new submarines. Prime Minister Tony Blair stated during the Commons debate that "we need to take the decision today if we want to get parliamentary approval for the work that has to begin now on the concept and design phase – of course, the actual contracts for the design and construction are to be left for a later time" and that "It is absolutely right that this Parliament cannot bind the decisions of a future Parliament and it is always open to us to come back and look at these issues."[21]

Figure 2: The CADMID cycle



Source: *UK Defence Statistics 2009*, Ministry of Defence, London, chapter 1, table 1.16 "Major Equipment Projects"

Concept phase activities have been split into two parts. The first has concentrated on major system functions will take, including propulsion, combat systems, and strategic weapon systems. The second is developing costed submarine designs in terms of unit production cost and whole-life cost based on major option sets.[22]

Assessment phase 'Initial Gate' decision

The next decision to move to the 'Assessment' phase was originally scheduled for September 2009. This is referred to as the 'initial gate' decision. The Assessment phase involves further detailed refinement of a set of options to enable selection of a preferred solution.[23] The decision has been delayed. In March 2010 Defence Secretary Bob Ainsworth stated that a decision "will now, I think, take place around about the end of the year".[24] Foreign Minister Ivan Lewis also stated in March 2010 that "New technical options are being considered, and a few more months are needed to evaluate them fully before taking a decision".[25]

In 2007 MoD's Investment Approvals Board approved a budget of £309.45 million for the concept phase work on the submarine platform and propulsion plants (£130.5 million from 2007-2008 to 2009-2010 on platform and £179 million on propulsion plant).[26] Defence Secretary Bob Ainsworth stated in February 2010 that "The final spend on reaching Initial Gate cannot be calculated until after that point is reached; however, the total spend on the replacement submarine and associated propulsion system since the beginning of April 2007 to the end of December 2009

[21] House of Commons, *Official Report,* March 14, 2007, Columns 279 and 284.
[22] Denise Hammick and Richard Scott, "Trident – Revisiting the UK Deterrent Debate", *Janes Defence Weekly*, March 11, 2008.
[23] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 18.
[24] House of Commons, *Official Report,* March 29, 2010, Column 507.
[25] House of Commons, *Official Report,* March 4, 2010, Column 349WH.
[26] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 18.

is some £380 million", indicating an increase of £70 million.[27] Overall spending on the Trident replacement programme is expected to be £200 million in 2008-09, £400 million in 2009-10, and £400 million in 2010-11 with much of £620 million difference being spent on development of a Common Missile Compartment with the US (see below).[28]

Nuclear reactor decision

MoD began considering nuclear reactor propulsion requirements for future submarines in 2005 and agreed a 10-year partnering contract worth up to £1 billion with Rolls Royce in May 2007. Lord Drayson, Minister of State at MoD, stated that "the contract sustains the UK's capability to support nuclear steam raising plants, as stated in the [2005] defence industrial strategy".[29] The government reported in mid-2008 that it was involved in extensive discussions with Rolls Royce to determine the requirements for the Next Generation Nuclear Propulsion Plant.[30] The National Audit Office (NAO) stated in November 2008 that the nuclear reactor design needs to be completed by the middle of the next decade to ensure new submarines are delivered on time. It stated that a decision about facilities at the Rolls Royce reactor core manufacturing facility in Derby was needed in 2009 to enable work to begin on a new reactor core in 2012.[31] Bernard Gray's independent review of defence acquisition in 2009 highlighted new cost lines in MoD's Equipment Procurement Plan related to Trident replacement, including lines on a "New generation nuclear propulsion plant" and "Regeneration of the Submarine Nuclear Core Manufacturing Capability".[32]

MoD must decide whether to use a variant of the current reactor design (the PWR2) or develop a new reactor for the new submarine. The NAO reported that "There are risks attached to both of these options. The PWR2 reactor has the benefit of being based on existing technology, but will still require some updating to deal with obsolescent components and emerging regulatory requirements…The PWR3 proposal offers the prospect of a more efficient and cheaper reactor through life. This option nonetheless presents more of an immediate risk to the timetable, since it will require a major research and development effort, although work is underway to see how this risk can be minimised."[33]

It was reported in January 2010 that disagreement over the choice of reactor was the primary reason for the Initial Gate delay.[34] As MoD's Director General Equipment Guy Lester stated in 2008, "On the propulsion plant, that is from my point of view the most tricky issue we have to deal with in the run up to Initial Gate, which is having enough evidence to judge the trade-off

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[27] House of Commons, *Official Report*, February 2, 2010, Column 211W
[28] Response by Bob Ainsworth, Minister of State for the Armed Forces, to written a question. House of Commons, *Official Report*, October 9, 2007, Column 505W; House of Commons, *Official Report*, April 28, 2009, Column 1160W; *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 18
[29] House of Commons, *Official Report,* July 25, 2007, Column WS89; *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 15.
[30] House of Commons, *Official Report*, June 16, 2008, Column 729W.
[31] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 15.
[32] "Review of Acquisition for the Secretary of State for Defence: An Independent Report by Bernard Gray", October 2009, p. 93. Available at <http://www.mod.uk/NR/rdonlyres/78821960-14A0-429E-A90A-FA2A8C292C84/0/ReviewAcquisitionGrayreport.pdf>.
[33] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 15.
[34] Rob Edwards, "Revealed: Trident replacement postponed", *Sunday Herald*, January 10, 2010.

between initial costs, through life costs and risk to programme schedule between the different propulsion options that we are looking at."[35]

Demonstration and Manufacture phase 'Main Gate' decision

A decision to move to the Demonstration and Manufacture phase, known as the 'Main Gate' decision, is expected no later than 2014 according to the government's timeline if the first Successor submarine is to be ready for operational service by 2024 to maintain 'continuous-at-sea deterrence'. Approval for the procurement of long-lead items for the new submarine is needed by 2011.[36] Main Gate is point at which the submarine design is finalised, contracts to build the new boats are tendered, billions are committed and the process becomes politically difficult to reverse.

Warhead decision

The government stated in the 2006 White Paper on Trident replacement that the "existing nuclear warhead design will last into the 2020s. We do not yet have sufficient information to know whether it can, with some refurbishment, be extended beyond that point or whether we will need to develop a replacement warhead".[37] A decision is likely to be needed on whether to refurbish or replace the current UK Trident warhead during the current parliament (2010-2015).[38] Defence Secretary John Hutton stated on March 31, 2009 that he expected a vote in the House of Commons before a decision is taken (See the timeline in Appendix II).[39]

In November 2007 it was revealed that studies on the potential need for a new warhead were being undertaken by a Warhead Pre-Concept Working Group at AWE.[40] Some of the work is being undertaken in co-operation with the US under the terms of 1958 US-UK Mutual Defense Agreement (MDA) that facilitates wide-ranging cooperation on nuclear weapon matters. US weapons laboratories have been exploring options for a Reliable Replacement Warhead (RRW) to replace the W76 Trident warhead since 2005. The RRW programme emerged in 2005 as part of the US National Nuclear Security Administration's (NNSA) plans to consolidate the sprawling and aging nuclear weapons production complex.[41]. RRWs would be based on existing tested designs but incorporate less exacting design requirements, enhanced safety features and be easier to monitor and maintain than the existing arsenal of Cold War-era warheads and thereby facilitate a smaller weapons complex.[42] It has been suggested that the UK is also exploring options for a new warhead that could be developed without nuclear testing, a so-called High Surety Warhead.[43]

MoD officials deny any UK involvement in the US RRW programme. Nevertheless, evidence suggests that the UK has worked closely with the US on the RRW programme. In 2004 the

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[35] Guy Lester, oral evidence taken before the House of Commons Committee of Public Accounts hearing on *The United Kingdom's Future Nuclear Deterrent Capability*, November 19, 2008, Q49. Available at <http://www.publications.parliament.uk/pa/cm200809/cmselect/cmpubacc/250/08111904.htm>.

[36] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 12.

[37] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 7.

[38] Ibid., p. 7.

[39] House of Commons, *Official Report*, March 30, 2009, Column 651.

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

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

[42] Linton Brooks, *Testimony of Ambassador Linton F. Brooks, Administrator, National Nuclear Security Administration,* Hearing before the Senate Armed Services Committee, April 4, 2005 (Washington, D.C.: Government Printing Office).

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

Mutual Defence Agreement was extended for a further 10 years and amended to facilitate US-UK cooperation on nuclear warhead research related to the RRW concept. In 2008 John Harvey, policy and planning director at the US National Nuclear Security Administration, stated in an audio interview for the Center for Strategic and International Studies in Washington, D.C., that "we have recently, I can't tell you when, taken steps to amend the MDA, not only to extend it but to amend it to allow for a broader extent of cooperation than in the past, and this has to do with the RRW effort."[44] He also stated that UK scientists "are observers on some of the working activities that are chaired by the Navy for the Reliable Replacement Warhead."[45] Frank Miller, a civil servant who was Senior Director for Defense Policy and Arms Control at the National Security Council under George W. Bush and previously held senior positions in the Department of Defense with responsibility for nuclear weapons policy under Bush senior and Clinton, also stated in a CSIS interview in 2008 that "They [UK] will need a Reliable Replacement Warhead of their own. In fact they are working on one. It has a different name. It's got a different acronym. But they are working on the same kind of a thing for their W76 variant".[46] In addition, David Overskei, chair of the Secretary of Energy's Advisory Board reportedly said in 2006 that "as far as I know they [the British] are not involved with the RRW…but they are keenly, keenly interested".[47] Congress stripped the programme of all funding from the programme from 2007-2010 and it was terminated in its current iteration by the Obama administration in 2009.[48]

Vanguard submarine life extension

The timeline for the Successor programme is based on a programme to extend the service life of the current *Vanguard* submarines by five years. The 2006 White Paper stated that the original design life of the submarines was 25 years. When the submarines were being built MoD stated that the *minimum* life of the system was 25 years.[49] Independent experts argue that the service life could be extended much further.[50] It is stated the Rolls Royce Nuclear Steam Raising Plant that powers the submarines has a safety justification of 25 years. If the submarines are to be operated for a longer period then a new safety case must be made. Commodore Tim Hare, former Director Nuclear Policy at MoD, stated before the Commons Defence Committee in 2006 that "To renew that safety justification is a non-trivial activity because of the very laudable, strong safety rating and criteria that have to be met. To extend the safety justification is non-trivial. It can be done but, to my understanding, not for much more than five or six years."[51]

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

45 Interview with John Harvey.

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

47 Cited in Geoff Brumfiel, "The Next Nuke", *Nature*, vol. 442, no. 6, July 2006.

48 Jeffrey Lewis, "After the Reliable Replacement Warhead: What's Next for the U.S. Nuclear Arsenal?", *Arms Control Today*, Vol. 38, December 2008; Jonathan Medalia, *The Reliable Replacement Warhead Program: Background and Current Developments*, CRS Report for Congress (Congressional Research Service, Washington, D.C., September 2008).

49 *Progress of the Trident Programme*, House of Commons Defence Committee, HC 350 (London: HMSO, July 1995), p. 16.

50 See in particular evidence to the House of Commons Defence Committee hearing on *The Future of UK's Strategic Nuclear Deterrent: The White Paper* submitted by Richard Garwin, Ted Postol, Philip Coyle and Frank von Hippel arguing that the service life of the submarines could be extended to from 25-30 to 40-45 years.
The Future of the UK's Strategic Nuclear Deterrent: the White Paper: Volume II Oral and Written Evidence, House of Commons Defence Committee, HC 225-II (London: HMSO, February 2007), p. EV23.

51 Evidence by Commodore Tim Hare, *The Future of the UK's Strategic Nuclear Deterrent: The Strategic Context*, House of Commons Defence Committee, HC 986 (London: HMSO, June 2006), p. Ev 38.

To this end MoD initiated a Vanguard Life Optimisation Programme (VLOP) to examine the process, assess the implications and undertake research work required to support the design life extension of the reactor plants.[52] The programme, however, "remains an area of considerable uncertainty, with the potential for rapid cost and risk growth" according to the National Audit Office.[53] Sir Bill Jeffrey, MoD's Permanent Undersecretary, later stated that the life extension could be much longer than five years.[54]

Missile decision

In the mid-1990s the US Navy embarked on a programme to extend the service life of its *Ohio*-class Trident SSBNs from 30 to 45 years. The Trident II (D5) production line was due to close in 2007 with the first missiles due for retirement in 2019.[55] In order to ensure a full complement of Trident missiles for the flotilla the US Navy initiated a programme in 2002 to procure a new variant, the D5LE (life extension). The US Navy awarded a procurement contract to Lockheed Martin in April 2007 to extend the life of the missiles from 30 to 45 years.[56] Production of D5LE missiles began in 2008 with initial deployment in 2011. The UK government's 2006 White Paper announced a decision to participate in the life extension programme. The UK had to make a decision on whether to participate by 2007 and the decision was formalised in an exchange of letters between London and Washington two days after the release of the White Paper.[57] US Trident missiles will be fully withdrawn from service in 2042 when the last *Ohio*-class submarine is due to retire. The US will likely begin development of a new SLBM to replace Trident in the late 2020s. The first Trident II (D5) missile was deployed by the US Navy in 1990, 16 years after the US Deputy Secretary of Defense issued a requirements order in March 1974for a D5 missile as a follow-on to the less capable Trident I (C4).[58]

The United States' next-generation SSBN

The future of the British nuclear weapons programme is intimately linked to the United States. US-UK nuclear weapons cooperation dates back to the 1940s Manhattan project but Britain's nuclear *dependence* on the US was cemented in the 1963 Polaris Sales Agreement (PSA) that allowed the UK to acquire, support and operate the US Polaris and later the Trident II (D5) ballistic missile systems and the 1958 Mutual Defence Agreement (MDA) that provides for extensive cooperation on nuclear warhead and reactor technologies, in particular the exchange of classified information through a range of Joint Working Groups (JOWOGs).[59]

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[52] House of Commons, *Official Report*, December 16, 2009, Column 1219W.
[53] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 13.
[54] Uncorrected transcript of oral evidence to the Committee of Public Accounts hearing on *The United Kingdom's Future Nuclear Deterrent Capability*, November 19, 2008.
[55] *Report of the Defense Science Board Task Force on Nuclear Deterrence*, Office of the Under Secretary of Defense for Acquisition and Technology (Washington, D.C.: U.S. Department of Defense, October 1998), p. 36.
[56] "Lockheed Martin Receives $135-million Contract Modification from the Navy for Trident II D5 Missile Life Extension", Lockheed Martin, Press Release, April 9, 2007.
[57] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent,* p. 11.
[58] Federation of American Scientists, "Trident II D-5 Fleet Ballistic Missile". Available at <http://www.fas.org/nuke/guide/usa/slbm/d-5.htm>. Accessed May 24, 2010.
[59] Nigel Chamberlain, Nicola Butler and Dave Andrews, *US-UK Nuclear Weapons Collaboration Under the Mutual Defence Agreement*, Special Report 2004.3 (London: BASIC, June 2004).

The UK is now entirely dependent upon the United States for supply, refurbishment and test firing of its Trident missiles and the software used for missile targeting and firing.[60] UK nuclear targeting is also integrated into US nuclear targeting plans at US Strategic Command (STRATCOM) in Omaha, Nebraska.[61] The UK Trident warhead is an Anglicised version of the US Trident W76 warhead,[62] it was tested three times at the US Nevada Test Site during its development,[63] and the US is thought to have supplied key components for the UK warhead.[64]

The US currently deploys 14 *Ohio*-class SSBNs that deploy the Trident II (D5) missile with the first due to retire in 2027. The remaining 13 will reach the end of their service lives at a rate of roughly one boat per year thereafter, with the last retiring in 2042.[65] The US Navy began preliminary studies for its next-generation SSBN, labelled SSBN(X), in July 2007.[66] In August 2008 a new office was established for the SSBN(X) programme.[67] In November 2008 the US Navy initiated a year-long Analysis of Alternatives (AoA) concept study to develop and assess the capabilities required and to undertake preliminary conceptual work ahead of more detailed research and design to begin in 2010.[68] In 2010 the US initiated a Sea Based Strategic Deterrent (SBSD) Advanced Submarine System Development project to design and prepare for construction of the SSBN(X).[69]

Current plans envisage a detailed blueprint for a next generation submarine by the end of 2018 with construction beginning in 2019 for seven years, followed by two years of sea trials for initial deployment in 2029.[70] The US Navy's *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2011* states that "Detailed design for the first SSBN(X) begins in FY 2015, and the first boat in the class must be procured no later than FY 2019 to ensure that 12 operational ballistic missile submarines will always be available to perform the vital strategic deterrent mission. Eight more SSBN(X)s will be procured between FY 2021 and FY 2030 (with the final three coming in the next planning period, beyond FY 2031)."[71] The second ship of the class will begin in FY 2022 with follow-on serial production for the balance of the force beginning in FY 2024.[72] The SSBN(X) will be designed for a 40-year life.[73]

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60 John Ainslie, 'The Future of the British Bomb', (Glasgow: Scottish CND, October 2005), pp. 12, 67.

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

62 Mark Bromley and Nicola Butler, *Secrecy and Dependence: The UK Trident System in the 21st Century* (London: BASIC, November 2001).

63 *Progress of the Trident Programme*, House of Commons Defence Committee, HC 549 (London: HMSO, June 1993), p. 9.

64 These include the re-entry body, Arming Fusing and Firing system, neutron generator, and probably the tritium gas transfer system. John Ainslie, 'What Next for Aldermaston?' (Glasgow: Scottish CND, 2006).

65 Ron O'Rourke, *Navy SSBN(X) Ballistic Missile Submarine Program: Background and Issues for Congress*, Congressional Research Service, March 2010, p. 3.

66 Ibid., p. 6.

67 Dan Taylor, "Navy Stands Up Program Office To Manage Next-Generation SSBN," *Inside the Navy*, August 17, 2008.

68 Elaine Grossman, "Strategic Arms Funds Tilt Conventional in 2009", *Global Security Newswire*, November 7, 2008. Available at <http://www.nti.org/d_newswire/issues/2008/11/7/2E8D226C-261C-4209-8B38-147F3CD8012B.html>.

69 Department of the Navy, "Fiscal Year (FY) 2011 Budget Estimates Justification of Estimates: Research, Development, Test & Evaluation Navy Budget Activity 4", February 2010, p. 2.

70 "Sub officials: missiles will decide design of strategic deterrent", *Inside the Navy*, February 23, 2009.

71 Office of the Chief of Naval Operations, *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2011,* US Department of Defense, February 2010, p. 5.

72 Ibid., p. 20.

73 Office of the Chief of Naval Operations, *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2011,* US Department of Defense, February 2010, p. 24.

International context

Why should the government revisit the policy set out in the 2006 White Paper in order to facilitate further reductions in the size and operational readiness of the UK nuclear arsenal? The answer lies in two important processes that have unfolded since the White Paper was published and warrant a serious re-appraisal of the case for a like-for-like replacement.

A nuclear weapons-free world

The first is the emergence of a new global opportunity to rethink current nuclear weapons policies and take significant steps towards a nuclear weapons-free world. In 2007 four influential former US statesmen (Henry Kissinger, William Perry, George Schultz and Sam Nunn) urged the international community to work towards a world free of nuclear weapons in a seminal article in the *Wall Street Journal*.[74] The article stemmed from a conference convened in 2006 to commemorate 20 years since Presidents Reagan and Gorbachev met in Reykjavik and came close to agreeing the total elimination of their nuclear arsenals within 10 years.[75] The article argued that: "The end of the Cold War made the doctrine of mutual Soviet-American deterrence obsolete. Deterrence continues to be a relevant consideration for many states with regard to threats from other states. But reliance on nuclear weapons for this purpose is becoming increasingly hazardous and decreasingly effective". The four asked: "What will it take to rekindle the vision shared by Reagan and Mr. Gorbachev? Can a world-wide consensus be forged that defines a series of practical steps leading to major reductions in the nuclear danger?" They set out a number of steps requiring US leadership and said "Reassertion of the vision of a world free of nuclear weapons and practical measures toward achieving that goal would be, and would be perceived as, a bold initiative consistent with America's moral heritage. The effort could have a profoundly positive impact on the security of future generations. Without the bold vision, the actions will not be perceived as fair or urgent. Without the actions, the vision will not be perceived as realistic or possible."

In January 2008 they repeated their call for progress with a second article. This time they had the formal support of Gorbachev in Russia and a host of senior former foreign and defence officials in the US, including former Secretary of State General Colin Powell. They reiterated that "Progress must be facilitated by a clear statement of our ultimate goal. Indeed, this is the only way to build the kind of international trust and broad cooperation that will be required to effectively address today's threats. Without the vision of moving toward zero, we will not find the essential cooperation required to stop our downward spiral" towards a dangerous world of many nuclear weapon states.[76]

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[74] Henry Kissinger, William Perry, George Shultz and Sam Nunn, "A World Free of Nuclear Weapons", *Wall Street Journal*, January 4, 2007.

[75] Reykjavik Summit 20th Anniversary Conference, The Hoover Institution, Stanford, CA, October 2006. Available at <http://www.nuclearsecurityproject.org/site/c.mjJXJbMMIoE/b.5160797/k.920B/2006_Reykjavik_Summit_20th_Anniversary_Conference.htm>.

[76] Henry Kissinger, William Perry, George Shultz and Sam Nunn, "Toward a Nuclear Free World", *Wall Street Journal*, January 15, 2008.

This powerful call for the international community to work towards a world free of nuclear weapons has injected the possibility and urgency of nuclear disarmament with new credibility. It has become a central plank of the Obama administration's foreign policy articulated in full in Prague in April 2008.[77] US leadership has been demonstrated through negotiation of a new START treaty with Russia, changes in nuclear posture set out in the administration's April 2010 Nuclear Posture Review and transparency over the size of its nuclear arsenal announced at the May 2010 NPT Review Conference.

This has spread beyond America's shores to many countries where citizens, officials, parliamentarians, business and faith leaders, and former senior policy-makers have joined that call. It has led to a major international 'Global Zero' initiative launched in Paris in December 2008 by a host of influential political, business and faith leaders, including many from the UK.[78] It has resulted in statements by senior former foreign and defence statesmen and women echoing those of Kissinger *et al* from Australia[79], Belgium[80], France[81], Germany[82], Italy[83], the Netherlands[84], Norway[85], Poland[86], 204 Japanese parliamentarians[87], 40 European military and political leaders[88] and a major International Commission on Nuclear Non-Proliferation and Disarmament sponsored by Japan and Australia that released its final report on *Eliminating Nuclear Threats - A Practical Agenda for Global Policymakers* in December 2009.

These hardened Cold War warriors have championed nuclear disarmament for two reasons: first, the impact of the 9/11 attacks and spectre of nuclear terrorism; and second, the global turn to new nuclear power generation capability as part of the solution to climate change and energy security demands. These two dynamics have come together to place a question mark over whether the international community, particularly the West, can indefinitely restrain the spread of nuclear weapons technology and knowledge; have high confidence that complex relations between a growing number of nuclear powers can be managed indefinitely through the practice of nuclear deterrence; keep the fissile materials needed for making nuclear weapons out of terrorists' hands; and adequately control access to the uranium enrichment and plutonium reprocessing plants that

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77 Barack Obama, "Remarks by President Barack Obama", Hradcany Square, Prague, Czech Republic, April 5, 2009.

78 "Scrapping Nuclear Arms is Now Realpolitik", Global Zero authors, *The Times*, April 1, 2009. See www.globalzero.org.

79 Malcolm Fraser, Gustav Nossal, Barry Jones, Peter Gration, John Sanderson and Tilman Ruff, "It's time to get Serious about Ridding the World of Nuclear Weapons", *Sydney Morning Herald*, April 8, 2009.

80 Willy Claes, Guy Verhofstadt, Jean-Luc Dehaene and Louis Michel, "Toward a Nuclear Weapons Free World", *The Standaard*, February 19, 2010.

81 Alain Juppe, Michel Rocard, Alain Richard, and General Bernard Norlain "For Global Nuclear Disarmament, the only Means to Prevent Anarchic Proliferation", *Le Monde*, 14 October 14, 2009.

82 Helmut Schmidt, Richard von Weizsäcker, Egon Bahr and Hans-Dietrich Genscher, "Toward a Nuclear-Free World: a German View", *International Herald Tribune*, January 9, 2009.

83 F Massimo D'Alema, Arturo Parisi Gianfranco Fini, Giorgio La Malfa, Francesco Calogero, "Towards a Nuclear-Weapon-Free World", *Il Corriere della Sera*, July 24, 2008.

84 Ruud Lubbers, Max van der Stoel, Hans van Mierlo and Frits Korthals Altes, "Toward a Nuclear Weapon Free World", *NRC Handelsblad*, November 23, 2009.

85 Odvar Nordli, Gro Harlem Brundtland, Kåre Willoch, Kjell Magne Bondevik and Thorvald Stoltenberg, " Nuclear Weapons Free World", *Aftenposten*, June 3, 2009.

86 Aleksander Kwaśniewski, Tadeusz Mazowiecki and Lech Wałęsa, "The Unthinkable Becomes Thinkable: Towards Elimination of Nuclear Weapons", *Gazeta Wyborcza*, April 3, 2009.

87 "204 Japanese Legislators Support Obama's Vision of Nuclear Disarmament", Parliamentarians for Nuclear Non-Proliferation and Disarmament, February 2010. Available at <http://www.gsinstitute.org/gsi/archives/Diet_Obama.html >.

88 "Influential European Figures Issue Unprecedented Statement on Nuclear Dangers to Coincide with the Washington Summit", Top-Level Group, April 13, 2010. Available at <http://toplevelgroup.org/events/europeanstatement/>.

produce these materials but also constitute a legitimate component of a civilian nuclear power programme under the Nuclear Non-Proliferation Treaty (NPT).

The answer for a number of Cold War nuclear deterrence advocates is 'no': maintaining a sufficient level of control is looking increasingly problematic; possession of nuclear weapons is unlikely to provide an adequate response to the breakdown of nuclear order; and as nuclear weapon programmes and sources of weapon-usable fissile material proliferate, nuclear weapons will eventually be used to the enormous detriment of global society and stability. The solution, then, is one rooted in global collective security; a common security solution to a common threat of nuclear conflict: global nuclear disarmament.

It is widely acknowledged that reducing the salience of, or 'devaluing', nuclear weapons in the security policies of the nuclear weapon states is an essential process along the road to a world free of nuclear weapons. The 2000 Review Conference of the Nuclear Non-Proliferation Treaty (NPT) called for a "diminishing role for nuclear weapons in security policies"[89]; the 2006 Commission on Weapons of Mass Destruction stipulated "an urgent need to reduce the role of nuclear weapons in the security policies of states"[90]; and the 2009 International Commission on Nuclear Non-proliferation and Disarmament urged the "progressive delegitimation of nuclear weapons".[91]

The UK response

The British government has declared its full commitment to this goal and a desire to take an active leadership role in examining the practical steps and challenges involved. In June 2007 Foreign Secretary Margaret Beckett declared that "When it comes to building this new impetus for global nuclear disarmament, I want the UK to be at the forefront of both the thinking and the practical work. To be, as it were, a 'disarmament laboratory'."[92]

In January 2008 Prime Minister Gordon Brown said in a Speech at the Chamber of Commerce in Delhi that "I pledge that in the run-up to the Non Proliferation Treaty review conference in 2010 we will be at the forefront of the international campaign to accelerate disarmament amongst possessor states, to prevent proliferation to new states, and to ultimately achieve a world that is free from nuclear weapons."[93] In February 2008 Defence Secretary Des Browne gave a speech on 'Laying the Foundations for Multilateral Disarmament' at the Conference on Disarmament in Geneva.[94]

Outside government Malcolm Rifkind, David Owen, Douglas Hurd and George Robertson wrote in the *Times* in June 2008 that the world must 'Start Worrying and Learn to Ditch the Bomb'. The four declared that "Substantial progress towards a dramatic reduction in the world's nuclear

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[89] 2000, *Final Document of the 2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapon*s, NPT/CONF.2000/28 (Parts I and II), United Nations, New York, May 2000, p. 15.

[90] Hans Blix, *Weapons of Terror: Freeing the World of Nuclear, Biological and Chemical Arms*, (Stockholm: Weapons of Mass Destruction Commission, June 2006), p. 88.

[91] Evans, G. and Kawaguchi, Y., *Eliminating Nuclear Threats - A Practical Agenda for Global Policymakers*, (Canberra and Tokyo: International Commission on Nuclear Non-Proliferation and Disarmament, November 2009), p. 63.

[92] Margaret Beckett, "A World Free of Nuclear Weapons?", Carnegie International Nonproliferation Conference, Keynote Address, June 25, 2007.

[93] Gordon Brown, "Speech at the Chamber of Commerce in Delhi", January 21, 2008.

[94] Des Browne, "Laying the Foundations for Multilateral Disarmament", address to the Conference on Disarmament, February 5, 2008.

weapons is possible. The ultimate aspiration should be to have a world free of nuclear weapons. It will take time, but with political will and improvements in monitoring, the goal is achievable. We must act before it is too late, and we can begin by supporting the campaign in America for a non-nuclear weapons world".[95] 277 MPs signed an Early Day Motion in July 2008 on the "Nuclear Security Project" endorsing the calls by Kissinger *et al* and Rifkind *et al*.[96] In January 2009 three former senior military figures, Field Marshal Lord Bramall , General Lord Ramsbotham, and General Sir Hugh Beach argued in the *Times* that "UK does not need a nuclear deterrent" and that "it is difficult to see how the United Kingdom can exert any leadership and influence on this issue [nuclear disarmament] if we insist on a costly successor to Trident that would not only preserve our own nuclear-power status well into the second half of this century but might actively encourage others to believe that nuclear weapons were still, somehow, vital to the secure defence of self-respecting nations."[97]

Britain certainly has the potential to take a major leadership role as the most progressive of the five recognised nuclear weapon states. It has ended nuclear testing and ratified the Comprehensive Test Ban Treaty; ended production of fissile materials for use in nuclear weapons; published accounts of its holdings and history of fissile material production; reduced to a single nuclear system in Trident; and undertaken important research on the technical verification of nuclear disarmament.[98]

Britain can and should continue on this trajectory and demonstrate international leadership to the electorate and international leaders by taking concrete steps to reduce the salience of nuclear weapons in national security policy and thereby reinforce the crucial but threatened global Nuclear Non-Proliferation Treaty (NPT). This could include a detailed exploration of the obstacles to reducing the operational readiness and size of its nuclear arsenal and the degree to which further steps could lead and inform comparable steps by other countries and build confidence between nuclear weapon states and non-nuclear weapon states.

At the recent NPT Review Conference in May 2010 the Nuclear Weapons States, including the UK, agreed to "further diminish the role and significance of nuclear weapons in all military and security concepts, doctrines and policies" and to "commit to undertake further efforts to reduce and ultimately eliminate all types of nuclear weapons, deployed and non-deployed, including through unilateral, bilateral, regional and multilateral measures".[99]

It is in this context that examining progressive options for Trident replacement between a like-for-like replacement and unilateral nuclear disarmament is essential. This report seeks to make a significant contribution to that debate.

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[95] Malcolm Rifkind, David Owen, Douglas Hurd and George Robertson, 'Start Worrying and Learn to Ditch the Bomb', *The Times*, June 30, 2008.
[96] "Nuclear Security Project", Early Day Motion 2053, sponsored by James Arbuthnot, MP, July 16, 2008. Available at <http://edmi.parliament.uk/EDMi/EDMDetails.aspx?EDMID=36395&SESSION=891 >.
[97] Field Marshal Lord Bramall, General Lord Ramsbotham and General Sir Hugh Beach, "UK does not need a nuclear deterrent", Letter to the Editor, *The Times*, January 16, 2009.
[98] See "Verifiable Multilateral Nuclear Disarmament", Fact Sheet 9, Verification Research Training and Information Centre (VERTIC), London, April 2009.
[99] Final Document of the 2010 Nuclear Non-Proliferation Treaty Review Conference, p. 18.

Financial pressure

The second key development since the 2006 White Paper was published is the emergence of a very serious fiscal crisis and deep recession. The Labour government's budget delivered in April 2009 suggested that the national debt will increase substantially over the next five years with little prospect of any major increase in public spending for the next two parliaments.[100] The Conservative-Liberal Democrat coalition government has pledged to ring-fence the health, education and international development budgets from the inevitably severe cuts in public spending over the current parliament. Those cuts will be borne by other government departments, including defence.

MoD is therefore set to get hit on two fronts. First, the defence budget was already under severe pressure before the full impact of the recession. It was clear that it could not afford all of the large military projects that were in the pipeline or in the planning stages. Major procurement programmes included the new *Astute*-class attack submarine programme (£3.5bn for the first three of a possible seven), six *Daring*-class Type-45 destroyers (£3.6bn), two new aircraft carriers and Joint Combat Aircraft (£12-14bn), the Future Rapid Effects System range of armoured vehicles for the Army (£6bn for 3,500 vehicles), 232 Typhoon fighter aircraft (£21bn), and 14 new Future Strategic Tanker Aircraft (£13bn).[101] Estimates suggested a multi-billion pound black hole in the procurement budget long before the recession began to bite. The National Audit Office reported in 2009 that "If the Defence budget remained constant in real terms, and using the Department's forecast for defence inflation of 2.7 per cent, the gap [between estimated funding and the cost of the Defence budget over the next ten years] would now be £6 billion over the ten years. If, as is possible given the general economic position, there was no increase in the defence budget in cash terms over the same ten year period, the gap would rise to £36 billion".[102]

MoD has announced a series of cutbacks in recent years in response to the budget shortfall. In December 2008 Defence Secretary John Hutton announced that "Since May 2008 the Ministry of Defence has been examining its equipment programme. The aims of the examination were to adapt to the rising cost of high-end defence equipment and to provide more support for current operations. The key conclusions I am announcing today help us meet these objectives". The FRES programme was to be restructured and delayed; the in service date of the new aircraft carriers delayed by one to two years; the Future Lynx helicopter programme reduced; and the new RAF tanker fleet delayed.[103] A year later in December 2009 Defence Secretary Bob Ainsworth announced plans to reprioritise the defence budget in an attempt to balance the books. He

[100] Steve Schifferes, "UK economy 'faces decade of pain'", *BBC News*, April 23, 2009. Available at <http://news.bbc.co.uk/1/hi/business/8015063.stm>.

[101] House of Commons, *Official Report*, November 20, 2008, Column 667W.

[102] *Ministry of Defence: The Major Projects Report 2009*, National Audit Office, HC 85-1 (London: HMSO, December 2009), p. 4.

[103] House of Commons, *Official Report*, December 11, 2008, Column 67WS. Written statement on 'Defence equipment' by John Hutton.

announced plans to cut MoD service personnel by 2,500 and a review to identify further MoD staff cuts, early withdrawal of some assets and cuts to ongoing procurement programmes.[104]

But MoD is also facing a major budget cut as part of the government's long-term plan to reduce public spending and cut the country's structural fiscal deficit. Professor Malcolm Chalmers at the Royal United Services Institute (RUSI) estimates that MoD will be required to make a real terms budget reduction over the period 2010/16 of around 10-15% in real terms.[105] He argues that savings will have to be made in capital procurement expenditure, combat operations, pay, and capability operating costs. On capital expenditure he warns that "the scope for savings on major procurement projects may be relatively limited, given an overhang of outstanding contractual commitments amounting to some £18 billion" and suggests that procurement programmes that are currently less well advanced maybe subject to delay, reduction or cancellation, including the two new aircraft carriers and their associated F-35/JCA aircraft, the Trident replacement programme based at this stage of four new ballistic missile submarines, and the Future Surface Combatant ship.[106] Chalmers notes that "Postponement of the new Vanguard-replacement submarines could be particularly tempting, given that this project is currently due to replace Typhoon as the MoD's largest single procurement project, with annual costs due to reach as much £1 billion in the period from 2016/17 onwards".[107] The new Strategic Defence and Security Review will have to make tough choices to balance the defence books to meet public spending plans that will be set out in the forthcoming Comprehensive Spending Review.[108]

Trident costs

In 2006 the government estimated that the capital cost of replacing the current Trident system will be £15-20 billion, although in November 2008 MoD's Permanent Undersecretary Sir Bill Jeffrey warned that these were only "ballpark estimates".[109] The National Audit Office also reported in 2008 that "the White Paper cost estimates are not sufficiently robust to provide an accurate baseline against which progress can be measured and budgetary control exercised. There remain a number of major areas of uncertainty in the budget, including the provision for contingency, inflation and Value Added Tax".[110] History suggests that this procurement figure is likely to be too low because of the impact of defence inflation.

Estimates carried out on behalf of the Liberal Democrat Party in 2007 set the total *lifetime* capital and operating cost of replacing Trident over 30 years at £76 billion.[111] A 2009 Greenpeace report estimated a total lifetime cost of least £97 billion.[112]

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104 "Defence Budget reprioritised to support Afghanistan operation", Ministry of Defence, December 15, 2009. Available at <http://www.mod.uk/DefenceInternet/DefenceNews/EquipmentAndLogistics/DefenceBudgetReprioritisedToSupportAfghanistanOperation.htm>.
105 Malcolm Chalmers, "Preparing for the Lean Years", Royal United Services Institute, London, July 2009.
106 Ibid., p. 13.
107 Ibid., p. 13.
108 Paul Cornish and Andrew Dorman, "Blair's wars and Brown's budgets: from Strategic Defence Review to strategic decay in less than a decade", *International Affairs,* 85: 2, 2009, p. 260.
109 Uncorrected transcript of oral evidence to the Committee of Public Accounts hearing on *The United Kingdom's Future Nuclear Deterrent Capability*, November 19, 2008.
110 *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 5.
111 Richard Norton-Taylor, "New Trident System may Cost £76 billion, figures show", *The Guardian*, September 21, 2006.
112 *In the Firing Line: An Investigation into the Hidden Cost of the Supercarrier Project and Replacing Trident* (London: Greenpeace UK, September 2009).

Over the course of the original Trident procurement programme the House of Commons Defence Committee produced annual reports on *The Progress of the Trident Programme*. The last report to provide a detailed breakdown of costs was published in July 1995. Budget reporting figures for the original Trident procurement programme were broken down into seven broad categories: 1) Submarine; 2) Strategic Weapon System (SWS) Equipment; 3) Strategic Weapon System Missile; 4) Tactical Weapon System (TWS); 5) Shore Construction; 6) Dockyard Projects[113]; 7) Warhead, Miscellaneous, and Unallocated Contingency.

At the time of the last report the projected total cost of the programme at 1994-95 prices was £11,682 million in hybrid (i.e. outturn) prices. Approximately 75% of total projected expenditure had been spent or committed at this point. Breakdown by category was:[114]

Table 1: Breakdown of original Trident procurement cost by category

	£ millions	% of total
Submarines	4,243	36.32
SWS equipment	1,366	11.69
SWS missile	1,240	10.61
TWS	985	8.43
Shore Construction	1,368	11.71
Dockyard Projects	169	1.45
Warhead, Misc., Cont.	2,130	18.23
TOTAL	**11,682**	**100**

The estimated cost of the programme in 2008 at 2008-09 prices was £15,700 million.[115] Applying the same percentage of total cost to the 2008-09 estimate provides a reasonable estimate of costs for components of the original Trident programme in today's prices.

Table 2: Breakdown of original Trident procurement cost by category in 2008-09 prices

	1994-95 £ millions	% of total	2008-09 £ millions
Submarines	4,243	36.32	5702
SWS equipment	1,366	11.69	1836
SWS missile	1,240	10.61	1666
TWS	985	8.43	1324
Shore Construction	1,368	11.71	1839
Dockyard Projects	169	1.45	227
Warhead, Misc., Cont.	2,130	18.23	2863
TOTAL	**11,682**	**100.00**	**15,700**

The 2006 White Paper's breakdown of costs at 2006/07 prices for replacing the Trident system were:

113 Includes Trident attributable costs of the Rosyth Dockyard Emergency Docking Facility and Submarine Refitting Facility. *Progress of the Trident Programme*, House of Common Defence Committee, HC 350 (London: HMSO, July 1995), p. 22.
114 Ibid., p. 21. Discrepancy due to rounding to nearest million.
115 House of Commons, *Official Report*, November 13, 2008, Column 1302W.

- £11,000-14,000 million for four new submarines.
- £2,000-3,000 million for the possible future refurbishment or replacement of the warhead.
- £2,000-3,000 million for infrastructure over the life of the submarines.
- £1,500 million as a speculative estimate of the cost of replacing the D5 missile
- £250 million to participate in the US Trident II missile life extension programme.[116]

This gives a range of total project cost from £16,750 million to £21,750 million. This report assumes that:

1) The 'submarine' category includes Submarines, Strategic Weapon System Equipment, and Tactical Weapon System categories from the House of Commons Trident programme reports.
2) The 'infrastructure' category covers the equivalent of 'shore construction' and 'dockyard projects'.
3) The speculative estimate for the replacement of the Trident II (D5) missile covers the Strategic Weapon System Missile category.
4) The 'warhead' category covers the 'warhead' component of 'Warhead, Miscellaneous, and Unallocated Contingency'. In 1988 it was estimated that the warhead programme comprised just over £1 billion with the miscellaneous category at just under £1 billion of around £2.5 billion for the overall category.[117]

Table 3: Comparison of original Trident programme costs and 2006 estimate for Trident replacement

	2008-09 £ millions	2006 Trident replacement costs £ millions
Submarine		
Submarines	5702.4	
SWS equipment	1835.8	
TWS	1323.8	
	8860	11000-14000
Missile		
SWS missile	1666.5	
	1666.5	1500
Infrastructure		
Shore Construction	1838.5	
Dockyard Projects	227.1	
	2065.6	2000-3000
Warhead		
Warhead, Misc, Cont.	2862.6	
Of which Warhead	~1,000	2000-3000

'Miscellaneous' and 'contingency' components of the 'Warhead, Miscellaneous, and Unallocated Contingency' category are excluded from the 2006 White Paper estimate. The extent of shore infrastructure required is unlikely to be comparable to the size and scope of the facilities constructed during the original Trident programme. It will likely involve renovating and replacing current facilities as they age rather than building extensive new and original facilities.

[116] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 26.
[117] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 422 (London: HMSO, May 1988), p. xix.

Defence inflation

In "Defence Inflation: Reality or Myth" Malcolm Chalmers argues that the unit production cost (UPC) of major weapon systems tends to escalate over time at a rate greater than inflation in the rest of the economy as measured by the GDP deflator.[118] Chalmers argues that the primary explanation for the escalation of unit costs over time is inter-generational improvements in unit performance. By examining data on three of the biggest current procurement programmes (the Typhoon aircraft, *Astute*-class submarines and Type 45 destroyers) he calculates an overall UPC inflation rate of around 2-3% in real terms based on "comparisons between actual realised costs, i.e. between the end of one project cycle and the end of the next project cycle".[119] This reflects the National Audit Office's figure of 2.7%.[120] The inflationary figures below are therefore based on inter-generational improvements in unit performance. If the replacement SSBNs are practically identical to the current *Vanguard* submarines then the performance improvement expected will be much less, and the cost increase accordingly much less.[121]

Cost of new submarines

The total cost of the original Trident programme in 2008-09 prices was £15,700 million. The estimate above suggests that the cost of the submarine (here including the costs of submarines, SWS Equipment and TWS) was approximately £8,860 million. Chalmers measures the inter-generational period from the end of one project cycle to the end of the next project cycle. For Trident this is measured from the operational deployment of the first *Vanguard*-class SSBN in 1994 to the planned operational deployment of the first Successor SSBN in 2024, a period of 30-years. An upper figure of 3% annual inflation gives a total of £21,500 million in 2008-09 prices based on an initial figure of £8,860 million in Table 3. A lower figure of 2% gives a figure of £16,050 million.

A new missile

The cost of purchasing the Trident II (D5) missiles as a percentage of the 2008-09 total Trident procurement programme was approximately £1,660 million. Assuming inter-generational improvement this time over a 45-year period a 3% inflation figure gives a cost of £6,277 million for purchasing the same number of next generation SLBMs from the US. A 2% figure gives £4,046 million (a 45-year period is used from the first deployment of the Trident II in the US in 1990 to the likely deployment of a successor missile in the mid-2030s). The UK originally planned to purchase 65 Trident missiles. For illustrative purposes this equates to roughly £97-62 million per missile at 3% and 2% UPC inflation respectively. It is likely for reasons outlined below that the UK will only procure in the region of 40 new missiles to replace the Trident II (D5). This would cost between £3,863 (3%) and £2,490 (2%) million based on this illustrative unit cost.

The UK also paid a nominal fee of $116 million in US FY1982 dollars towards US research and development costs for the Trident II (D5) missile payable over 10 years from 1988 adjusted for

[118] Malcolm Chalmers, "The Myth of Defence Inflation", *RUSI Defence Systems*, June 2009, pp. 12-16.
[119] Chalmers, "The Myth of Defence Inflation", p. 15.
[120] *Ministry of Defence: The Major Projects Report 2009*, National Audit Office, HC 85-1 (London: HMSO, December 2009), p. 4.
[121] Thanks to Malcolm Chalmers for this point.

inflation.[122] This represented 5% of US R&D costs.[123] In addition, the UK was obliged to pay for the manning the *Rapier* air defence system for USAF bases in the UK until 2001 as part of its contribution to R&D costs.[124] In 1982 the cost of the *Rapier* commitment was estimated at $285 million, giving a total offset R&D fee of $501 million. These offset costs were not included in the original Trident costs estimates.[125] A 1982 exchange rate of £1:$1.78 gives at total UK R&D contribution of £225 million, or around £505 million in 2008-09 prices. A comparable R&D contribution for a new missile based on a 3% annual inter-generational inflation figure gives £1,909 million and a 2% figure gives £1,231 million.

A new warhead

The cost of warhead research, development and production is difficult to ascertain. The figure for Warhead, Miscellaneous, and Unallocated Contingency in 1994-95 was £2,130 million. Unallocated contingency was approximately 6% of the total (6% of £15,700 is £942 million) and 'miscellaneous' was a relatively small percentage of the 'Warhead, Miscellaneous, and Unallocated Contingency' category. In 1989 warhead costs were estimated to be around £1,000 million.[126] Using the 1989 figure a 30-year inter-generational cost inflation gives £2,427 million (3%) and £1,811 million (2%), well within the £2-3 billion estimate in the 2006 White Paper.[127]

Running costs

The 2006 White Paper reported that once the new fleet of SSBNs comes into service, the in-service costs of the UK's nuclear deterrent, which will include AWE Aldermaston's costs, are expected to be similar to today at around 5-6% of the defence budget.[128] The defence budget for 2007-08 was £32,600 million, but MoD says its estimates are based on the 'near cash' budget figure, which was £29,400 million.[129] 5-6% gives a range of £1,470-£1,764 million. For a planned 25-year service life this gives upper and lower figures of £36,750 million and £44,100 million respectively. In March 2007 Defence Secretary Des Browne stated that "Total expenditure on the capital and running costs of the Trident nuclear deterrent, including the costs of the Atomic Weapons Establishment, in 2006-07 is expected to be around £1,500 million".[130] In January 2008 he stated that "The annual expenditure for capital and running costs of the current Trident nuclear deterrent, excluding costs for the Atomic Weapons Establishment, is expected to be around £720 million in 2007-08" suggesting annual capital and running costs of the *Vanguard* fleet and Trident missiles of £780 million.[131]

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[122] *Ministry of Defence: Trident Project,* National Audit Office, HC 287 (London: HMSO, February 1984), p. 5.
[123] *Strategic Nuclear Weapons Policy*, House of Commons Defence Committee, HC 674-iv (London: HMSO, October 1980), p. 94.
[124] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 337 (London: HMSO, March 1992), p. x.
[125] *The Trident Programme*, House of Commons Defence Committee, HC 479 (London: HMSO, July 1985), p. viii.
[126] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 374 (London: HMSO, June 1989), p. xix.
[127] A 1998 estimate projected the total Trident warhead *production* costs to be in the region of £300 million. House of Commons, *Official Report,* July 14, 1998, Column: 167.
[128] House of Commons, *Official Report*, December 3, 2007, Column 845W.
[129] See: <www.mod.uk/DefenceInternet/AboutDefence/Organisation/KeyFactsAboutDefence/DefenceSpending.htm>. MOD says it refers to near cash budget in MOD supplementary memorandum to *The Future of the UK's Strategic Nuclear Deterrent: the White Paper*, House of Commons Defence Committee HC 22 (London: HMSO, 2007), Ev 206.
[130] House of Commons, *Official Report*, March 12, 2007, Column 55W.
[131] House of Commons, *Official Report*, January 31, 2008, Column 526W.

AWE Aldermaston capital investment

In the 1980s AWE received significant infrastructure investment. In 1988 32 projects were planned or underway at an estimated cost of £1,031 million. Only £35 million was attributed to the Trident programme.[132] The costs of procuring finished warheads were allocated to the programme, but it is not clear whether the full research and development costs were also attributed.

AWE is undergoing a further period of significant infrastructure investment almost exclusively in support of the current Trident warhead and any future warhead requirements for the Successor system. Plans were revealed in 2008, for example, for a number of new facilities for warhead design and manufacture. These include a new Conventional Manufacturing Facility, a new warhead assembly/disassembly facility, a new uranium handling facility to store, cast, machine and recycle enriched uranium for Trident warheads and submarine reactor fuel, and a new Hydrodynamic Facility for non-explosive nuclear testing.[133]

AWE was contractorised in 1993. Following a competition held by MoD, the contract for a second term was awarded on April 1, 2000 to AWE Management Limited (AWEML) for a period of ten years that was extended to 25 years in January 2003. The total value of the contract is £5.3 billion.[134] In the early 2000s a government review of AWE concluded that additional investment was required in order to maintain the UK's nuclear weapons capability.[135] In response in July 2005 Defence Secretary John Reid announced a new programme of investment in manpower and replacement of many of the major science, manufacturing and assembly facilities at Aldermaston and Burghfield. This amounted to an additional £1,050 million investment for a Nuclear Weapons Capability Sustainment Programme (also known as the Warhead Assurance Programme) over three years from 2006-07 through to 2008-09 to ensure that AWE could continue to support the Trident warhead and build a replacement if needed.[136] This additional £1,050 million was in addition to the £5.3 billion management contract.[137] In September 2009 it was announced that a further £1 billion *per annum* was being invested Nuclear Weapons Capability Sustainment Programme through to March 31, 2013.[138]

None of this expenditure will fall under the "£2-3 billion for the possible future refurbishment or replacement of the warhead" set out in the 2006 White Paper. Defence Secretary John Hutton stated in June 2009 a decision on whether to refurbish or replace the warhead had not yet been made and therefore the cost of refurbishment or replacement was not reflected in the additional expenditure at AWE.[139]

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[132] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 374 (London: HMSO, June 1989), p. 37.
[133] House of Commons*, Official Report,* June 28, 2008, Column 447W.
[134] House of Commons, *Official Report*, January 22, 2003, Column 14WS
[135] Heather Pragnell, "Discussion on Key Elements and Enablers of the UK Version of a 'Responsive Infrastructure" in *A Collection of Papers from the 2007 PONI Conference Series*, Project on Nuclear Issues (Washington, D.C.: Center for Strategic and International Studies, 2008), p. 72.
[136] House of Commons, *Official Report*, March 11, 2005, Column 1257W.
[137] House of Commons, *Official Report,* March 11, 2005, Column 1257W.
[138] House of Commons, *Official Report*, September 9, 2009, Column 136WS.
[139] House of Commons, *Official Report*, June 1, 2009, Column 41W.

It also clear that this additional investment is now much greater that the £720 million annual running costs of AWE Aldermaston for 2007-08.[140] Either these additional costs now totalling £10,350 million are in addition to annual running costs or annual running cost are set to increase substantially from 2009-2013. This report uses an annual running AWE cost of £720 million but cost tables include the additional AWE investment for illustrative purposes.

Conventional protection forces

In 2007 Defence Secretary Des Browne outlined the costs of conventional forces assigned to protect the Trident submarines as they enter and leave Gare Loch at Faslane. He stated that "A broad order estimate, however, of the annual operating costs of committed conventional force elements would be around £25-30 million." 'Committed' forces are defined as "force elements committed to the military task as their primary role" and constitute a single mine warfare vessel and a single survey vessel. A second category of 'contingent' forces are also relevant, but "force elements held contingent are assigned to a number of tasks and are not planned routinely to deploy in support of the deterrent". These include two SSN attack submarines, a single destroyer or frigate, three additional mine warfare vessels, a single Royal fleet auxiliary vessel, 5 Merlin anti-submarine warfare helicopters, and 8 maritime reconnaissance aircraft. The estimated cost of generating these forces for a range of tasks and not just to protect the SSBN fleet is £250-300 million.[141] The cost of generating committed forces over 25 years is £625-750 million. If a token 10% of the cost of generating contingent forces at £250-300 million per year is directly connected to deploying Trident submarines, this adds an additional £625-750million.

Reactor development

MoD began considering nuclear reactor propulsion requirements for future submarines in 2005 and agreed a 10-year partnering contract worth up to £1,000 million with Rolls Royce in May 2007.[142] This covers the period relating to development of a new reactor plant for the Successor fleet but additional MoD funding beyond 2015 cannot be ruled out.

The original Trident contract let to VSEL to build the *Vanguard*-class fleet included the PWR2 reactor that VSEL purchased from Rolls Royce. None of the costs of developing the PWR2 that began in 1978 were to be attributed to Trident since it was under development for future classes of submarine. The cost of modifying the PWR2 for the Trident boats and the costs of the reactor cores purchased by MoD from Rolls Royce for installation by VSEL *were* borne by the Trident programme. Each propulsion unit (the Nuclear Steam Raising Plant and secondary Propulsion Machinery) cost £70 million in 1987/88 prices and was including in the overall cost of the submarines.[143]

Vanguard Life Extension cost

A further cost associated with the Trident replacement programme is the decision to extend the service life of the current *Vanguard* SSBN fleet. In evidence before the House of Commons

[140] House of Commons, *Official Report*, January 21, 2008, Column 526W.
[141] House of Commons, *Official Report,* March 8, 2007, Column 2131W.
[142] House of Commons, *Official Report*, July 25, 2007, Column WS89; *The United Kingdom's Future Nuclear Deterrent Capability*, p. 15.
[143] *The Progress of the Trident* Programme, House of Commons Defence Committee, HC 422 (London: HMSO, May 1988), para. 32.

Defence Committee MoD's Tom McKane, Director General of Strategic Requirements, stated that the cost of extending the life of the Vanguard by around 5 years "will be generated as we get closer to the point where work actually has to be done on the boats, but the work that we have done shows that we are probably talking in round terms of hundreds of millions for the five years for the four boats".[144] This report assigns a provisional figure of £500 million to the VLOP effort.

Decommissioning

A final cost involves decommissioning the new submarines. In 2007 Defence Secretary Des Browne stated that "The estimate for the in-service costs of the UK's nuclear deterrent, once new submarines come into operation, set out at paragraph 5-14 of the White Paper includes an allowance for the decommissioning costs of a successor system".[145] He went on to state that the nuclear liabilities in MoD's annual report and accounts for 2005-06 included a figure of £333 million for all current in-service submarines, including the *Vanguard* class.[146] In 2007 Defence Secretary Bob Ainsworth stated that the projected cost for decommisioning the seven planned *Astute*-class SSNs was £1,000 million.[147] Actual decommissioning costs may prove much higher.

Table 4: Trident replacement capital cost estimates based on 2006 White Paper

	Lower end £ millions		Upper end £ millions	
Submarines (Based on original Trident programme)	11000	Lower 2006 estimate	14000	Upper 2006 estimate
Warhead (Based on 2006 White Paper estimate)	2000	Lower 2006 estimate	3000	Upper 2006 estimate
Infrastructure (Based on 2006 White Paper estimate)	2000	Lower 2006 estimate	3000	Upper 2006 estimate
D5LE programme (Based on 2006 White Paper estimate)	250		250	
D5 replacement (40 missiles) (Based on 2006 White Paper estimate)	1500		1500	
D5 replacement R&D contribution (Based on original Trident programme)	505		505	
Reactor development to date	1000		1000	
VLOP to date	500		500	
TOTAL	18755		23755	
Inc. AWE investment 2003-2013	*10350*		*10350*	
TOTAL	*29105*		*34105*	

144 *The Future of the UK's Strategic Nuclear Deterrent: the White Paper*, House of Commons Defence Committee HC 22, (London: HMSO, 2007), p. Ev 59.
145 House of Commons, *Official Report,* March 13, 2007, Column 207W.
146 House of Commons, *Official Report,* March 13, 2007, Column 207W.
147 House of Commons, *Official Report,* December 10, 2007, Column 55W.

Table 5: Trident replacement capital cost estimates based on inter-generational unit cost inflation				
	Lower end £ millions		Upper end £ millions	
Submarines (Based on original Trident programme)	16048	2% inflation	21505	3% inflation
Warhead (Based on 2006 White Paper estimate)	2000	Lower 2006 estimate	3000	Upper 2006 estimate
Infrastructure (Based on 2006 White Paper estimate)	2000	Lower 2006 estimate	3000	Upper 2006 estimate
D5LE programme (Based on 2006 White Paper estimate)	250		250	
D5 replacement (40 missiles) (Based on original Trident programme)	2490	2% inflation	3863	3% inflation
D5 replacement R&D contribution (Based on original Trident programme)	1231	2% inflation	1909	3% inflation
Reactor development to date	1000		1000	
VLOP to date	500		500	
TOTAL	25519		35027	
Inc. AWE investment 2003-2013	*10350*		*10350*	
TOTAL	*35869*		*45377*	

Table 6: Trident replacement operational cost estimates over 25 years				
	Lower end £ millions		Upper end £ millions	
Running costs inc. AWE / 25 years (Based on 5-6% MoD budget)	36750	5% MoD budget	44100	6% MoD budget
Committed protection forces / 25 years (Based on £25-£30 million)	625	Lower 2007 estimate	750	Upper 2007 estimate
10% contingent forces / 25 years (Based on £250-£300 million)	625	Lower 2007 estimate	750	Upper 2007 estimate
Decommissioning	?		?	
Contingency	?		?	
Total	38000		45600	

Table 7: Illustrative total Trident replacement capital and operational cost estimates over 25 years				
	White Paper £ millions		Defence inflation £ millions	
	Lower	Upper	Lower	Upper
Capital costs	18755	23755	25519	35027
Operating costs	38000	45600	38000	45600
TOTAL	56755	69355	63519	80627
Inc. AWE investment 2003-2013	*10350*	*10350*	*10350*	*10350*
Total inc. AWE:	*67105*	*79705*	*73869*	*90977*

Source of Successor funding

The government stated that the costs of procuring the new Successor SSBNs will not come from MoD's core budget. At the time of the 2006 White Paper Prime Minister Tony Blair stated explicitly that the Trident replacement would "not be at the expense of the conventional capabilities that our armed forces need".[148] Nevertheless, Lord Boyce, former Chief of the Defence Staff, expressed extreme scepticism that sufficient additional funding would be provide by the Treasury to pay for the Successor programme, stating that "I fear we will see the Treasury conducting some underhand activity in the current spending round to shave the defence budget in order to allow headroom for the new strategic force. This will have a disastrous effect on our conventional military capability where already we are seeing running rife rumours that to meet savings targets, dramatic cuts are to be made."149

Historical precedent suggests that there will in fact be important opportunity costs for MoD. In 1982, for example, Defence Secretary John Nott stated that "I have not been given any extra money for Trident. I have negotiated a 3 per cent real growth up until 1985/86".[150] The cost of Trident came from the MoD budget in part supported by an increase in the defence budget. During the new procurement cycle the defence budget is set to be cut over the next parliament, if not the next two.

Comparison with the original Trident programme costs

It is regularly stated that the original Trident programme came in on time and under budget and that, by implication, the Successor programme will also be on time and on budget. Whilst this overall claim is true it requires further elaboration.

First, changes in the US exchange rate resulted in significant expenditure increases in the original programme. 29% of expenditure was projected to be spent in the US and 71% in the UK. Exchange rate variations increased the original November 1981 programme estimate by £1,103 million by 1994/95. The effect of exchange rate changes will be reduced in the proposed Successor programme given the likely reduction in programme expenditure in the United States (in particular the Successor programme will not involve procurement of US designed and built SLBMs until the 2030s or 2040s). Nevertheless, some expenditure will occur in the United States, although at what level is not known, and that budget will be subject to exchange rate variation.[151]

Second, this additional exchange rate cost was offset by the decision to refurbish the UK's Trident II (D5) missiles in the US rather than build a custom facility in the UK. The decision saved an estimated £1,164 million by 1994/95. This saving will not be available to the Successor procurement programme assuming that current arrangements for refurbishing UK Trident missiles in the US will continue.[152]

[148] House of Commons, *Official Report,* December 4, 2006, Column 23.
[149] House of Lords, *Official Report,* January 24, 2007, Column 1163.
[150] *Strategic Nuclear Weapons Policy*, House of Commons Defence Committee, HC 266 (London: HMSO, March 1982), para. 70.
[151] *Progress of the Trident Programme*, House of Commons Defence Committee, HC 350 (London: HMSO, July 1995), p. 20.
[152] Ibid., p. 20.

Third, the ability of MoD to bring the Trident programme in on budget was due to significant cost savings in the US as well as the UK. Key elements of the programme brought in under budget according to 1994/95 estimates were: the costs for building the four submarines that were projected to fall by £1,336 million to £4,243 million; the costs for 'warhead, miscellaneous and unallocated contingency' that were projected to fall by £915 million to £2,310 million; the costs for Strategic Weapon System Equipment that were projected to fall by £545 million to £1,366 million; and the costs for Strategic Weapon System Missile that were projected to fall by £910 million to £1,240 million. The latter two were almost exclusively based on cost reductions in the US.[153]

A number of UK-only programme elements experienced substantial cost increases: costs for the Tactical Weapon System were projected to rise by £292 million to £985 million; costs for Shore Construction works encompassing 110 projects[154] were projected to rise by £822 million to £1,368 million; and costs for 'dockyard projects' were projected to rise by £79 million to £169 million. The potential for comparable cost overruns will be reduced by the smaller infrastructure element of the Successor programme expenditure, although the major infrastructure programme at AWE Aldermaston could experience significant costs overruns.[155]

Experience with the D154 project at HMNB Devonport in the 1990s and the current *Astute*-class SSN highlight the likelihood of cost overruns. In 1993 it was confirmed that Devonport would be the single UK site that would carry out future deep maintenance, refitting and refuelling of the UK submarine fleet, including the *Vanguard*-class submarines. This meant that all the existing submarine support facilities within the dockyard would be upgraded to meet the modern stringent standards for nuclear safety. The contract for the facility redevelopment programme became known as the D154 Project.[156] Project D154 involved upgrading nuclear facilities at Devonport in three phases. The Phase 1 concept and design contract ran from 1993 to 1996. It was originally envisaged that the construction work would begin in 1996, with completion in 1999. The Phase 2 contract was eventually awarded in March 1997 and construction work began in 1998. The estimated date for completion of the contract was April 2004.

During 2001 it became clear that the approved maximum cost for Phase 2 would be exceeded and the Phase 2 contract was renegotiated and re-scoped.[157] In 1999 the government stated that "The contracted target price range for the provision of refitting and refuelling facilities for nuclear submarines at Devonport is £335 million-£359 million. The figures relate both to the refurbishment of existing facilities and the provision of new facilities for Trident submarines". Three years later it was reported that the cost of upgrading the facilities at Devonport to cope with the refits of the nuclear fleet was likely to be £638 million to £659 million.[158] The *Scotsman* reported that "Tougher safety standards and a lack of clarity at the time of the original decision about what the regulators – primarily the Nuclear Installations Inspectorate – would accept as a

153 Ibid., p. 20. £150 million of the £1,366 million on SWS (Equipment) was spent in the UK. All of the £1,240 million on SWS (Missile) was spent in the US.
154 For details see *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 374 (London: HMSO, June 1989), p. 24.
155 *Progress of the Trident Programme*, House of Commons Defence Committee, HC 350 (London: HMSO, July 1995), p. 20.
156 Malcolm Smith, "The D154 Project", *Ingenia* (Royal Academy of Engineering), No. 13, August 2002. Available at <http://www.ingenia.org.uk/ingenia/issues/issue13/Smith.pdf>.
157 House of Commons, *Official Report*, October 21, 2005, Column 1232W.
158 House of Commons, *Official Report* January 31, 2002, Column 498W.

safe site are being blamed."[159] The cost of Project D154 and its substantial cost increase were not included in maintenance costs for the *Vanguard* SSBNs.[160]

MoD has also experienced major budget and schedule overruns for the *Astute*-class SSN programme. A contract to build three *Astute* submarines was placed with GEC-Marconi in March 1997 worth £1,961 million for full development and initial production.[161] The contract was restructured in December 2003 to £2.6 billion.[162] Costs shot up by £1,003 billion in 2002 and by 2006 the estimated project cost was £3,492 million with £1,104 as research and development costs.[163] The *Astute* programme is now forecast to cost £3,806 million on completion of the initial tranche of three submarines.[164] The National Audit Office forecasts that the *Astute* programme will overrun its "most likely" cost at approval by 48% and is now 47 months behind its 'most likely' in-service date at approval.[165] By 2004 the in-service date for HMS Astute had already been pushed back to 2009.[166] The first submarine was delivered to the Navy in November 2009, over four years after the original in-service date of June 2005.[167] The planned service lives of the older *Swiftsure* and *Trafalgar*-class SSN submarines had to be adjusted to take into account the expected in-service dates of the *Astute*-class submarines.[168] The submarines are powered by the same Rolls Royce PWR2 nuclear reactor and armed with the same Spearfish torpedoes as the *Vanguard*-class and have the same planned service life of 25 years.[169]

MoD had to look to the US to get the programme back on track by employing General Dynamics Electric Boat to apply its proven expertise from its current *Virginia*-class attack submarine programme. The US Department of Defense facilitated this via a Government to Government Foreign Military Sale for up to $98 million.[170] The lessons learnt from the problems with the *Astute* programme are being applied to the design and build phase of the Successor programme.[171]

Fourth, at the time of the submarine build contracts there were two suppliers competing to purchase the Barrow shipyard, a competition that drove down contracted costs for the *Vanguard* submarine building programme. The original price contract for HMS Vanguard was £650 million of which £460 was for the submarine – this was £45million below VSEL's initial tender and was reduced due to competition between two potential purchasers of the VSEL yard at Barrow and

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159 Andrew Porter and Sharon Ward, "Calls for investigation as cost of Trident refit rises by £400m", *The Scotsman*, February 10, 2002.
160 House of Commons, *Official Report*, March 8, 2010, Column 23W.
161 House of Commons, *Official Report*, March 7, 1997, Column 381; *Ministry of Defence: Major Projects Report 1999*, National Audit Office, HC 613 (London: HMSO, July 2000), p. 2.
162 House of Commons, *Official Report*, December 9, 2004, Column 687W; House of Commons, *Official Report*, March 9, 2006, Column 1692W
163 *Ministry of Defence: Major Projects Report 2002*, National Audit Office, HC 91 (London: HMSO, December 2002), p. 8; House of Commons, *Official Report*, May 17, 2006, Column 953W; House of Commons, *Official Report*, December 6, 2006, Column 448W.
164 *Ministry of Defence: The Major Projects Report 2008*, National Audit Office, HC 64-1 (London: HMSO, December 2008), p. 8.
165 Ibid., pp. 26 & 28.
166 House of Commons, *Official Report*, December 9, 2004, Column 687W.
167 House of Commons, *Official Report*, July 17, 2001, Column: 149W.
168 House of Commons, *Official Report*, December 19, 2006, Column 1900W.
169 House of Commons, *Official Report*, March 17, 1997, Column: 381; House of Commons, *Official Report*, January 20, 1999, Column 459.
170 House of Commons, *Official Report*, November 17, 2004, Column 1541W.
171 House of Commons, *Official Report*, January 12, 2009, Column 111W.

improved productivity at the yard.[172] The same does not hold today. Today there is no competition. The UK submarine-building industry has been rationalised and nuclear-powered submarine building has been consolidated at Barrow under BAE Systems.[173] MoD and the nuclear submarine building industry are co-dependent. It is a unique and symbiotic defence-industrial partnership that involves a high-technology industry specialising in one product (nuclear-powered submarines), provided by a single submarine-building supplier (BAE Systems), for a single customer (MoD), with no exports, small-scale orders, and constant pressure to drive down costs.[174] The submarine industry and MoD have institutionalised their partnership through the 2008 Submarine Enterprise Collaborative Agreement (SECA) to reduce overall submarine procurement costs and ensure MoD can continue to place orders.[175] This represents a monopoly/monopsony supplier risk with BAE Systems at the centre of the UK nuclear-powered submarine building industry. As Greenpeace warned in 2009, "BAE Systems is well known for delivering projects late and over budget, with recent examples including the *Astute* Class submarines (three and a half years late, and around £1.3bn and 47.3% over budget), the Type 45 Destroyer ships (two years late and £1.5bn and 29% over) and the Nimrod reconnaissance aircraft rebuild (six years late and £700m and 25% over)".[176]

In addition, given the difficulties of developing the *Astute*-class and the restructuring of submarine building capacity that has occurred at Barrow it is not clear how nuclear-powered submarine building practices could be further streamlined to drive down costs in a manner comparable to the original Trident programme.

A like-for-like replacement will cost between £56.7 and £80.6 billion for capital and operating costs over 25 years based on the illustrative cost estimates above. If current additional investment in AWE through to 2013 is not covered by annual operating costs, then the totals rise to £67.1 and £91 billion. These estimates are illustrative because they exclude key unknowns, that will affect the overall cost, including:

- The extent of inter-generational unit performance increase for the next-generation submarines, missiles and warheads (less performance increase means less unit cost inflation).
- The UK contribution to US R&D costs for a next-generation Trident missile and whether this will be attributed to the Successor budget.
- R&D costs for the Next Generation Nuclear Propulsion Plant and whether this will be attributed to the Successor budget.
- Ongoing warhead R&D at AWE Aldermaston and whether this will be attributed to the Successor budget.
- The extent of AWE capital investment beyond 2013 and whether this is part of annual AWE costs and attributed in some part to the Successor budget.
- Whether the Successor programme will require a new Tactical Weapon System or sonar system and whether these costs will be attributed to the Successor budget.

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172 *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 422 (London: HMSO, May 1988), p. xiv, p. 7

173 Maggie Mort, *Building the Trident Network* (Cambridge, MA: MIT Press, 2002).

174 Keith Hartley, "The UK Submarine Industrial Base: An Economics Perspective", in Edmonds, M. (ed), *100 Years of The Trade: Royal Navy Submarines Past, Present & Future* (University of Lancaster: CDISS, February 2001).

175 "MoD Response to the Submarine Enterprise Collaborative Agreement (SECA) Consultation", Defence Equipment and Support, Ministry of Defence, June 2008, p. 1.

176 *In the Firing Line,* Greenpeace UK.

- VLOP programme costs and whether this will be attributed to the Successor budget or whether it is part of Trident 'running costs'.
- The degree of contingency allocated to the overall budget.

Most of the submarine and warhead recapitalisation expenditure is set to fall between 2014 and 2024 with capital costs for a replacement missile falling in the 2030s and 2040s.[177]

[177] Paul, Dunne, Paul Ingram and Samuel Perlo-Freeman, *The Real Cost Behind Trident Replacement and the Carriers* (BASIC: London, October 2007), p. 6.

Part 2: Options

There are two powerful incentives for reconsidering the decision to begin the process of replacing Trident: British leadership towards a world free of nuclear weapons and reducing the huge fiscal deficit facing the country. Nevertheless, the previous Labour government and the current Conservative-Liberal Democrat coalition government remain committed to retaining a nuclear capability beyond the current system. Options that reduce the salience of UK nuclear weapons, make progress towards the vision of a nuclear weapons-free world, and reduce overall costs are available, but it means rethinking prevailing understandings of 'minimum deterrence'.

Potential options will inevitably be shaped by the perceived benefits afforded by the current Trident system, notably the capabilities it provides (invulnerability at sea, long-range, high precision, high reliability, variable warhead yield, flexible force configuration), and the considerable costs already sunk into industrial support and command and control infrastructure at HMNB Clyde and HMNB Devonport.

Options will also be shaped by the very close nuclear relationship the current Trident system affords with the United States that has enabled the UK to maintain a strategic nuclear capability at an 'affordable' cost. In the 1960s and 70s the UK embarked on an indigenous and expensive programme called 'Chevaline' to upgrade the front-end of its US-supplied Polaris A3 missiles in order to overcome the anti-ballistic missile system the Soviet Union was deploying around Moscow. The US opted to deploy a new missile called Poseidon. A key lesson drawn from the defence establishment's difficult experience with Chevaline was that any future UK nuclear system must remain in step with US nuclear hardware and weapon programmes. The government's 1980 statement on *The Future United Kingdom Strategic Nuclear Deterrent Force* stated that "there is great financial advantage in the maximum commonality with the United States, especially in view of their high technology, the massive scale of their own missile procurement and our long experience of working together".[178]

In 1980 the US agreed to sell the Trident I (C4) missile to the UK for its new *Vanguard* submarines. The US subsequently decided to deploy the more advanced Trident II (D5) and phase out the older C4. This would occur just as the UK *Vanguard* submarines were coming into service. In 1982 the UK opted to procure the new D5 missile instead of the C4 with US blessing. The 'penalties of uniqueness' were the key driver behind the decision in terms of cost to the UK of deploying and maintaining the C4 missile over the long-term when the US had moved on to the D5.[179]

[178] *The Future United Kingdom Strategic Nuclear Deterrent Force*, Defence Open Government Document 80/23, Ministry of Defence, July 1980.

[179] Note by Professor Lawrence Freedman, Adviser to the Committee, *Strategic Nuclear Weapons Policy*, House of Commons Defence Committee, HC 266 (London: HMSO, March 1982), p. 23.

Maintaining the nuclear-powered submarine-building industry is also a key driver of potential options. The 2005 *Defence Industrial Strategy* stated that the UK must retain the sovereign capability and skills to design, develop, build, support, operate and decommission nuclear-powered submarines and their nuclear power reactors.[180] BAE Systems and other key suppliers in the submarine industrial base[181] argue that if new Successor submarines are not built the UK will sacrifice this technological autonomy, lose critical skills, risk closure of the Barrow shipyard, the collapse of the submarine production industry and attendant regional job losses.[182] Industry representatives argue that a new SSN or SSBN should be built every 22 months to ensure skills are retained.[183] The House of Commons Defence Committee concurred in 2006, stating that "without a new SSBN it is possible that there would be insufficient demand for nuclear submarines to sustain the industry".[184]

If the UK is to opt for an alternative nuclear force structure beyond a direct like-for-like replacement, then a variant of the current submarine-based Trident missile system represents the path of least operational, financial, and political risk. Nevertheless, a submarine-based cruise missile solution should not be dismissed. An air-launched cruise missile solution based on the Eurofighter Typhoon or the F-35 Joint Combat Aircraft the UK intends to procure form the US is perhaps the least likely option and is not considered in detail here.

Four options

This report examines four broad options:

1) A 'Trident lite' replacement programme that adheres to current understandings of 'minimum deterrence'.
2) A 'reduced readiness' downsized Trident replacement programme that ends 'continuous-at-sea deterrence' and scales down the requirements for 'minimum deterrence'.
3) A flexible, dual-use 'hybrid' submarine programme for conventional and nuclear missions that also ends 'continuous-at-sea deterrence' and scales down the requirements for 'minimum deterrence'.
4) A nuclear-armed cruise missile capability aboard current or new submarines.

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180 Ministry of Defence, *Defence Industrial Strategy*, Cm 6697 (London: HMSO, December 2005), p. 7.

181 Other key companies include Rolls Royce, Thales, Wellman Defence, Weir Strachan and Henshaw, Alstom, Sheffield Forgemasters, Ultra Electronics. MacTaggart Scott, L3, and York. Rolls Royce is particularly important since it design, builds and tests the nuclear power plants and fuel for the UK's nuclear-powered submarines.

182 *The Future of the UK's Strategic Nuclear Deterrent: the Manufacturing and Skills Base*, House of Commons Defence Committee, HC 59 (London: HMSO, December 2006), p. 14.

183 *Ibid.*, p. 18.

184 *Ibid.*, p. 19.

Trident lite

The first option labelled 'Trident lite' examines the potential for incremental reductions in current nuclear force structure whilst maintaining 'continuous-at-sea deterrence' (CASD) and adhering to current conceptions of minimum deterrence. Current understandings of 'minimum deterrence' reflect the force size, technological capability, and principles guiding the operation of the current Trident system. Key features include: the degree of nuclear destruction required for a 'minimum' nuclear deterrent threat; the requirement for a nuclear weapon system with global reach; absolute invulnerability to a surprise attack by continuously deploying Trident missiles at sea aboard undetectable submarines at sea; and the ability to fire nuclear warheads at an adversary within days or even hours of a decision to do so.

Future 'Trident lite' options that retain a CASD operational posture are:

- A possible reduction from 4 to 3 new SSBNs.
- A reduction from 16 to 12, or possibly 8, missile tubes per SSBN.
- A smaller stockpile of missiles through test-firing attrition.

Submarine numbers

The UK currently deploys four *Vanguard* SSBNs in order to ensure at least one is always on operational patrol in the Atlantic at all times whilst the other three are either preparing for patrol, returning from patrol, or undergoing maintenance or long-term refit in port. The Labour government examined whether CASD could be maintained with three Successor SSBNs rather than four. [185] Prime Minister Gordon Brown stated at the UN Security Council in September 2009 that "subject to technical analysis and to progress in multilateral negotiations, my aim is that when the next class of submarines enters service in the mid-2020s, our fleet should be reduced from four boats to three".[186] The key change lies with the reactor. When the current *Vanguard* SSBNs were built they were fitted with Rolls Royce's PWR2 reactor and fuelled with a reactor fuel assembly (Core G) that would only last about half the expected service life of the submarine. The *Vanguard* submarines therefore require refuelling at the Devonport dockyard in Plymouth midway through their service life. The new submarine nuclear reactor core developed by Rolls Royce (Core H) will last the full service life of the planned Successor submarines and reduce the time each submarine needs to spend in a long and expensive 3-4 year mid-life overhaul.[187] The Defence Procurement Agency, for example, reported in 2003 that "The advanced science and technology that has gone into the Core H design and build means it has reached far higher levels of efficiency than previous designs. This will render the costly and time intensive refuelling of nuclear

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[185] See comments by Defence Secretary Des Browne in *The Future of the UK's Strategic Nuclear Deterrent: The White Paper. Volume II: Oral and Written Evidence*, House of Commons Defence Committee, HC 225-II (London: HMSO, March 2007) p. Ev 69.

[186] Statement by Gordon Brown, MP at the UN Security Council summit on nuclear disarmament and counter-proliferation, New York, September 24, 2009.

[187] MoD's Defence Equipment and Support reported in 2008 that the process of refuelling the reactors with a new core and subsequent reactor commissioning dictates the overall duration or the LOP(R) process. *Desider*, Defence Equipment and Support, Ministry of Defence, November 2008, Issue 7, p. 20.

submarines a thing of the past."[188] This will increase the operational availability of the proposed Successor submarines and may allow CASD to be maintained with three boats.

The Core H fuel assembly is currently being installed in the new *Astute*-class SNN attack submarines and in the current *Vanguard*-class SSBNs as they undergo their mid-life overhaul. Prime Minster Gordon Brown instructed his National Security Committee to provide an answer by the end of 2009 as to whether CASD could be maintained with three submarines. No formal response was provided by the Labour government, but in April 2010 Quentin Davies, MoD's Minister for Defence Equipment and Support, reportedly stated at the Barrow shipyard that four Successor submarines would be built, not three.[189] A MoD spokesperson subsequently stated that "No final decision has been made but it is expected that four boats will be needed to ensure the necessary level of capability."[190]

The key issue is the degree of contingency in a three-boat fleet. When the current Trident system was under development Rear Admiral Ian Pirnie, MoD's Chief Strategic Systems Executive, stated in 1992 that "it is possible to construct a programme on paper that makes assumptions about commission lengths, about refit lengths, about the periods on work-up and all the other things I was mentioning that would show on paper that continuous patrolling could be achieved [with three boats] but that ideal programme… would contain no contingency at all".[191]

When the UK was preparing to procure the Polaris system in the 1960s the option of a three-boat submarine fleet was considered. A Ministry of Defence Memorandum in November 1964 on *The Size of the British Polaris Force* stated that "With three boats it would be possible barring accidents and extended refit delays, to keep one boat (16 missiles) on station for nearly all the time. Even in the best case there would, however, be periods lasting some four weeks every four and a quarter years when no submarine would be available for deployment. On the other hand, there would be periods, if all went well, when two boats would be on station". But it warned that "A force of this size would allow no margin for unforeseen contingencies – which over the total life of the force (some twenty years) are almost certain to occur…any delay in refit or work-up would result in further periods when no submarine could be deployed on patrol". Nevertheless, "a United Kingdom force of this size, could be regarded as a minimal deterrent for national purposes – but only just".[192] This was during the Cold War with 1960s SSBN technology.

Missile numbers

The Labour government also announced in March 2009 that the Successor submarine will have 12 rather than the current 16 missile launch tubes suggesting a reduction in current capability.[193] In fact, the decision to reduce the size of the missile compartment for the planned Successor submarines reflects the steadily reducing size of the UK Trident arsenal (Table 8).

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[188] *Preview*, Defence Journal of the Defence Procurement Agency, March 2003. Available at <http://webarchive.nationalarchives.gov.uk/tna/+/http://www.mod.uk:80/dpa/preview_mar03.htm >.

[189] Jon Simpson, "Campaigners delighted by MP's sub pledge", *North West Evening Mail*, March 24, 2010.

[190] James Kirkup, "General election 2010: Labour ditches Trident pledge" *The Telegraph*, April 12, 2010.

[191] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 337 (London: HMSO, March 1992), p. 6.

[192] TNA, PRO, CAN 130.213. MoD Memorandum for MISC 17 on "The Size of the British Polaris Force", November 20, 1964. Reproduced in Peter Hennessey, *Cabinets and the Bomb* (Oxford: Oxford University Press, 2007), p. 176.

[193] Gordon Brown, "Speech on nuclear energy and proliferation", London, March 17, 2009.

Britain's Trident missiles are part of a much larger arsenal of missiles deployed by the US Navy aboard its *Ohio*-class SSBNs and refurbished at its Atlantic and Pacific Strategic Weapons Facilities (SWF). When each *Vanguard* submarine was commissioned into service it sailed to the Atlantic SWF at King's Bay, Georgia, to be loaded with Trident missiles. Each submarine then underwent a Demonstration and Shakedown Operation (DASO) process culminating in a live test fire of an unarmed Trident missile at the US missile test range at Port Canaveral in Florida. As the submarines approach their mid-life 3-4 year overhaul and refuelling they offload their missiles at King's Bay before returning to the UK. Upon being recommissioned after their overhaul the submarines return to King's Bay to be reloaded with missiles before undertaking a second DASO and live test fire. HMS Vanguard, for example, was commissioned into service in August 1993, conducted two live test firings on May 26 and June 19, 1994 and entered operational service in December 1994. It returned to Kings Bay and offloaded its missiles in December 2001 and began its Long Overhaul Period and Refuel (LOP(R)) at the Devonport dockyard in March 2002. It left refit in December 2004, returned to Kings Bay and conducted a live test fire on October 10, 2005 before returning to operational service.[194]

Table 8: UK Trident II (D5) missile stockpile and test firings

Commissioning DASO	Missiles tested
HMS Vanguard : May 26 and June 19, 1994	2
HMS Victorious: July 24 and August 22, 1995	2
HMS Vigilant: October 15, 1997	2
HMS Vengeance: September 21, 2000	1
Post-refit DASO	
HMS Vanguard: October 10, 2005	1
HMS Victorious: May 24, 2009	1
HMS Vigilant: ~ 2013	1
HMS Vengeance: ~ 2017	1
Commissioning DASO	
Successor #1: ~ 2023	2
Successor #2: ~ 2025	2
Successor #3: ~ 2027	2
Successor #4: ~ 2029	1
Post-refit DASO	
Successor #1	1
Successor #2	1
Successor #3 (New SLBM in service?)	1
Successor #4 (New SLBM in service?)	1
Total test firings	22
Processing margin	4
Total Missiles Procured	58
Remaining operational stockpile	32

[194] See "Chronology: Polaris-Poseidon-Trident", US Navy Strategic Systems Program Office. Available at <http://www.ssp.navy.mil/about/history_chronology_86-05.shtml>. Accessed February 2, 2010.

The UK originally purchased 65 missiles from the US. This order was reduced to 58 in the 1998 Strategic Defence Review.[195] The Trident missile will remain in service until 2042. A new missile will probably be phased in to the US SSBN fleet in the mid-late 2030s. The planned Successor submarines will deploy the Trident II (D5) missile until it is retired and a new missile is available. The 2006 White Paper stated that the UK had 50 missiles left after test firings. Further DASO test firings for the remaining *Vanguard* submarines that are currently undergoing or scheduled to undergo a major mid-life overhaul, plus test firings for a new fleet of up to four Successor SSBNs when they are first commissioned, plus retention of a 'processing margin' of four missiles will leave a stockpile of around 37 operational Trident missiles for a four-boat Successor fleet.[196] It is likely that Successor submarines will still have to undergo a midlife overhaul, even though the reactors will not require refuelling. Some Trident missiles will therefore be required for test firings after each Successor submarine's mid-life overhaul in the 2030s and 2040s.

As the number of missiles in the UK stockpile steadily reduces it will not be possible to equip three Successor submarines in the operational cycle with 16 missiles unless new missiles are purchased from the US (which remain in low rate production). The Labour government stated in the 2006 White Paper that "We believe that no further procurement of Trident D5 missiles will be necessary through its planned in-service life".[197] It is therefore likely that the UK will only purchase around 40 replacement missiles – 12 for three submarines in the operational cycle plus four as a processing margin.

Warhead numbers

The Trident system also enables the UK to potentially deploy hundreds of nuclear warheads. In the 1998 *Strategic Defence Review* the Labour government reduced the maximum number of warheads on each submarine to 48. Current conceptions of 'minimum deterrence' are therefore judged to require to capability to fire up to 48 independently-targetable 100kt nuclear warheads against another state.

The number of warheads deployed aboard each submarine need not change with a reduced missile loading. A *Vanguard* submarine with 16 missiles and on an average three warheads per missile provides the same capability as a Successor submarine with 12 missiles and an average of four warheads per missile, or 8 missiles and an average of 6 warheads per missile (see Table 9). Nevertheless, if the UK decided to limit the number of warheads to an average of three per missile, this would reduce the number of warheads per submarine to 36. The current operational stockpile of 160 allows for 48 warheads for three submarines in the operational cycle plus a 10% margin. A comparable calculation for 36 warheads for three submarines gives an operational stockpile of 119 warheads. This would require a change in 'minimum deterrence' criteria. This is explored in the context of the next option, 'reduced readiness', after an examination of the case for ending 'continuous-at-sea deterrence'.

195 Ministry of Defence, *The Strategic Defence Review*, Cm 3999 (London: HMSO, July 1998), paragraph 65.

196 In 1998 the government stated that four missiles constituted a processing margin. House of Commons, *Official Report*, July 30, 1998, Column 448.

197 MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 12.

Ending CASD[198]

A further reduction of the current system that reduces the salience of nuclear weapons in UK national security policy will require a decision to end to 'continuous-at-sea deterrence' and rethink prevailing understandings of 'minimum deterrence'. This would open up a range of options that would allow the UK to retain a smaller nuclear force at a reduced rate of readiness in a number of possible configurations and push nuclear weapons further into the background of UK national security policy in line with renewed commitments at the 2010 NPT Review Conference. This section examines the arguments for ending CASD and a 'reduced readiness' option involving a fleet of dedicated SSBNs that are regularly but not continuously at sea.

Ending CASD will require rethinking how we define 'minimum deterrence'. The rationale for maintaining a CASD posture is based on three arguments:

1) Credibility: A credible and effective nuclear deterrent threat requires an assured capability to retaliate against a strategic attack. This in turn requires a nuclear delivery platform that is invulnerable to a surprise first strike, which means maintaining an undetectable submarine at sea at all times.
2) Crisis stability: Under a 'reduced readiness' non-CASD posture any decision to sail a nuclear-armed submarine in a crisis risks unintentional escalation leading to heightened chances of conflict. Far better to avoid such a scenario by maintaining a submarine at sea at all times.
3) Operational expertise: Operating a ballistic missile submarine fleet requires a high tempo of operations to maintain crew cohesion, morale and unquestioned confidence in the firing chain. Only a CASD posture can provide the morale, surety and tempo required.

All three arguments can be robustly challenged and the need for CASD has been questioned over recent years. Former Chief of the Defence Staff Lord Guthrie urged the government in March 2009 to "seriously examine the number of submarines that we have and whether we always need to have one boat at sea".[199] Former Foreign Secretary Lord Owen has argued that the requirement for a nuclear deterrent that provides "100 per cent assurance that a retaliatory blow can be delivered via an invulnerable delivery platform" to defend against a 'bolt from the blue' attack is unnecessary. "Such a sophisticated, high deterrent threshold for the UK is considered by many in 2009 to be excessive".[200] The Liberal Democrats have also questioned the need for CASD in a policy review published in March 2010 on *Policy Options for the Future of the United Kingdom's Nuclear Weapons*. They argued that "The logic of maintaining Continuous At-Sea Deterrence (CASD) patrols in the post-Cold War era is no longer so compelling" and that "Without a major nuclear threat of a Soviet scale, the purpose of an assured second strike is no longer clear and the case for CASD weak".[201]

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[198] A version of this section was published as "A Progressive Nuclear Weapons Policy: Rethinking Continuous-at-Sea Deterrence", *RUSI Journal*, April 2010, with Paul Ingram.
[199] House of Lords, *Official Report,* March 26, 2009, Column 806.
[200] Owen, *Nuclear Papers*, p. 13.
[201] *Policy Options for the Future of the United Kingdom's Nuclear Weapons*, Liberal Democrats, March 2010, pp. 5 and 16.

Credibility and invulnerability

The UK consistently refers to its nuclear weapons as 'political' as opposed to 'war fighting' weapons. The possession of nuclear weapons in this sense is meant to exert a deterrent *effect* by influencing the political calculus of a would-be aggressor.

The credibility of a nuclear deterrent threat depends fundamentally on an opponent's belief that the threat is credible, i.e. that the UK has deliverable weapons capable of inflicting unacceptable damage and the political will to use them in extreme circumstances given the perceived interests at stake.[202] For example, a threat to use nuclear weapons when there is little or no evidence of a nuclear capability is not credible, and a threat to use nuclear weapons in response to a minor border incursion is not credible.

Ending CASD would not mean mothballing the SSBN fleet and mooring the UK's SSBNs in port indefinitely. It means ending continuous patrols and operating a 'reduced readiness' posture in which there may be periods of weeks, or even months, in which the UK does not a have a nuclear-armed SSBN at sea. This would mean that the probability of being able to fire nuclear weapons in response to a surprise strategic attack would diminish from near certain under CASD to a lower percentage, but only under the specific scenario of a pre-emptive strike (most likely a nuclear strike) against the UK's nuclear weapons at Faslane/Coulport and AWE Aldermaston.

The core purpose for Trident when it was originally procured, according to Defence Secretary John Nott, was to provide "an ultimate defence of this country against a nuclear strike, a pre-emptive strike by a nuclear power".[203] The only country that can deliver such an attack against the UK now and for the foreseeable future is Russia. It is widely and officially acknowledged that the Cold War is truly over and that the possibility of a surprise Russian nuclear first-strike is so low as to be near zero.[204] Indeed the government acknowledges that the UK faces no major direct nuclear threat and hasn't for at least a decade.[205] Yet we continue to insist on a CASD posture, at some considerable cost, as an 'insurance' against the remote (if not vanishingly small) possibility of the most extreme case.

Nevertheless, current conceptions of minimum deterrence are judged to require a 100% guaranteed capability to retaliate against a 'bolt from the blue' pre-emptive nuclear attack. A credible and effective nuclear deterrent threat is still judged to require the absolute certainty of retaliation in all conceivable circumstances. Any sign of invulnerability, any chink in the nuclear armour, is seen to carry huge risk in that it could be seized upon as a weakness and invite a devastating pre-emptive attack in a crisis.[206]

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[202] See Nick Ritchie, "Deterrence Dogma: Challenging the Relevance of British Nuclear Weapons", *International Affairs* 85(1), January 2009.

[203] *Strategic Nuclear Weapons Policy* House of Common Defence Committee, HC 266 (London: HMSO, April 1982) p. 21.

[204] "Joint Declaration by the President of the Russian Federation and the Prime Minister of the United Kingdom of Great Britain and Northern Ireland", Moscow, February 15, 1994.

[205] This was stated in the MoD *Strategic Defence Review*, paragraph 23 and reiterated in the 2009 *National Security Strategy of the United Kingdom*, Cabinet Office, Cm 7590 (London: HMSO, June 2009), p. 65.

[206] See MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 22 and Box 5-2, p. 27; Tim Hare, "Nuclear Policy all at Sea: A Part Time Deterrent Will Not Do!", *RUSI Journal*, 154: 6 December 2009, p. 54.

The validity of this logic is questionable. A pre-emptive attack against the UK would rest on a judgement that the advantages of striking first clearly outweigh the potential consequences of waiting for our next move. A state contemplating a pre-emptive strategic attack would have to be absolutely confident that: 1) there was no nuclear-armed SSBN at sea at the time of its attack: 2) the UK's entire nuclear retaliatory capability could be eliminated; and 3) that they would not suffer a devastating response from the United States and other NATO allies. Would an adversary's calculus change dramatically in favour of pre-emptive strike if there were, for example, an 80% chance of nuclear retaliation, or 60% or 40%, rather than 100%? The burden of proof regarding certainty of response in this context does not lie with the specific configuration of the UK's nuclear arsenal, but rather in the calculations of an aggressor. It is the inherent uncertainty of response and the potential for the UK to inflict an unacceptably high cost through nuclear retaliation with even a handful of warheads that undermines the 'credibility' argument of CASD advocates. As the late Sir Michael Quinlan observed in 2006, "Even a modest chance of a huge penalty can have great deterrent force",[207] assuming, of course, that the aggressor is 'deterrable'.

Quinlan also stated that until 1998 the UK's ballistic missile submarines were at "15 minutes' readiness to fire, because they were our last resort insurance against the hypothesis, remote though it might seem, of a bolt from the blue by an immensely powerful superpower. That hypothesis no longer has to be seriously entertained...".[208]

Crisis stability

Crisis stability/instability refers to the mutual interaction of processes for mobilising and heightening the alert-status of military forces during a crisis that could be interpreted by one or more sides as aggressive, escalatory and a prelude to an attack such that the risks of not firing first become unacceptable.

The UK's declaratory nuclear policy is that it would only ever consider using nuclear weapons in "extreme circumstances of self-defence."[209] This phrase is borrowed from the 1996 International Court of Justice (ICJ) Advisory Opinion on the "Legality of the Threat or Use of Nuclear Weapons". The Court concluded that "the threat or use of nuclear weapons would generally be contrary to the rules of international law applicable in armed conflict, and in particular the principles and rules of humanitarian law" applicable in armed conflict because the destructive blast, incendiary and radiation effects of nuclear weapons cannot be contained either in space or time. It could not, however, "conclude definitively whether the threat or use of nuclear weapons would be lawful or unlawful in an *extreme circumstance of self-defence, in which the very survival of a State would be at stake*" (emphasis added).[210]

Proponents of CASD argue that in a future crisis in which the survival of the state is at stake the government may not have an SSBN at sea capable of firing Trident missiles in a retaliatory strike if

[207] Michael Quinlan, 'Deterrence and Deterrability', in Ian Kenyon and John Simpson (eds), *Deterrence and the New Global Security Environment* (Routledge, London, 2006), p. 5.
[208] Evidence from Sir Michael Quinlan, *The Future of the UK's Strategic Nuclear Deterrent: The Strategic Context*, House of Commons Defence Committee, HC 986 (London: HMSO, June 2006), p. Ev 2.
[209] *The Future of the UK's Strategic Nuclear Deterrent: The Strategic Context: The Government's Response to the Committee's Eighth Report of 2005-06*, House of Commons Defence Committee, HC 1558 (London: HMSO, July 2007), p. 3.
[210] *Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion at the request of the UN General Assembly, ICJ Reports, July 8, 1996, para 97.

CASD is abandoned. This could limit the government's options because a decision to sail a Trident submarine could be interpreted by an adversary as an escalatory move signalling an intention to use, or threaten to use, nuclear weapons. This could be met with a bellicose response that destabilises the crisis and increases the risk of conflict or even a pre-emptive attack. Far better, it is argued, to maintain CASD and avoid this hypothetical scenario altogether.[211]

Research on nuclear weapons 'signalling' during a crisis and crisis stability is less conclusive. Certainly a nuclear 'signal' like sailing a Trident submarine during a crisis could be misinterpreted and lead to inadvertent escalation but such signals can also send a clear, credible and verifiable message that a crisis is serious enough to warrant recourse to implicit or explicit nuclear deterrent threats. This can reinforce deterrence and reduce the risk of conflict by changing an adversary's strategic calculations.[212] Sailing a Trident submarine in a crisis could therefore becalm or stoke the situation depending upon the political context. In addition, under a non-CASD posture any decision to sail a Trident submarine would likely be part of a wider and observable mobilisation of armed forces rather than singular event.

Furthermore, maintaining CASD does not eliminate the potential for crisis instability any more than ending CASD might exacerbate it. In a crisis where the use of nuclear weapons is considered a genuine possibility because the survival of the state is at stake it is quite possible (perhaps probable) that the government would prepare a second Trident submarine for operational deployment to complement the single submarine routinely on operational patrol in a CASD posture given the seriousness of the crisis.

The unintended impacts of a decision to launch a Trident submarine could be reduced in a number of ways that reinforce the credibility a UK nuclear deterrent threat under a 'reduced readiness' posture. The UK could

1. Modify the duration and tempo of SSBN sailing patterns during a crisis or a period of prolonged tension to create uncertainty in the mind of the adversary as to whether a nuclear-armed submarine is at sea. Operational patrols for current *Vanguard* submarines routinely last 3 months, but this can be extended. For example in September 2008 HMS Vengeance had its patrol extended by 35 days.[213] In 2007 the *Swiftsure*-class SSN HMS Sceptre with a crew of 116 spent nine months at sea.[214] This might include a return to continuous patrols for a limited period. The Navy has operated two ballistic missile submarines in a continuous deployment pattern with back-to-back consecutive patrols for several deployment cycles in the past. This was the case in February and March 2009 when HMS Vigilant was in mid-life overhaul and HMS Vanguard was undergoing repairs at Faslane following its collision with the French SSBN Le Triomphant in February 2009.

[211] MoD, *The Strategic Defence Review*, paragraph 13.
[212] Owen Price, "Preparing for the Inevitable: Nuclear Signalling for Regional Nuclear Crises", *Comparative Strategy*, 26:2, 2007, p. 105.
[213] "Scott Hailed As HMS Vengeance's 'Man of the Boat'", Royal Navy News, September 18, 2008, available at <http://www.royalnavy.mod.uk/operations-and-support/submarine-service/ballistic-submarines-(ssbn)/hms-vengeance/news/scott-hailed-as-hms-vengeances-man-of-the-boat>. The average length of a Trident patrol is between 70 and 80 days at sea. There is no set patrol length as this is varied between each individual patrol. House of Commons, *Official Report*, October 27, 2005, Column 521W.
[214] "Submarine's Return Makes History", *BBC News online*, October 24, 2007. Available at <http://news.bbc.co.uk/1/hi/scotland/glasgow_and_west/7059093.stm>. Accessed November 4, 2009.

For a substantial period between 1996 and 1998 CASD was achieved with HMS Vanguard and HMS Victorious without the back-up of a third boat.[215]

2. Enhance security and counter-intelligence measures at Faslane to reduce an opponent's ability to gather intelligence on SSBN movements, including increased anti-submarine warfare activities to provide enhanced protection of UK SSBNs entering and leaving Faslane.

3. Develop and subsequently activate emergency plans to coordinate SSBN patrols with France for the duration of a crisis to complicate an adversary's cost-benefit calculus based on the fact that a genuine strategic threat to the survival of the UK would automatically constitute a major threat to France. The potential for such coordination was reinforced by Prime Minister Gordon Brown in March 2010 when he announced that he had held talks on nuclear arrangements with President Sarkozy.[216]

4. Minimise any incentives for a nuclear first strike if a UK SSBN is sailed from Faslane by communicating clearly to an adversary UK nuclear firing options (including the ability to fire whilst docked at port), early warning capabilities, conventional stand-off power projection (in particular from undetectable attack submarines), and cyber warfare capabilities targeted at the aggressor state's leadership and core economic infrastructure. Clear communication is essential to avoid miscalculation and inadvertent crisis escalation. Policy options that highlight the practice of launching an SSBN in the early period of any crisis as a matter of routine might also reduce the risk of unintended escalation.[217]

5. Demonstrable plans for holding a nuclear-armed SSBN in port for a period of months on enhanced alert ready to sail at short notice if intelligence suggests an imminent attack. The UK regularly maintained a second *Resolution*-class SSBN armed with Polaris SLBMs at 24 hours notice for fire its missile in port and 47 hours notice to sail to join the SSBN on patrol during the Cold War.[218]

Operational surety and tempo

The third argument often marshalled in favour of a CASD posture relates to the operation of the SSBN fleet. The fundamental issue is whether a non-CASD posture will degrade the professionalism and exacting standards of stealth, safety and technical reliability for maintaining and operating an SSBN fleet and absolute confidence in the firing chain (the process from Prime Ministerial authorisation for release of nuclear weapons to the actual firing of Trident missiles from the SSBN at sea) should a decision be made by the Prime Minister to use nuclear weapons in conflict.

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[215] See *Progress of the Trident Programme*, House of Commons Defence Committee, HC 350 (London: HMSO, July 1995), p. vi.
[216] "Britain in the World", remarks by Gordon Brown before the Foreign Press Association, London, March 19, 2010. Available at http://www.number10.gov.uk/Page22876. See also Julian Borger and Richard Norton-Taylor, "France offers to join forces with UK's nuclear submarine fleet", *The Guardian*, March 19, 2010.
[217] Wyn Bowen, 'Deterrence and Asymmetry: Non-State Actors and Mass Casualty Terrorism', in Ian Kenyon and John Simpson (eds), *Deterrence and the New Global Security Environment* (Routledge, London, 2006), pp. 50-51.
[218] *UK Strategic Nuclear Forces – Short Term Working Party Report*, June 3, 1971, TNA, DEFE-19-190-e6. Cited in John Ainslie, "Overcoming Operational Obstacles to Reduced Readiness", working paper for a workshop at the University of Bradford on options for Trident replacement in September 2009.

CASD advocates insist that the only way to maintain crew cohesion, expertise and surety in the firing chain is through a high tempo CASD posture. It is argued that required standards of operational readiness, crew training and morale will inevitably decline if the nuclear deterrence mission is 'downgraded' through a reduced readiness posture and the ability to deploy Trident at sea with absolute confidence in the firing chain will degrade. This reflects an 'all or nothing' view in which deployment of Trident must treated as a priority elite mission requiring high-tempo continuous-at-sea deterrence or it must not be done at all.[219]

Nevertheless, the options outlined here envisage regular operation of nuclear-capable submarines. A sufficient level of operational readiness and technological, industrial and military expertise could be maintained under a reduced readiness posture through regular operation of the submarines, onshore simulation and intensive training before, during and after operational patrols, as well as regular redeployment drills and war games to exercise the redeployment option and nuclear targeting and war planning operations in a crisis scenario, all overseen by the current or modified stringent assessment and examination process. The UK has a substantial submarine training and assessment programme and facilities including HMS Raleigh Royal Naval Submarine School in Cornwall, in the Trident Training Facility at Faslane that houses a full size Trident II (D5) Active Inert Missile (AIM) in its launch tube and associated control system, and the Vanguard simulator that replicates the machinery control room system in the *Vanguard* submarines.[220] It is entirely conceivable that a robust training and operational regime can be devised that enables the Navy and Ministry of Defence to manage all aspects of the Trident capability to the required standard.

It could be possible to implement a non-CASD posture in which the time submariners spend at sea relative to time ashore (Personnel Tempo or PERSTEMO) remains similar to the current CASD posture although the submarines themselves would spend less time at sea (a reduced Operational Tempo or OPTEMPO). Nevertheless, regular operational patrols that exercise crew capabilities and expertise combined with extensive on-shore simulation and training should leave little room to doubt the surety of the firing chain under a non-CASD posture beyond that which may exist already.

The United States has faced and overcome problems associated with neglect of some aspects of its national nuclear mission over the post-Cold War period and some of the challenges faced by the US are relevant to operation of a reduced readiness British nuclear posture.[221] In particular in 2007 six nuclear-armed cruise missiles were inadvertently flown by a B-52 from Minot Air Force Base to Barksdale Air Force Base. The subsequent investigation of the unauthorised movement of nuclear weapons across the United States led to the December 2008 "Report of the Secretary of Defense Task Force on DOD Nuclear Weapons Management" (the Schlesinger report) that highlighted the importance of exercising the nuclear capability regularly and ensuring sufficient levels of expertise and senior-level attention to the nuclear mission within the Air Force.[222] Concern in the UK that stepping back from CASD could undermine long term institutional

[219] *The Future of the UK's Strategic Nuclear Deterrent: The White Paper. Volume II: Oral and Written Evidence*, House of Commons Defence Committee, HC 225-II, (London: HMSO, March 2007), p. Ev 69.

[220] Clifford Funnell, "Training and Simulation Systems" *Janes Underwater Warfare Systems 2008-2009* (Surrey: Janes Information Group, 2008), pp. 616-617.

[221] See Nick Ritchie, *US Nuclear Weapons Policy since the end of the Cold War* (Abingdon: Routledge, 2008), chapter 8; Defense Science Board, *Report on Nuclear Capabilities* (Washington, D.C.: US Department of Defense, December 2006), p. 33.

[222] *Report of the Secretary of Defense Task Force on DOD Nuclear Weapons Management*, Office of the Secretary of Defense (US Department of Defence: Washington, D.C., December 2008).

attention to and resourcing of the nuclear mission within the Royal Navy may therefore have to be addressed through organisational re-structuring in the Navy/MoD to ensure the senior advocate for the nuclear mission is represented at a suitably high level within the bureaucracy, if this is not already the case.

Arguments that the UK must perpetually be prepared to deter a surprise nuclear attack primarily from Russia and that ending CASD will fatally undermine the credibility of a UK nuclear deterrent threat are deeply questionable. Crisis stability, too, is not a compelling reason to preclude a reduced operational readiness posture. A non-CASD posture does not guarantee that the UK will not have an SSBN at sea during a crisis – only that it *might* not. In such event the government will have alert options at its disposal to prepare an armed submarine for sailing at short notice with protection forces at the ready. Whilst this could conceivably risk destabilising a crisis, the manner in which the decision is communicated will be as important as the act itself. Finally, there is no automatic relationship between stepping back from CASD and degradation of the professionalism of Trident crews and commanding officers and their ability to maintain the exacting standards required to operate Trident submarines and provide total confidence in the firing chain.

Reduced Readiness

The second option examined in this report is a 'reduced readiness' operational posture based on three new SSBNs deploying Trident missiles. Under a 'reduced readiness' posture a Successor SSBN could be regularly, but not continuously, deployed at sea. There may be gaps of weeks and perhaps months when there is no Trident submarine on operational patrol with some flexibility in terms of deployment and duration patterns. During periods where no submarine is at sea a single SSBN in port and 'committed' protection forces could be maintained in a state of readiness measured in weeks, or possibly days if necessary, providing policy-makers with reassurance that a Trident-equipped submarine could be at sea at relatively short notice. The operation of the SSBN fleet on 'reduced readiness' could begin to reflect the operation of the UK's SSN fleet with a mixture of long and short training and operational deployments and sustained readiness to deploy for combat/deterrent operations.

A reduced readiness posture would reduce the salience of nuclear weapons and the practice of nuclear deterrence in UK national security policy, enable a reduction in submarines and crews, extend the service life of the SSBN flotilla, and facilitate a rethinking of minimum deterrence criteria in terms of missile and warhead numbers.

Submarine numbers

Ending CASD would permit a reduction to three SSBNs with a corresponding reduction in procurement costs. In 1998 the cost of the fourth and final *Vanguard* SSBN was £863 million, representing 20% of a total £4,277 million for the four submarines.[223] The cost of building the four *Vanguard* SSBNs today would be approximately £8,860 million in 2008-09 prices. A 20% saving equates to £1,765 million. If inter-generational unit cost inflation is factored in at 2% a 20% saving on £16,050 million is £3,020 million. At a higher 3% annual inflation a 20% saving on £21,500 million is £4,300 million. Actual savings would likely be lower. If a decision was made to build three boats from the outset then the unit cost would probably increase in order to improve the durability of internal systems, reduce time in refit and maximise time at sea. If a decision is made to build four submarines and subsequently cancel construction of the final boat, then expenditure on long lead items will be forfeited. For example in 1993 it was reported that by the time the contract for the fourth *Vanguard* SSBN had be placed in July 1992 £169 million had been spent in long lead funding, representing 30% of contract value.[224]

A reduction to three boats would also save a percentage of overall running costs. How much is difficult to quantify. A reduction to two boats could be considered, although this would carry a greater risk of having no submarine at sea for a prolonged period if circumstances prevented sailing of the operational SSBN whilst the other was in refit.

[223] House of Commons, *Official Report*, July 31, 1998, Column 722.
[224] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 549 (London: HMSO, June 1993), p. xiii.

Service life

Less frequent sailing of the submarines under a reduced readiness posture will also reduce wear on the submarines and burn-up of nuclear fuel resulting in extended service lives.[225] This may require a more advanced nuclear reactor pressure vessel that can be certified for 30 or more years. The current Nuclear Steam Raising Plant (NSRP) reactor, Rolls Royce's Pressurised Water Reactor 2 (PWR2), has a safety justification of 25 years.[226] Peter Whitehouse of Devonport Management Ltd stated in 2007 that the life of the reactor "is an inherent function of the design features, metallurgy and duty cycle when the system is in use" suggesting that reduced operation of the submarines could extend the life of the reactor. [227] In 2007 in a response to a question by David Borrow MP on whether reduced operations would extend the life of the submarines, Rear Admiral Andrew Mathews stated that "It would help to extend, for instance, the core life… Hull fatigue is not an issue for the UK. The hull itself is good for as long as we want to operate these submarines".[228]

Ending CASD now with the current *Vanguard* fleet would likely extend the service life of the *current* submarines allowing decisions on a replacement submarine to be postponed. Current plans envisage the first Successor SSBN entering operational service in 2024 when the second *Vanguard*-class (HMS Victorious) retires. If the Vanguard Life Optimisation Programme (VLOP) is able to extend the service life of the submarines beyond the current five year target out to perhaps 10 years, aided by reduced operation of the reactor and a second refit if necessary to replace aging internal systems (that would come at a cost), then the first Successor submarine would not be required until 2029. The Main Gate decision is currently required by 2014. Ending CASD and extending the service life of the current SSBN fleet could push this decision back to 2019 (see timeline in Appendix I).

This would enable the UK Trident submarine replacement programme to synchronise with the SSBN(X) next-generation submarine programme in the US, where the first new SSBN to replace its current Trident submarines is scheduled for operational deployment in 2029, five years behind the UK (see timeline in Appendix I).

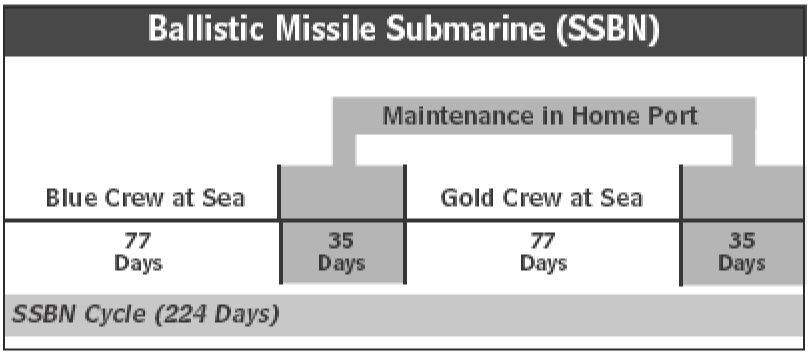
Submarine crews

Ending CASD could also enable an overall reduction in submarine crew strength. Each *Vanguard* submarine in the current operational cycle has two crews – a Port crew and a Starboard crew. Submarines are generally in port for 30-40 days after operational patrol during which the second crew takes over and prepares the submarine for its return to sea whilst the first crew takes some leave and undergoes shore-based training. The US also operates its SSBNs with a double crew system whereby: "one crew operates the ship on station while the other rests, trains, and prepares to relieve the onstation crew. The onstation crew operates the submarine on patrol for 74 days and then returns to port where both crews work together for 38 days covering inspections, conducting maintenance, and turning over responsibility for the ship. While one crew is at sea

[225] See Rear Admiral Andrew Mathews, *The Future of the UK's Strategic Nuclear Deterrent: The White Paper. Volume II: Oral and Written Evidence*, House of Commons Defence Committee, HC 225-II, (London: HMSO, March 2007), p. Ev 70.
[226] Evidence from Commodore Tim Hare, *The Future of the UK's Strategic Nuclear Deterrent: The Strategic Context*, House of Commons Defence Committee, HC 986 (London: HMSO), June 2006, p. Ev 38.
[227] Evidence from Peter Whitehouse, Ibid., p. Ev 38.
[228] *The Future of the UK's Strategic Nuclear Deterrent: The White Paper. Volume II: Oral and Written Evidence*, House of Commons Defence Committee, HC 225-II, (London: HMSO, March 2007), p. Ev 70.

with the submarine, the "offcrew" remains ashore and goes through the offcrew training cycle. These crewmembers attend school, train, and hone their skills at the shore-based training centers located at the Trident bases."[229]

Figure 3: Deployment cycle of US SSBN



Source: *Crew Rotation in the Navy: The Long-Term Effect of Forward Presence*, (Washington, D.C.: Congressional Budget Office October 2007), p. 3.

A non-CASD posture based on three Successor SSBNs could continue to operate with double crews to minimise time with no submarine at sea. Alternatively, ending CASD and moving to a reduced readiness posture with three submarines would facilitate single crewing through a reduced operational tempo.

Single crewing would result in longer periods with no submarine at sea, assuming the split between crew time at sea and time ashore remains the same. For example, it is estimated that if US SSBNs were to reduce to single crews readiness would reduce from around 67% (two thirds of SSBN at sea at all times) to 50%.[230] If submariners spent longer at sea under a single crewing system then the length of time with no submarine at sea could be reduced. The Congressional Budget Office reports that "the operating tempo of a [US] Trident submarine (the amount of time, on average, that it spends under way in a year) is 65 percent, whereas the personnel tempo (the amount of time, on average, that a sailor spends at sea in a year) is only about 40 percent."[231] Similarly in the UK in 1995 MoD reported that the Trident SSBNs will spend around 60% of their time at sea.[232] Royal Navy guidelines determine that personnel spend, on average, 60% of their time deployed and 40% in their home port during a three-year period.[233] Assuming UK SSBN crews currently spend about 40% of their time at sea like their US counterparts, then the Navy's harmony guidelines would allow single SSBN crews to spend more time at sea over a three-year period thereby reducing the duration of periods with no SSBN at sea.

[229] Michelle A. Dolfini-Reed, Martha E. Koopman, and Kletus S. Lawler, *Alternative Sea Manning Concepts: Practices and Policy Implications*, (Washington, D.C.: Center for Naval Analyses, May 2006), p. 11.
[230] Robert Rudney and Willis Stanley, "Dealerting Proposals for Strategic Nuclear Forces", *Comparative Strategy* 19: 1, 2000, p. 18.
[231] *Options for Increasing the Mission Capability of Attack Submarines*, (Washington, D.C.: Congressional Budget Office, March 2002), p. 21.
[232] *Progress of the Trident Programme*, House of Commons Defence Committee, HC 350 (London: HMSO, July 1995), p. 4.
[233] House of Commons, *Official Report*, February 11, 2009, Column 1994W.

Alternative forms of crewing are also available. The Labour government announced in the 1998 Strategic Defence Review its intention to reduce from double to single crews, presumably to reduce costs and pressure on recruitment and retention.[234] In May 1998 HMS Vanguard was reduced to one enhanced 'Gold' crew of 200 rather than the usual 135 but the single crewing experiment ended and the double crew system remained in place.[235]

The US 'Horizon' concept involves one or two more crews than hulls, such as five crews for four ships, and is based on a posture of sustained readiness by maintaining people and platforms in a continually ready state. Under this concept one ship is continuously forward based while the rest are in port for training or maintenance. The extra crew stay ashore in to train, work or instruct in a 'Readiness Centre' facility or are assigned to a 'Readiness Unit' for training aboard ships in port and at sea followed by "2 weeks of intensive 'online' turnover by fully trained and qualified crew" and six months on the forward-deployed platform before returning to a Readiness Centre or Unit.[236] The 'Sea swap' involves an equal number of crews and ships in which the first crew spends six months aboard the forward deployed ship until relived by second crew at sea. The first crew returns home to take over the ship the second crew was manning for training.[237]

Ending double-crewing would reduce operational costs and recruitment and retention problems. Cost savings are difficult to quantify with little publicly available data. Nevertheless, the Congressional Budget Office stated in 2007 that "A [US] Trident submarine costs about one-third more to operate than a single-crewed attack submarine. That difference mainly occurs because of the higher personnel costs of having two crews per submarine, but part of the difference reflects higher maintenance costs for Trident submarines. (Excluding personnel costs, operating costs for a dual-crewed ballistic missile submarine are $46 million per year, compared with $32 million per year for a single-crewed attack submarine.) Some of the difference may also be attributable to the different sizes of the ships: SSBNs weigh more than 18,000 tons, whereas Los Angeles class attack submarines weigh about 7,000 tons."[238] In 1994 Rear Admiral Richard Irwin, MoD's Chief Strategic Systems Executive, stated that a reduction from a possible eight crews for the four *Vanguard* SSBNs to six "would be quite a saving".[239] A reduction to single or 'enhanced' crews for three Successor SSBNs could reduce the number of crews from 6 to 3 or 4.

The UK submarine service suffers perennial recruitment and retention problems. The 2002 Submarine Manning and Retention Review recommended a range of remuneration measures to address the problem.[240] By 2008 these measures were having only limited impact. The Armed Services Pay Review Body reported that "Widespread shortfalls in the Submarine Service continued and the shortages were almost unsustainable despite a number of targeted measures including FRIs [Financial Retention Initiatives] and 'Golden Hellos'."[241] Evidence from MoD to the Commons Defence Committee in 2008 highlighted ongoing shortages in submarine manpower, particular in the areas of Able Rate Warfare Systems (Tactical Submariner), Strategic

[234] MoD, *The Strategic Defence Review*, "Supporting Essay 5: Deterrence, Arms Control and Proliferation", paragraph 12.
[235] House of Commons, *Official Report*, July 28, 1998, Column 200.
[236] Ibid., pp. 15-16.
[237] Dolfini-Reed *et al*, *Alternative Sea Manning Concepts*, p. 23.
[238] *Crew Rotation in the Navy: The Long-Term Effect of Forward Presence*, (Washington, D.C.: Congressional Budget Office October 2007), p. 17.
[239] *Progress of the Trident Programme*, House of Commons Defence Committee, HC 297 (London: HMSO, May 1994), p. 4.
[240] *Armed Services Pay Review Body*, Thirty Third Report 2004, Cm 6113 (London: HMSO, February 2004), p. 13.
[241] *Armed Services Pay Review Body*, Thirty Seventh Report 2008, Cm 7315 (London: HMSO, February 2008), p. 16.

Weapon System Junior Rates, nuclear watchkeepers, and Reactor Panel Operators.[242] Reducing overall SSBN crew strength would go some way to alleviating these challenges.

The key issue in any decision to end CASD and operate a 'reduced readiness' posture is the difficulty of returning quickly to a permanent return to CASD posture with three submarines. CASD could be operated for a period of time with three submarines and available crews, but a permanent return to CASD would require a training programme to generate one or two new crews that would take many years, perhaps 5-10.[243] As Defence Secretary Des Browne commented in 2007, "I believe that if we did not continue [CASD] we could not be certain that we could recreate it, that we could step it up in the timescale that we might need to if the need arose at some time in the future."[244] One option would be to second SSN submariners since much of the expertise and training required to operate an SSN is the same as that required to operate an SSBN, the key difference being operation of the strategic weapon systems. In 1994 Rear Admiral Richard Irwin indicated that the Navy was examining the "recovery time to get back up to full crews" if plans to man the four-boat *Vanguard* fleet with six crews proved insufficient.[245] In 1995 he stated that if SSBN crews needed to be quickly augmented the Navy could bring in people from nominated billets elsewhere.[246]

Warhead numbers and 'minimum deterrence'

Ending CASD could facilitate a reconceptualisation of the 'minimum deterrence' criteria that are currently judged to require up to 48 warheads for the submarine on operational patrol, leading to a further reduction in missile and warhead numbers.

Quantitative calculations for sizing the UK nuclear arsenal based on the number and type of targets that must be held at risk by British nuclear weapons and the degree of destruction required to deter attack historically centred on the so-called 'Moscow Criterion' during the Cold War.

The 'Moscow Criterion' stipulated that Britain must be able to destroy Moscow and a number of other major Soviet/Russian cities in a retaliatory nuclear attack if the Soviet Union struck first.[247] This was complicated by the deployment of an anti-ballistic missile (ABM) system of 100 interceptors around Moscow that could destroy some of the UK's incoming nuclear warheads. The Soviet ABM system prompted the secret and very expensive Chevaline upgrade of Britain's

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[242] Memorandum from the Ministry of Defence in *Recruiting and Retaining Armed Forces Personnel*, House of Commons Defence Committee, HC 424 (London: HMSO, July 2008), p. Ev 92.

[243] The Congressional Budget Office reported in 2005 that the US Navy says developing the first of new crews for SSNs would take at least 10 years. CBO contested this, arguing that "Although some development time would certainly be necessary, 10 years may be an overestimate. In testimony before the Congress, the Navy has vigorously pressed for a larger attack submarine fleet, which would also require more crews. It has not indicated that if the construction rate for attack submarines increased to two per year in the 2003 or 2004 budget—resulting in more submarines six or seven years later—the Navy's personnel system would be unable to staff those submarines". *Increasing the Mission Capability of the Attack Submarine Force* (Washington, D.C.: Congressional Budget Office, March 2005), p. 23.

[244] *The Future of the UK's Strategic Nuclear Deterrent: The White Paper. Volume II: Oral and Written Evidence*, House of Commons Defence Committee, HC 225-II (London: HMSO, March 2007), p. Ev 69.

[245] *Progress of the Trident Programme*, House of Commons Defence Committee, HC 297 (London: HMSO, May 1994), p. 4.

[246] *Progress of the Trident Programme*, House of Commons Defence Committee, HC 350 (London: HMSO, July 1995), p. 4.

[247] Kristan Stoddart, "Maintaining the 'Moscow Criterion': British Strategic Nuclear Targeting 1974–1979", *Journal of Strategic Studies,* 31: 6 December 2008, p. 920.

Polaris missiles in the 1970s.[248] The Chevaline system deployed dummy warheads and counter-measures along with nuclear warheads in order to overwhelm the Soviet ABM system and ensure a sufficient quantity of nuclear warheads would detonate above Moscow. The operational status and capability of this Soviet-era ABM system against modern Trident warheads and sophisticated missile defence penetration aids is unclear.

During the 1980s and 1990s there was a shift away from targeting 5-10 Soviet/Russian cities, including Moscow, and towards a focus on "key aspects of Soviet state power", including the Soviet and later Russian nuclear and military command and control infrastructure.[249] This did not constitute a radical departure from the Moscow Criterion since the Soviet command and control system was centralised in and around Moscow.[250]

Since the end of the Cold War criteria for specifying the quantity and type of targets that must be held at risk and level of destruction required for a 'minimum deterrent' threat have not been articulated. In 1993 Nick Witney, Director of Nuclear Policy and Security at MoD, stated that with the 'Moscow Criterion' "clearly no longer operative", the purpose of the UK nuclear force was to "hold out to the potential aggressor a scale of damage which would manifestly outweigh any gain he could hope to make from aggression. In making that calculation obviously we have regard to the possible attrition of a strategic strike by ABM defences", suggesting that the 'Moscow Criterion' still served as a benchmark for the UK's nuclear capability.[251]

This still seems to the case 20 years after the end of the Cold War. The 2006 White Paper, for example, argued that the UK must retain a nuclear capability in part to guard against the re-emergence of a major nuclear threat: "There are risks that, over the next 20 to 50 years, a major direct nuclear threat to the UK or our NATO Allies might re-emerge".[252] Whilst not naming Russia, this justification seems to suggest that a UK nuclear capability provides a necessary 'insurance' against a future Russian leadership reverting to a Soviet-style dictatorship threatening the West with mass destruction. However unlikely this scenario, a very conservative view of nuclear doctrine would stipulate that the UK must continue to maintain the capability to overcome Russian anti-ballistic missile defences now and in the future in order to hold Russian command and control facilities in and around Moscow at risk.

The credibility of such a worst-case scenario must be questioned. As Professor Michael Clarke argued in 2004, "The essence of a case for a genuinely strategic deterrent rests on the danger of the UK being drawn into a nuclear crisis between its ally the US, and perhaps Russia or China; or else somehow being involved, perhaps with France, on behalf of the Europeans to confront a resurgent Russia making nuclear threats in ways that question our survival, and in the absence of US involvement. In principle, such circumstances could arise—as indeed could circumstances in which the US turns vengefully and coercively on its former allies—but none of these existential possibilities are worth much of the time of a policy planner, still less a politician; and as Sir

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[248] John Baylis and Kristan Stoddart, "Chevaline: The Hidden Programme, 1967-1982", *The Journal of Strategic Studies*, 26: 3 December 2003, pp. 124-155.
[249] *The Future United Kingdom Strategic Nuclear Deterrent Force*, Defence Open Government Document 80/23 (DOGD 80/23), July 1980. Cited in David Owen, *Nuclear Papers* (Liverpool: Liverpool University Press, 2009), p. 48.
[250] John Ainslie, *Trident: Britain's Weapon of Mass Destruction* (Glasgow: Scottish CND, 1999).
[251] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 549 (London: HMSO, June 1993), p. 14.
[252] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 19.

Michael Quinlan implies, they would be unlikely to attract the resources necessary to hedge against such exotic scenarios when the next major financial commitments have to be made".[253]

Nevertheless, it remains unclear how 'minimum deterrence' is quantified beyond a subjective set of general guidelines for the deterrence of 'strategic threats' set out in successive government documents. Sir Michael Quinlan, former Permanent Under-Secretary at MoD, argued in 2004 that "It is possible, given now the very general 'to-whom-it-may-concern' character of UK nuclear deterrence, that there is currently little or no such planning in specific terms."[254]

The steady reduction of the concept of 'minimum deterrence' from an assured capability to destroy 30-40 Soviet cities, to 20, to 10 and then to 5 during the Cold War[255] and in the post-Cold War period from a cap of 512 strategic nuclear warheads for the Trident system with 128 warheads per SSBN,[256] to 300 under the Conservative government with up to 60 per SSBN[257], to 200 announced in Labour's 1998 Strategic Defence Review[258] and later reduced to 160 in the 2006 White Paper[259] with 48 per SSBN, demonstrates that 'minimum deterrence' is a moveable feast.[260]

The current force size criterion for 'minimum deterrence' requiring the capability to deliver 48 warheads could therefore be revisited with a fresh examination of the level and type of destruction deemed necessary to deter a strategic attack, particularly if any residual requirement to be able to destroy Moscow is categorically removed from nuclear force planning. A useful analysis provided by a 2009 study on *From Counterforce to Minimal Deterrence: A New Nuclear Policy on the Path toward Eliminating Nuclear Weapons* by the US Federation of American Scientists argues that: "A minimal deterrence doctrine requires only that nuclear weapons be able to impose sufficient costs on a potential attacker to make the initial nuclear attack appear too costly".[261] Based on this definition they adopt a minimum deterrence targeting approach based on infrastructure targeting against "a series of targets that are crucial to a nation's modern economy, for example, electrical, oil, and energy nodes, transportation hubs"[262] with Russia as a case study. They selected 12 targets from oil refineries and steel works to thermal power plants and aluminium plants and calculated the level of destruction and casualties with nuclear warheads of various yields. Such an attack, they argue, would threaten economic collapse: "Given the complex interconnectedness of modern societies such as Russia and the United States and a rapidly changing China, we believe that the destruction of key targets meeting our criteria would have a profound effect upon the national infrastructure and economy and would negate any conceivable advantage an enemy might calculate it could gain by attacking the United States or its allies with nuclear weapons."[263] If executed with 100kt warheads comparable to the UK's Trident warhead, casualties would be around 1.2 million, even though the 12 targets are in relatively remote areas. The study throws into sharp relief the level of

[253] Michael Clarke, "Does my Bomb Look Big in This?", *International Affairs*, 80: 1 2004, p. 56.
[254] Michael Quinlan, "The British Experience", in Henry Sokolski (ed), *Getting MAD: mutual assured destruction, its origins and practice* (Strategic Studies Institute, Army War College: Carlisle, PA, November 2004), p. 265.
[255] Quinlan, "The British Experience", p. 274; Stoddart, "Maintaining the 'Moscow Criterion", p. 901.
[256] Nicholas Whitney, *The British Nuclear Deterrent after the Cold War*, (RAND: Santa Monica, CA, 1995), p. 36.
[257] House of Commons, *Official Report,* July 16, 1998, Column 237
[258] MoD, *The Strategic Defence Review*, paragraph 64.
[259] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 5.
[260] Stoddart, "Maintaining the 'Moscow Criterion", p. 923.
[261] Kristensen, H., Norris, R., and Oelrich, O., *From Counterforce to Minimal Deterrence: A New Nuclear Policy on the Path Toward Eliminating Nuclear Weapons* (Washington, D.C.: Federation of American Scientists, April 2009), p. 21.
[262] Ibid., p. 32
[263] Ibid., p. 41

nuclear destruction required to threaten the functioning of a country even the size of Russia. If two warheads were allocated to each target this would still only require 24 warheads for a UK Trident submarine – half the current complement.

A shift in minimum deterrence criteria could facilitate a reduction in the number of missile and warheads for current and future SSBNs, for example a reduction to eight or even four missile tubes with a corresponding reduction in operationally available warheads. Based on these variables a number of 'reduced readiness' configurations involving generation of two or three submarines in the operational cycle, 16, 12, 8 and 4 missile tubes and 3 or 4 warheads per missiles gives:

Table 9: Trident system configuration options

SSBNs in operational cycle	Missile compartment launch tubes	Average warheads per missile	Warheads per boat	Total operational warheads	Plus 10% spares
3	16	3	48	144	158
2	16	4	64	128	141
2	16	3	48	96	106
3	12	4	48	144	158
3	12	3	36	108	119
2	12	4	48	96	106
2	12	3	36	72	79
3	8	4	32	96	106
3	8	3	24	72	79
2	8	4	32	64	70
2	8	3	24	48	53
3	4	4	16	48	53
3	4	3	12	36	40
2	4	4	16	32	35
2	4	3	12	24	26

Furthermore, when rethinking conceptions of 'minimum deterrence' it is essential to note that current understandings are in part defined by the capabilities of the sophisticated Trident II (D5) missile system on offer from the United States in the early 1980s. As noted above, the Trident II (D5) missile was not procured primarily for its technological capability, although this did offer certain advantages such as greater range enabling UK submarines to operate in larger areas of the Atlantic[264], but for economic and political reasons. As Rear Admiral Richard Irwin, MoD's Chief Strategic Systems Executive, stated in 1993, "we did not procure Trident for the large number of warheads it could carry. We procured it because it was the most economical system we could buy and would be supported by an ally for the length of time we expected to operate in".[265] Michael Quinlan also noted in 2004 that "Purely in weight of strike potential the United Kingdom could have been content with less than Trident could offer, even in C4 version originally chosen (let alone D5 version to which the United Kingdom switched in early 1982, when it had become clear that the United States was committed to proceed with its acquisition and deployment). The original choice and the switch were driven in large measure by the long-term financial and logistic

[264] *Strategic Nuclear Weapons Policy,* House of Common Defence Committee, HC 266 (London: HMSO, April 1982) p. 19.
[265] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 549 (London: HMSO, June 1993), p. 15.

benefits of commonality with the United States. After the end of the Cold War, the United Kingdom announced a series of discretionary reductions in warhead load to well below what Trident was capable of carrying."[266]

Before Trident the Polaris A3TK missile had a range of approximately 2,800 miles and a single *Resolution*-class SSBN at sea was equipped with only 32 warheads after the Chevaline upgrade reduced each missile's capacity to two warheads per missile.[267] Furthermore, Polaris warheads were not independently-targetable meaning that the 32 warheads on the 16 Polaris missiles could in reality only target 16 sites, compared to the 48 that a single *Vanguard* submarine can target today with a greater degree of accuracy. Nevertheless, the capability offered by Polaris was judged sufficient for a Cold War minimum strategic deterrent.[268] The capability of the current Trident system is a reflection of the technological options on offer by the United States in 1980 rather than an objective requirement. Conceptions of minimum nuclear deterrence going forward should not be conflated with the capabilities offered by the current Trident II missile in terms of range, multiple warhead capability and total warhead capacity.

[266] Quinlan, "The British Experience", p. 271.
[267] Dave Wright, "And then there were two: The Polaris ASTK Penetration Aids Carrier (PAC), *British Contemporary History*, 11: 4, Winter 1997, pp. 119-122.
[268] *Progress of the Trident Programme*, House of Commons Defence Committee, HC 297 (London: HMSO, May 1994), pp. 11-12 and Memorandum submitted by Dr Stephen Pullinger, pp. 37-42.

Dual-use submarines

The third option after 'Trident lite' and 'reduced readiness' is a dual-use submarine option for conventional and nuclear missions. The armed services and government ministers increasingly place a premium on maximising the flexibility of major military platforms to deliver strategic effect as costs rise, budgets are squeezed, and military missions become more varied and complex. The purpose of the 1998 *Strategic Defence Review*, for example, was "not only to meet the challenges of today's complex international scene but also to provide the flexibility to respond to those we may face well into the new century."[269] The 2003 MoD White Paper on *Delivering Security in a Changing World* stated that "Since the end of the Cold War our force planning has been increasingly more capability-based than threat-driven – reflected in the steadily increased flexibility of our forces"[270] and that "the expanding range of tasks and greater geographical scope of deployment will require our forces and their supporting structures to be more flexible and adaptable".[271] More specifically it argued that "We will not be able to hold on to platforms or force elements that do not have the flexibility to meet the demands of future operations."[272] The premium on flexibility runs to the Royal Navy where its 2007 *Future Maritime Operational Concept* stressed the need for flexible maritime forces, including the submarine force.[273]

Today's *Vanguard*-class submarines perform a singular mission: deploying the Trident missile to deter a strategic attack. These SSBNs are not fungible across the Navy's range of effects-based operations. Given the hugely diminished strategic threat the country faces now and for the foreseeable future[274], and given the dire straits of MoD and wider public finances, it is valid to ask whether the expensive single-mission Successor submarine platforms should instead be designed for a range of operations based on a rethinking of 'minimum deterrence'. In short, should the UK build dual-capable submarines that can engage in some of the missions assigned to the SSN attack submarine fleet whilst retaining the capability to deploy and fire Trident missiles if required to do so at varying levels of readiness that reduce the salience of nuclear weapons in national security policy?

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[269] MoD, *The Strategic Defence Review*, paragraph 14.
[270] Ministry of Defence, *Delivering Security in a Changing World*, Cm 6041-I (London: HMSO, December 2003), p. 10
[271] Ibid., p. 7
[272] Ibid., p. 11.
[273] *Future Maritime Operational Concept*, Joint Doctrine and Concepts Board, Ministry of Defence, November 2007. In 2008 Lee Willett report that Commodore John Gower, MoD's Director Equipment Capability for Under Water Effect, argued that "navies need to pack as much capability into a submarine hull as they can afford". Lee Willett, "Submarines in British Defence Policy: Making the Case", paper presented at *Delivering Effect in the Under Water Battlespace: Capability Requirements, Technology Options and Industry Infrastructures*, the RUSI/DEM SUBTECH08 Under Water Warfare Conference, RUSI, London, January 15, 2008.
[274] *National Risk Register*, Cabinet Office (London: HMSO, 2008), p 24. Available at <http://www.cabinetoffice.gov.uk/media/cabinetoffice/corp/assets/publications/reports/national_risk_register/national_risk_register.pdf>.

Attack submarines

British attack submarines now perform a wide range of roles far beyond their primary Cold War role of anti-submarine warfare (ASW) operations conducted largely in the North Atlantic against Soviet SSNs and SSBNs. Today's SSN fleet is involved in Intelligence, Surveillance and Reconnaissance (ISR), delivery of Special Operations Forces (SOF), anti-ship warfare, anti-surface warfare (ASuW) primarily through delivery of conventionally-armed Tomahawk Land Attack Missiles (TLAM), and other elements of sea control including anti-submarine warfare. In particular, they can gather, process and deliver intelligence undetected for prolonged periods of time.[275]

SSNs have key advantages over other military platforms, not least their speed, stealth and endurance that generate a unique ability to arrive in a conflict zone quickly to shape the early stages of a crisis and operate independently of supporting forces and air cover.[276] Gavin Ireland highlights the versatility of the SSN flotilla, noting that "In the 2001 strikes on Afghanistan, one Tomahawk equipped SSN was able to transit from exercises off Iceland to its firing position in the North Arabian Sea within twenty-one days, a journey of some 8,000 miles which no other type of vessel could have completed as quickly."[277]

The number of UK attack submarines has been reduced considerably since the mid-1990s. The 1998 SDR reduced the number from 12 to 10. This was reduced to 8 in the 2003 Defence White Paper. This could be reduced further if only 7 new *Astute*-class SSNs are built to replace the current *Swiftsure*-class and *Trafalgar*-class submarines. A dual-capable Successor SSBN that could perform SSN missions would be a significant complement to a diminishing SSN fleet, provided it did not come at the expense of current planned SSN capability.

Three developments lend credence to the credibility of this option: 1) The conversion of four US SSBNs to conventionally-armed guided missile submarines called SSGNs; 2) the leveraging of technologies developed for SSGNs into SSN attack submarines; 3) the potential for a flexible SSGN/SSBN hybrid submarine.

Guided missile submarines (SSGNs)

The US Navy has demonstrated that a large Trident SSBN can be adapted to undertake a range of missions previously assigned to smaller SSN attack submarines. In 2002 the US Navy began converting four of its 18 *Ohio*-class Trident missile submarines for conventional war-fighting missions. Conversion of the four submarines was completed between 2006 and 2008 for an estimated $1 billion per boat including refuelling of the nuclear reactors and replacement of the Trident SLBM fire control systems with tactical missile fire control systems.[278] In contrast a regular 'engineered refuelling overhaul' (ERO) costs roughly $260 million per SSBN.[279]

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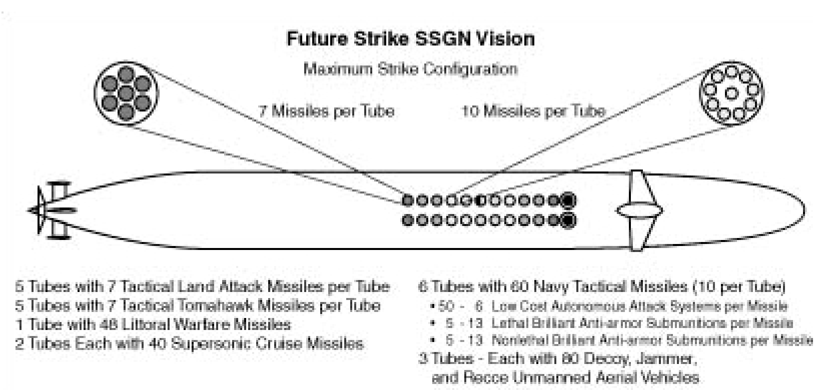
[275] Gavin Ireland, *Beyond Artful: Government and Industry Roles in Britain's Future Submarine Design, Build and Support*, Whitehall Report 3-07 (London: RUSI, 2007), p. 8.
[276] Lee Willett, "The *Astute*-Class Submarine: Capabilities and Challenges", *RUSI Defence Systems*, Summer 2004.
[277] Ibid, p. 8.
[278] Ronald O'Rourke, *Navy Trident Submarine Conversion (SSGN) Program: Background and Issues for Congress*, CRS Report for Congress (Washington, D.C.: Congressional Research Service, May 2008).
[279] O'Rourke, *Navy SSBN(X) Ballistic Missile Submarine Program*, p. 3.

Cruise missile capability

The *Ohio* SSBNs are bigger than the UK *Vanguard* boats with 24 rather than 16 missile tubes. The conversion process involved adapting 22 of these missile tubes to accommodate seven conventionally-armed Tomahawk Land Attack Missiles giving a full capability of 154 per submarine. These cruise missiles are loaded in 'seven-shot' Multiple All-Up-Round Canisters (MACs). This provides a quantitative leap in submarine fire power. As RUSI's Lee Willett describes, "one SSGN can deliver 154 TLAMs (an entire battle group's worth) in six minutes, quick reaction missiles that – as was seen in Kosovo and Afghanistan – could be put over target faster than an aircraft from a carrier deck".[280] In comparison the UK *Astute*-class SSN has six torpedo tubes that can fire TLAMs and weapons stowage capacity for 38 missiles or Spearfish torpedoes.[281]

Figure 4: SSGN configured for land attack



Source: Floyd D. Kennedy Jr., "Transforming the Submarine Force: Integrating Undersea Platforms into the Joint Global Strike Task Force", Air & Space Power Journal, Fall 2002

Special Operations Forces (SOF)

SSGNs can also operate as covert platforms for Navy SEAL SOF-support missions, allowing SSNs to concentrate on other missions. Eight of the 22 tubes configured for TLAMs can be used instead to carry equipment and supplies for SOF. The remaining two missile tubes were converted to serve as lock-out chambers for SOF. Each chamber is equipped to connect to an Advanced SEAL Delivery System (ASDS) or Dry Deck Shelter (DDS). The ASDS is a new mini-submarine that can accommodate two operators and up to eight SOF with equipment; the DDS is a less-capable predecessor.[282]

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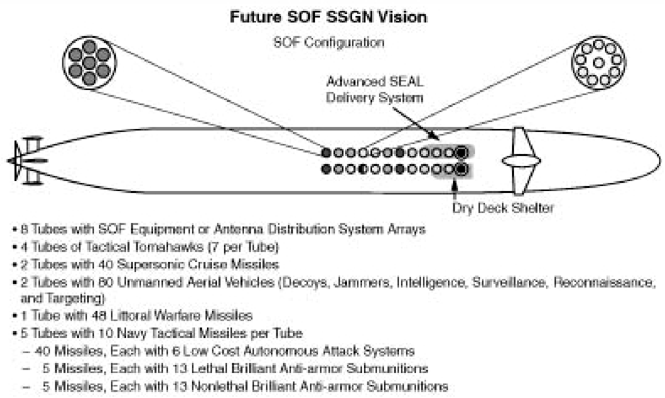
[280] Lee Willett, "Astute, Trident and SSGN: Land Attack for the Royal Navy Submarine Service", *RUSI Defence Systems*, Summer 2005, p. 106.

[281] Ibid, p. 104.

[282] O'Rourke, *Navy Trident Submarine Conversion (SSGN) Program*, p. 3.

Figure 5: SSGN configured for SOF



Source: Floyd D. Kennedy Jr., "Transforming the Submarine Force: Integrating Undersea Platforms into the Joint Global Strike Task Force", *Air & Space Power Journal,* Fall 2002

SSN submarines can accommodate and deliver SOF but lack the space for larger SOF units or for the physical conditioning that SOF must perform every day to remain at high levels of readiness. The SSGNs have space to accommodate 66 SOF for 90 days without significant readiness degradation. A SOF-configured SSGN can loiter off a coast, executing mission after mission while the SSGN remains ready to launch other sensors or weapons as required.[283]

Other payloads

SSGNs are also able to deliver unmanned aerial vehicles (UAVs), unmanned undersea vehicles (UUVs), and autonomous underwater vehicles (AUVs) for intelligence collection. The size of Trident submarines limits deployment in littoral waters, but use of UUVs could "covertly extend the reach of the submarine in these cases by 100 and 200 nautical miles, respectively. In principle, UUVs could make irrelevant the water depth restrictions on submarines, which is critical to extending the reach of the ship's sensors to the littoral areas that were previously denied".[284] UUVs can be used for a variety of missions, including intelligence, surveillance and reconnaissance, mine countermeasures, anti-submarine warfare, oceanography, communications, payload delivery, information operations, and strike operations.[285] In early 2003 the US Navy demonstrated the concept by deploying the Seahorse UUV from a SSGN missile tube to support SOF during the war game "Giant Shadow".[286] Robert Work, now Under Secretary of the Navy at the Pentagon, argued in 2008 that current SSGNs should evolve into UUV command ships for an undersea combat network.[287] New payloads deployable from a Trident vertical missile tube are

[283] Capt Floyd D. Kennedy Jr. (Rtd), "Transforming the Submarine Force: Integrating Undersea Platforms into the Joint Global Strike Task Force", *Air & Space Power Journal,* Fall 2002

[284] Edward A. Johnson, Jr., Commander, USN, "Unmanned Undersea Vehicles and Guided Missile Submarines: Technological and Operational Synergies", February 2002, Occasional Paper No. 27, Center for Strategy and Technology, Air War College, Air University, Maxwell Air Force Base, Alabama, p. 5.

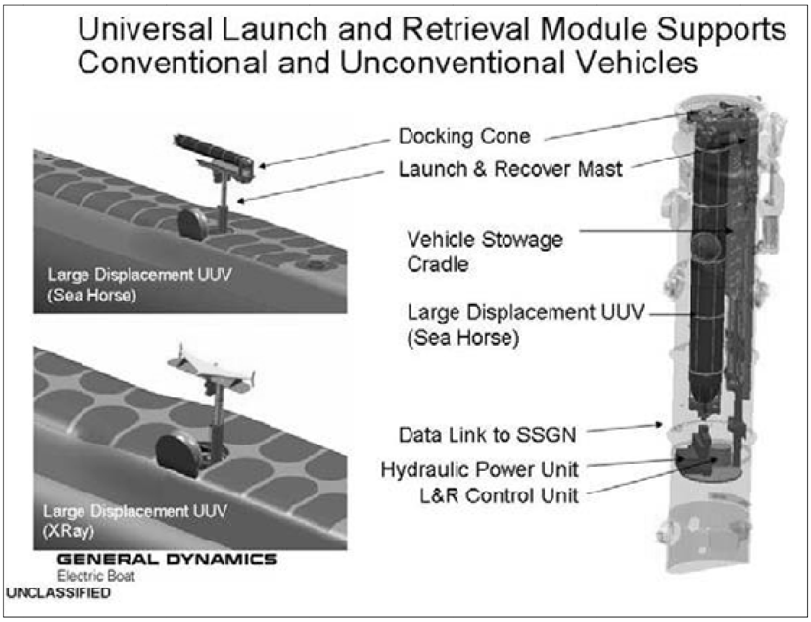
[285] Robert W. Button, John Kamp, Thomas B. Curtin, James Dryden, *A Survey of Missions for Unmanned Undersea Vehicles* (Arlington, VA: RAND Corporation, 2009).

[286] Ibid., p. 150.

[287] Robert Work, *The US Navy: Charting a Course for Tomorrow's Fleet*, (Washington, D.C.: Center for Strategic and Budgetary Assessments, 2008), p. 67.

also being developed and tested on SSGN patrols as operations permit.[288] The Navy is developing a Universal Launch and Recovery Module for the SSGN that will allow a wide variety of payloads, including UAVs and UUVs, to be stowed, launched, and retrieved from an SSGN launch tube.[289]

Figure 6: SSGN Universal Launch and Recovery Module



Source: Marc Stewart and John Pavlos, "A Means to Networked Persistent Undersea Surveillance", General Dynamics Electric Boat, paper prepared for the 2006 Submarine Technology Symposium, Laurel Maryland, May 16-18, 2006.

Operation

US SSGNs are operated in a similar fashion to the Trident-carrying Ohio SSBNs with double crews rotating on and off the boats every three to four months and two of the four continuously forward deployed. The submarines spend approximately 70% of their time at sea with a longer operational cycle than their SSBN counterparts of 461 days, compared to a 224-day SSBN cycle. This is achieved through deployment by the first crew for 73 days followed by a 23 period at an overseas port, during which time the second crew will arrive (overseas ports include Guam and Diego Garcia, British Indian Ocean Territories).[290] Both crews perform maintenance on the submarine, the first crew then flies back to the US to train at onshore facilities whilst the second crew takes the submarine to sea for 73 more days. That part of the cycle is repeated once more

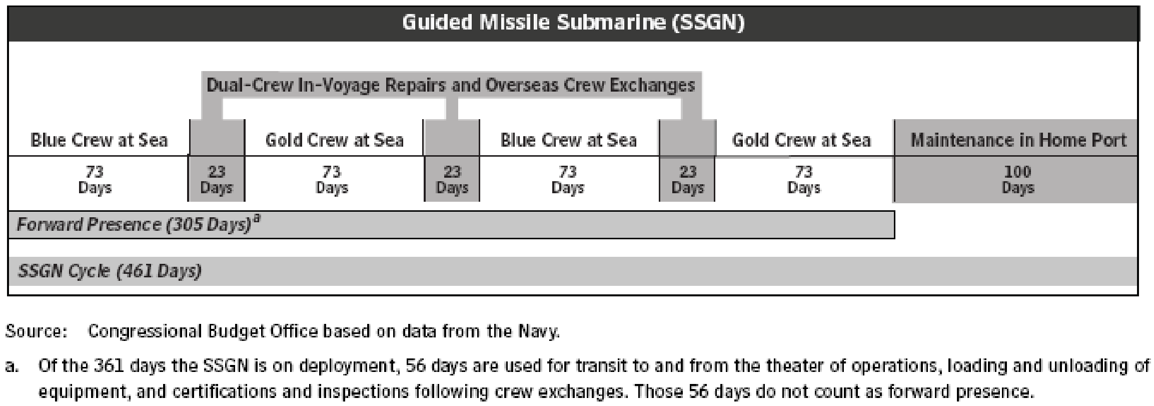
288 Captain Charles Sykora, "SSGN: A transformation limited by legacy command and control", *Naval War College Review,* Winter 2006, 59:1, pp. 41-62.

289 Marc Stewart and John Pavlos, "A Means to Networked Persistent Undersea Surveillance", General Dynamics Electric Boat, paper prepared for the 2006 Submarine Technology Symposium, Laurel Maryland, May 16-18, 2006.

290 *Force Structure: Ship Rotational Crewing Initiatives Would Benefit from Top-Level Leadership, Navy-wide Guidance, Comprehensive Analysis, and Improved Lessons-Learned Sharing*, (Washington, D.C.: Government Accountability Office, May 2008), p. 53. In fact, the US Navy invested some $32 million for wharf improvements and Shore Support Facilities at the US Naval Support Facility to facilitate SSGN operations. This has included the deployment to the island of the USS *Emory S. Land*, one of the USN's two submarine tenders that serve as floating shipyards to repair and supply submarines and surface ships. See "$31.9M for SSGN Support Facilities at Diego Garcia", *Defence Industry Daily*, April 4, 2007. Available at <http://www.defenseindustrydaily.com/319m-for-ssgn-support-facilities-at-diego-garcia-03191/>.

before the submarine returns to the US for 100 days of maintenance in its home port.[291] This reflects the 'sea swap' crewing option outlined above. A detailed operational regime was developed through production of a Standard Operations and Regulations Manual, a Concept of Operations, working groups to address operational, manning, and logistics issues, and a formal study of SSGN command and control issues.[292]

Figure 7: Deployment cycle of US SSGN



Source: *Crew Rotation in the Navy: The Long-Term Effect of Forward Presence*, (Washington, D.C.: Congressional Budget Office October 2007), p. 3.

The development and operation of SSGNs demonstrates that ballistic missile submarine platforms can perform a variety of roles beyond strategic nuclear deterrence.. If, as expected, the US further reduces its number of Trident-equipped SSBNs from 14 to 12, there will be pressure to convert the two redundant boats to SSGNs.[293] The UK took a small step along this path when the 1998 the *Strategic Defence Review* announced changes, albeit minor, in what UK *Vanguard* submarines will do. It stated that the submarines will now be at several days "notice to fire" and that this reduced state of alert "will enable greater use of ballistic missile submarines for secondary tasks such as exercises with other vessels, equipment trials and hydrographic work".[294]

SSGN technology and future SSNs

The flexible payload capabilities developed for the SSGNs are now being leveraged into the US Navy's *Virginia*-class SSN programme, signifying growing synergy between SSN, SSGN and SSBN platforms that has implications for next-generation SSBNs under development in both the US and the UK.

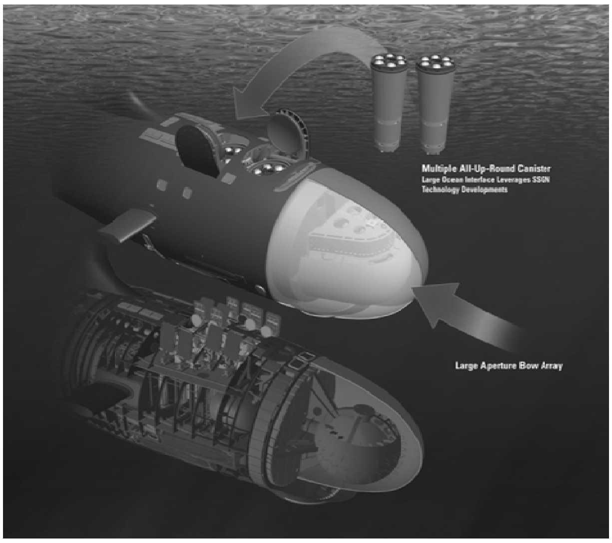
At the end of 2008 the US deployed 53 SSNs: 45 *Los Angeles*-class (deployed between 1976 and 1996), 3 *Seawolf*-class (deployed in 1997, 1998 and 2005) and 5 *Virginia*-class, the first of which entered service in October 2004. 11 *Virginia* boats of a planned 42 have been procured so far (Blocks I and II) and 7 more are planned for procurement during the period FY2010-FY2013

[291] *Crew Rotation in the Navy,* CBO, p. 2.
[292] Sykora, "SSGN: A transformation", pp. 41-62.
[293] Work, *The US Navy: Charting a Course for Tomorrow's Fleet*, p. 67.
[294] MoD and FCO, *Strategic Defence Review*, chapter 4 para 68.

(Block III) as part of a multiyear procurement (MYP) arrangement.[295] *Virginia* SSNs can launch 12 TLAMs from individual vertical launch tubes (VLT). Like the SSGNs, the *Virginia*-class can also carry a Dry Deck Shelter or Advanced SEAL Delivery System on its hull above a lock-in/lock-out chamber.

A series of design changes beginning with the first Block III submarine, authorised for construction in 2008, included replacing the 12 individual launch tubes with two new reconfigurable Virginia Payload Tubes (VPT) that are exactly the same as the converted ballistic missile tubes on the SSGNs, although a little shorter to account for a Virginia's smaller size.[296] Each of the two tubes will accommodate a 'six-shooter' MAC based on the 'seven-shooter' version developed for the SSGN (the seventh tube in the VPT is an access tube). The tubes will also be able to utilise many of the SOF, UUV and UAV payloads developed and under development for the SSGN.[297]

Figure 8: Virginia Payload Tube redesign and Flexible Payload Module



Virginia Payload Tube redesign

Flexible Payload Module

Source: John Pavlos, "A New Strategy for Submarine Payload Integration", October 25, 2005.

Robert Work suggested in 2008 that "Future Virginias might be lengthened by inserting a new payload module aft of the sail, with four more payload tubes, giving the boats an internal torpedo capacity of twenty-seven weapons, and up to thirty-six payload tube-launched TLAMs (or other weapons). These boats would be the first step toward a hybrid SSN/SSGN force capable of employing a wide variety of undersea weapons."[298]

[295] Ronald O'Rourke, *Navy Attack Submarine Procurement: Background and Issues for Congress*, CRS Report for Congress (Washington, D.C.: Congressional Research Service, October 2009).
[296] Work, *The US Navy: Charting a Course for Tomorrow's Fleet*, p. 22.
[297] Rear Admiral Mark Kenny and Commander James Belz, USN, "SSGN: Supporting the Navy's Irregular Warfare Campaign", *RUSI Defence Systems*, October 2008, p. 32.
[298] Work, *The US Navy: Charting a Course for Tomorrow's Fleet*, p. 67.

A new Interface Module is being developed to facilitate truly reconfigurable missile tubes that will allow different payloads to be swapped and operated with relative ease.[299] In 2005 the "Silent Hammer" war game tested several new technologies, including a new Flexible Payload Module for use in SSGNs and *Virginia*-class SSNs. This will allow submarines to deploy a range of Navy surface- or air-launched payloads and payloads from the other armed services without the need to redesign them for launching in an undersea environment.[300]

Potential for an hybrid SSGN/SSBN

These developments highlight the potential integration of SSN, SSGN and SSBN technologies and hull designs to develop a submarine capable of performing the range of tasks traditionally undertaken by SSNs, those now undertaken by SSGNs, as well as a submarine-based strategic nuclear mission currently conducted exclusively by SSBNs.

Pressure to reduce SSBN costs

Both the UK and US are engaged in detailed studies on next generation SSBN platforms. Both countries face constraints on defence spending, pressures to reduce unit costs, and an appetite for flexible undersea platforms. In 2008 the US Navy estimated that its next-generation SSBN labelled SSBN(X) would cost $3.4 billion per submarine. The Congressional Budget Office disputed this figure are and presented an average unit cost of $6.1 billion based on the cost of current *Virginia*-class SSNs.[301] Two years later in February 2010 the Navy increased the projected unit cost to $6-7 billion based on what it might cost today to build *Ohio*-class submarines under current production conditions.[302] The CBO estimated in 2010 that 12 new SSBN(X) submarines to replace the current fleet of 14 *Ohio*-class submarines will cost an average $8.2 billion and "another $10 billion to $15 billion would be needed for research and development, for a total program cost of more than $110 billion".[303]

The expense of the US SSBN recapitalisation programme will limit the US Navy's ability to procure other ship classes over the 2020s. The US Navy declared in 2010 that "The SSBN(X) procurements will be concurrent with wholesale end-of-service-life retirements of SSN 688 submarines, CG 47 class guided missile cruisers, DDG 51 class guided missile destroyers, and LSD 41/49 class dock landing ships" and that the consequent slowdown in procurement "will occur when the Navy needs to be procuring at least 10 ships per year to maintain its force level against the anticipated ship retirements from the 1980s and 1990s."[304]

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[299] Kenny and Belz, "SSGN: Supporting the Navy's Irregular Warfare Campaign", p. 30.

[300] Captain Dave Duryea, "USS Georgia – The Silent Hammer", *Undersea Warfare*, 7: 2, Winter 2005.

[301] *Resource Implications of the Navy's Fiscal Year 2009 Shipbuilding Plan*, (Washington, D.C.: Congressional Budget Office, June 2008), pp. 28-29.

[302] *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2011* (Washington, D.C.: Office of the Chief of Naval Operations, US Department of Defence, February 2010), p. 20; O'Rourke, *Navy SSBN(X) Ballistic Missile Submarine Program*, p. 12.

[303] *An Analysis of the Navy's Fiscal Year 2011 Shipbuilding Plan*, (Washington, D.C.: Congressional Budget Office, May 2010), p. 16.

[304] *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2011*, (Washington, D.C.: Office of the Chief of Naval Operations, US Department of Defence, February 2010), p. 24.

The projected unit cost and impact on future shipbuilding plans have already raised concern at the highest levels of policy-making. In May 2010 US Secretary of Defense Bob Gates expressed concern at the cost of recapitalising major Navy weapon platforms such as aircraft carriers and SSBNs, suggesting that unit costs and/or numbers will have to be reduced, perhaps through greater flexibility across platforms. Gates noted that "Right now, the Department proposes spending $6 billion in research and development over the next few years – for a projected buy of twelve subs at $7 billion apiece. Current requirements call for a submarine with the size and payload of a boomer [an SSBN] – and the stealth of an attack sub. In a congressional hearing earlier this year, I pointed out that in the latter part of this decade the new ballistic missile submarine alone would begin to eat up the lion's share of the Navy's shipbuilding resources" and declared that "At the end of the day, we have to ask whether the nation can really afford a Navy that relies on $3 to 6 billion destroyers, $7 billion submarines, and $11 billion carriers".[305]

Influential members of Congress are not impressed with the price tag. Rep. Gene Taylor, Chairman of the House of Representatives Committee on Armed Services' Subcommittee on Seapower and Expeditionary Forces, complained to Gates that the Navy "refuses to share" the analysis of alternatives (AoA) for the SSBN(X) programme conducted in 2008-09. Until that document has been received funding for the SSBN(X) development program me will be cut. It is reported that "Taylor wants to see what a smaller, *Virginia*-class submarine armed with a less-lethal ballistic missile would cost. Instead, he says, the Navy already has decided it wants the bigger and more expensive ships" and has called for an investigation of why the SSBN(X) programme has already begun system design and development and seemingly bypassed acquisition requirements. Taylor is not convinced that the Trident II (D5) missile is the only solution to provision of a sea-based strategic deterrent.[306]

It has been reported that the US is examining two options: adapting the *Virginia*-class SSN to accommodate the Trident II (D5) SLBM or a new hull design based on an overhaul of the current *Ohio*-class SSBN. Amy Woolf of the Congressional Research Service reported in 2009 that "Although the Navy has not finalized its design for the new submarine, it will probably be based on the Virginia-class attack submarines, because, as Admiral Johnson [Director, Navy Strategic Programs Office] has said, leveraging the 'success of the Virginia-class SSN program' will help hold down costs".[307] The SSBN(X) is likely to have 16 missile tubes rather than the current 24 bringing it closer in size to current SSNs than the *Ohio*-class SSBN.

Joint UK-US work

The UK has already begun working with the United States on possible new submarine designs under the auspices of the 1963 Polaris Sales Agreement.[308] In February 2008 it set up a programme office in the US alongside key American officials to facilitate liaison to influence the

[305] Remarks by Secretary of Defense Robert Gates, Navy League Sea-Air-Space Exposition, Gaylord Convention Center, National Harbor, Maryland, Monday, May 3, 2010. Available at <http://www.defense.gov/Speeches/Speech.aspx?SpeechID=1460>.

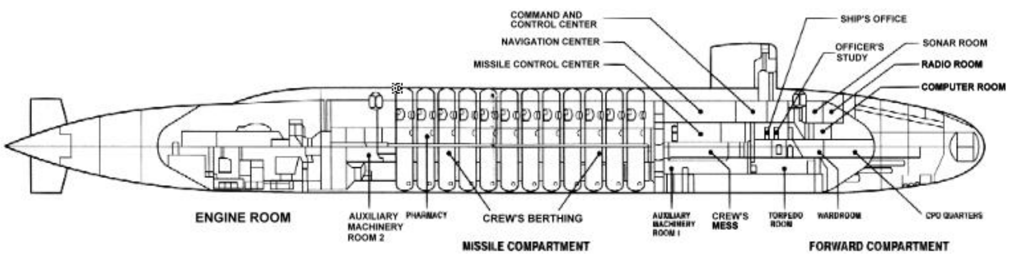
[306] Christopher Cavas, "Lawmaker wants key submarine document", *Navy News*, April 26, 2010; "Chairman Gene Taylor Opening Statement Seapower and Expeditionary Forces Subcommittee Mark-up of H.R. 5136, the FY11 NDAA", May 13, 2010. Available at <http://armedservices.house.gov/apps/list/speech/armedsvc_dem/TaylorOS0513101.shtml>.

[307] Amy Woolf, *U.S. Strategic Nuclear Forces: Background, Developments, and Issues*, CRS Report for Congress, (Washington, D.C.: Congressional Research Service, July 2009), p. 19.

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

SSBN(X) design process.[309] MoD is also contracting out aspects of its own concept studies to US companies. The central focus of current collaborative work is the development of a Common Missile Compartment for the UK Successor and US SSBN(X) submarines to ensure that the missile that succeeds the Trident II (D5) will be compatible with the UK's new Successor submarines (the proposed Successor SSBNs will initially deploy the Trident II missile but will remain in service into the 2050s, long after the Trident II is retired with the last of the US *Ohio*-class SSBNs in 2042). Studies and design of a Common Missile Compartment (CMC) for UK and US replacement SSBNs is being paid for in part by the UK but run through the Naval Sea Systems Command in Washington.[310]

Figure 9: US Ohio-class SSBN showing missile compartment



The UK received assurances in an exchange of letters between Prime Minister Tony Blair and President George W. Bush in 2006 that any successor to the D5 will be "compatible, or can be made compatible, with the launch system to be installed in our new SSBNs".[311] In November 2008 Guy Lester, MoD's 'Senior Responsible Owner' for the Trident successor programme, stated that "we hope very early in the new year to reach an agreement with the Americans both on our financial contribution and on the exact specification of the missile compartment to provide us with the long term guarantee of compatibility".[312] This was reconfirmed with the new Obama administration in an exchange of letters between UK Defence Secretary John Hutton and US Defense Secretary Bob Gates in February and May 2009. [313]

Dual-capable options for the UK

Development of the Common Missile Compartment for the next generation US and UK SSBNs and a range of flexible payloads for the US SSGN programme that have been leveraged into the *Virginia*-class SSN programme, particularly the Virginia Payload Tube, Flexible Payload Module and Multiple all-up-round Canister technologies, and the substantial investment in the UK's *Astute*-class SSN design and technologies provide an attractive opportunity to develop a flexible dual-capable SSBN/SSGN capability combining nuclear and conventional roles. A hybrid

[309] *The United Kingdom's Future Nuclear Deterrent Capability*, National Audit Office, p. 19.
[310] "CMC Contract to Define Future SSBN Launchers for UK, USA", *Defense Industry Daily,* December 26, 2008.
[311] P. 31
[312] Uncorrected transcript of oral evidence to the Committee of Public Accounts hearing on *The United Kingdom's Future Nuclear Deterrent Capability*, November 19, 2008.
[313] Department of the Navy, "Fiscal Year (FY) 2011 Budget Estimates Justification of Estimates: Research, Development, Test & Evaluation Navy Budget Activity 4", February 2010, p. 41.

Successor submarines could incorporate a 12 or 8-tube Common Missile Compartment that can deliver the Trident II (D5) missile as well as a range of non-nuclear payloads to provide a SSGN/SSBN capability. This would facilitate a reduction in the UK nuclear force, reduce the salience of nuclear weapons in national security policy, and augment the Navy's conventional power projection and intelligence capabilities.

Cost pressures could facilitate the development of a single modular hull for SSN/SSGN/SSBN missions based on flexible Trident launch tube technology. Lee Willett, for example, suggests that: "beyond Astute and Trident, is the possibility of developing a modular submarine hull that could carry more flexible capability packages whether they be strategic nuclear weapons, cruise missiles or special forces. This would allow the UK to develop a generic fleet of submarines, with a pool of 14 boats being available for SSBN or SSN roles, as required".[314] Robert Work also noted in 2005 that "Should mixed conventional/nuclear missile loads be considered in the future, perhaps a combination SSBN and nuclear-powered attack submarine (SSN) might be possible".[315] Furthermore, in 2009 the US House Armed Services Committee stated that it "strongly encourages the design of the CMC [Common Missile Compartment] module account for a non-strategic use with minimal back-fitting". This would enable SSBNs to be used in an SSGN role.[316]

The UK has yet to develop vertical launch systems or MACs for its attack submarines, but it is conceivable that a second tranche of 'Block II' *Astute*-class SSNs after boat six or even boat four could incorporate such technologies with "a large part of the research and development costs...borne by the US" if the US were willing.[317] Boat one, Astute, is currently undergoing an extensive programme of sea trials while boats two to four, Ambush, Artful, and Audacious, are in various stages of construction. A contract was placed for HMS Audacious in May 2007. Initial build work on boat five has begun and long lead items for boat six have been ordered.[318]

A dual-capable submarine flotilla could fulfil a nuclear mission in a number of ways. First, some of the new submarines' missile tubes could be equipped with Trident missiles (e.g. 4 of 8) and operated at near CASD with three boats. Even if equipped with four Trident missiles, if each were armed with 8 warheads each submarine could deploy with 32 warheads – the same number deployed by the UK's previous *Resolution*-class Polaris A3TK missiles after the Chevaline upgrade. The remaining tubes could be equipped with alternative payloads to supplement SSN missions where appropriate.

The submarines could be forward-deployed for longer periods than the current *Vanguard* SSBNs. The US, for example, currently generates two SSGNs from four on continuous forward deployment based on double crews. The UK could operate a SSBN/SSGN flotilla with dual-crews or with single/augmented crews depending on level of availability required for conventional and/or nuclear missions. The submarines could therefore engage in conventional missions but rapidly return to SSBN operations if required to do so.

[314] Lee, "The Astute-class Submarine", p. 59.
[315] Robert Work, *Winning the Race: A Naval Fleet Platform Architecture for Enduring Maritime Supremacy*, (Washington, D.C.: Center for Strategic and Budgetary Assessments, March 2005), p. 291.
[316] *National Defense Authorization Act For Fiscal Year 2010*, Report of the Committee on Armed Services, House of Representatives on H.R. 2647, June 18, 2009.
[317] Willett, "The Astute-class Submarine", p. 59.
[318] House of Commons, *Official Report,* March 29, 2010, Column 645W.

Second, new hybrid submarines could operate exclusively in an SSGN/SSN role with all the missile tubes fitted with a range of non-nuclear payloads. The submarine crews could retain nuclear certification through sea- and shore-based training and in the event of a deterioration of relations with a nuclear-armed state one or more of the submarines could return to port and redeploy with a Trident missile payload. This could be part of the routine deployment cycle of hybrid SSGN/SSBNs. The primary mission of the submarines would be conventional military missions together with an enduring secondary mission to deploy and fire nuclear-armed Trident missiles in a crisis within a fixed time frame.

Storing missiles and warheads at Faslane and Coulport for redeployment is a feasible option. The UK has 16 bunkers at RNAD Coulport for storing Trident missiles and, according to the government, can "onload and offload of Trident II D5 missiles as required".[319] Trident missiles can also be removed from SSBNs at Faslane with warheads remaining on the missile and stored ashore as a complete assembly, or warheads can be removed from the missile whilst still in the submarine launch tube and the missile and warheads can be moved and stored separately ashore, with warheads subsequently reloaded on to the missile after it had been loaded back into an SSBN launch tube.[320] It would probably take up to a week to reload an SSBN.[321] 16 missiles maintained ashore could arm two operationally available hybrid SSGN/SSBN submarines with eight missiles each. It is unclear how long Trident missiles can be maintained ashore but each current *Vanguard* submarine has maintained is load-out of missiles acquired at King's Bay for 7-9 years before off-loading. Routine servicing of warheads is also done at Coulport.[322]

This posture reflects the 'strategic escrow' scenario set out by former CIA Director Admiral Stansfield Turner in 1997. Turner envisaged a staggered 'de-alerting' of the US and Russian nuclear arsenals by removing increasing numbers of nuclear warheads from their delivery vehicles and storing them in a secure facility.[323] It also reflects aspect the concept of a 'virtual arsenal' set out by Michael Mazarr in 1995. In this context nuclear deterrence rests on the ability to reconstitute and re-deploy a survivable nuclear arsenal rather than the ability to retaliate within hours or days of an attack.[324]

Safety issues

There is reluctance in some quarters to entertain the notion of dual-capable strategic submarines due to a desire to retain nuclear and non-nuclear mission as distinct and separate operations. Nevertheless, the UK deployed dual-capable fighter bombers for many years during the Cold War

[319] House of Commons, *Official Report*, December 18, 2006, Column 1478W.
[320] Dr John Catchpole, Director General Strategic Weapon Systems at MoD, in *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 549 (London: HMSO, June 1993), p. 17.
[321] In a US context Rudney and Stanley report that "A 'strategic loadout' to remount all 24 SLBMs on an SSBN would take about two week. Missiles and warheads are stored separately…they are mated at each base's vertical-assembly building and then transported to be loaded onto the SSBN". Robert Rudney and Willis Stanley, "Dealerting Proposals for Strategic Nuclear Forces", *Comparative Strategy* 19: 1, 2000, p. 17.
[322] *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 374 (London: HMSO, June 1989), p. 6. Loading 4-8 missiles would take less time.
[323] Adm. Stansfield Turner, *Caging the Nuclear Genie, An American Challenge for Global Security* (Boulder, CO: Westview Press, 1997).
[324] Michael Mazarr, "Virtual Nuclear Arsenals", *Survival* 37:3, Autumn 1995; Michael Mazarr, "The Notion of Virtual Arsenals" in Michael Mazarr (ed), *Nuclear Weapons in a transformed World: The Challenge of Virtual Nuclear Arsenals* (New York: St. Martin's Press, 1997), p. 15.

and US and Soviet/Russian navies regularly deployed conventional and nuclear-armed cruise missiles and depth-bombs on the same delivery platforms, be it surface ships or submarines. During the 1991 Gulf War, for example, US Air Force B-52 bombers launched 35 Conventional Air-Launched Cruise Missiles (CALCMs) against targets in Iraq.[325] CALCMs are nuclear-armed Air-Launched Cruise Missiles (ALCMs) that the US Air Force converted for conventional operations in 1986 in a secret 'black' development, acquisition and testing process.[326]

The concept of a hybrid SSGN/SSBN also raises important issues about the safety of a nuclear-armed submarine operating in littoral waters, but particularly the risk of detection after firing conventional TLAMs. No UK SSBN has ever been detected at sea and it is unlike that an SSN has been detected. Kennedy argues that "The location of the previously undetected submarine (datum) is potentially provided to the enemy by a missile-launch event. However, the datum is very fleeting, especially if the submarine uses a 'shoot and scoot' tactic. Enemy antisubmarine forces would need to be poised and ready to attack in the immediate area of the submarine to have any chance at success, a potential risk the submarine's preceding and succeeding stealthiness would minimize. In fact, studies have concluded that even with an enemy submarine positioned within two nautical miles of a submerged TLAM launch event, no enemy firing solution on the launching submarine could be achieved. Navy submarines engaged in these attack missions will necessarily be maintaining situational awareness by sharing a common, relevant, operational picture with other forces in the joint task force—thus being provided warning of proximate enemy antisubmarine warfare (ASW) forces".[327]

The US National Academy of Sciences also argued that the dangers flowing from a possible identification of the location of the submarine resulting from the launch of conventional missiles from an SSBN are minimal: "The problem would be no worse than with a nuclear warhead, and the Navy long ago developed techniques to protect SSBNs after missile launch". With rapid SSBN movement from the launch point "Within a short period of time, an SSBN's location would be unknown within an area large enough to deny plausible effective attack."[328]

Concerns are also raised about the accidental launch of nuclear weapons from a dual-use hybrid SSGN/SSBN. Such concerns are also overstated according to the US National Academy of Sciences. They argue that "There are multiple measures – effectively 'fail-safe' procedures and mechanisms –that can reduce, and in principle eliminate, any risk of an accidental launch of a nuclear weapon when a conventional strike has been ordered. These include taking procedural and physical steps to prevent (and if possible make physically impossible) (1) the launch of a nuclear missile in response to a conventional launch order, (2) the loading of nuclear-armed missiles into launch tubes for conventionally armed missiles, or (3) the transmission of a nuclear launch order when a conventional launch order is intended."[329]

[325] *Cruise Missiles: Proven Capability Should Affect Aircraft and Force Structure Requirements*, GAO/NSIAD-95-116 (Washington, D.C.: Government Accountability Office, April 1995), p. 2.
[326] Major Stephen R. Hes, "Conventional Air Launched Cruise Missile Development - Employment And The Cost Of Global Presence", Military Issues Paper, Command and Staff College, April 1995.
[327] Kennedy, "Transforming the Submarine Force".
[328] *U.S. Conventional Prompt Global Strike: Issues for 2008 and Beyond* (National Academies Press: Washington, D.C., 2008) p. 68.
[329] Ibid., p. 71.

Precedents from US nuclear weapons policy

Recalling an SSGN/SSBN to port to be equipped with Trident missiles as a serious crisis begins to emerge will present a number of operational challenges. A difficult political decision will have to be made to deploy nuclear-armed missiles, a decision governments may be reluctant to make. It may take several weeks for a submarine to return to Faslane and then several more weeks to load a handful of Trident missiles, rotate crews, resupply the boat if necessary, and then redeploy on operational patrol. US SSGNs currently spend 56 days travelling to and from home port, loading and unloading equipment from the submarine's dry-deck shelter, and undergoing the certifications and inspections that are required as part of the crew-exchange over a forward-deployed cycle. This suggests an average turnaround of four weeks for the SSGN to return to home port, resupply, rotate crews, recertify and redeploy.[330]

In a future three-boat hybrid SSGN/SSBN submarine fleet it should be possible to bring one of the two non-deployed submarines up to readiness for short-notice deployment within a period of weeks, including loading a number of Trident missiles. Procedures would need to be in place to manage these two contingencies of 1): recalling, re-roling for a nuclear mission and redeploying a SSGN/SSBN currently at sea, and 2) bringing a submarine in port up to operational readiness within a reduced timeframe.

Three precedents from US nuclear weapons policy and practice highlight the practicability of maintaining dual-capable nuclear weapon platforms at reduced readiness and re-roling conventional platforms for nuclear missions within fixed time periods:

1) Standing plans through the 1990s and 2000s to redeploy the B-1B bomber fleet for nuclear missions.
2) The US experience with the Tomahawk Land-Attack Missile-Nuclear (TLAM-N) arsenal.
3) The reduced readiness posture of NATO Dual Capable Aircraft (DCA).

In September 1991 and January 1992 President George H. W. Bush announced major unilateral withdrawals, cancellations and reductions in ongoing nuclear weapons programmes that were mirrored by Soviet/Russian actions. These became known as the Presidential Nuclear Initiatives (PNIs). The two PNIs announced, amongst other measures, withdrawal of all tactical nuclear weapons from surface ships, submarines and land based naval aircraft including nuclear-armed cruise missiles, and reorientation of most heavy bombers to conventional roles.[331]

In 1994 President Clinton initiated a wide-ranging review of the purpose and nature of US nuclear forces after the Cold War in a Nuclear Posture Review (NPR).[332] The subsequent policy was

[330] *Crew Rotation in the Navy*, CBO, p. 3.

[331] Richard Cheney, *Prepared Statement by Richard B. Cheney, Secretary of Defense,* Hearing before the Senate Committee on Armed Services on "Military implications of START I and START II", July 28, 1992, (Washington, D.C: U.S. Government Printing Office).

[332] William Owens and John Deutch, *Questions and Responses, Adm. William A. Owens, USN, Vice Chairman, Joint Chiefs of Staff, Dr. John Deutch, Deputy Secretary of Defense,* Hearing before the Senate Committee on Armed Services on "Briefing on Results of the Nuclear Posture Review", September 22, 1994, (Washington, D.C: U.S. Government Printing Office).

described as 'lead but hedge' – asserting leadership in reducing nuclear weapons whilst hedging against reversal and uncertainty by retaining the capability to redeploy withdrawn nuclear forces in case Russia reverted to a hostile foreign policy.[333] The hedge would allow relatively rapid reconstitution of a larger nuclear force with timelines for reconstitution that could be extended as Russia stabilised and relations with the former Soviet Union improved.[334] Two specific recommendations included switching all 95 of the US B-1B bombers to conventional roles (this was achieved in 1997) and retaining the ability to restore TLAM-N cruise missiles to attack submarines.[335]

B-1B re-role plan

The B-1B is a multi-role, long-range bomber, capable of flying intercontinental missions and penetrating sophisticated enemy air defences. The first aircraft, a derivative of the earlier B1-A, entered operational service in 1986. The bomber fleet was originally dedicated to a nuclear role in US strategic nuclear war planning. It was officially removed from nuclear-strike missions in October 1997 following the PNIs and 1994 NPR. In 1993 the US Air Force Air Combat Command began developing a B-1B 're-role' plan to return the bombers to nuclear missions if required as part of the 'lead but hedge' nuclear reductions strategy. This involved retention of additional B61 and B83 nuclear bombs in the US 'active reserve' nuclear weapons stockpile – nuclear weapons that are not operationally deployed but maintained at a state of readiness for redeployment if required. Part of this process meant ensuring that the B-1B's Conventional Mission Upgrade Program would not preclude future deployment of nuclear weapons.[336]

The official *B-1 Nuclear Re-Role Plan* states that "In the event of a national emergency...the Air Force will be directed by the National Command Authority (NCA) to recapture a B-1 nuclear capability. This plan is feasible only if the NCA directs that the nuclear mission of the B-1 will take priority over all other B-1 missions".[337] This would involve some movement of aircraft, personnel, weapons, support equipment and spares, personnel training and certification, reinstallation of sensors and alarms in storage and maintenance facilities, reconfiguration/test of suspension equipment, and software modifications and certifications.[338]

The report also states that "As the length of time the B-1 is relieved from a nuclear capability increases, expect a loss of nuclear expertise among the operational and support personnel. Once nuclear expertise is completely exhausted, the most experienced personnel available will use existing nuclear tech data to gain the required nuclear expertise".[339] This includes "all pertinent B-

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333 Krepinevich, A. F. and Kosia, S. M., "Smarter Bombs, Fewer Nukes", *Bulletin of the Atomic Scientists,* vol. 54, no. 6 (November/December 1998); *DOD Recommends Reduction in Nuclear Force,* Office of the Assistant Secretary of Defence (Public Affairs), U.S. Department of Defense, Washington, D.C., September 22, 1994. Retrieved from <http://www.nautilus.org/archives/nukestrat/USA/Npr/dodpr092294.pdf>.

334 *Nuclear Forces, Post 1994*, Strategic Advisory Group paper for Henry Chiles, C., Strategic Command, July 12, 1994. Retrieved from <http://www.nukestrat.com/us/stratcom/96-84h_STRATCOM071294.pdf>.

335 Amy Woolf, U.*S. Nuclear Weapons: Changes in Policy and Force Structure*, (Washington, D.C.: Congressional Research Service February 2004); William Arkin and Stan Norris, "Nuclear Notebook: U.S. Nuclear Weapons Stockpile, July 1997", *Bulletin of the Atomic Scientists,* vol. 53, no. 4 (July/August, 1997).

336 Hans Kristensen, "The Unruly Hedge", *Arms Control Today* Vol. 31, December 2001.

337 "B-1 Nuclear Re-Role Plan", US Air Force Air Combat Command, October 14, 1998. Released under the US Freedom of Information Act to Hans M. Kristensen in January 2001, p. 2.

338 Ibid., p. 3.

339 Ibid., p. 3.

1 related tech orders, diagrams, facility drawing, photographs, nuclear safety assessments, operating instructions, regulations and course training standards" and the development and validation of maintenance, operations and training concepts and plans.[340] The plan concludes by observing that "there continues a risk that as time and events move forward, the expense – both dollars and duration – to accomplish B-1 nuclear rerole may make it unrealistic and impractical. This plan, by encapsulating actions necessary to reconstitute the B-1, seeks to minimize that risk".[341] The timeline envisaged is redacted in the declassified plan.

The B-1B nuclear re-role plan highlights the feasibility of retaining a dual-capable nuclear delivery system that is routinely assigned to conventional missions with plans in place to return the platform to nuclear missions if required.

TLAM-N redeployment plan

The United States Navy began developing a nuclear-armed sea-launched cruise missile (SLCM) in 1971. The first submarine-launched TLAM-N entered into service in 1984 as a nuclear-armed version of the Block II TLAM-A missile.[342] 100 were deployed at sea at a time with a range of 1,500 miles.[343] They could deliver a W80-0 nuclear warhead that has a variable yield of between 5 and 150k, similar in capability to the UK's Trident warhead that has strategic and sub-strategic yields. The

All TLAM-Ns (approximately 350) were withdrawn from operational service by the end of 1992. President Bush stated at the time that "under normal circumstances, our ships [including submarines] will not carry tactical nuclear weapons. Many of these land- and sea-based warheads will be dismantled and destroyed. Those remaining will be secured in central areas where they would be available if necessary in a future crises".[344].

The 1994 NPR recommended that the US Navy and Air Force eliminate the ability of carriers and other surface to ships to deploy the nuclear weapons that were withdrawn under the first PNI in 1991 but maintain the ability to redeploy TLAM-N missiles on nuclear attack submarines (SSNs).[345]

After 1997 the missiles were transferred to the Strategic Weapons Facility Atlantic at King's Bay, Georgia, and the Strategic Weapons Facility Pacific at Bangor, Washington, to be stored alongside Trident nuclear warheads.[346] By 2007 it was estimated that only 100 remained in the operational stockpile with approximately 220 in reserve or inactive status.

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[340] Ibid., p. 11.
[341] Ibid., p. 13.
[342] "Nuclear Supplement to the Joint Strategic Capabilities Plan for FY1996", Joint Chiefs of Staff, February 12, 1996, p. GL-15 (heavily redacted). Obtained under the Freedom of Information Act by Hans Kristensen. Available at <www.nukestrat.com/us/jcs/98-53h_AnnexC96.pdf>.
[343] Joshua Handler, "PNIs and TNW elimination, storage and security", in Brian Alexander and Alistair Millar (eds), *Tactical Nuclear Weapons* (Dulles, VA: Brassey's, Inc., 2003), p. 22.
[344] Cited in Ibid., p. 169.
[345] "Overview of Nuclear Posture Review (NPR) Results", U.S. Strategic Command, September 22, 1994. Obtained under the Freedom of Information Act by Hans Kristensen. Available at <www.nukestrat.com/us/reviews/usstratcom0994.pdf>.
[346] Joshua Handler, "PNIs and TNW elimination, storage and security", in Brian Alexander and Alistair Millar (eds), *Tactical Nuclear Weapons*, (Dulles, VA: Brassey's, Inc., 2003), p. 23; Amy Woolf, *Nuclear weapons in U.S. Defense Policy: Issues for Congress*, (Washington, D.C.: Congressional Research Service, July 1997), p. 8.

According to Joshua Handler, "Every unit that has a nuclear-weapons mission of transporting, storing, or firing nuclear weapons must be certified to do so by its service and by the Department of Defense".[347] A number of SSNs in the Pacific and Atlantic fleets are therefore required to undergo periodic certification to ensure they can deploy and fire TLAM-Ns if called upon to do so in a crisis.[348] After passing inspections the SSNs are then de-certified to save resources for more urgent, non-nuclear responsibilities.[349]

According to the 1998 *Report of the Defense Science Board Task Force on Nuclear Deterrence* processes were established to ensure TLAM-N missiles could be redeployed on SSN attack submarines within 30 days of a decision.[350] This involves live test firing of un-armed missiles. A 1997 US Department of Defense report on *Nuclear Weapons Systems Sustainment Programs* reported that "Twice a year, Navy selects an attack submarine and conducts a regeneration exercise that demonstrates and appraises the capability to redeploy nuclear-armed cruise missiles on such submarines. This exercise tests the ability of the submarine and crew to re-establish nuclear weapons capability in a relatively short time."[351] The February 2004 *Report of the Defense Science Board Task Force on Future Strategic Strike Forces* confirmed that "DOE requires two annual operational Quality Assurance Surveillance Testing test launches be conducted to track reliability", including live test firing of an unarmed TLAM-N' [352]

In 1998 two submarines participated in unusual Tomahawk exercise launches in 1998. USS Atlanta conducted a dual launch consisting of a TLAM-C and a TLAM-N Quality Assurance Test (QAST). This was the first combined conventional and unarmed nuclear test launch from the same platform.[353] The command history for the USS Bremerton, a Los Angeles-class SNN, for the period March 18, 2000 to March 5, 2002 operating out of US Naval Submarine Base San Diego stated that "BREMERTON successfully completed a Nuclear Weapons Acceptance Inspection, and proceeded to Bangor, Washington to load an exercise TLAM-N and conduct a successful QAST-TLAM-N launch in March."[354]

The ability to redeploy TLAM-Ns was enhanced through new command and control systems in the early 2000s with the development of the submarine Combat Control System (CCS) Improvement programme (CCS MK2 Programme). Block II of this programme included an "AN/BSG-1 (formerly known as Tomahawk Land Attack Missile – Nuclear (TLAM-N) Portable Launching System (PLS)) [that] provides SSN submarines with a stand-alone TLAM-N missile launching capability".[355] This was described as a programme to "provide a cost-effective, timely

[347] Handler, "PNIs and TNW elimination, storage and security", p. 25.
[348] Norris *et al* reported in 2001 that in the Pacific Fleet less than half of the attack submarines undergo regular nuclear certification. Robert Norris, William Arkin, Hans Kristensen and Joshua Handler, "U.S. Nuclear Forces, 2001", *Bulletin of the Atomic Scientists*, March-April 2001.
[349] Robert Norris, William Arkin, Hans Kristensen and Joshua Handler, "U.S. Nuclear Forces, 2002", *Bulletin of the Atomic Scientists*, May-June 2002, p. 74.
[350] *Report of the Task Force on Nuclear Deterrence*, (Washington, D.C.: Defense Science Board, Department of Defense, October 1998), p. 28.
[351] *Nuclear Weapons Systems Sustainment Programs*, (Washington, D.C.: Department of Defense, May 1997).
[352] *Report of the Defense Science Board Task Force on Future Strategic Strike Forces*, (Washington, D.C.: Office the Secretary of Defense, Department of Defense, February 2004). Available at <http://www.acq.osd.mil/dsb/reports/fssf.pdf>.
[353] See <www.navy.mil/navydata/cno/n87/usw/Issue_3/Pullout/submarine_strike.htm>.
[354] Command history available at <www.history.navy.mil/shiphist/b/ssn-698/2000.pdf>.
[355] Se FY 1999 request at http://www.finance.hq.navy.mil/FMB/99pres/RDTEN/RDTEN_BA_5_book.pdf and FY 2001 request at http://www.dtic.mil/descriptivesum/Y2001/Navy/0604562N.pdf.

approach to meeting TLAM-N regeneration requirements and a common launcher interface across all attack submarines maximizing capabilities while minimizing operation, training and supportability costs".[356] The February 2004 Report *of the Defense Science Board Task Force on Future Strategic Strike Forces* says that "the AN/BSG-1 TLAM-N Weapon Launching System, which will provide increased flexibility and retargeting capability" [357] and allow redeployment of TLAM-Ns on a range of US SSNs.[358]

The missile has now been withdrawn from service. The 2008 *Report of the Secretary of Defense Task Force on DoD Nuclear Weapons Management* estimated that the missile's service life would end in 2013 and said that a decision on developing a replacement was deferred to the next administration. No such decision was taken and the missile was retired it the 2010 Nuclear Policy Review.[359]

NATO Dual Capable Aircraft

Nuclear deterrence remains a key part of NATO's military posture. In its 1999 Strategic Concept the organisation stated that "Nuclear weapons make a unique contribution in rendering the risks of aggression against the Alliance incalculable and unacceptable. Thus, they remain essential to preserve peace".[360] They also serve a second purpose of keeping America tied to the defence of Europe such that "Nuclear forces based in Europe and committed to NATO provide an essential political and military link between the European and the North American members of the Alliance."[361]

It is in this context that the United States still maintains between 150 and 240 forward-deployed non-strategic B61 nuclear bombs at six airbases in Turkey, Germany, Italy, Holland and Belgium under 'dual key' arrangements. They are assigned for delivery by F-15, F-16 and Tornado fighter aircraft referred to as Dual-Capable Aircraft (DCA).[362]

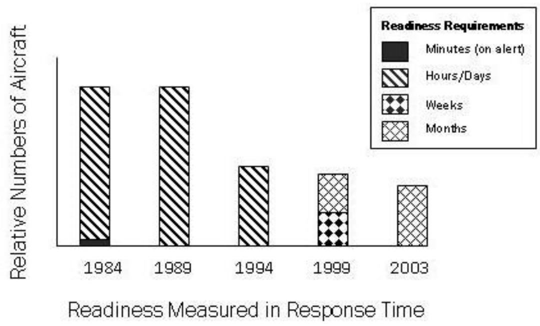
This forward-deployed nuclear arsenal has been reduced considerably in terms of size and operational readiness and NATO argues that it represents "the minimum level consistent with the prevailing security environment".[363] Kristensen reports that at the end of the Cold War there were approximately 1,400 forward-deployed nuclear bombs that were reduced to around 700 by 1992 and 480 by the mid-1990s. This was reduced further after Greece withdrew from the NATO

[356] "Department of the Navy Fiscal Year (FY) 2001 Amended Budget Submission, Justification of Estimates June 2001", Other Procurement, Navy Budget Activity 4", Department of the Navy.
[357] *Report of the Defense Science Board Task Force on Future Strategic Strike Forces*, (Washington, D.C.: Department of Defense, February 2004). Available at <http://www.acq.osd.mil/dsb/reports/fssf.pdf>.
[358] John Keller, "Raytheon readies COTS upgrade of U.S. submarine combat systems", *Military & Aerospace Electronics,* 12: 5 May 2001. Available at <http://mae.pennnet.com/articles/article_display.cfm?Section=ARCHI&C=News&ARTICLE_ID=100148&KEYWORDS=Ohio-class&p=32>; Robert Norris and Hans Kristensen, "U.S. Nuclear Forces, 2007", *Bulletin of the Atomic Scientists*, January-February 2007, p. 82.
[359] *Nuclear Posture Review*, Department of Defence, Washington, D.C., April 2010, p. 46.
[360] "The Alliance's Strategic Concept", NATO, April 1999. Available at <http://www.nato.int/docu/pr/1999/p99-065e.htm>.
[361] Ibid.
[362] Hans Kristensen, *U.S. Nuclear Forces in Europe*, Natural Resources Defense Council, Washington, D.C., February 2005, p. 11.
[363] "The Alliance's Strategic Concept", NATO, April 1999.

nuclear strike mission in 2001 and weapons were withdrawn from two bases in Germany and from RAF Lakenheath in the UK between 2005 and 2008.[364]

The operational readiness of Dual Capable Aircraft has also been reduced significantly. NATO reports that "In 1995, in a first major step of relaxation, the readiness posture of dual-capable aircraft was greatly reduced, so that nuclear readiness was measured in weeks rather than in minutes. In 2002, in a second step, the readiness requirements for these aircraft were further reduced and are now being measured in months".[365] Kristensen argues that "a readiness level of 'months' suggests that some of the mechanical and electronic equipment on the fighter aircraft needed to arm and deliver the nuclear bombs may have been removed and placed in storage".[366]

Figure 10: Numbers and readiness of NATO Dual Capable Aircraft



Source: "NATO's Nuclear Forces in the New Security Environment" at <http://www.nato.int/issues/nuclear/secenvironment.html>.

The circumstances in which NATO Allies might contemplate use of nuclear weapons are described as "extremely remote".[367] In June 1996 NATO's Nuclear Planning Group said that alliance nuclear forces "are no longer targeted against anyone"[368] and John Ainslie argues that NATO probably stopped maintaining standing nuclear plans between 1995 and 1998.[369]

The NATO nuclear mission in Europe is maintained, however, through regular training missions where US and NATO pilots can practice their skills in dropping nuclear bombs, through regular Nuclear Surety Inspections and through NATO Tactical Evaluations. This includes annual ABLE

364 Hans Kristensen, "United States Removes Nuclear Weapons From German Base, Documents Indicate", FAS Security Blog, July 9, 2007. Available at <http://www.fas.org/blog/ssp/2007/07/united_states_removes_nuclear.php>; Hans Kristensen, "The Minot Investigations: From Fixing Problems to Nuclear Advocacy", FAS Security Blog, January 14, 2009. Available at <http://www.fas.org/blog/ssp/2009/01/schlesingerreport.php#more-669>; Hans Kristensen, "U.S. Nuclear Weapons Withdrawn from the United Kingdom", FAS Security Blog, June 26, 2008. Available at <http://www.fas.org/blog/ssp/2008/06/us-nuclear-weapons-withdrawn-from-the-united-kingdom.php>.

365 "NATO's Nuclear Forces in the New Security Environment", NATO, 1995. Available at <http://www.nato.int/issues/nuclear/sec-environment.html>.

366 Hans Kristensen, *U.S. Nuclear Forces in Europe* (Washington, D.C.: Natural Resources Defense Council, February 2005), p. 68.

367 "The Alliance's Strategic Concept", NATO, April 1999.

368 "Final Communiqué of the Meeting of the Defence Planning Committee in Ministerial Session2, NATO, June 13, 1996. Available at <http://www.nato.int/docu/pr/1996/p96-088e.htm>.

369 Ainslie, *The Future of the British Bomb*, p. 67.

ALLY and ABLE TEAM war game exercises to plan for the use of DCA nuclear weapons and test the NATO Nuclear Planning System (NNPS).[370]

The forward-deployed NATO nuclear arsenal operates under a different conception of 'minimum deterrence' than the UK Trident arsenal and again demonstrates how a nuclear force can be maintained at much lower levels of readiness for a long period of time.

Relevance for the UK

The United States maintained a fleet of nuclear-armed cruise missiles ashore for 18 years and maintained operational and training procedures to ensure their redeployment aboard attack submarines within 30 days of a decision to do so.

This process has implications for future options to reduce the operational readiness of the UK Trident fleet as part of a national or international process of reducing reliance on nuclear weapons in national security policy. Based on this example of a long-term working practice it is possible to envisage a fleet of 2-4 dual-capable Successor submarines routinely operating at sea performing non-nuclear military missions but able to redeploy a handful of nuclear-armed Trident missiles within a specific period of time from weeks to months and to sustain that nascent capability over many years with the requisite onshore submarine, missile and warhead support facilities and annual nuclear certification, redeployment exercises, and technological adaptations.

Clearly there are important differences. Operating the UK's Trident II (D5) missile arsenal in this way would mean reconceptualising prevailing understandings of minimum deterrence. The scale is altogether different since applying these precedents to the UK would mean placing the UK's entire nuclear capability in a reduced readiness or re-role posture. Nevertheless, the development of SSGN technologies, the potential for hybrid SSGN/SSBN submarines, the TLAM-N operational posture, B-1B re-role plan, and reduced readiness of NATO DCA demonstrate the practicability of such an operational posture.

[370] Kristensen, *U.S. Nuclear Forces in Europe*, p. 64; Ainslie, *The Future of the British Bomb*, p. 68.

A cruise missile option

The fourth option examined in this report is the potential for deployment of submarine-launched nuclear-armed cruise missiles aboard the UK's new *Astute*-class attack submarines. A similar option was explored in some detail in the late 1970s when options for replacing the Polaris system were examined.[371]

The 2006 White Paper dismissed cruise missile options on the grounds that such a system would not meet the government's criteria for a 'credible' nuclear deterrent threat. It argued that "ballistic missiles are more effective than cruise missiles because they have much greater range and payload, and are far harder to intercept."[372] Dismissal of a cruise option rests on the fact that cruise missiles only carry a single warhead, not multiple warheads like the Trident missile; the Trident missile can travel up to 4,600 miles fully armed, whereas most long-range cruise missile can only travel around 1,500-1,800 miles allowing less 'sea-room' in which the submarine on patrol can avoid detection; ballistic missiles travel much faster than cruise missiles; and cruise missiles are more prone to interception by advanced air defences because of their slower speed and lower trajectory, whereas current missile defence systems would be unable to defeat the Trident missile.[373]

Cruise missile options

In order to achieve the same confidence in the ability to destroy a particular target with a nuclear strike a greater number of cruise missiles would be required compared to the number of ballistic missile warheads required, given their reduced reliability and greater susceptibility to interception.[374] To replicate the "weight of strike" of an SSBN armed with 16 Trident missiles and up to 48 warheads with cruise missiles would likely require two cruise missile submarines continuously at sea with 60+ nuclear-armed cruise missiles.

For example, in 1980 Michael Quinlan, then Deputy Under Secretary (Policy and Programmes) at MoD, stated that MoD rejected an SLCM solution on just such a like-for-like comparison, stating that the key factor was "whether for a given weight of strike for deterrence the cruise missile provides an equal assurance at lower cost".[375] On that basis he argued that 11 SSNs armed with 80 cruise missiles each would provide the equivalent of five SSBNs armed with 16 Trident ballistic missiles each (original plans envisaged five rather than four *Vanguard* SSBNs).

A cruise missile solution may not be able to provide a direct replacement for the current Trident system in terms of range, interception, and MIRVed warhead capability, but it could provide an alternative minimum nuclear force if 'minimum' is not defined by the characteristics of the Trident

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[371] See Owen, *Nuclear Papers*.
[372] MoD and FCO, *The Future of the United Kingdom's Nuclear Deterrent*, p. 7.
[373] See note by Professor Lawrence Freedman, Adviser to the Committee, *Strategic Nuclear Weapons Policy*, House of Commons Defence Committee, HC 266 (London: HMSO, March 1982), p. 23.
[374] Franklin Miller, "The Future of the United Kingdom's Nuclear Deterrent", *RUSI Journal*, 155: 2, April/May 2010, p. 37.
[375] *Strategic Nuclear Weapons Policy*, House of Commons Defence Committee, HC 674-v (London: HMSO, November 1980), p. 100.

system. A single SSN equipped with 16 cruise missile vertical launch tubes could provide a 'minimum' nuclear deterrent capability, as reportedly suggested by submarine designers at Barrow in 2006.[376] Alternatively, a single SSN equipped six Virginia Payload Tubes based on the Trident missile tube each fitted with a 'six-shooter' MAC fully loaded with long-range nuclear-armed cruise missiles would provide 36 warheads, plus additional cruise missiles for launching through torpedo tubes. This would provide more warheads than a single Polaris SSBN equipped with 32 Chevaline warheads that was judged sufficient for 'minimum deterrence' during the Cold War.

The argument for a cost-effective alternative to Trident should not be constrained by the significant and largely unnecessary enhancement of capability provided by Trident when the system was originally procured.[377] A shift in conceptions of minimum deterrence would make a cruise missile option more feasible, particularly under a non-CASD posture with dual-use SSNs/SSGNs equipped with conventional and nuclear-armed cruise missiles

Cruise missile options outlined in this section include:

1) Develop new nuclear warheads for current TLAMs based on US W80-0 warhead or a new UK design possibly based on preliminary work completed for a Tactical Air-Surface Missile warhead.
2) Develop new nuclear warheads and purchase a new cruise missile with greater speed, range, and survivability, possibly based on the US nuclear-armed Enhanced Cruise Missile currently in development, a longer range TLAM Bock V, the US JASSM-XR or RATTLRS programmes, or a longer range Naval SCALP missile.
3) Develop new nuclear warheads and develop a new, indigenous, long-range, stealthy sub-sonic or supersonic cruise missile.

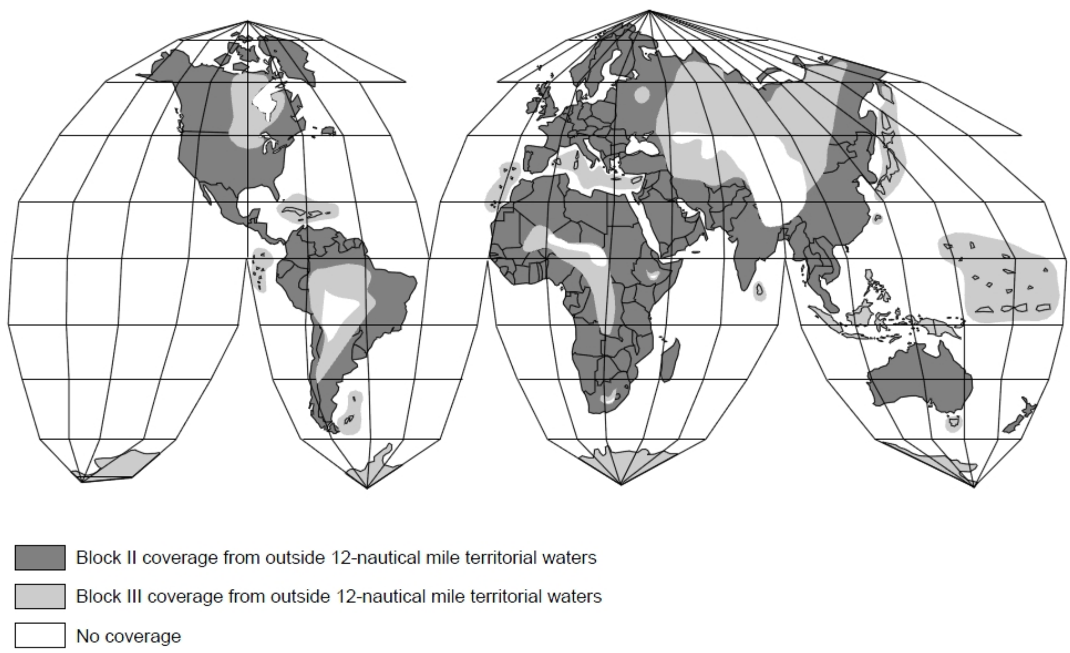
Nuclear-armed Tomahawk cruise missiles

The UK currently deploys Block III and Block IV conventionally-armed Tomahawk cruise missiles aboard its attack submarines. The MoD purchased 64 TLAM Block IV missiles and Tactical Tomahawk Weapon Control Systems (TTWCS) from the US in a £70 million contract in 2004 and spent an additional £25 million to provide the necessary submarine and on-shore command and control systems. The missile became operational in the fleet in 2008.[378] Whilst the early nuclear-armed Block II variant had a range of 1,500 miles, current Block III and Block IV conventional variants in the UK inventory have a range of 800 and 1,000 miles respectively compared to the Trident II (D5) range of 4,600 miles fully armed.[379] Nevertheless, this would still provide considerable coverage (see Figure 11). There are also concerns about the missile's reliability. Operation Iraqi Freedom in 2003 demonstrated the missile's liability to drift off course when, according to Jeffrey Lewis, approximately ten out of 800 conventionally-armed Tomahawk missiles went astray, crashing in Turkey, Saudi Arabia and Iran. In response to the political fallout

[376] J. Simpson, "We'll Save you cash on Submarines", *North-West Evening Mail*, April 17, 2006.
[377] Robin Laird, "The Future of the British Strategic Nuclear Force", *Comparative Strategy*, 5: 4, 1986, p. 341.
[378] "Attack Submarine Returns to the Fleet", Defence News, Ministry of Defence, April 4, 2008. Available at <http://webarchive.nationalarchives.gov.uk/tna/+/http://www.mod.uk:80/defenceinternet/defencenews/equipmentandlogistics/attacksubmarinereturnstothefleet.htm>. Accessed May 12, 2010.
[379] "Tomahawk cruise missile", US Navy FactFile. Available at <http://www.navy.mil/navydata/fact_display.asp?cid=2200&tid=1300&ct=2>. Accessed May 1, 2010.

from these stray missiles, the Navy suspended launches of Tomahawk missiles from ships in the Mediterranean and Red Seas.[380]

Figure 11: TLAM Block II and III range



Source: *Cruise Missiles: Proven Capability Should Affect Aircraft and Force Structure Requirements*, GAO/NSIAD-95-116 (Washington, D.C.: Government Accountability Office, April 1995), p. 55.

Nevertheless, the UK could opt to develop a new or redesigned nuclear warhead for its Tomahawks. The idea is not without merit. Even in 1977 when the US TLAM programme was in its infancy an MoD paper on options for Polaris replacement reproduced in former Foreign Secretary David Owen's *Nuclear Papers* argued that: "It would be possible to deploy cruise missiles in a combination of different launch modes as part of a strategic nuclear force. It is possible moreover that cruise missiles may be considered an attractive option for British forces for other forms of strike, for example theatre nuclear strike or deep conventional strike against fixed targets. The same missile could be used for any of these purposes: the only difference would be in the warhead, the amount of fuel carried and in the particular flight programme fed into the guidance system. It is not yet clear whether the cruise missile will in fact be cost-effective for use in these other roles. But if it is, then there could be economies of scale in relying, for a strategic nuclear capability, on missiles and delivery modes which had other applications".[381] The economy of scale argument, both in terms of missiles and submarines, remains salient today.

If the US were to share the design of the W80-0 nuclear warhead that equipped its recently retired nuclear-armed TLAMs, as it has done with its W76 Trident warhead design, it is conceivable the UK could design and manufacture an Anglicised version without nuclear testing and within acceptable tolerances using US test data and the array of 'stockpile stewardship' facilities at AWE

[380] Jeffrey Lewis, "Why the Navy should Retire TLAM-N", December 13, 2009, Arms Control Wonk. Available at <http://www.armscontrolwonk.com/2560/why-the-navy-should-retire-tlam-n>.
[381] Reproduced in Owen, *Nuclear Papers*, p. 93.

Aldermaston. The same 1977 MoD report stated that "As far as is known, there would not be any major problems over installing British warheads (without the need for testing) into cruise missiles and the amount of extra research and development required for adapting the warheads would probably not be all that high".[382]

The UK would also have to develop appropriate procedures for marrying these warheads to existing conventionally-armed Tomahawk missiles. This would require continued support of the TLAM missile by the United States throughout its service life in the UK fleet. The February 2004 *Report of the Defense Science Board Task Force on Future Strategic Strike Forces* reported that development of a nuclear variant of the Tactical Tomahawk missile (Block IV TLAM-E TacTom) had been proposed in the US.[383]

The UK would also have to configure and certify its *Astute*-class SSNs for nuclear operations with fire control systems for targeting and launching nuclear-armed Tomahawk missiles, as opposed to their conventionally-armed variants. As RUSI's Lee Willett stated in May 2010, "The *Astute*-class submarines are neither designed for nor certified to carry nuclear weapons…You cannot just put a nuclear weapon in there and get on with it. You would have to redesign and re-certify Astute."[384] Nevertheless, the US developed an annual certification process and a portable launch system and command and control capabilities for its SSNs to allow them to fire TLAM-Ns.

A new warhead

The warhead could alternatively be based on an entirely new design, or on design and testing work initiated in the late 1980s and early 1990s on a new warhead for the proposed Tactical Air-Surface Missile (TASM) to be carried by a variety of NATO Dual Capable Aircraft. The UK identified a requirement for a new stand-off nuclear missile of 500km range for deployment board Tornado, Buccaneer and Sea Harrier aircraft as part of the modernisation of NATO nuclear forces in the late 1980s to replace the WE-177 A/B gravity bomb.[385] Three options were on the table: the new US Short Range Attack Missile – Tactical (SRAM-T) planned for operational deployment in the late-1990s (this was a variant of the longer-range SRAM-II missile); Martin Marietta's Supersonic Low Altitude Target (SLAT) missile; and development with France of an Air-Sol Longue Portée (ASLP) missile.[386] The reported cost in 1993 was £1.8 billion in 1993.[387] Others put it at £3 billion.[388]

The US began development of new W89 warhead for the SRAM-II and W91 warhead for the SRAM-T. Following the termination of the SRAM-II and SRAM-T programmes in the 1991 Presidential Nuclear Initiative development of the W89 warhead continued as a possible

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382 Ibid., p. 93.
383 *Report of the Defense Science Board Task Force on Future Strategic Strike Forces*, February 2004.
384 Joel Shelton, "In Defence of Trident", *Defence Management,* May 7, 2010. Available at <http://www.defencemanagement.com/feature_story.asp?id=14133>.
385 Robert Norris, Thomas Cochran, Richard Fieldhouse and Andrew Burrows, "Nuclear Weapons" in *SIPRI Yearbook 1990: World Armaments and Disarmament*, p. 38.
386 Oliver Ramsbotham and Scilla Elworthy, "The 'Political' Weapon: The Tactical Air-to-Surface Missile", *Current Decisions Report No. 3*, Oxford Research Group, Oxford, July 1990.
387 Christopher Bellamy, "Missile system 'no longer needed': Christopher Bellamy looks at the reasons behind cancellation of the TASM project", *The Independent,* October 19, 1993.
388 Ainslie, *The Future of the British Bomb*, p. 34.

replacement for the W88 Trident II warhead. The W91 warhead development was cancelled.[389] The W89 warhead was tested in 1990 with a variable yield up to 200kt.[390]

The UK began developing a new TASM warhead in 1988.[391] Tom McLean, Director of AWE, confirmed in March 1989 that AWE was developing a warhead for the TASM project.[392] Ainslie reports that "The development of a warhead for TASM reached an advanced stage".[393] Nuclear tests conducted in 1970s and 1980s at the US Nevada Test Site were in part designed to provide the foundations for future tactical nuclear warhead designs to replace the WE-177.[394] In October 1993 the Conservative government scrapped the TASM project, relying on the new Trident system to provide a 'sub-strategic' nuclear option with the retirement of the WE-177.[395] It is possible that additional nuclear tests through the 1980s and early 1990s supported the design and development of the TASM warhead before the project was terminated.

The UK could potentially use the research and design for the TASM warhead conducted over 1988-1993 and nuclear test data as the basis for a new cruise missile warhead. In the US work undertaken on the W89 SRAM-II warhead formed the basis of the Lawrence Livermore National Laboratory's proposed Reliable Replacement Warhead (RRW) design labelled WR-1.[396]

This would however, be a contentious decision since developing a 'new' warhead even if based on previous designs and tests would be deeply controversial. The divisive debate over the RRW in the United States revolved around strong disagreement as to the necessity of the programme given the huge investment in life extension programmes for current warheads and the potential impact of a decision to develop 'new' warheads on US nuclear non-proliferation objectives. The House Appropriations Committee, for example, stated in 2007 that "a particularly troubling issue for the Committee related to the RRW proposal is the contradictory U.S. policy position of demanding other nations give up their nuclear ambitions while the U.S. aggressively pursues a program to build new nuclear warheads".[397] Sensitivity to developing 'new' nuclear weapons in the UK undermines the political feasibility of this option.

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389 Reproduced in Ray E. Kidder, "Assessment of the Safety of U.S. Nuclear Weapons and Related Nuclear Test Requirement: A Post-Bush Initiative Update", Lawrence Livermore National Laboratory, December 10, 1991, p. 2.

390 David Albright, Peter Gray and Tom Zamora, "Retire Rocky Flats", *Bulletin of the Atomic Scientists,* December 1991, p. 13; Tom Zamora, "New Jobs for Old Labs?", *Bulletin of the Atomic Scientists,* November 1992, p. 18.

391 Lawrence Freedman, paper on Anglo/French nuclear cooperation presented at a seminar at Kings College London on March 13, 1991 on Anglo-French Defence Cooperation. Reprinted in *Anglo/French Defence Cooperation*, House of Commons Defence Committee, HC 91 (London: HMSO, November 1991), p. 20.

392 *The Progress of the Trident Programme*, House of Commons Defence Committee, HC 374 (London: HMSO, July 1989), p. 7.

393 Ainslie, *The Future of the British Bomb*, p. 35.

394 Brian Burnell, "Nuclear Weapons: A Guide to British Nuclear Weapon Projects". Available at <http://www.nuclear-weapons.info/vw.htm>. Accessed May 24, 2010. Burnell cites archival evidence from "TNA DEFE 19/181. UK underground nuclear tests 1978 Jun 06 - 1979 Dec 11" available at the National Archives, Kew, in particular a letter to the Secretary of State for Defence dated 27 June 1979, from V. Macklen, Director of the Atomic Weapons Research Establishment seeking approval for the an underground nuclear test at the US Nevada Test Site. Macklen wrote ""This test is a key part of our programme of warhead development for deterrent successor systems…"Our warhead development programme aimed at successor systems and *modernisation of our tactical nuclear weapons* would require at least two more successful tests …" (emphasis added).

395 House of Commons, *Official Report,* October 18, 1993, Column 34.

396 David Biello, "New Nukes are Good Nukes?", *Scientific American,* April 30, 2007; Ian Hoffman, "Lab Officials Excited by New H-Bomb Project", *The Oakland Tribune*, February 7, 2006; Jonathan Medalia, *Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program*, (Washington, D.C.: Congressional Research Service, July 2007), p. 16.

397 Medalia, *The Reliable Replacement Warhead Program*, p. 32.

A new missile

The UK could also opt to develop, co-develop or purchase a new long-range, stealthy and highly reliable cruise missile, most likely from the US under an amended Polaris Sales Agreement Very few countries deploy long-range cruise missiles. The longest range of current cruise missiles is reported to be in the region of 1,500 miles, although range is reduced if a missile has to transit heavily defended airspace, which would require the missile to fly lower and more evasively.[398] A cruise missile of 2,000-2,500 nautical mile range (2,300-2,800 mile range) comparable to the Polaris missile would be required for a UK strategic nuclear capability, according to Frank Miller.[399]

The United States Air Force Nuclear Weapons and Counter-proliferation Agency (AFNWCA) Advanced Technology Division (AT) is currently developing a new joint Enhanced Cruise Missile as part of a programme known as the Follow-On Long Range Stand-Off (LRSO) Vehicle to develop a replacement for the Air Launched Cruise Missile (ALCM).[400] The nuclear-armed ALCM was first deployed in 1986. It has a range of 1,500 miles and caries a warhead of variable yield up to 150kt.[401] Plans suggest the new missile that began development in 2004 will be deliverable from land, air and sea with a longer range to support global strike missions and with improved safety, reliability, and performance.[402] New warhead studies are underway but there has been no decision to proceed.[403] Air Force studies are reportedly exploring the possibility of a joint enhanced cruise missile. The study entered Phase 6.2 (feasibility study and option select) in 2008 along with production of Nuclear Weapons Requirements Documents for the new missile.[404] It may be possible to procure a long-range submarine-launched variant from the US and equip with indigenous nuclear warheads through an amended Polaris Sales Agreement.

The US is also developing long-range conventional sub-sonic cruise missiles as part of its long-range conventional strike programme. The US Air Force and Navy first deployed the Joint Air to Surface Standoff Missile (JASSM) stealthy cruise missile in 2003. Planned improvements, however, include a JASSM-ER (extended range) variant to double JASSM's range from 250nm to 500nm and a JASSM-XR (extra extended range) to increase range to 1,000nm to launch from bombers and heavy strike aircraft due its larger size.[405] The US Navy is reportedly interested in JASSM-XR as a replacement for the Tomahawk.[406] JASSM entered serial production in 2001. JASSM-ER development work is continuing and a production decision is scheduled for FY2010.[407] It

[398] Duncan Brewer, "UCAVs or Cruise Missiles?", *RUSI Defence Systems*, December 2008, p. 90.
[399] Miller, "The Future of the United Kingdom's Nuclear Deterrent", p. 37.
[400] Hans Kristensen, "Testing the 'no new nuclear weapons' pledge", *Strategic Security Blog*, Federation of American Scientists, March 18, 2010. Available at <http://www.fas.org/blog/ssp/2010/03/newnukes.php>.
[401] U.S. Nuclear Forces, 2007" *Bulletin of the Atomic Scientists*, 63(1) January/February 2007, p. 81.
[402] Ibid., p. 80; "Concepts and Technologies Study for Enhance Cruise Missile (ECM)", US Federal Business Opportunities, Solicitation Number: Reference-Number-AFNWCA-002.
[403] "Nuclear Cruise Missiles", *Bulletin of the Atomic Scientists*, 63(6) November/December 2007, p. 60.
[404] "U.S. Nuclear Forces, 2009" *Bulletin of the Atomic Scientists*, 65(2) March/April 2009, p. 65; US Air Force, "RDTE, PB and OCO Vol. III", FY2010 budget request, p. 293.
[405] *Report of the Defense Science Board Task Force on Time Critical Conventional Strike from Strategic Standoff*, (Washington, D.C.: U.S. Department of Defense, March 2009), p. 35.
[406] Peter La Franchi, "Sure Strike", *Flight International*, September 19, 2006.
[407] *Defense Acquisitions: Assessments of Selected Programs*, GAO-09-326S (Washington, D.C.: Government Accountability Office, March 2009), p. 89.

completed its sixth successful flight test in November 2009.[408] There is no indication at present that the US intends to develop a nuclear variant.

Supersonic cruise missiles

Supersonic cruise missiles travel at speeds in excess of the speed of sound (Mach 1 and above) and are currently deployed by a number of countries, notably Russia, China, India and France. France deployed the Mach 2-3 ASMP standoff cruise missile in 1986 with a 300-kiloton nuclear warhead and a range of 300km. A modernised and longer range ASMP-Amélioré (ASMP-A), entered service in 2009 with 400-500km range. The joint Russia-India BrahMos missile has a range of 290km with speeds of Mach 2.5+. Current plans envisage delivery from land, ship, air and submarine. Russia currently deploys and exports (including to China) the supersonic SS-N-22 Moskit or 'Sunburn' cruise missile. Operational since 1984 it has a range of 100 miles, can reach speeds of up to Mach 2.5 and can carry a 200kt nuclear warhead of a conventional payload.

In the US Raytheon is currently exploring the option of a supersonic Block V Tomahawk, although this would be of limited range of around 600-650 miles.[409] The US is also developing supersonic cruise missile technology through a joint NASA, USN, USAF technology demonstration programme called Revolutionary Approach to Time Critical Long Range Strike (RATTLRS). The concept has "a turbine engine that operates at Mach 3.0 for about 5 minutes. It could be air-launched, as well as ship- and sub-launched."[410] Reports suggest a range in the region of 500 miles. The US Navy's Office of Naval Research states that "The supersonic cruise speed and high cruise altitude for a RATTLRS-derived high-speed weapon could make it less vulnerable to defensive systems relative to operational weapons. In addition, the use of a turbine engine propulsion system and the resulting long range and high survivability offers significant improvements in mission flexibility to the warfighter over other approaches. An operational RATTLRS-derived tactical weapon system will also provide launch compatibility with ships, submarines and tactical and strategic aircraft."[411]

A second joint initiative, the Joint Supersonic Cruise Missile (JSSCM) was initiated in 2002 as an Advanced Concept Technology Demonstration (ACTD) programme. Performance parameters include a range of at least 400nm and a speed of at least Mach 3.5.[412] Very long-range cruise missiles (2,000 miles plus) that combine supersonic velocity and the accuracy and stealth characteristics of current advanced sub-sonic cruise missiles are not currently in development as weapon programmes in the United States.

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408 "Lockheed Martin's JASSM-Extended Range Missile Maintains Perfect Success Rate with Latest Flight Test", Lockheedmartin.com. Available at <http://www.lockheedmartin.com/news/press_releases/2009/MFC_111109_LockheedMartinsJASSM.html>.

409 Douglas Barrie, "Raytheon Studies Supersonic Tomahawk", *Aviation Week & Space Technology*, June 18, 2007, p. 56.

410 Ibid

411 "RATTLRS Flight Demonstration Program", Office of Naval Research. Available at http://www.onr.navy.mil/en/Media-Center/Fact-Sheets/RATTLRS-Flight-Demonstration-Program.aspx>.

412 http://www.globalsecurity.org/military/systems/munitions/jsscm.htm

Hypersonic cruise missiles

Very high velocity hypersonic cruise missile technology is also in development in the US for a conventional global strike mission. Hypersonic cruise missiles are long-term Mach 6+ systems that could be forward-deployed, for example on SSGNs or launched from long-range aircraft.[413]

The US has several hypersonic technology demonstration programmes. These include: HyFly – a National Aerospace Initiative to develop and demonstrate advanced technologies for hypersonic flight that could include surface ship, submarine, and air-launched missiles with ranges of around 600 nm, at speeds up to and greater than Mach 6.0; FALCON (Hypersonic Force Application and Launch from the Continental United States) – a reusable hypersonic cruise vehicle that can carry several munitions, including cruise missiles and bombs; X-43A (Hyper-X) – a cruise missile size hypersonic flight research aircraft, with speeds of Mach 7 to Mach 10; and X-51 (Waverider) – an air-launched hypersonic cruise missile for the B-52 that accelerates to Mach 4.5, then scramjet to Mach 6 to Mach 7+.[414]

In 2008 the US National academy Sciences warned that "The air-breathing Mach 6 missile (hypersonic cruise missile) represents a new class of delivery system, which is immature relative to the ballistic systems".[415] It went on to say that "Technology associated with air-breathing hypersonic propulsion systems has been under development in a laboratory environment for the past 30 years and has recently begun transition to the flight-test environment in programs such as the NASA-funded X-43, DARPA/ONR-funded HyFLY, and USAF/DARPA-funded X-51 programs. These programs have demonstrated or will demonstrate critical aspects of the propulsion technology necessary to enable a Mach 6 cruise missile…In 1998 the National Research Council conducted a study evaluating the U.S. Air Force Hypersonic Technology (HyTECH) program. This study concluded that the development of a Mach 6 missile in 2015 was feasible. Although not all recommendations in that report were implemented, the technology readiness of hypersonic cruise missiles is such that this type of capability can be deployed in about 2020."[416]

The NAS report did envisage deployment of long-range hypersonic cruise missile from SSGNs in the future: "If the SSGN launch tubes are modified to hold three hypersonic cruise missiles, calculations indicate that the powered range of the missile would be greater than 2,000 nmi (i.e., roughly the same range capability of a submarine-launched, intermediate-range ballistic missile)."[417]

Nevertheless, cost effective, long-range, hypersonic, submarine-launched, nuclear-armed cruise missile options are unlikely to be available to the UK within the current 2020-2025 timeframe for deploying a replacement for the current Trident-SSBN system. They carry high cost and high technical risk and would still have to penetrate defences.[418]

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[413] *U.S. Conventional Prompt Global Strike: Issues for 2008 and Beyond*, p. 6.
[414] *Report of the Defense Science Board Task Force on Time Critical Conventional Strike from Strategic Standoff,* p. 37.
[415] *U.S. Conventional Prompt Global Strike: Issues for 2008 and Beyond*, p. 134.
[416] Ibid, p. 135.
[417] Ibid, p., p. 118.
[418] Ibid., p. 15

A new UK cruise missile

The UK could, of course, develop an indigenous long-range, stealthy sub-sonic or supersonic cruise missile capable of evading current and projected air defence technology and delivering a nuclear payload with very high reliability. The costs of such a project are difficult to determine.

Some comparisons can be gained from the UK's Storm Shadow stealthy Conventionally Armed Stand-off Missile (CASOM). The highly-accurate missile was first deployed aboard Tornado GR4 aircraft in 2003 and has a range in excess of 250km. An international competition was launched in 1994 to meet the UK's CASOM requirement.[419] The Anglo-French MBDA (Matra BAE Dynamics) Storm Shadow option (labelled SCALP in France) was selected by MoD in June 1996 and a development and production contract signed in February 1997. The total estimated procurement cost of the Storm Shadow missile in 2002 was £981 million including development, production and initial support costs.[420] Reports suggest around $1.3 million / £900,000 per missile.[421] MBDA is developing a longer range SCALP Naval sea-launched variant with a range of over 1,000km It will be vertically launched from France's future FREMM frigates and through the torpedo tubes on France's future *Barracuda*-class SSN.[422]

In the US total research and development costs for the JASSM programme by 2009 were $1,340 million with an average unit cost was $1.14 million.[423] The unit cost of TLAMs is estimated at $1.5 million in FY2006 dollars (the UK's contract for 64 missiles at £70 million gives a unit cost of £1.1 million). This has reportedly dropped to $750,000.[424] The US is planning to reduce TLAM unit costs to $600,000.[425]

A cruise missile solution is feasible but it requires a number of compromises. First, a change in minimum deterrence requirements to reflect the reduced range and increased vulnerability to interception compared to the Trident II (D5) missile. Second, these options involve greater financial and technological risk through the development and deployment of a new warhead without nuclear testing; potentially relying on the maturity of advanced US cruise missile programmes in time to develop and deploy a UK nuclear-armed variant; or developing a new long-range, stealthy, reliable cruise missile either alone or in partnership (possibly with France on an extended range NAVAL Scalp). A cruise missile solution would also likely require development of a 'Block II' *Astute*-class SSN for nuclear certification possibly incorporating Virginia Payload Tube and MAC technologies from the US.

[419] *Ministry of Defence: Major Projects Report 1999*, National Audit Office, Cm 613 (London: HMSO, July 2000), p. 97.
[420] House of Commons, *Official Report,* July 16, 2002, Column 156W.
[421] Norman Friedman, *World Naval Systems,* 5th edn, (Naval Institute Press: Annapolis, MD, 2006) P. 518.
[422] "Storm Shadow / SCALP", MBDA factsheet. Available at <http://www.mbda-systems.com/mbda/site/ref/scripts/siteFO_contenu.php?lang=EN&noeu_id=120&page_id=115>.
[423] *Defense Acquisitions: Assessments of Selected Programs*, GAO, p. 89.
[424] Bob Aldridge, "Land Attack Tomahawks: A Background Paper on Long-Range, Sea-Launched Cruise Missiles", *Pacific Life Research Center,* Santa Clara, CA, April 2003, p. 3.
[425] Barry D. Watts, Six Decades of Guided Munitions and Battle Networks: Progress and Prospects, Center for Strategic and Budgetary Assessments, March 2007, p. 237.

Cost and flexibility

Flexibility

With major pressure on the defence budget the armed services are increasingly opting for flexible, multi-use capabilities. Whilst there is a strong desire to keep the Trident system as a separate capability it is clear from the operation of dual-use strike aircraft capable of delivering nuclear and conventional munitions for many years during the Cold War that the Ministry of Defence is comfortable with dual-use military capabilities. The key to an affordable nuclear arsenal that reduces the salience of nuclear weapons in national security policies and the size of the nuclear arsenal could well be a reduced readiness operational posture together with an effective capability to redeploy nuclear forces by integrating a reduced readiness nuclear force with conventional forces and infrastructure, rather than mothballing a nuclear capability for reconstitution at a later date.[426]

If the premium on flexible military platforms is applied to the Trident replacement programme, then the most flexible option would be to procure two or three hybrid SSGN/SSBN submarines capable of deploying a smaller number of Trident II (D5) missiles in missile tubes that incorporate Flexible Payload Module and Multiple All-up-around Canister technology. This provides a number of options:

1) An expanded SSN/SSGN capability in which Trident missiles and warheads are routinely stored ashore for redeployment, or even dismantled if a decision is taken in the future to relinquish nuclear weapons.
2) The ability to return to an exclusive nuclear mission operating under CASD for a period of time with single or augmented crews should circumstances dictate and/or operating a near-CASD nuclear mission for a longer period if required with a three-boat fleet.
3) A future nuclear-armed cruise missile solution if the new submarines are capable of firing a range of munitions, including cruise missiles, from flexible payload tubes. When the time comes to replace the current Trident missile in the mid-late 2030s, a decision could be taken to purchase or develop a long-range nuclear-armed, stealthy cruise missile deliverable by hybrid SSGN/SSBNs and SSNs in the fleet.

This will enable retention of submarine operation, support, protection, and targeting capabilities, and expertise; industrial submarine-building capability at Barrow; and expertise, capabilities and specialised procedures at AWE Aldermaston for ensuring the safety and reliability of the nuclear stockpile that are currently deemed essential national assets.

[426] Patrick Garrity, "Managing Asymmetries and Instabilities in Nuclear Reconstitution", in Mazarr (ed), *Nuclear Weapons in a Transformed World* (New York: St. Martin's Press, 1997), pp. 345-46.

Delay

Further flexibility is afforded by delaying the replacement programme. Ending CASD, adopting a reduced readiness operational posture, and further extending the life of the current *Vanguard* fleet would allow key decisions on Trident replacement to be delayed, perhaps by up to five years beyond the planned five-year Vanguard Life Optimisation Programme. The length of the Vanguard life extension will determine when Main Gate decisions are needed. This would delay significant capital expenditure at a time when public spending is due to be cut significantly, and enable the UK Successor programme to harmonise with the US SSBN(X) programme that is currently five years behind the UK, potentially reducing financial and technological risk.

Critics argue that delay could undermine the long-term viability of an indigenous UK nuclear-powered submarine building industry. The industry stated in 2006 that it needs to be building nuclear-powered submarines (either SSNs or SSBNs) at a rate of one every 22 months. Nevertheless, the National Audit Office's report on MoD's current major procurement programmes stated that MoD had decided to save cash in the short term by delaying delivery of the second, third and fourth *Astute*-class SSNs and deferring the start of work on boats 5-7. This "will not affect the first boat, but will slip the entry into service of each subsequent boat by an average of nine months".[427] If all six remaining boats are delayed by nine months then the current submarine building programme at Barrow will be extended by 4½ years, suggesting that a delay in Successor Main Gate of five years would not mean the end of the submarine-building industry.

Cost

The options explored above are shaped by many interconnected variables in three categories:

1) Conceptions of minimum deterrence including CASD, missile range and reliability, warhead numbers.
2) Political considerations, including the UK's relationship with the US and NATO, maintaining the UK submarine-building industry, and leadership on progress towards nuclear weapons-free world; timing in terms of the VLOP programme, the Main Gate decision, and US SSBN(X) programme.
3) Cost, in terms of capital expenditure on submarines, warheads, missiles and infrastructure and operational costs.

Cost has become the most salient variable in current political discourse. Three illustrative costings are outlined below based on options examined in this report (Table 10). They are not comprehensive. The cheapest option, of course, is to relinquish nuclear weapons after the current *Vanguard* SSBNs retire. Assuming that AWE Aldermaston retains nuclear warhead decommissioning and verification science and technology programmes and infrastructure at, for example, half current operational costs (for comparison purposes calculated over 25 years) and that the VLOP programme continues, the cost would be £10,250 million, or £20,600 if the ongoing capital investment in the Atomic Weapons Establishment (AWE) Aldermaston through to 2013 is not covered by annual operating costs.

[427] *Ministry of Defence: The Major Projects Report 2009*, National Audit Office, HC 85-1 (London: HMSO, December 2009), p. 25.

Table 10: Illustrative costed totals for three options (£ millions)			
	Capital	Operational	Total
Nuclear-armed TLAMs on planned *Astute* SSNs	7000	21000	28000
New nuclear cruise missile on 4 new 'Block II' *Astute* SSNs	15000	39400	54400
Trident missile on 3 new hybrid SSGN/SSBNs (lower)	14917	38000	52917
Trident missile on 3 new hybrid SSGN/SSBNs (upper)	27915	45600	73515

The first costed option is the development of a nuclear warhead for current Block IV TLAM missiles for deployment aboard current *Astute*-class SSNs, based on a redesigned 'Block II' batch for boats 5-7. Costs incurred would be development of the warhead, redesigning some aspects of the *Astute*-class for nuclear certification, nuclear fire control systems for the submarines, and some additional infrastructure costs. Compromises would be reduced missile range, a limited number of nuclear-armed TLAMs on a nuclear-capable SSN, and no SSN on dedicated nuclear missions. The illustrative cost of this option is estimated at £30,000 million.

Table 11: Nuclear-armed TLAMs on planned *Astute* fleet	
Capital expenditure	**£ millions**
Redesign costs for *Astute* Block II (Total *Astute* R&D costs in 2006 were £1,000 million)	500
New cruise missiles warheads (Upper range in 2006 White Paper estimate)	3000
Infrastructure (Upper range in 2006 White Paper estimate)	3000
VLOP to date	500
Sub-total	**7000**
Operational expenditure	
AWE running costs / 25 years (Based on 2007 £780M per year)	19500
Submarine annual capital and running costs (Already budgeted for in planned *Astute* fleet)	0
Committed protection forces / 25 years (Based on 2007 £30 million)	750
10% contingent forces / 25 years (Based on 2007 £300 million)	750
Decommissioning	?
Contingency	?
Sub-total	**21000**
TOTAL	**28000**
Additional AWE investment 2003-2013	*10350*
Total	***38350***

The second option is for a three or four boat hybrid SSN/SSGN submarine fleet with a new nuclear-armed cruise missile and 120-160 warheads operated over 25 years. The current proposed flotilla of seven *Astute*-class SSNs is less than the Navy originally hoped for. An SSN-based cruise missile solution would therefore likely require additional SSNs for permanent deployment of nuclear-armed cruise missiles for an exclusive nuclear role, or for partial deployment in mixed nuclear and conventional role enabling nuclear-capable SSNs to augment the planned SSN capability.

Table 12: Nuclear-armed TLAMs on four new 'Block II' *Astute* fleet

Capital expenditure	**£ millions**
Four Block II *Astute* SSNs	4000
(Based on contract for first three)	
Redesign costs for *Astute* Block II	500
(Total *Astute* R&D costs in 2006 were £1,000 million)	
New cruise missiles warheads	3000
(Upper range in 2006 White Paper estimate)	
Infrastructure	3000
(Upper range in 2006 White Paper estimate)	
New cruise missile (R&D and procurement)	4000
(Notional estimate)	
VLOP to date	500
Sub-total	**15000**
Operational expenditure	
AWE running costs / 25 years	19500
(Based on 2007 £780M per year)	
Annual capital and running costs for 4 new *Astutes*	18400
(Based on 2007 seven-boat cost)	
Committed protection forces / 25 years	750
(Based on 2007 £30 million)	
10% contingent forces / 25 years	750
(Based on 2007 £300 million)	
Decommissioning	?
Contingency	?
Sub-total	39400
TOTAL	**54400**
Additional AWE investment 2003-2013	*10350*
Total	***64750***

This cost estimate assumes an additional four new Block II *Astute* boats designed for nuclear missions. The estimated cost of the contract for the first three *Astute*-class submarines in 2008 was £3,798 million, including the first of class.[428] MoD reported in 2007 that "Current projections suggest that in steady state production *Astute*-class submarine will cost under £1,000 million per hull.[429] Building three or four new Block II *Astute*-class SSNs with a nuclear capability could therefore cost around £3-4,000 million, perhaps more if a Block II redesign proves expensive, perhaps less if production cost are further reduced through boats 5-7. Each Block II *Astute* could be equipped with six flexible launch tubes with six cruise missiles each giving a total of 36 single

[428] House of Commons, *Official Report,* June 18, 2008, Column 1092W.
[429] *Ministry of Defence: Major Projects Report* 2007, House of Commons Committee of Pubic Accounts, HC 433 (HMSO: London, June 2008), p. Ev 16.

warhead cruise missiles. Additional missiles could be stored aboard for release from the submarine's six torpedo tubes. Equipping three or four submarines would with 36 warheads plus spares would require an operational stockpile of around 120-160 warheads.

Running costs for the seven-boat *Astute* flotilla were estimated by MoD in 2007 at £32,000 million over a 25-year service life and including crew costs, support, maintenance and spares, roughly £4600 million per boat, equating to £18,400 million for a further four.[430]

Additional SSNs would also require more Block IV conventional TLAMs and either a new warhead for the Block IV TLAM or a new warhead for a new long-range cruise missile. Developing a new warhead would probably be achievable within the government's £2-3 billion allocation for a new or revamped Trident warhead. The costs of procuring a long-range cruise missile from the US would likely be far less than procuring a replacement for the Trident II (D5) in the 2040s, if one were available in the time frame required, but the expenditure would be required in the 2020s rather than the 2040s. The cost of developing and procuring an indigenous long-range cruise missile is very difficult to determine. A notional cost of £4 billion is used in the illustrative costs estimates in this example. Past experience suggests a 10-12 year timeline for developing a new warhead. A few years into the process and it would be essential to know the dimensions of the missile into which the warhead would be incorporated. A decision on a cruise missile could therefore be required by the mid 2010s at the latest.

Additional infrastructure costs for a cruise missile solution would likely be minimal. The *Astute*-class will be based at Faslane where there are already facilities for storing, transporting, servicing and loading nuclear warheads. The UK has the capability to store, service, load, and fire conventional TLAM cruise missiles from submarines.

The third option is for a three boat hybrid SSGN/SSBN submarine fleet with 22 Trident missiles and 100 warheads. Procurement of 65 Trident II (D5) SLBMs as originally ordered as a percentage of the 2008-09 total Trident procurement programme was approximately £1,660 million. As outlined above, defence inflation over a 45-year inter-generational period give figures of £3,863 million (3%) and £2,490 million (2%) for purchasing 40 next-generation SLBMs from the US.[431] For illustrative purposes this equates to roughly £97-62 million per missile. Procuring 6 missiles to equip three hybrid SSGN/SSBNs with some spare for a stockpile of 22 missiles for redeployment under a reduced readiness posture would cost between £1,369-£2,125 million.

Procurement of new a 'reliable replacement warhead' or a refurbished Trident warhead is budgeted at £2-3 billion. The current total UK stockpile stands at 225 warheads. A smaller arsenal of perhaps 100 warheads would reduce this cost considerably, though by what percentage is difficult to determine. This estimate uses a two-thirds cost. Projected infrastructure costs and the annual costs of running AWE are unlikely to change as long as the UK retains an operational nuclear arsenal.

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430 House of Commons, *Official Report,* December 10, 2007, Column 55W.

431 The first D5 was deployed in 1990. The D5 is due to be withdrawn from service in 2042. Assuming new missiles will be introduced over the preceding decade during the mid-2030s gives a 45 year period from the introduction of the first D5 to the introduction of the first 'E3' SLBM).

Development of dual-capable SSGNs/SSBNs would also entail new costs for developing flexible payload tubes, or more likely procuring from the US Flexible Payload Module, Virginian Payload Tube, and MAC technologies and fire control systems, plus more Block IV TLAMs to equip the submarines with a significant conventional capability.

Table 13: Illustrative upper and lower estimates of a Three-boat hybrid SSBN/SSGN fleet

	2006 White Paper estimates	3% UPC defence inflation
Capital expenditure	**Lower end £ millions**	**Upper end £ millions**
3 new hybrid Submarines (inc. SWS Eq and TWS) (Based on 80% of 4 boat flotilla)	8800	17204
100 Warheads (Two-thirds 2006 White Paper estimate)	1300	2000
Infrastructure (Based on 2006 White Paper estimate)	2000	3000
D5LE programme (Based on 2006 White Paper estimate)	250	250
D5 replacement (22 missiles) (Based on original Trident programme)	562	2052
D5 replacement R&D contribution (Based on original Trident programme)	505	1909
Reactor development to date	1000	1000
VLOP to date	500	500
Sub-total	**14917**	**27915**
Operational expenditure	**Lower end £ millions**	**Upper end £ millions**
Running costs inc. AWE / 25 years (Based on 5-6% MoD budget)	36750	44100
Committed protection forces / 25 years (Based on £25-£30 million)	625	750
10% contingent forces / 25 years (Based on £250-£300 million)	625	750
Decommissioning	?	?
Contingency	?	?
Sub-total	**38000**	**45600**
TOTAL	**52917**	**73515**
With additional AWE investment 2003-2013	*10350*	*10350*
TOTAL	*63267*	*83865*

Conclusion

Reconsidering like-for-like replacement

The previous Labour government set in motion a long and expensive process for procuring new submarines, warheads and in time the missiles to replace the current Trident system with a direct like-for-like system. Since that decision was taken in December 2006 a new global opportunity has emerged to rethink current nuclear weapons policies and take significant steps towards a nuclear weapons-free world and the UK has entered a deep recession with the prospect of deep cuts in public expenditure over the next decade.

As a result the economic, political and military wisdom of pursuing a like-for-like Trident replacement has faced increasing scrutiny on three grounds:

1) The financial case for a like-for-like replacement.
2) The strategic case for a like-for-like replacement, both in terms of the necessity of the indefinite continuation of current nuclear posture and current conceptions of 'minimum deterrence' and incentives for procuring a flexible dual-use nuclear weapon platform.
3) The disarmament case in terms of demonstrating international leadership in reducing the salience of nuclear weapons in national security policy reflected in renewed commitments at the 2010 NPT Review Conference.

Leading figures in the Conservative Party announced in May 2009 that they will reconsider the need for a full like-for-like replacement of the Trident system on grounds of cost if they win the election.[432] Nevertheless, on entering office Defence Secretary Liam Fox bluntly declared "Let me say that there is no lack of clarity in the Government's policy: we believe in a continuous, at-sea, minimum, credible, nuclear deterrent, based on the Trident missile system."[433]

The Liberal Democrats have accepted that a like-for-like replacement is strategically and economically unsound. They explored some of the issues around alternative force structures and operational postures in an April 2010 policy document on *Policy Options for the Future of the United Kingdom's Nuclear Weapon*" but did not present a preferred option.[434] In order to satisfy Liberal Democrat concerns the government's coalition agreement stated that "We 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".[435] This, in fact, leaves little room for alternatives. The Conservatives have set the parameters for nuclear weapons policy and if fresh scrutiny can reduce the cost of a like-for-like Trident replacement system by a few billion then so much the better. But options that push the role of nuclear weapons in UK national security policy further into the background, reduce the UK's nuclear stockpile,

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432 Patrick Wintour and Nicholas Wyatt, "Tories Cast Doubt on £21bn Trident Nuclear Missile Upgrade", *The Guardian,* May 1, 2009.
433 House of Commons, *Official Report* May 26, 2010, Column 272.
434 "Policy Options for the Future of the United Kingdom's Nuclear Weapons", Liberal Democrats, April 2010.
435 "The Coalition: Our Programme for Government", The Cabinet Office, May 20, 2010, p. 15. Available at <http://www.cabinetoffice.gov.uk/media/409088/pfg_coalition.pdf>.

support the Obama administration's determination to make progress towards a world free of nuclear weapons, and reduce the cost of maintaining a nuclear arsenal all require a rethink of current nuclear weapons policy and prevailing understandings of 'minimum deterrence', not least the out-dated need for a nuclear-armed submarine continuously at sea to deter a 'bolt from the blue' nuclear attack.

Options

This report has highlighted the potential for options between a like-for-like replacement and unilateral nuclear disarmament that could reduce the salience of nuclear weapons in UK national security policy and reduce costs:

1) A 'Trident lite' replacement programme that adheres to current understandings of 'minimum deterrence'.
2) A 'reduced readiness' downsized Trident replacement programme that ends 'continuous-at-sea deterrence' and scales down the requirements for 'minimum deterrence'.
3) A flexible, dual-use 'hybrid' submarine programme for conventional and nuclear missions that also ends 'continuous-at-sea deterrence' and scales down 'minimum deterrence' requirements.
4) A nuclear-armed cruise missile capability aboard current or new attack submarines.

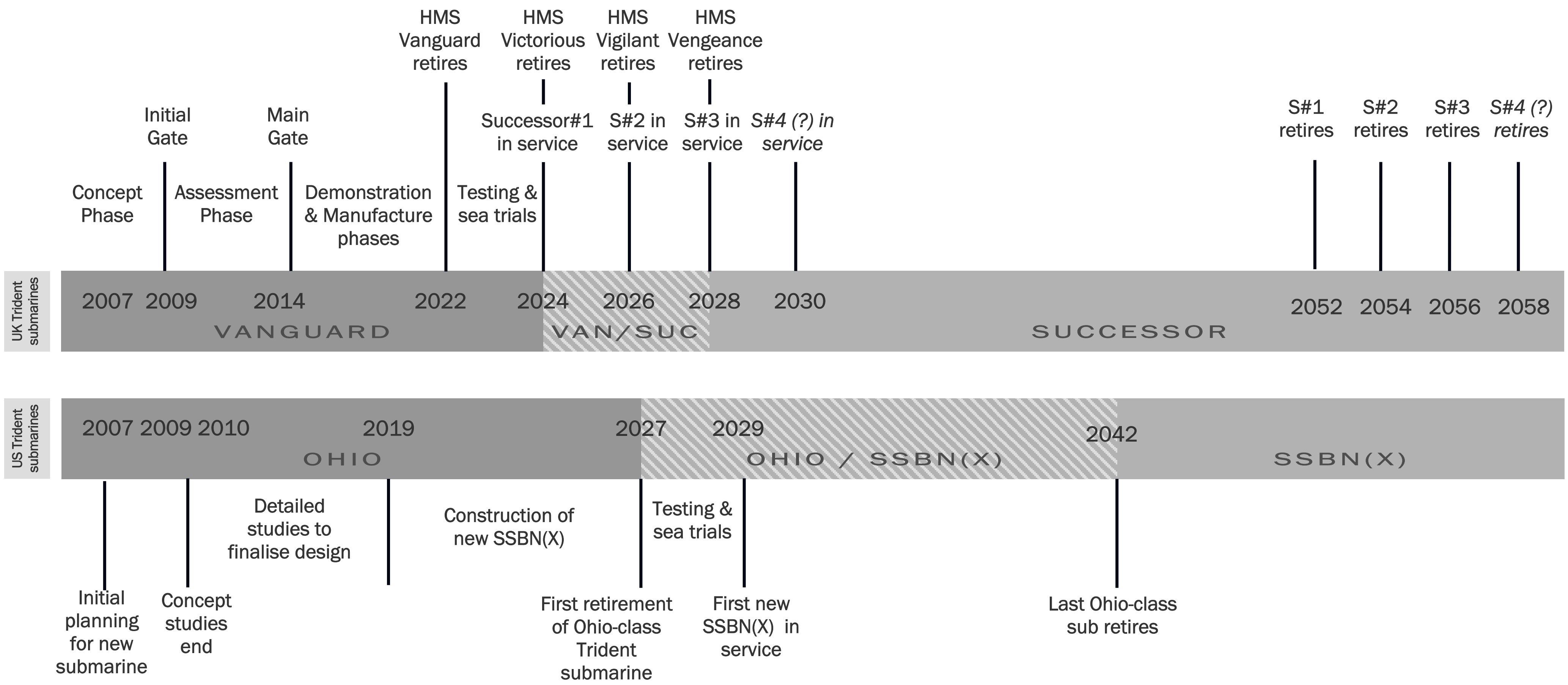
The key to opening up some of these options is ending the current operational posture of 'continuous-at-sea deterrence' (CASD). Ending CASD will require rethinking the necessity of 100% assured retaliation and invulnerability to a 'bolt from blue' strategic attack, a realistic assessment of the impact of a reduced readiness posture on 'crisis stability', and a reassessment of the level of destructiveness required to constitute a 'minimum deterrent'. It will also require detailed analysis of the training and capability management structures necessary to operate the Trident or nuclear-armed cruise missile system at various levels of reduced readiness over a long period of time and redeploy a nuclear capability within a specified period of time if required to do so in a period of international tension.

The development of SSGN technologies and a new Common Missile Compartment, the potential for hybrid SSGN/SSBN submarines, the TLAM-N operational posture, B-1B re-role plan, and reduced readiness of NATO Dual-Capable Aircraft all demonstrate the practicability and flexibility of alternative options, particularly a dual-capable hybrid SSGN/SSBN submarine.

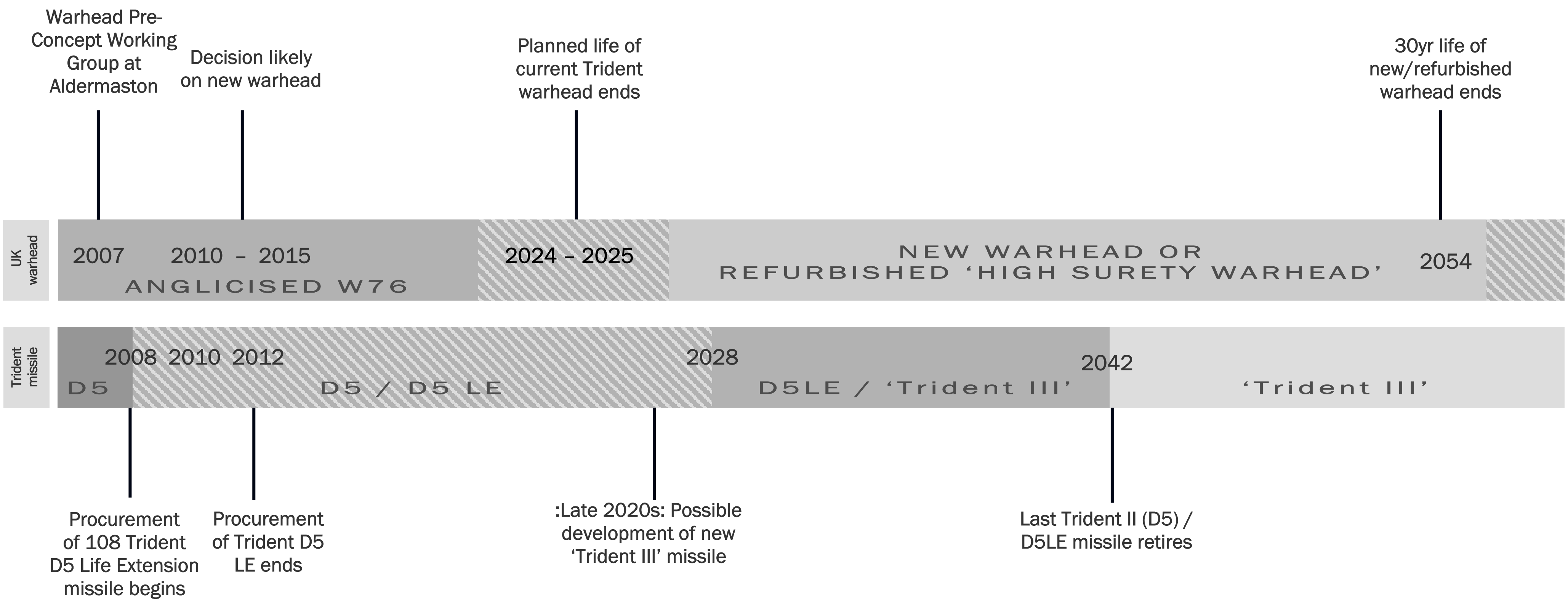
British security (and the exchequer) does not require a 'Rolls Royce' nuclear system.[436] If the coalition government continues to insist that terminating the Trident replacement process and relinquishing Britain's nuclear weapons capability is strategically and politically out of bounds then at the very least it should seriously explore some of these options for reducing the size and readiness of the future Trident system and demonstrate genuine international leadership and a 'disarmament laboratory' ethic by stepping back from continuous alert, further reducing the nuclear arsenal, and reducing costs in the process.

[436] From Colin McInnes, *Trident: the Only Option?* (London: Brasseys Defence Publishers, 1986).

Appendix I: Timeline for UK and US Trident submarine replacement programmes



Appendix II: Timeline for UK warheads and Trident missiles



Bradford Disarmament Research Centre
Department of Peace Studies
University of Bradford
Richmond Road
Bradford
West Yorkshire, BD7 1DP

Tel: +44 (0)1274 232323
Email: n.ritchie@bradford.ac.uk
Web: www.brad.ac.uk

CONTINUITY / CHANGE:

RETHINKING OPTIONS FOR TRIDENT REPLACEMENT

This report examines options for the UK's Trident replacement programme between a like-for-like replacement and unilateral nuclear disarmament.

It examines the progress of the replacement programme to date and two key changes since the decision to proceed was taken in December 2006: first, renewed international momentum to work towards a world free of nuclear weapons and expressions of UK leadership; and second, a deep financial crisis that will severely constrain future public spending.

The report then examines four options:

- A 'Trident lite' programme that adheres to current understandings of 'minimum deterrence'.
- A 'reduced readiness' downsized Trident replacement programme that scales back 'minimum deterrence' requirements.
- A flexible, dual-use 'hybrid' submarine programme for conventional and nuclear missions based on rethinking the requirements for 'minimum deterrence'.
- A nuclear-armed cruise missile capability aboard current or new submarines.

The report concludes by exploring the potential flexibility and cost of the options examined.

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