nuclear information service

TROUBLE AHEAD

RISKS AND RISING COSTS IN THE UK NUCLEAR WEAPONS PROGRAMME

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A note on terminology

The terms 'project' and 'programme' are both used within government in different contexts to describe the same thing. Although referred to as 'projects' in the annual data produced by the government's Infrastructure and Projects Authority (IPA), the large MOD projects discussed in this report refer to themselves as 'programmes' in their titles, and contain within them major streams of work which are no doubt managed as separate projects in their own right.

As a general rule, this report aims to use the terms project and programme to mean different things – a project being a relatively streamlined body of work with a single purpose, and a programme being a larger-scale endeavour potentially encompassing several bodies of work which may themselves be separate projects.

The report considers the nuclear weapons programme as a whole. In this report the term 'nuclear weapons programme', and its shorter variant 'the programme', refers to all of the major MOD projects discussed in this report and all the supporting activity across government and industry that enables the UK to retain its nuclear weapons capability.

Projects within the programme may be referred to by name (i.e. 'the Dreadnought programme'), or as a 'project', but when the term 'the programme' is used it is only in reference to the nuclear weapons programme in its totality.

The National Audit Office (NAO) uses the term 'Defence Nuclear Enterprise'. This refers to all of the elements in the programme but also includes elements which are technically and bureaucratically intertwined with it as part of the Astute submarine programme. The term has also been adopted by the MOD in recent publications. This report will also employ the term with the same meaning, usually preferring the shorter 'the Enterprise'.

This report also uses the NATO shorthand 'SSBN' to refer to submarines which are nuclear powered and nuclear-armed and 'SSN' to refer to submarines which are nuclear powered but not nuclear-armed.

A full glossary of terms and acronyms can be found at the end of the report on page 53.

CONTENTS

EXECUTIVE SUMMARY

- This report looks at the problems arising in the UK nuclear weapons programme, the overall total cost of the programme and the need for policy changes to address a situation that is becoming increasingly unsustainable.

- The UK's nuclear weapons are currently being upgraded. The existing system comprises four nuclear powered 'Vanguard' submarines, which carry Trident missiles armed with nuclear warheads. Building four new 'Dreadnought' submarines is the most expensive of the upgrade projects.

- The nuclear weapons upgrade projects are entering a critical phase, with the building of the new Dreadnought submarines well under way. There is growing evidence that the upgrade projects are experiencing mounting problems, meaning it is unlikely that key aspects of the programme will be delivered on time and to budget. Despite warnings from the Public Accounts Committee (PAC) and the National Audit Office (NAO), there is little public awareness about these problems and an apparent lack of political appetite to acknowledge or tackle them.

- Due to complexity of the programme, secrecy restrictions and the difficulty in drawing together information from disparate and highly technical documents, the full picture of what is happening in the programme, and the overall cost, are obscured from public view. It is in the interests of the Ministry of Defence (MOD) for this state of affairs to continue in order to minimise public opposition to the programme.

- This report tries to redress the situation and thereby increase the democratic accountability of a programme which both opponents and supporters agree is of unparalleled national importance.

- The report also shows that problems with different elements of the UK's existing nuclear weapons system could create knock-on effects, increasing overall costs and risks to the programme. These problems include: the need to extend the life of ageing Vanguard submarines; limited dock capacity in Devonport; and a failure to dismantle out-of-service submarines.

- As well as the issue of cost there is serious potential for delays to impact on the ability of the submarine fleet to maintain the continuous deployment of one nuclear-armed submarine at sea at all times, known as Continuous At Sea Deterrence (CASD).

- This report uses a new method for estimating the true cost of the UK's nuclear weapons, including a wider range of elements than previous studies and extrapolating from the MOD's own figures and historical spending to estimate average costs of each element over time. This method estimates the total cost of the UK's nuclear weapons programme between 2019 and 2070 to be £172bn. This is almost certainly a low estimate, and is far higher than the government's prediction of £31bn plus an additional £10bn contingency for building four new Dreadnought submarines.

- The MOD's overall spending projections for all of its military equipment procurement are based on optimistic assumptions about future savings. The MOD's Modernising Defence Programme, which was supposed to address the large funding gap in its equipment plans, including the nuclear weapons programme, does not contain any concrete proposals for reducing spending.

- As a consequence, the government is likely to soon face a 'trilemma', consisting of a choice between increasing the overall MOD budget at the expense of other government priorities, reducing spending on conventional weapons to fund nuclear weapons or reducing spending on the nuclear weapons programme.

- The report identifies two broad paths for making savings on the UK's nuclear weapons programme. The first involves retaining a slightly reduced nuclear capability, which would yield relatively modest savings. The second would produce greater savings, but would involve at least a temporary period where nuclear weapons were not deployed at sea and are either kept in storage or scrapped altogether.

- Eventually, without greater funding, policy options are likely to narrow to a choice between either paying the full cost of nuclear weapon upgrades at the expense of conventional defence or other public spending priorities, or abandoning the submarine-based nuclear weapons system altogether.

- Rather than continue to pursue upgrade projects intended to maintain a posture that may be unachievable, it makes sense to re-examine the UK's nuclear weapons policies and the assumptions underpinning them. This should include a reappraisal of the full costs and perceived benefits of possession of nuclear weapons and, given the UK's international legal obligations to disarm and support the creation of a nuclear weapons free world, the case for nuclear disarmament.

Recommendations

1. **Parliament should hold a review of the UK's nuclear weapons programme to consider the full costs and risks of the UK's possession of nuclear weapons and the best route towards achieving a nuclear free world.**

2. **The MOD should publish full-life costings of all elements of the nuclear weapons programme.**

3. **The MOD should publish annual figures which show the total cost of all parts of the nuclear weapons programme, with risks and assumptions explicitly identified.**

4. **The MOD should develop a plan to bring its equipment plan spending within the available budget from the next financial year onwards.**

5. **The NAO should work with the Infrastructure and Projects Authority (IPA) to publish detailed assessments of progress on major MOD projects.**

6. **Parliamentarians should ensure that the above steps are taken.**

7. **All political parties should re-examine their nuclear weapons policy and ensure it addresses the threats faced by the UK population and fulfils the government's disarmament commitments.**

8. **All political parties should set out a clear position on nuclear weapons spending that identifies how they would make savings or change budgets.**

1. INTRODUCTION

CREDIT: MOD

A computer generated image of a Dreadnought submarine.

In the mid-2000s the Ministry of Defence (MOD) devised plans to replace its entire submarine based nuclear weapons system: a new submarine, missile and warhead were planned alongside each other.[1] While the timings of the various projects have changed so that the different elements are due to come into service over the course of a decade[2] it still seems likely that all these elements of the UK's nuclear weapons programme will be replaced by the late 2040s.

The UK is entering a critical time for its nuclear weapons upgrades. The project to build four new Dreadnought submarines is beginning the second stage of its build phase against a backdrop of nearly a decade of public spending restraints, with costs rising both in the Dreadnought programme and across the nuclear weapons programme as a whole.

Current projections show that the next few years of the Dreadnought programme between now and the next spending control point in 2022 will see the project straining against its budgetary constraints at the same time as the MOD tries to reckon with a multi-billion pound gap in its wider equipment plan.

Although the UK Parliament voted in 2016 to go ahead with the Dreadnought programme, polling shows that public support for the UK's nuclear weapons is sensitive to the issue of cost.[3]

While there is mounting evidence of problems and consequent cost increases in the programme, there is little evidence of an appetite within the largest political parties to address these problems. In the near future it seems that the government will face a nuclear weapons spending trilemma: they will either need to increase the overall MOD budget at the expense of other spending priorities, allow the nuclear weapons programme to increase at the expense of conventional defence spending or find a way to reduce costs in the programme.

At the same time the UK, along with the other nuclear-weapon states, is facing diplomatic pressure to show

progress on their commitment to take steps towards disarmament ahead of the 2020 Non-Proliferation Treaty Review Conference.

As parties to the Nuclear Non-Proliferation Treaty (NPT), the UK and the four other recognised nuclear-weapon states, are committed to bring about nuclear disarmament.[4] Although the UK has reduced the overall size of its arsenal, many states within the NPT are concerned about nuclear weapon upgrades and the ongoing research and development programmes in the UK and other nuclear-weapon states.[5]

In order to emphasise the continuing relevance of the NPT, the UK is keen to see the 2020 NPT Review Conference agree a consensus outcome document. At previous NPT Review Conferences the nuclear-weapon states have agreed to a number of measures, including rapid reductions in the levels of global nuclear weapon stockpiles and reducing the role of nuclear weapons in security doctrines.[6] Given the lack of progress on these measures and the fact that so many previous commitments require multilateral action,[7] it is particularly crucial for the UK to demonstrate progress in the steps it can take unilaterally in order to achieve its diplomatic goals.

This report draws together the growing evidence of problems within the programme and lists the different risks it is facing, as well giving an overview of the different elements of the programme, the costs of the different elements and providing a new estimate of the overall programme cost based on current spending patterns.

Chapter 2 of the report gives an overview of the nuclear weapons programme and the overall MOD cost estimates for each element. Chapter 3 discusses the evidence of emergent problems, beginning with the current situation in various programme elements before turning to some of the complex interdependencies within the programme and finally highlighting risks which could impact on multiple areas of the programme. Chapter 4 uses a new methodology to estimate the total cost of the programme. Chapter 5 discusses some of the policy implications of the previous chapters. Chapter 6 sets out the report's conclusions and recommendations.

Almost all of the material in this report is drawn from publicly available sources, particularly reports by the National Audit Office (NAO) and data compiled by the Infrastructure and Projects Authority (IPA). This information has been supplemented with the answers to Parliamentary Questions and Freedom of Information Requests.

Decisions about the UK's nuclear weapons are notoriously difficult to monitor for a number of reasons. These include the lack of publicly available information, the need to cross-reference between different sources, the difficulties of understanding complex, technical and often heavily redacted texts and the need to situate information within complex overlapping national and international contexts.

This report aims to address this by summarising the range of publicly available material, and analysing the implications. The accuracy of figures and calculations is dependent on publicly available figures and the assumptions that are set out in the report.

The intention of this report is to draw attention to an issue which currently suffers from both a lack of attention and a certain amount of fatalism about the inevitability of cost increases in the programme. The report aims to increase the public accountability of the UK's nuclear weapons programme and stimulate broader work in this area, building upon the calculations, and considering future policy options. By drawing attention to the current status of the nuclear weapons programme and exploring the ramifications, this report hopes to begin the process of identifying policy solutions which both address the problems in the programme and help to fulfil the UK's international disarmament obligations.

2. OVERVIEW OF THE UK NUCLEAR WEAPONS PROGRAMME

This chapter explains what is included in this report and why. It gives an overview of the main elements in the UK's nuclear weapons programme and the MOD's estimate of the annual cost of the upgrade project for each element. Alongside each physical element, the key sites and organisations involved in the production and maintenance of that element are also introduced, as well as how they relate to the other elements.

Management and scrutiny of the programme

In recent years the MOD has overseen a significant restructuring of its internal arrangements for management of the Defence Nuclear Enterprise. It has set up an internal body called the Defence Nuclear Organisation (DNO), which oversees the Enterprise and acts as a 'customer' to another internal body, the Submarine Delivery Agency (SDA), which is in charge of building and supporting the submarine fleet.

The DNO also acts as customer in the contract managing the Atomic Weapons Establishment.[8] The SDA manages 52 procurement and support projects within the Enterprise.[9] The Navy, as operator of the submarine fleet, also acts as a customer of the SDA. The anticipated running costs of the SDA, DNO and Navy command in 2018–19 were £220m.

The procurement and maintenance of the different elements within the nuclear weapons programme are paid for through the MOD equipment budget. The MOD maintains an equipment plan which is updated annually and gives cost projections for spending on equipment for the current financial year and the following nine years. This means that for many of the upgrade projects within the nuclear weapons programme which run for longer than a decade, spending estimates for the later part of the project may not be as reliable as costs which occur during the time covered by the current 10-year equipment plan.

The process of producing equipment plans was intended to help the MOD to keep equipment spending within the overall funding levels agreed by Parliament. In practice, however, recent equipment plans have included budgets for equipment spending which are billions of pounds greater than the available funds.[10] The equipment plan process also cannot account for, or prevent, unexpected increases in near-term spending within the equipment budget,[11] for example the increased cost of the Dreadnought trim and compensation system.[12]

Spending on the nuclear weapons programme is scrutinised by the NAO, which examines government spending on behalf of Parliament. The NAO produces an analysis of the MOD equipment plan annually, and in 2018 it also published an overview analysis of the Defence Nuclear Enterprise.[13]

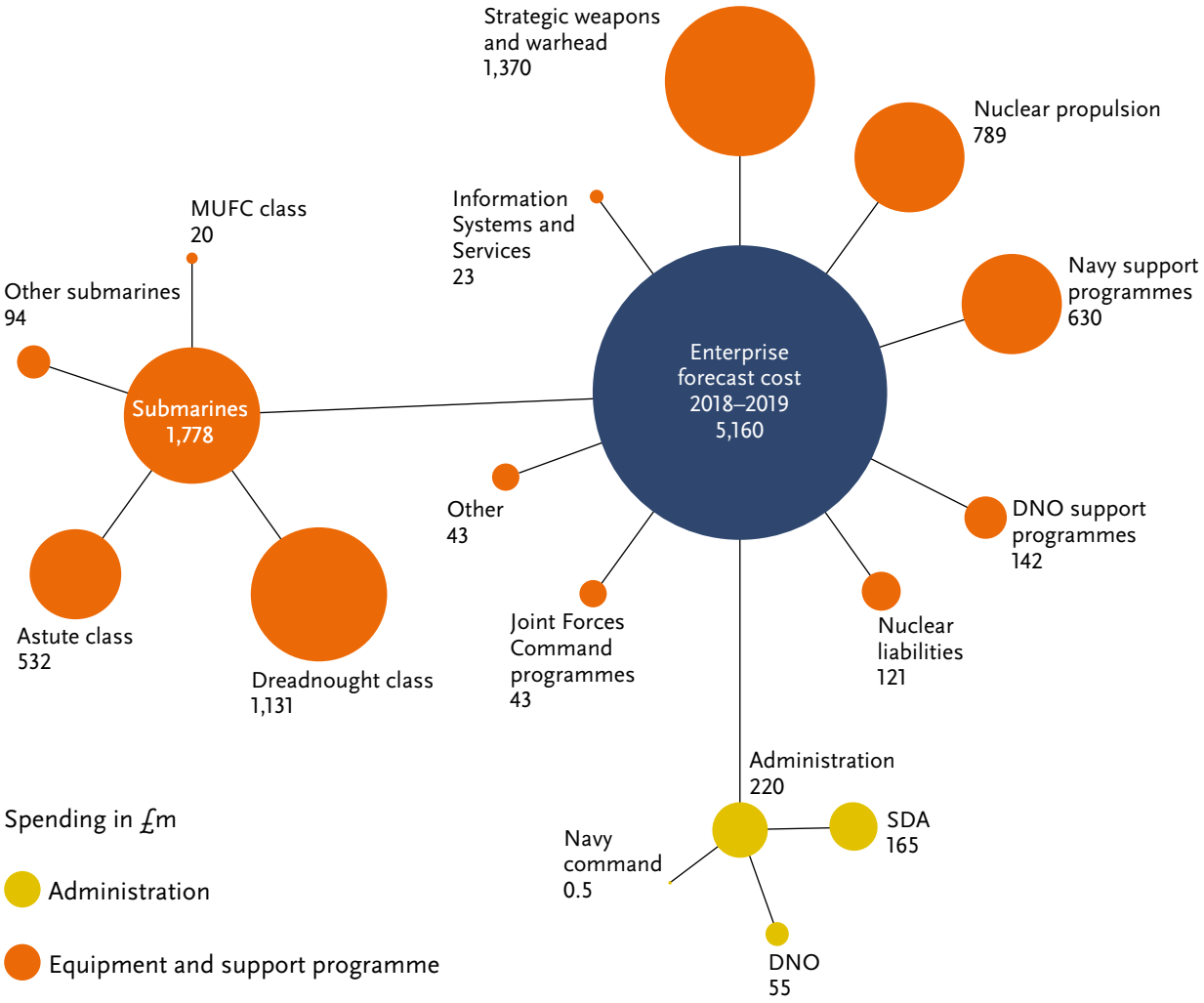
Until 2015 the NAO also published an annual update of progress and the prospects for success for the MOD's large value projects. The Major Projects report is now published by the government's Infrastructure and Projects Authority. The information released by the Infrastructure and Projects Authority is less detailed than the earlier NAO reports, but provides a valuable insight into the upgrade projects within the programme.

Overall cost of the Enterprise

The MOD expects to spend £5.2bn on the Defence Nuclear Enterprise in 2018–19, 14% of the defence budget. Between 2018 and 2028 a total of £50.9bn[14] is forecast to be spent on the Enterprise, of which £43.9bn will be spent through the DNO, £6.7bn through the Navy, and £355m through Joint Forces Command.[15]

These figures include smaller support projects for the Enterprise as well as the major projects listed above. Support costs are predicted to be £772m in 2018–19. These include staffing costs, the costs of the nuclear legacies of the programme, administration, and IT.[16] The breakdown of forecast Enterprise spending for 2018–19 can be found in Figure 1. An assessment of the full long-term cost of the nuclear weapons programme is given in Chapter 4 of this report.

Figure 1. Breakdown of Enterprise agreed forecast spend, 2018–2019



Notes

1. Categorisation of costs does not necessarily reconcile with the Department's broader definition of some programmes, such as its description of Dreadnought-class in the Strategic Defence and Spending Review 2015.
2. Excludes Joint Forces Command administration spend and non-civilian Royal Navy staff spend.
3. MUFC, the Maritime Underwater Future Capability, will replace the Astute class.
4. SDA – Submarine Delivery Agency; DNO – Defence Nuclear Organisation.
5. Navy support covers in-service submarines, combat systems and spares.
6. Other includes £45 million of efficiencies and an £88 million forecast spend.
7. Figures do not sum due to rounding.

Figure 2. SSBN submarines

Name (current)	Upgrade project	Name (upgraded version)	Key sites	Companies involved
Vanguard class	Dreadnought programme	Dreadnought class	Faslane, Barrow-in-Furness, Devonport Royal Dockyard	BAE Systems

Submarines: Dreadnought and Vanguard

Since 1998 the UK's only nuclear weapons have been submarine-based. We are now approaching the end of the life of the UK's Vanguard-class submarines. These second-generation nuclear-armed and nuclear-powered submarines, are often termed 'Trident Submarines' after the missile system that they share with US ballistic missile submarines. The Vanguard submarines replaced the first-generation Resolution class, which were equipped with US-made Polaris missiles, in the 1990s.

The UK began the process of replacing the Vanguard class with publication of a white paper in 2006,[17] eight years after the last Vanguard submarine entered service. The preliminary work was undertaken following a parliamentary vote in 2007. A further parliamentary vote in 2016 was intended to approve the main spending decision on construction of new submarines, but the project is instead being approved in a staged process of decisions,[18] with spending control points occurring in 2016, 2018 and 2022.[19]

Later in 2016 it was announced that the Successor class of submarines would be named the Dreadnought-class.[20] In 2018–19 spending on the Dreadnought programme was planned to be £1.249bn.

As with the two previous generations of nuclear-armed submarines, four Dreadnought submarines are planned. The UK's nuclear-armed submarines are based in Faslane (formally known as HMNB Clyde), in the Gare Loch on the Clyde estuary, west of Glasgow. From around 2020 Faslane will be home to the UK's entire submarine fleet[21] and in 2017 the UK government announced a plan to spend £1.3bn upgrading facilities at Faslane.[22] Further infrastructure upgrades at Faslane costing £4bn are also being considered, but are not currently included in MOD spending projections.[23]

The Dreadnought submarines are being built at Barrow-in-Furness in the shipyard which has produced the vast majority of the UK's nuclear-powered submarines. The site is owned and run by BAE Systems Marine, a subsidiary of the UK's largest arms manufacturing company.

The deep maintenance of Royal Navy submarines takes place at 9 Dock in the Devonport Royal Dockyard, Plymouth. Submarine refits have been done at Devonport since the 1970s, and it became the sole site for submarine deep maintenance in the 1990s.[24] The Devonport Dockyard is on the same site as the Devonport Naval Base, but is owned and operated by the private company Babcock Marine Systems.

Submarine reactors: PWR3

The Dreadnought submarines will be powered by a new reactor design, the PWR3,[25] which will be built at Rolls-Royce's Raynesway factory in Derby. The PWR3 is based on a US submarine reactor design,[26] and will run on Highly Enriched Uranium fuel.[27]

While the site at Derby is privately owned and operated by Rolls-Royce, since 2013 the MOD has been running the Core Production Capability (CPC) programme, which aims to build new facilities at Derby and produce reactor cores for the first Dreadnought submarine and for Astute-class attack submarines.[28] In 2018–19 planned spending on the CPC was £187m.

Figure 3. Submarine reactor

Name (current)	Upgrade project	Name (upgraded version)	Key sites	Companies involved
PWR2	Core Production Capability programme	PWR3	Rolls-Royce Raynesway	Rolls-Royce

Missiles: Trident D5

As mentioned above, the Vanguard submarines are often called by the name of the missile system that they carry: Trident. The Trident D5 missile was developed and produced in the US and first went into service in the UK in the 1990s. The UK negotiated the purchase of the Trident system from the US as part of the replacement of the Resolution-class submarines which were armed with Polaris missiles. The UK owns the rights to 58 Trident missiles.[29] Missiles are taken at random from a common pool of missiles shared with the US for loading onto UK submarines. The UK government contributes about £12m a year to maintain the shared facility in the US where the common pool of Trident D5 missiles are kept.[30]

The Dreadnought submarines will also carry the Trident D5, although the D5 is planned to be replaced in the 2040s, about 10 years after the first Dreadnought-class submarine comes into service. The US is also replacing its nuclear armed submarine fleet with new Columbia-class submarines and the missile compartment will be a shared component, identical across the Dreadnought and Columbia-class submarines. The UK has actually paid for a significant proportion of the development costs for the Common Missile Compartment (CMC), since it was expected that the Dreadnought submarines would come into service ahead of the Columbia class, although this now looks unlikely to happen.[31] The CMC has been designed to allow for transition to a replacement for the D5 missile, as both the Dreadnought and Columbia submarines are expected to remain in service long past the expected life of the D5.

The UK is also financially contributing to the costs of a US-run Life Extension project for the Trident D5 missile which has been running since 2002 and involves updating the electronics and guidance systems on the missile.[32] The UK's total contribution to the Life Extension project is expected to be £352m.[33] The work is being primarily carried out by US arms manufacturer Lockheed Martin and will allow the D5 to remain in service until the 2040s, when it is due to be replaced.[34]

Life extended Trident missiles are now being deployed on US submarines[35] and HMS Vanguard will probably be fitted with life extended missiles after it departs Devonport following its current period of deep maintenance.

Figure 4. Ballistic missiles

Name (current)	Upgrade programme	Name (upgraded version)	Key sites	Companies involved
Trident D5	Trident Life Extension programme	Trident D5LE	Strategic Weapons Facility (Kings Bay, Georgia USA)	Lockheed Martin

Figure 5. Nuclear warhead

Name (current)	Upgrade programme	Name (upgraded version)[53]	Key sites	Companies involved
Trident Holbrook warhead	Nuclear Warhead Capability Support Programme	Mark 4A	HMNB Coulport, AWE Aldermaston, AWE Burghfield	AWE Management Ltd

Nuclear warhead: Mark 4A

Each Trident D5 missile carries multiple warheads, each independently targeted. The warheads are designed and built in the UK at two Atomic Weapons Establishment (AWE) sites: Aldermaston and Burghfield. While there are some differences, the UK Trident warheads draw on the design of, and share components with, the US W76 warhead.[36]

The AWE sites are government owned, but run by a private consortium. AWE Management Ltd is 51% owned by Lockheed Martin, with Serco and Jacobs Engineering each holding 24.5% of the shares.

The UK's warhead production facilities are currently in the process of a major series of upgrades, the Nuclear Warhead Capability Sustainment Programme (NWCSP). This involves a number of large-scale building projects and the production of an upgraded Mark 4A version of the UK's nuclear warhead.[37] The upgraded components increase the likelihood that the warhead will explode close enough to its target to destroy it. This increased precision potentially reduces the number of warheads assigned to some hardened targets in the UK's targeting plan, meaning that a greater number of sites could be targeted with the same number of warheads, or the same number of sites could be targeted with fewer warheads.[38] In 2018–19 planned spending on the NWCSP was £1,014bn.

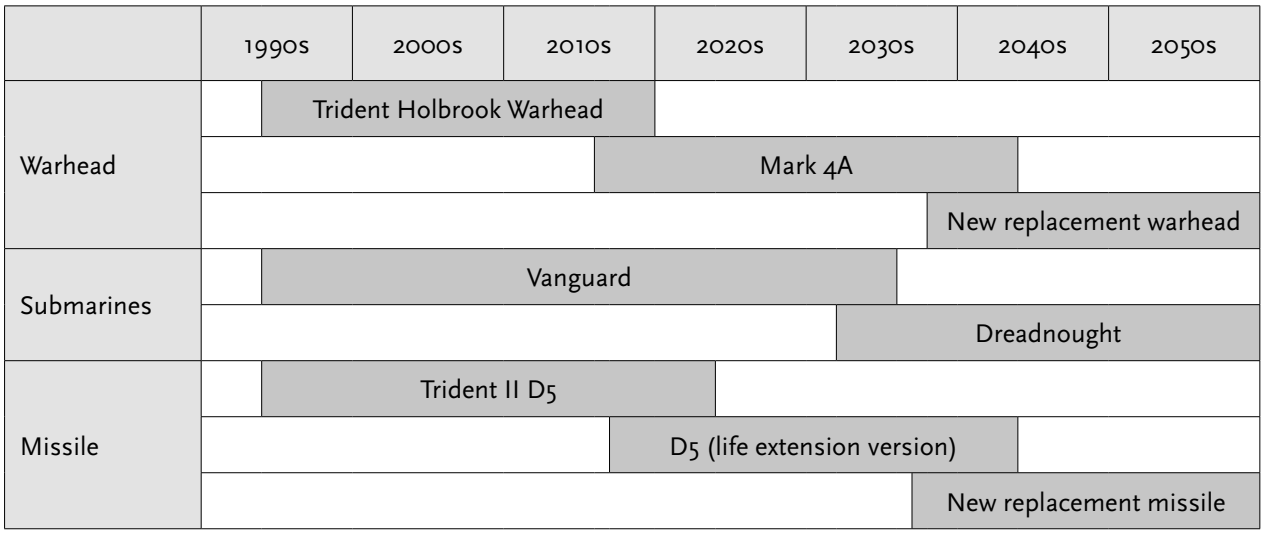
The end goal of the NWCSP is for the UK to have the capacity to produce an entirely new warhead to replace the Mark 4A, both in terms of physical infrastructure and skills. The initial planning for this new warhead is under way. Design work has already begun and options for the decision are currently being refined.[39] The formal decision itself is expected by 2022,[40] but the timing and outcome will to some extent depend on decisions by the US.[41] Production of a new warhead will take around 17 years after work begins,[42] and as part of the NWCSP there are ongoing projects to reduce "technical, cost and schedule risks" once the decision is made.[43]

In the 2010 Strategic Defence and Security Review (SDSR) the UK government decided to reduce the number of nuclear warheads per submarine from 48 down to 40. As a consequence it was also decided to reduce the total number of operationally available warheads from under 160 to fewer than 120 and the overall stockpile to a maximum of 180.[44] This decision appears in part to have been driven by cost,[45] but in the long run it may not result in a reduction in the number of sites targeted in the UK's nuclear attack plans, due to the increased accuracy of the Mark 4A. The reduction in warhead numbers was completed in 2015,[46] and the deployment of the Mark 4A warhead is thought to have begun shortly afterwards.[47]

Astute submarines

As well as nuclear-armed submarines, the UK also produces nuclear-powered SSN submarines which are armed with conventional weapons. It is currently in the process of replacing its fleet of Trafalgar-class submarines with seven newer Astute-class submarines. While these submarines do not carry nuclear weapons, they are deeply enmeshed in the UK's nuclear weapons programme and support it through a number of mechanisms.

Figure 6. Indicative timeline of programme upgrades[54]



Both types of submarine are built by BAE Systems at Barrow and are powered by the same type of nuclear reactor. The Highly Enriched Uranium fuel pellets for all submarine reactors are fabricated at AWE Aldermaston.[48] In 2018–19 planned spending on the Astute programme was £541m.

Although the Astute programme has a separate budget, allowing us to track the cost of building these submarines separately, the SSN and SSBN fleets have common support and maintenance projects meaning that separate costs for the different types of submarine are not available.[49]

The Dreadnought submarine design draws upon the Astute design, and directly incorporates several of its technological systems.[50] Projects to build successive SSN and SSBN classes support each other through iterations of technological development, and the problems encountered in the former hold many lessons for the Dreadnought build. SSN production also supports the nuclear weapons programme by funding infrastructure and a workforce that would otherwise face decades-long fallow periods between the production of successive classes of SSBN. The consequences of the much shorter gap between the production of Vanguard and Astute submarines[51] strongly suggests that the programme would be unable to survive a much longer period of downtime in its current form.

Operationally the SSBN fleet also relies on SSNs to ensure that they are not being followed by foreign submarines when they are deploying, in an operation known in the submarine service as 'delousing'.[52] The operational requirement that the position of a deployed SSBN is unknown to anyone outside the submarine is the key driver of the choice of a submarine-based nuclear weapons system and is fundamental to the deterrence theory used to justify the UK's possession of nuclear weapons. Without submarines to perform the delousing role, the assumptions and justifications that underpin the UK's nuclear weapons programme are invalid.

Just as the Astute programme plays a supporting role in the UK's nuclear weapons programme, it also plays a supporting role in this report. A portion of the costs of both the Astute programme and of the submarine support costs are included in our calculations of the overall cost of the UK remaining a nuclear weapon state.

3. EMERGENT PROBLEMS IN THE PROGRAMME

This chapter discusses the problems which are emerging in the upgrades to the UK nuclear weapons programme, problems with the in-service elements of the programme and the relationships between them. It is divided into three sections. The first section examines the status of the upgrade projects described in Chapter 2 and gives an overview of the MOD's approach to estimating the costs of the Enterprise.

The second section looks at interdependencies between different elements of the programme by discussing issues which either impact upon several other programme elements or are exacerbated by problems in other areas. The issues discussed in this section are: extending the service life of the Vanguard-class submarines, a fuel element breach issue in the PWR2 reactor design, dock capacity at Devonport and delays in the Submarine Dismantling Project. A list of all the risks identified in this report can be found in Figure 7, and a diagram of the connections between the interdependent risks can be found in Figure 9.

The third section looks at issues that don't arise in the upgrade projects themselves, but are either caused by external factors or have the potential to impact upon multiple aspects of the programme which may result in cost-overruns and/or delays to the upgrade projects.

Programme Status: Enterprise cost over the next 10 years

The DNO held a bottom-up review of all of their equipment and support projects in the Enterprise in summer 2017, soon after it was set up,[55] and set out predicted spending for 2018–2028. Amongst other things the review tried to standardise the confidence levels used to estimate the cost of their projects. Before the review many of the projects used the 50% cost estimate confidence level, meaning that there was a 50% chance the cost would be higher or lower than the estimate. The review required that the internal DNO teams use a common standard to calculate risk and manage uncertainty, resulting in more of the projects being costed at a higher 70% confidence level.[56]

The review found spending in the first 4 years would be 26% higher than previous forecasts and predicted that overall spending on the Enterprise would exceed the available budget by £2.9bn,[57] equivalent to 6% of forecast total spending for 2018–2028.[58] The predicted overspend would have been even higher if the MOD had not included assumed savings in their calculations. These savings included delaying development of the Marine Underwater Future Capability (the submarine class that will replace the Astute submarines at the end of their service life), £669m of savings at AWE, suspending work on the defuelling of old submarines and reducing Astute acquisition support costs from £590m to £430m.[59]

Delaying spending is a common tactic used by the MOD to manage gaps between their budget and spending plans.[60] While these measures may result in short-term savings, delaying work on defuelling old submarines and reducing the budget for supporting the Astute submarines increases the risk of cost escalation in the long run,[61] and the MOD concedes that higher costs are often the result of delaying work on projects.[62]

In January 2018 the NAO reviewed the MOD 2017–27 equipment plan and declared it unaffordable, with a potential shortfall of £20.8bn.[63] In September 2018 the Public Accounts Committee released a report that built on earlier work by the NAO,[64] with the committee chair declaring the infrastructure supporting the Enterprise "not fit for purpose."[65]

The most recent equipment plan released by the MOD, which covers the years 2018–2028 and includes the figures produced by the DNO bottom-up review, estimates that the equipment plan is likely to cost £7bn more than the available budget. Of this £7bn overspend, 84% is predicted to fall in the first four years, presumably in part due to the 26% increase in estimated Enterprise costs during that time period. The NAO have not published their own assessment of the likely size of the hole in the budget for the equipment plan, but they say even the MOD's worst case scenario

Figure 7. Programme risks identified in this report

Description of risk	Page in report
MOD overall equipment plan costings are an underestimate	14–16
Late changes are made to the Dreadnought design	16
Increased cost of individual components within the programme	17
Reductions in anticipated Enterprise spending from 2026 onwards do not occur	18
Delays to the Astute programme cause delays in Dreadnought programme	19
Delays to MUFC mean Astute service life has to be extended	19
Delays and cost increases in the Nuclear Warhead Capability Sustainment Programme	20
Delays to the Vanguard submarine maintenance schedule	21
Delays to Dreadnought require Vanguard life extension	21–24
Life extension work on Vanguard submarines does not deliver expected increases in service life	21–24
Submarine availability issues cause an interruption to CASD	24 & 41
Fuel element breach problems in the PWR2 reactor design	24–26
Focus on the PWR2 fuel breach issue prevents necessary research on the PWR3	25–26
Limited dock space at Devonport causes delays to the maintenance schedule of in-service submarines	26
Upgrading docks at Devonport costs more than predicted	26
Cost pressures or limited dock space delays work on dismantling old nuclear submarines	26–27
Currency fluctuations increase the cost of components sourced from overseas	27–28
A shortage of qualified staff to work on the programme	28
Poor contractor performance or financial difficulties in key companies cause problems in the supply chain	29–30
A stagnant civil nuclear sector means the programme needs more financial support than currently anticipated	35
The MOD is unable to realise all the savings that are currently included in its cost projections	38–39

of a £14.8bn maximum risk may be optimistic.[66] The MOD's senior civil servant has conceded that without a fundamental change to the MOD's funding settlement it is inevitable that planned projects will have to be delayed, altered or cancelled outright.[67]

Programme Status: Dreadnought

In 2007 when the UK Parliament initially voted to begin the process of building a replacement for the Vanguard-class submarines the Dreadnought-class submarines were planned to come into service from 2024 and the estimated total cost of the project was £15–20bn. At present the estimated total cost of the project is £31bn with a £10bn contingency.

The MOD has not given a public in-service date for the first boat, just maintaining that it will be delivered in "the early 2030s".[68] The 2018–28 equipment plan gives no in-service date or performance indicators for the Dreadnought programme, saying that these will be set "when the decision to manufacture is taken".[69] The MOD have also declined to let the Public Accounts Committee know the key milestones for the Enterprise, citing national security concerns and commercial confidentiality.[70] The slippage of over 6 years from the original 2024 date is due to a number of reasons: delays in design and engineering plans, a desire to save money and getting agreement across government for the plans.[71]

The government's Infrastructure and Projects Authority, which monitors progress in high value government projects gives the Dreadnought programme an 'Amber/Red' rating, meaning that "successful delivery of the project is in doubt, with major risks or issues apparent in a number of key areas" and that "urgent action is needed to address these problems and/or assess whether resolution is feasible."[72]

After the 2007 vote the Dreadnought programme entered the concept phase, which settled key decisions about the submarines and propulsion systems and agreed the outline design.[73] As a condition of the 2010 Coalition Government Agreement the MOD carried out what it claimed was a "rigorous value for money review" which calculated project costs as being in line with the initial estimate of £15–20bn, once inflation was taken into account.[74]

The 2010 SDSR had predicted savings of £3.2bn in the Dreadnought programme, which allowed the MOD to claim that the project would stay within the earlier estimate.[75] One significant element of these savings was the decision to move the Dreadnought delivery back from 2024 to 2028 and to delay the project's Main Gate decision to 2016.[76] While this reduced expenditure during that budget period, it did not reduce the overall cost of the Dreadnought programme. In fact, the MOD admits that delays of this type can often increase costs in the long run.[77]

As a consequence of these changes the assessment phase of the Dreadnought programme, which was scheduled to complete before the build phase began, now overlaps with the build phase by around 4 years until 2020.[78] It is unclear whether this meant construction began in October 2016 when submarine design was less complete than originally envisaged. The original intention was for the design to be 70% finalised by 2016,[79] and it was described as 84% complete 14 months later in December 2017.[80]

However, senior civil servants were still describing the design as only 80%–85% settled more than six months later in July 2018.[81] This suggests that progress on the design maturity of the submarines was either static or even regressing in the first half of 2018. The December 2018 update to parliament simply described progress on the design as "good".[82] While the MOD maintains that it is usual for a project of this type that the design is not fully settled[83] at this stage in the process, there is a risk that if changes are made to the boat design at a late stage in the process this could increase costs.[84] Following the second spending control point in March 2018,[85] the build phase entered its second stage.

Construction of the second Dreadnought submarine will begin during this phase, and major submarine

Figure 8. Project health rating over time[235]

Project	2013	2014	2015	2016	2017
Astute	Amber	Amber	Amber/Red	Amber/Red	Amber/Red
Core Production Capability	Green	Green	Amber	Amber	Red
Dreadnought (previously 'Successor')	Amber/Red	Amber	Amber/Red	Amber/Red	Amber/Red
Nuclear Warhead Capability Sustainment Programme	Redacted	Redacted	Redacted	Redacted	Redacted

components such as the gearboxes, main engines and generators will be purchased. Funds have also been provided for building work at Barrow-in-Furness and Raynesway. Construction of the first Dreadnought submarine began after the 2016 vote in parliament and the main pressure hull units for the submarine are currently under construction.[86] The submarines will be built in separate modular sections, before being brought together towards the end of the process.[87]

The estimated cost of the Dreadnought programme was dramatically scaled up in the 2015 SDSR to nearly double the £15–20bn that had been previously claimed. The MOD said this was the result of the "first really rigorous estimate of costs",[88] contradicting what had been claimed about the 'rigorous value for money review' five years earlier. The burgeoning cost of the project was the cause of Treasury opposition to the choice of the PWR3 reactor over less expensive alternatives, meaning further delays to the project.[89]

Of the claimed £3.2bn savings in the 2010 SDSR, £2bn were simply the result of deferring spending into the future by postponing the Dreadnought in-service date.[90] As mentioned above,[91] both the MOD and NAO are aware of the potential for delays like this to increase costs. In the long run, the likely consequence of such measures is of higher costs due to inflation as well as time and other pressures later in the project.

Given how quickly overall costs have risen since, the savings claimed in 2010 appear to have been either illusory, or completely dwarfed by the degree to which the cost of the project had been underestimated.

There are many indications that costs continue to escalate within the Dreadnought programme. In April 2018 it was reported that the cost of the trim and compensation system, which ensures the submarine remains level in the water,[92] was going to be five times more than originally expected. At the predicted cost of £270m this system alone will cost more than a Type 31 frigate.[93]

In August 2018 it was reported that faulty welds had been discovered in some of the Common Missile Compartments (CMCs) that are being produced for the Dreadnought programme and US Columbia-class submarines. As well as the likely cost implications, there has also been speculation that the faulty weld issue could affect the overall schedule for the project, since the CMCs were amongst the early lead-in items purchased before the 2016 vote.[94] While it appears that there has been a knock-on effect on costs and timings, the MOD has said that the overall Dreadnought budget and timescale will not change.[95]

When the first build phase of the Dreadnought programme was approved in June 2016 the MOD knew

CREDIT: BAE SYSTEMS

Astute-class submarines: HMS Audacious ready for launch, HMS Anson and HMS Agamemnon under construction.

that the project was unaffordable within the budget at that time.[96] Although the MOD publicly claims that the Dreadnought programme will remain within the £31bn budget, in March 2018 it was announced that £600m of the £10bn contingency would be used in the current financial year.[97] As this contingency is not currently part of any budget that has been allocated to the MOD, the Treasury had to sign off on the extra £600m.[98]

The MOD has declined to give details about what this £600m would be spent on,[99] but said it would be used to 'de-risk' the project and will ensure that it stays within the £31bn overall budget.[100] However, it is additional money and no details have been provided about how it will be allocated, so there is no evidence in the public domain that it will be offset by future savings.

A further £1bn of extra funding was awarded to the MOD in the October 2018 budget, with nuclear weapons being one of the named priorities for this money. £200m will be spent in financial year 2018–19 and £800m the following year. Initially the MOD said it had not decided how much of this £1bn will be spent on the Dreadnought programme,[101] but it seems likely that the £400m of extra funding for Dreadnought announced in December 2018 will be taken from this £1bn.[102] The Treasury has confirmed the money is additional funding but failed to confirm whether any of it would be taken from the £10bn Dreadnought contingency.[103]

Current projections predict annual spending on submarines will rise from £1.9bn in 2018–19 to £2.5bn in 2023–24. Spending is then predicted to reduce to £2.2bn in 2026–27, with spending in 2016–27 and 2027–28 predicted to be under budget.[104] The vast majority of the predicted overspend on the MOD equipment plan is due to occur in the years up to 2022,[105] meaning there is significant potential for intentional delays to equipment spending and other problems to drive up costs within the programme and across equipment spending as a whole. If submarine spending does not begin to fall after 2024 that would indicate that the future savings included in the MOD's cost estimates are unlikely to materialise.

In total, £1bn of extra funding for the Dreadnought programme has been announced in the 2018–19 financial year. The lack of clarity over whether the full sum will be taken from the £10bn Dreadnought contingency raises questions over both the MOD's financial planning and its commitment to transparency. Even if none of the additional funding from the 2018 budget is taken from Dreadnought contingency, the £600m of contingency funding alone represents overspending at such a rate that the £10bn will be spent by 2034 if it were to continue, long before all the submarines are built.[106]

Programme Status: Astute

The cost increases and delays to the Astute programme are well known, with the overall cost of the project expected to be about £1.7bn higher than the original budget[107] and the first three boats being nearly five years late.[108] This is often ascribed to the delay between the end of the Vanguard project and the building of the Astute-class submarines.

Although there were only three years between the completion of the last Vanguard-class submarine and work commencing on the first Astute-class submarine, this gap caused significant financial difficulties in the sector and the loss of key skills.[109] However, predictions that performance would improve later in the project proved optimistic. The 2015 major projects report predicted that the last three Astute boats would be on time and deliver savings of nearly £100m.[110] At the time of writing the last four submarines are on average 27 months behind schedule, compared to the average 19 month delay on the first three.[111] The project is predicted to go 4% over budget in 2018–19 and the most recent estimate for overall cost is £9.9bn: almost £100m over the forecast in 2015.[112]

The Infrastructure and Projects Authority (IPA) rates the health of the Astute programme as 'Red',[113] meaning that "successful delivery of the project appears to be unachievable" and there are "major issues with project definition, schedule, budget, quality and/or benefits delivery, which at this stage do not appear to be manageable or resolvable." The failure to significantly improve performance as the Astute programme has progressed suggests that the problems experienced during Astute-class production cannot be ascribed to teething difficulties and may well also arise in the Dreadnought programme.

To try and address the £1.3bn shortfall in the Defence Equipment Plan for 2018–19, the MOD decided to delay work on the Astute programme,[114] which had already seen a £199m cost increase and a 9 month delay the previous year.[115] As discussed above,[116] these delays have the potential to drive up costs in the long run. Delays to the Astute programme also have the potential to slow progress in building the Dreadnought-class submarines as they are being built in the same facility.

Although the Astute-class submarines are still being built, the MOD already has a timetable in place for building a successive SSN class for when the Astute-class submarines reach the end of their service life. In March 2018 the MOD delayed work on developing this replacement, known as the Marine Underwater Future Capability (MUFC), by two years in order to offset rising costs in the Enterprise.[117] As with the delays to other projects, delaying this spending may result in increases to the overall cost of the MUFC project, and long delays to the MUFC in-service date could result in the Astute-class submarines undergoing costly life-extension work.

Programme Status: Nuclear Warhead Capability Sustainment Programme

The MOD withholds information from the major projects data it releases about the Nuclear Warhead Capability Sustainment Programme (NWCSP). Apart from the predicted end date of the 3rd April 2025, a brief list of project aims and the total project cost, all other information is redacted.[118]

While this secrecy makes it impossible to be certain about the overall health of the project, information in the public domain about progress on three key

facilities being built as part of the project may be indicative of progress in the NWCSP as a whole.

The 2018 NAO Nuclear Landscape report revealed that work to replace the facility in AWE Burghfield where nuclear warheads are assembled and disassembled ('Project Mensa') was delayed by 6 years and expected to cost £1.8bn, an increase of 146% over the original budget of £734m.[119] The MOD is now aiming for a project completion date in 2023.[120] Due to the delays, the Office for Nuclear Regulation (ONR) has said that work in the current facility, which probably dates back to the 1950s, may have to stop.[121] The delays seem to have been due to the building work beginning when the design for the new facility was only 10% or 20% settled, which may have been done to forestall an earlier threat of regulatory action in 2008.[122]

The same NAO report revealed that work on a replacement uranium facility known as 'Pegasus' is currently suspended,[123] and the MOD is now reconsidering whether it is required.[124] The reasons for this have not been given, but the project was known to be behind schedule and over budget.[125] Safety concerns with the current uranium processing building, A45, have previously been the cause of regulatory action when corrosion was discovered in the steel columns supporting the building.[126] Failure to replace old facilities is one of the reasons that the two AWE sites remain in enhanced regulatory attention.[127]

The Teutates project is a joint France/UK initiative to build a hydrodynamics facility that will be used to support warhead design work.[128] Since 2015 the UK has been paying half the cost of building the facility.[129] The project is now over budget, again as a consequence of spending approval having been given while the facility design was "relatively immature".[130] The UK contribution to Teutates is taken from the NWCSP budget,[131] so savings elsewhere in the NWCSP have had to be found to offset the Teutates cost increases.[132]

The total projected cost of the Nuclear Warhead Capability Sustainment Programme is £19.9bn, around £2bn below the 2013 estimate.[133] It is unlikely this is entirely due to the suspension of the Pegasus uranium facility.[134] In answer to a parliamentary question in late 2018 the MOD revealed that four projects which had been planned under the NWCSP were no longer going ahead and existing facilities are planned to be used instead, including a new plutonium facility and a chemical processing facility.[135] It seems likely that the cancellation of these projects accounts for much of the £2bn reduction in overall cost since 2013, though savings elsewhere in the NWCSP may have also helped to offset the cost increases in the Mensa and Teutates projects. If any of these facilities will need to be built in the future, this would entail an additional cost that is not currently included in the MOD's projections.

Programme Status: Core Production Capability

In 2017 the CPC project was forecast to be £120m over budget,[136] and according to the NAO it is currently delayed by two years.[137] The IPA currently gives the project a 'Red' rating. The causes of these delays and cost increases are discussed in the section on Vanguard reactor problems later in this chapter.[138]

Programme Status: Devonport

The Office for Nuclear Regulation (ONR) has held Devonport under enhanced regulatory attention since 2013 and there is a Nuclear Safety Improvement Plan in place to try and improve safety standards at the site.[139] ONR inspections in 2017 identified numerous problems in the project to build a new defuelling facility in the submarine refit complex between 14 and 15 docks. These included problems with the fire alarm detection and emergency lighting systems.[140]

ONR inspections found operational problems in the procedures that deal with the Reactor Access House in 9 Dock, which is used to remove nuclear reactor components and spent fuel during defuelling operations.[141] Following a series of events over a five week period in May and June 2017, the Dockyard

temporarily ceased crane operations in 9 Dock, where HMS Vanguard is currently undergoing deep maintenance and refuelling. The ONR said that the way that crane lifting operations were carried out "fell short of the required standard".[142]

Operations only recommenced after the ONR approved temporary arrangements to ensure the safety of lifting operations and maintenance and Devonport Royal Dockyard Limited (DRDL) had to request a 3 week extension of the deadline for meeting improvement notices. The ONR approved the extension and the improvement notices were eventually closed at the end of 2017.[143] In spite of this two further crane incidents occurred at Devonport in September 2018, resulting in another halt to crane work on site and an investigation by the ONR.[144] It is not currently known whether these problems will affect the Vanguard submarine maintenance schedule.

Concerns have been raised in the press about the profitability of Babcock, the contractor who run operations at Devonport. These are discussed in the 'supply chain' section below.[145] It was also reported that the MOD was unhappy with Babcock's performance[146] and had given the company until the end of 2018 to demonstrate that maintenance work on HMS Vanguard would be completed on time.[147]

Interdependencies: Vanguard submarine life

When the Vanguard-class submarines were designed, their service life was planned to be 25 years.[148] For the oldest of the class, HMS Vanguard, 2018 marked its 25th year in service. As stated above,[149] the MOD does not give a firm in-service date for the first Dreadnought-class submarine, other than the 'early 2030s'. Even if HMS Vanguard is retired as soon as deep maintenance on all the Vanguard submarines has been completed in 2030, several years before the first Dreadnought comes into service, it will be 37 years old, a service life almost 50% longer than it was originally designed for.[150]

When it was revealed that the delivery date of the first Dreadnought submarine was being moved back to 2028 Admiral Lord West, previously Chief of Naval Staff, called the plan "bloody dangerous" and "very high risk", saying that it was contrary to the advice he had been given when he was in post.[151]

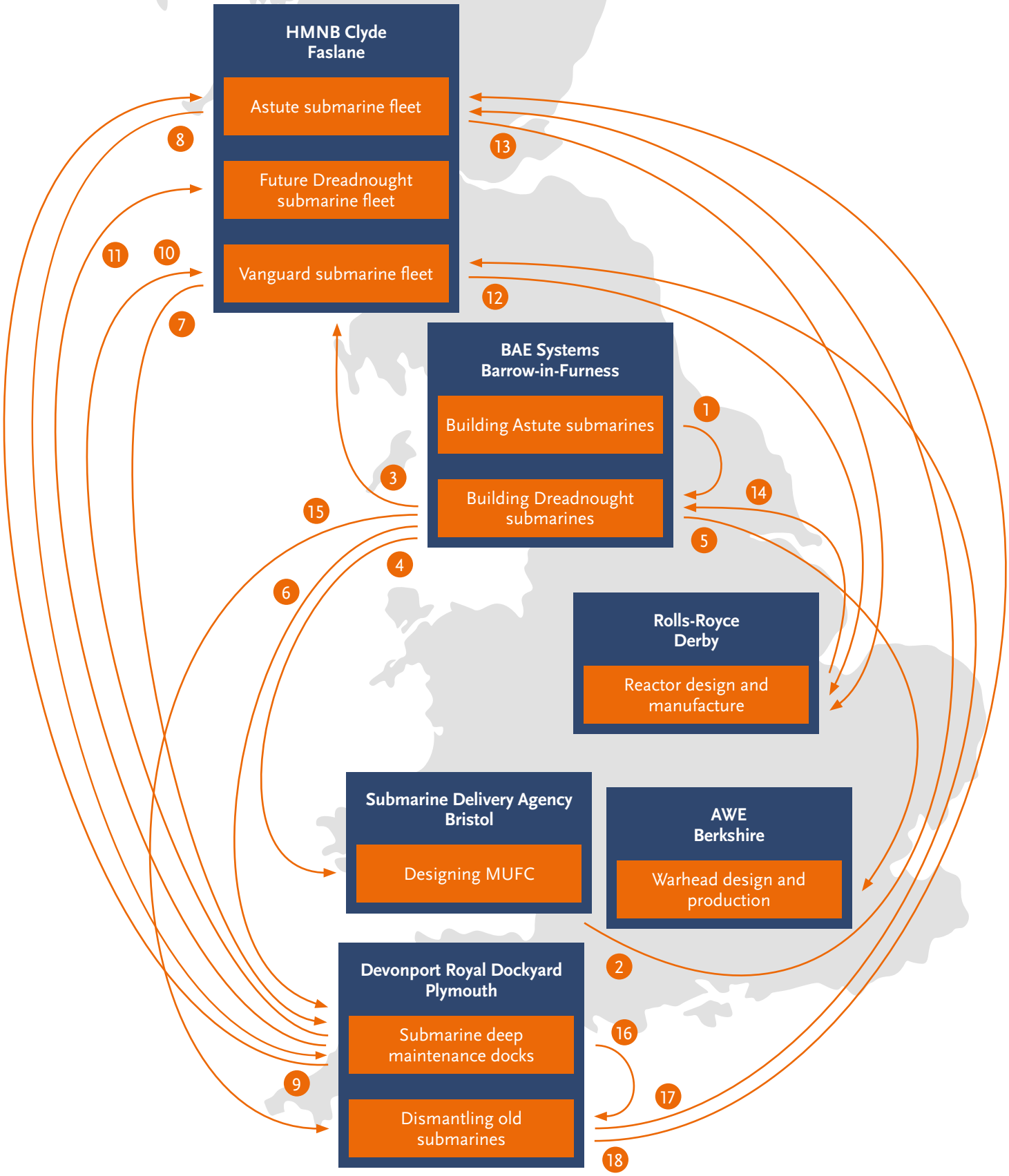
Limiting the extended service life of the Vanguard-class submarines to 37 years is also dependent on the Dreadnought-class submarines being delivered on time, which itself could be affected by further delays in the Astute programme. Given that the Astute-class submarines are being built by the same workforce at the same site in Barrow-in-Furness, and the last four are on average 27 months behind schedule,[152] there is definitely a risk of knock-on delays to the Dreadnought programme.

It is not at all clear that that the service life of the Vanguard-class submarines can continually be extended in the event of delays to the Dreadnought programme. The Trident Alternatives Review says that the service life of the Vanguard-class is determined by the life of certain critical components, and lists several parts of the propulsion system as examples: the reactor pressure vessel, steam generators, condensers and gearbox. While these parts could be refurbished or replaced this would need to happen during a scheduled deep maintenance period and the lead-in time for manufacturing the components means that they would have to be ordered years ahead of time.[153]

Given these limitations and the fact that only one dock is available at Devonport, it may not be possible to extend the life of the Vanguard-class submarines any further than currently planned. If it is possible, it would likely involve disproportionate cost for relatively modest increases in service life.

The Trafalgar-class submarines, which are being replaced by the Astute-class, have needed significant work for relatively short life extensions which will give them a service life of 32 years[154] compared to 37 years or more for the Vanguard class. HMS Trenchant

Figure 9. Interdependent risks in the UK's nuclear weapons programme



Key

Project delays

1. Delays to the Astute submarine manufacture could have a knock-on effect and cause delays in the Dreadnought programme.
2. Delays to the Marine Underwater Future Capability (MUFC) programme may mean that the service lives of Astute submarines have to be extended.
3. Further Delays to the Dreadnought programme would mean further extensions to the service lives of Vanguard submarines.

Cost pressures

4. Work on developing the Marine Underwater Future Capability (MUFC) has been delayed to offset cost increases elsewhere in the programme.
5. AWE have been asked to make savings to offset cost increases elsewhere in the programme.
6. Cost pressures elsewhere in the programme could delay spending approval for new dock capacity at Devonport.

Devonport dock capacity

7. Unscheduled Vanguard submarine refuelling or deep maintenance would increase the pressure on dock capacity at Devonport.
8. Unscheduled Astute submarine refuelling or deep maintenance would increase the pressure on dock capacity at Devonport.
9. The availability of Astute submarines for service could be impacted by a lack of dock capacity at Devonport.
10. The availability of Vanguard submarines for service could be impacted by a lack of dock capacity at Devonport.
11. The availability of Dreadnought submarines for service could be impacted by a lack of dock capacity at Devonport.

Unscheduled refuelling and core production

12. Unscheduled refuelling of Vanguard submarines would require unplanned production of new reactor cores at Rolls-Royce.
13. Unscheduled refuelling of Astute submarines would require unplanned production of new reactor cores at Rolls-Royce Raynesway.
14. Core production delays at Rolls-Royce Raynesway could delay the in-service dates for Dreadnought submarines.

Submarine dismantling

15. Cost pressures elsewhere in the programme are delaying the dismantling of old nuclear submarines.
16. A lack of dock capacity at Devonport could impede progress in the dismantling of old nuclear submarines.
17. Delays in submarine dismantling would reduce capacity for storing Vanguard submarines when they leave service.
18. Delays in submarine dismantling would reduce capacity for storing Astute submarines when they leave service.

went to sea in 2017 after a "complex and lengthy" maintenance period.[155] The maintenance, which seems to have finished in 2016, included a double motor generator change in dry dock, external hull paint, changing the main battery, extensive hull surveillance work, wide-ranging system surveys and a package of planned maintenance on the reactor system – amounting to more than 650,000 direct labour hours. All this work has extended the submarine's operating life for just two further years until 2019.[156]

A starker example is the Resolution-class submarine HMS Renown, which underwent a 5-year refit in the late 1980s and early 1990s at a cost of £200m, but was only able to complete three patrols before a defect took it out of service and resulted in its eventual scrapping.[157]

The decision to try and extend the life of the Vanguard submarines so far beyond their original service life calls into question whether it will be possible for the UK to continuously keep one submarine deployed at sea during the transition to the Dreadnought submarines. This issue is examined at length in the report '(Dis)Continuous Deterrence',[158] which makes the case that commitment to Continuous At Sea Deterrence (CASD) has been more flexible in the past than rhetorical commitments to it would suggest, and that the MOD will struggle to maintain CASD in the early 2030s.

Interdependencies: Vanguard reactor fuel breach

In 2012 radioactive material was discovered in the primary cooling circuit of HMS Vulcan – the on-shore nuclear reactor used to study the workings of PWR2 reactors which power Vanguard-class submarines. This was due to a breach in the cladding of the Highly Enriched Uranium fuel in the reactor, allowing radioactive material to contaminate the water. News of the breach was not made public until 2014, when it was announced that HMS Vanguard would have to undergo an unscheduled refuelling.[159]

Until this time it was assumed that the Vanguard-class submarines would not need refuelling for the rest of their service lives, as they had all been fitted with the latest PWR2 reactor cores (known as 'H Cores') during their first deep maintenance cycle. The Core Production Capability (CPC) project, which involved the production of the last H Cores, the replacement of the production line and the production of the first J Cores for the Dreadnought submarines, went from being a forecast £66m under budget in 2013[160] to a predicted 52 month delay and an increase in cost of nearly £250m in 2015.[161]

The refuelling of HMS Vanguard was part of a maintenance package described as the "largest single submarine refit package ever carried out in the UK"[162] and was due to complete in 2018 at an estimated £270m.[163]

The original plan for the CPC project involved the replacement of much of Rolls Royce's reactor core factory at Raynesway.[164] The facilities were to have been demolished, but instead it was decided to keep both production lines open to allow manufacturing of the H and J cores in parallel.[165] The cost of producing extra H cores for the refuelling also drove up the cost of the CPC.[166] The recent announcement of a £235m contract for Rolls-Royce[167] may also have been partly a consequence of the reactor issue.

Consequences for the Vanguard fleet

The government presented the refuelling of HMS Vanguard as a precaution, but decided not to refuel HMS Victorious, the second oldest Vanguard-class submarine. When this decision was announced in November 2018, it was said to be based on an "evidence-based assessment".[168] The MOD have declined to provide details on the scope of that assessment, but the decision was taken before a full examination had been done of the fuel from the HMS Vulcan on-shore reactor[169] or the fuel removed from HMS Vanguard.[170]

It is not possible to be certain about the level of risk entailed in deciding not to refuel HMS Victorious until more is known about the nature of the assessment. The MOD has refused to confirm whether there have been any problems with the fuel on either HMS Vanguard or HMS Victorious,[171] but has said there are no plans to refuel the remaining two Vanguard-class submarines.

Contamination of the cooling circuit due to a fuel breach on one the submarines would be unlikely to pose a serious risk to the crew, but it would be more likely to prevent the submarine being available for deployment. The costs of dealing with a further breach could be greater than the cost of refuelling HMS Vanguard as part of its deep maintenance. Given that the problem could only be remedied during a deep maintenance period at Devonport, there would also be uncertainties around the ability of the SSBN fleet to maintain continuous at sea deployment. Additional H cores would also need to be produced at Raynesway. It is unclear whether current CPC plans allow for this possibility.

Reactor safety on submarines is overseen by the Defence Nuclear Safety Regulator (DNSR), an internal MOD body. Until 2015 the MOD published annual reports by the DNSR, but since then it has refused to publish the reports or even the one-word safety assurance rating given by the DNSR (either 'substantial', 'limited', or 'no'), saying that to do so would "impact national security".[172]

In the 1980s a decision was taken by the Thatcher Government to overrule the concerns of safety regulators and keep the Renown-class Polaris submarines on continuous deployment despite there being known problems with the reactor pipework.[173] If an unanticipated fuel breach were to occur in one of the Vanguard-class submarines, the government could face similar choices over whether to heed safety advice or end continuous deployment.

While the specifics of the assessment that informed the decision not to refuel HMS Victorious have not been made public, the decision does provide some information about the MOD's risk appetite within the programme. Whatever the likelihood of these problems occurring in the other three Vanguard-class submarines, the MOD appear to have decided that accepting the risk is preferable to the cost of additional refuelling.

Wider consequences

The potential for fuel breaches to occur on the Astute-class submarines, which are also powered by the PWR2 reactor and fitted with H cores, is not yet known. There may be a greater risk of such problems occurring on Astute submarines, since the nature of their deployment means that they potentially make greater power demands on their reactors than the SSBN fleet, which usually patrol at a very slow speed in order to minimise the chances of detection.[174]

When the fuel breach was discovered, changes were made to the core production process for quality assurance[175] and a more stringent inspection was put in place for the J cores.[176] These changes have presumably reduced the risks of the problem occurring in the cores produced after 2012, but would not have been in place when the cores for the two oldest Astute-class submarines were produced.

The PWR3 reactors which will power the Dreadnought submarines are based on a US reactor design, so there is no reason to think that the fuel breach problem is likely to occur in Dreadnought submarines. However, the final design for the PWR3 reactor was formally settled in 2010, before the fuel breach issue came to light,[177] so it will not have been possible to make significant design changes based on learning from the problem.

Before the discovery of the fuel breach a decision was taken not to build a 'lead core' prototype for the PWR3 reactor, as had been done for the PWR2 with HMS Vulcan. When the fuel breach was discovered, the MOD commissioned a review of the decision not to build a prototype PWR3 reactor. The review concluded that other testing and modelling could substitute for

the lack of a prototype, but warned that in its attempts to reduce costs the MOD was introducing risks, and that dealing with problems such as the fuel breach was crowding out research which would provide a full understanding of the condition of the PWR3 reactors towards the end of their life.[178] In October 2018 the MOD refused to give details about which of the review recommendations had been put into place, saying that it would be too expensive to provide the information.[179]

Interdependencies: Devonport dock capacity

As mentioned above,[180] the limited dock space at Devonport for the maintenance and decommissioning of nuclear submarines has the potential to cause delays in other areas of the programme and to be exacerbated by problems occurring elsewhere. This is an issue for all types of submarine, but it is particularly acute for SSBNs, which can only be accommodated at 9 Dock. This means that the defuelling of the Vanguard submarines when they come out of service will have to be fitted around the deep maintenance cycle for the Dreadnought fleet.[181] Major bottlenecks are expected to arise when deep maintenance is being done on the Astute-class submarines in the early 2020s and on the Dreadnoughts in the early 2040s.[182] Any unplanned refuelling of the Vanguard fleet or further life-extension work will compound this problem and resultant delays to the schedules for Astute or Dreadnought deep maintenance could affect the availability of in-service submarines.

The Astute submarines will be accommodated in the smaller 14 Dock or 15 Dock[183] instead of competing with the Vanguard and Dreadnought submarines for space in 9 Dock. These docks were designed for the earlier Trafalgar and Swiftsure classes of SSN[184] and a new defuelling facility is currently being built to service them.[185] However, the UK's entire fleet of 20 out-of-service nuclear submarines are currently laid up in Devonport and Rosyth, and nine of them will need to be defuelled in these docks. The MOD's plans to upgrade an existing dock at Devonport to the regulatory standards required for work on SSNs are currently on hold because there is a recognition that a broader upgrade project is needed to further increase nuclear submarine dock space.[186]

It is not clear to what extent the problems in Devonport mentioned above[187] are the result of managerial culture, lack of funding or caused by other factors. Whatever the reason, the current problems at the site give rise to the question of whether Babcock would be able to effectively manage the building projects needed to mitigate the bottleneck issues.

Upgrading a dock for nuclear defuelling exercises is a major engineering and construction process. Refuelling the Vanguard submarines involves cutting an access hole in the top of the submarine and carrying out a chemical decontamination of the reactor before removing the spent fuel and reactor components into a shielded water tank. Machinery in 9 Dock allows this process to take place as well as incorporating services that allow the reactor to be cooled while operations are ongoing.[188] The upgrade project for 9 Dock, which was completed in 2002, saw its cost quadruple to £1bn.[189]

The MOD is reportedly considering a major upgrade project at Devonport to address dock capacity, which will incorporate the earlier dock upgrade plans. The NAO reported that the project will cost an estimated £1bn,[190] but this figure does not appear to be supported by a rigorous costing exercise. Given the eventual cost of the 9 Dock upgrade nearly twenty years ago was £1bn, it seems likely to be an underestimate. However it has been derived, this figure it is not currently included in the MOD's future budget estimates for the Enterprise, and given the history of the 9 Dock upgrade and the problems with the current work at Devonport, it seems likely that a major upgrade project there would face rising costs as time progressed.

Interdependencies: Submarine dismantling

Any pressure on operations at Devonport, and cost pressures on the Enterprise in general, are likely to lead to further delays to the submarine

dismantling project. As mentioned above, all of the UK's old nuclear submarines are yet to be disposed of. There are 20 submarines that still need to be decommissioned, nine of which are still carrying fuel.

The MOD has been planning to defuel and dismantle the submarines since 2000,[191] but it is clear that dealing with the issue is not a priority for the department. In evidence to the Defence Select Committee in 2016, three senior MOD civil servants were unable to say how many submarines had been dismantled, even though the correct answer was 'none'.[192]

Defuelling was suspended in 2004 after a review by the Office for Nuclear Regulation (ONR). Facilities were supposed to be upgraded and ready by 2017, but in 2016 MOD decided to delay the project with the intention of bringing it within a wider upgrade plan. This includes an aspiration to renegotiate the defuelling contracts.[193] As mentioned above, this wider upgrade is estimated to cost £1bn, which may well be an under-estimate. Given the existing cost pressures in the programme this price tag is likely to delay any approval of the upgrade plans, further delaying the defuelling and dismantling of the old submarines.

The MOD has £3.3bn set aside for the storage and disposal of the 20 submarines which are currently laid up, plus 7 more Trafalgar-class and Vanguard-class submarines that are still in service.[194] As well as the dock issue, the MOD has been clear that cost and a shortfall in skilled personnel who could undertake the work are also inhibiting progress on submarine dismantling.[195] No timetable has been agreed for the work, but the MOD intends to approve a plan and timetable in 2019.[196]

While delaying the dismantling work is an easy way for the MOD to defer costs in the short-term, and problems elsewhere in the Enterprise can translate into further delays,[197] the work cannot be deferred indefinitely. Maintenance and storage costs have averaged about £2.5m a year over the last 10 years and according to the NAO the backlog of laid-up subs will have to be cleared in order to make space for Vanguard and Astute subs when they come out of service.[198] There is also probably a limit to how long the ONR, not to mention local people and MPs, will tolerate the lack of progress on dismantling.[199]

The ongoing failure to deal with the legacy of the UK's old nuclear submarines is obscuring the full cost of the nuclear weapons programme from the public at the same time as driving up the overall costs by increasing storage fees. As time goes by there will probably also be cost implications as the submarines slowly degrade, due to the increasing complexity of the dismantling work and the declining quantity of scrap metal that can be reclaimed. While the sums involved are small in comparison to other costs within the programme, they are not negligible.

However, the greater risk in failing to move ahead with submarine dismantling is more likely to be that pressure from regulators, MPs or the public could force action to be taken at a time which is not of the MOD's choosing, diverting funds and staff attention from other priorities. In April 2019 the NAO published a detailed report on submarine dismantling,[200] prompting the chair of the Public Accounts Committee to decry the "dismal lack of progress" and call for the MOD to urgently "get a grip".[201]

External and cross-cutting risks: currency exchange rates

Given the close cooperation between the UK nuclear weapons programme and that of the United States, a substantial number of components for the programme are likely to be sourced from the US in addition to the Dreadnought Common Missile Compartment. Each year from 2018 to 2028, between 8% and 19% of the MOD's estimated equipment plan costs are priced in foreign currency.[202] The proportion of foreign currency costs in the nuclear weapons programme has not been made public, but one estimate puts it as high as 40%.[203] The MOD works with the Treasury to mitigate the risk of currency fluctuations by hedging against a proportion of its foreign currency costs for the next 3

years.[204] Any foreign exchange costs not covered by this mechanism will need to be paid for from one of the MOD's contingency budgets.[205]

This is a sensible strategy if the economic fundamentals mean that currency movements are likely to average out over a 3 year period. However, in the case of a decades-long project involving significant dollar purchases like Dreadnought it is risky. As some Brexit scenarios suggest the UK will suffer long-term economic damage and currency depreciation,[206] these long-term currency changes, which have not been hedged against, would drive up the overall cost of the programme.

While the exchange rates used in the 2018–28 equipment plan are more realistic than those used in the previous year, the NAO noted the long-term fall of the Pound against the Dollar when assessing the affordability of the plan.[207] In early 2019 the exchange rate was almost 10% below the levels used for every year of the current plan, and almost 35% below its level in early 2008.[208] The MOD says that 80% of its current foreign exchange risk is hedged against,[209] but even if the exposure within the programme is relatively small, exchange rate changes still represent a significant additional pressure on overall equipment plan costs at a time when budgets are under the greatest stress.

External and cross-cutting risks: staffing

The gap between building the Vanguard-class and Astute-class submarines, as well as the end of the Cold War and the end of construction of civilian nuclear power stations in the 1990s, resulted in a precipitous shrinkage of the UK's nuclear workforce. The workforce at Barrow-in-Furness shrank from 13,000 to 2,900 between 1992 and 2002 and the yard had to work on surface ships in order to survive.[210]

Although many in the nuclear industry, both civil and military, are bullish about future prospects, the historical thinning out and ageing of the workforce remains a significant risk to the nuclear weapons programme. The naval reactor prototype review identified the loss of staff as a specific risk to core manufacturing. Even with a workforce that had doubled in the previous few years, the review said there was no spare staff capacity at Rolls-Royce.[211]

A lack of staffing has been cited as a risk in many of the DNSR reports prior to them being censored in 2015.[212] In January 2018 the MOD lacked 337 skilled nuclear staff.[213] The Navy is also struggling to attract potential submariners[214] and is trying to find ways to make the service more attractive to potential recruits.[215]

Government and the nuclear industry both expect the shortage of skilled nuclear workers to continue. An additional 7,000 full-time staff are thought to be needed up to 2021, which will require a doubling of new recruits.[216] Skilled managers are also in short supply, with commercial management and project control skills being lacking. In March 2018 the SDA was using 80 contractors to cover gaps and the expected spend on contractors in 2018–19 is £6m.[217] In August 2018 the MOD disclosed that 15% of their civilian positions for Nuclear Suitably Qualified and Experienced Personnel (NSQEP) were unfilled. They refused to disclose the number of unfilled military NSQEP posts, saying that to do so would be detrimental to the armed forces.[218]

The naval test reactor review does discuss the damage caused by the fallow period in the civil and military nuclear industries to the skills base, but it also highlighted the risk that a resurgent civil nuclear sector could poach personnel from the military nuclear sector. Due to the security restrictions on military staff and the pay differences, the review expected traffic in the opposite direction to be minimal. Alongside the ageing expert community working on military reactors, this was described as having the potential to become a "perfect storm".[219]

"the MOD has to balance two competing imperatives when managing the relationship with its contractors: firstly to secure the best value for the taxpayer and secondly to ensure each contractor's business model is viable and the capability they represent is not lost."

External and cross-cutting risks: infrastructure and supply chain

A major source of risk in the nuclear weapons programme is the fact that delivery of almost every element of the programme is reliant on private contractors. Both the IPA and MOD identify contractor performance as a high risk factor in the Dreadnought and Astute projects.[220]

Given the fact that the infrastructure necessary to the nuclear weapons programme is considered an essential national asset, the MOD has to balance two competing imperatives when managing the relationship with its contractors: firstly to secure the best value for the taxpayer and secondly to ensure each contractor's business model is viable and the capability they represent is not lost.

In the case of warhead production at AWE this is achieved through a management contract which remains in place regardless of what the contractor is required to produce for the MOD. This gives AWE Management Limited (AWEML) a guaranteed income across the peaks and troughs of production during the long lifecycle of the warheads themselves. While the sum paid to AWEML varies from year to year, it is more accurate to think of the contract as being based on retainer payments rather than the purchase of discrete items for the programme.

No other element of the programme is funded in the same way, but the MOD's Core Production Capability (CPC) project, which is building infrastructure at the privately-owned Rolls-Royce Raynesway site, suggests it is moving away from a purchase model to a retainer model for submarine reactor production. The CPC project is not a direct purchase of reactor cores, but involves direct MOD funding of an infrastructure project at the Rolls-Royce factory with the company producing cores as one of the outputs of the project.[221]

The MOD committed to review the funding model in light of the current problems with the CPC project, and in February 2019 announced a £235m Nuclear Propulsion Lifetime Management contract, which it said would provide vital support to the programme. The actual outputs of the contract were not specified in the announcement, but it will last until 2022 and was said to sustain 500 jobs.[222] It is not clear whether this represents the beginning of a different funding model for Rolls-Royce, but evidently the MOD understands that core production at Raynesway cannot be sustained merely through purchase orders when the cores are supposed to last through the whole life of the submarines.

This approach is in line with the naval reactor review which warned that a desire for savings and short-term approach to funding would likely result in "a fractured and unsustainable capability base".[223] While increasing programme budgets in order to directly support contractors would be politically unpalatable, it is important to recognise that the MOD is likely to face pressures to do so in order to safeguard infrastructure and jobs, particularly after the current upgrades are completed.

The MOD agrees that safeguarding the supply chain is of critical importance to the sustainability of the programme.[224] BAE and Rolls-Royce have already

found it necessary to step in to guarantee a £30m loan to Sheffield Forgemasters, a key supplier of steel to the programme.[225] The MOD is carrying out a review of the role and interdependencies of the subcontractors in the Enterprise in 2018–19.[226] Mapping the supply chain and having Tier 1 suppliers participate in joint planning is one of the SDA's strategic objectives[227] and has already begun.[228]

In recent months questions have been raised over the financial position of two of the major contractors for the nuclear weapons programme. Rolls-Royce announced a major internal restructuring in 2018 with 4,600 job losses,[229] and have been engaged in a highly visible public campaign for the government to financially support the Small Modular Reactor (SMR) technology it has developed.

Large scale production of SMRs would build upon and support their existing submarine reactor business, even though the reactor design would be different. When governmental support was not forthcoming Rolls-Royce told the business press that they would have to shut down their SMR project and that only a "handful" of staff were now assigned to it.[230] Although these developments do not directly impact upon production of submarine reactors, a successful SMR business would have reduced the pressures on the MOD. Given the apparent failure of Rolls-Royce to diversify their reactor production business, concerns about long-term sustainability are likely to figure more heavily in MOD deliberations over the funding model for reactor core production, and are likely to have played a role in the decision to award the £235m Nuclear Propulsion Lifetime Management contract.

Babcock, who are responsible for refuelling operations in Devonport, faced a barrage of critical stories in the press in the second half of 2018. Beyond the reported MOD concerns about Babcock's performance and progress on HMS Vanguard's deep maintenance,[231] Babcock shares fell 12% in July when they announced that the SDA was delaying the purchase of some equipment.[232]

In October 2018 an anonymous city research firm circulated a highly critical report which accused Babcock's management of "burying bad news" about company performance and the firm's shares were targeted by short-sellers with over 10% of shares reportedly on loan.[233] There have been calls for the Chairman to be replaced,[234] and in November Babcock announced that they would be forced to close the Appledore shipyard in North Devon, which is part of their Marine division alongside their operations at Devonport.

There are no indications that either contractor is financially unviable, but their current problems are likely to make shareholders ill-disposed towards the areas of their businesses which service the nuclear weapons programme. The trend in both cases is away from a situation where these services are supported by thriving civil operations, meaning that in the future the MOD may be forced to prioritise sustaining these capabilities over keeping costs low if it wishes to retain a nuclear weapons programme.

4. COSTING THE PROGRAMME

In previous chapters this report has given an overview of the UK's nuclear weapons programme and the different elements that comprise it, and identified risks that mean it is unlikely that upgrade projects will be delivered within their official budgets. This chapter broadens the focus of the report to provide a realistic estimate of the total programme cost, in order to put the potential cost overruns in context.

Previous cost estimates

What does it cost the UK to remain a nuclear weapons state? Various attempts have been made to answer this question as part of the debate around nuclear weapon upgrades. As stated above, MOD estimates of the cost of the Dreadnought programme have risen from £15–20bn in 2007 (between £21bn and £28bn at 2019 values)[236] to the current estimate of £31bn plus the £10bn contingency. The MOD does not release figures for the total cost of the nuclear weapons programme, but as mentioned above the National Audit Office has released the current MOD estimate for spending on the Enterprise over the next 10 years: £50.9bn.[237]

Due to the lack of official figures for the overall cost, estimates from other sources have been introduced into public discussion. Conservative MP Crispin Blunt estimated that the life-cycle cost of the Dreadnought submarines would be £176bn. This figure was derived from an MOD estimate that the programme would cost 6% of MOD spending over the lifetime of the submarines, combined with the assumptions that the MOD budget would remain at 2% of GDP and the economy would grow at around 2.5% during the years in question.[238]

In 2016 the Campaign for Nuclear Disarmament (CND) produced an estimate of £205bn which included the costs of missiles, warhead infrastructure, security and decommissioning. This estimate used the same methodology as Crispin Blunt to calculate long-term support costs.[239]

In a briefing for MPs in June 2016 the House of Commons library estimated the annual running costs of the Dreadnought submarines at £2.3bn, and total lifetime costs until 2065 as £140bn. The long-term costs were again based on a percentage of the future MOD budget.[240]In 2009 a report by Greenpeace estimated acquisition and lifetime in-service costs to be £97bn.[241]

More recently, two reports by the British American Security Information Council (BASIC) gave estimate of total through-life costs for the Dreadnought programme of £110–£114bn[242] and between £71.4bn and £140.5bn[243] for lifetime in-service costs respectively.[244]

A common theme running through these reports is the question of how to estimate in-service costs, with most relying on the MOD estimate of 6% of the Defence budget. However, the estimates derived from this approach can vary considerably depending on the original assumptions, and for many of the estimates above in-service costs account for the largest proportion of the overall cost.

Methodology

This report takes the approach of extrapolating from historical MOD spending and current official estimates for different elements of the programme. This provides a greater level of detail than using a proportion of the defence budget to estimate support costs, and in this respect the methodology is broadly in line with the approach taken in the recent reports published by BASIC.[245] The following sections discuss the choices made in terms of what has been included, as well as other factors which cannot be easily quantified but could represent additional costs within the nuclear weapons programme.

The purpose of this method is to produce the most complete costings possible, while rigorously basing the figures on the MOD's own projections or current and historical spending. The method does not account for most of the potential cost increases discussed in the previous chapter, because they are not factored into MOD costings and no reliable estimates of the costs of problems or of the likelihood of them

"Not only has the MOD not produced full costings for future work that is not currently in the equipment plan... it also cannot reliably predict when spending will occur"

occurring are available. As a consequence, the figures produced by this method should be regarded as conservative estimates. The costings are based on information currently in the public domain, and could usefully be revisited as more information becomes available and the state of knowledge about the programme improves.

Although any calculation of this type necessarily requires certain assumptions, this methodology gives a much more detailed and complete picture than was possible when earlier estimates were made. It also allows a comparison to be made between the costs of different elements of the programme and for informed deductions to be made about the relative savings that could be made through cutting or scaling back different aspects of those elements.

Timescale

One difficulty in estimating the overall cost of the UK's nuclear weapons programme is that the different elements have different life spans and the money spent on them falls in different time periods. While we can estimate life-cycle costs for the Dreadnought submarines, what proportion of the development costs for a new warhead, for example, should we include in the costings? The warhead costs are an integral part of the nuclear weapons capability, but the spending on producing a new warhead does not match the production cycle of the submarines.

As such, looking at spending over any specific time period fails to give the full picture. To focus on the time when spending on upgrades is at its highest could be misleading, but neither is it correct to focus on the period when the upgrades have been completed and the only spending on the programme is for in-service costs. The amount of timetable slippage in the programme and the MOD's practice of managing short-term budget shortfalls by delaying procurement work are added complicating factors.

Not only has the MOD not produced full costings for future work that is not currently in the equipment plan, such as the dock upgrades at Devonport and a replacement warhead, it also cannot reliably predict when spending will occur.

Our calculations deal with this problem by calculating a 'per year' cost for each element of the programme, derived by dividing the whole life costs of the element by the number of years that element will be in service. This means that the costs of initial acquisition, upkeep and through-life maintainance for each element are included in the calculations. For the purposes of comparison, a cumulative figure is given by multiplying that average 'per year' cost up to 2070 when the first Dreadnought submarine is likely to have recently left service.[246] While this methodology will not be more accurate at estimating spending over the next decade, compared to MOD projections, it is a more precise method for estimating long term spending than simply using a proportion of estimated future MOD budgets.

Figures for past spending have been inflation adjusted to provide an accurate comparison with 2019 values. Costs which fall in the future have not been adjusted for future inflation, nor has a discount rate been applied. This is because figures that factor in future inflation or a discount rate would be more a product of the assumptions made than of current spending figures, due to the long timescales involved. The assumptions used in the calculations for each element are explained in detail in Annexe A.

Included costs

Figure 10 lists the costs which have been included in the calculations below. Figure 11 lists the costs which have not been included.

Dreadnought contingency

Our calculations assume that the Dreadnought programme will use up its full £10bn contingency, but that costs will not rise beyond that. As mentioned above,[247] additional spending is currently being included in the project at such a rate that the £10bn will be spent before 2034 if current trends continue. This assumption also broadly matches overspends seen in the Astute programme.[248] As the Dreadnought project is the most expensive element in the nuclear weapons programme, this assumption is one of the most significant factors determining our estimates of overall costings.

While there is plenty of evidence to suggest that the Dreadnought programme will go over budget, and will be subject to delays which have cost implications for other elements of the Enterprise, there is no way at this stage to be certain about the scale of the overspend. It is also possible that not all the contingency will be spent. As it is the only figure currently in play the £10bn contingency has been included, but given that the MOD has such a poor record in predicting costs even with the wealth of data and expertise at its disposal, it is not possible for an external organisation to make a precise estimate of the likely overspend.[249] Even if the overspend in the Dreadnought programme is not as high as the full £10bn, other additional costs that have not been included in the calculations may offset this. On balance it is considered prudent to include the full £10bn contingency in our costings.

Astute submarines and support costs

A portion of the costs for the Astute programme and SSN fleet have been included in our 'per year' costs. This is because the SSN fleet supports the SSBN fleet through a shared infrastructure, supply chain and workforce, and because of the essential role of

Figure 10. Costs included

Dreadnought programme
Core Production Capability (CPC)
Nuclear Warhead Capability Sustainment Programme (NWCSP)
AWE running costs
Astute programme
D5 Missiles (original purchase)
D5 Missiles (storage contribution)
D5 Missiles life extension (UK contribution)
Other submarine equipment and support costs
Navy support programmes
Announced Faslane base upgrades
Potential future Faslane upgrades
Nuclear programme decommissioning
Nuclear liabilities
Policing
Devonport upgrades
New replacement warhead
SDA running costs
DNO running costs
Navy command running costs

SSN submarines in 'delousing' operations to ensure SSBN's are not being trailed by foreign submarines when they go on patrol.[250]

Obviously the utility of the Astute submarines to the UK goes beyond the benefits to the nuclear weapons programme, so it would be inappropriate to include the full costs. Instead the estimate is based on a minimal Astute programme, where the submarines would be built one at a time in order to provide stable funding to sustain the UK's submarine building capacity. A reduced Astute programme of this type could maintain a fleet of two SSN submarines, which would be large enough to ensure that that submarines were available to carry out delousing operations.

The costs of submarine support cannot be easily split between SSBN support and support for the Astute and Trafalgar submarines of the SSN fleet. For our calculations, these support costs have been divided by the number of submarines to give a cost per submarine. The total cost figures include the costs for the SSBN fleet as well as for a minimal SSN fleet as described above.

According to the MOD, support for SSBN operations also requires one mine warfare vessel and one survey vessel, with support of SSBN deployment being their primary duty, as well as two attack submarines, one destroyer or frigate, three mine warfare vessels, five Merlin helicopters, and eight maritime and reconnaissance aircraft, which have other primary duties and are called on as needed.[251] The cost of these supporting ships and aircraft have not been included in our figures, due to the difficulties of identifying the appropriate proportion of costs to include.[252]

Core production

Due to the ongoing problems with the CPC project the MOD is reviewing the project funding model. It is impossible to make a reliable guess about what the future funding model for operations at Rolls-Royce will be following the review, let alone the cost of future core production. For this reason the estimated costs of the current project have been used. The £235m Nuclear Propulsion Lifetime Management contract[253] has not been included in the calculations as it is not clear what is being provided under the contract, or the timescale it pertains to.

Decommissioning costs

The MOD assesses the cost of the long-term liabilities of the Enterprise to be £18.5bn over the next 120 years.[254] The liabilities include decommissioning and disposing of sites and submarines and the nuclear waste generated by the programme. This figure has increased by over 186% over the last 3 years because the Treasury has changed its discount rate guidance.[255] A discount rate is the way that future costs are typically accounted for. Usually future costs are priced below the same cost incurred in the present, however the current Treasury discount rates are negative to account for the fact that the government can borrow very cheaply. The undiscounted figure for long-term liabilities of £9.2bn is used in our calculations.[256]

Liabilities and costs not included

The MOD also lists a number of liabilities related to the Enterprise in its annual accounts, many of which it is not able to quantify. These include indemnities given to AWEML, Rolls-Royce, BAE Systems and Babcock against various nuclear and non-nuclear risks, which presumably are part of the contracts they have with the MOD. Indemnities for nuclear and non-nuclear events at Faslane are also listed.

Rolls-Royce is indemnified for the fact that the core factory and the Neptune Test Reactor facility cannot be insured for death and personal injury to a third party and there is an upper limit to contractor liability during the Dreadnought design phase for BAE systems and contractors at Devonport. A shipbuilding indemnity for Astute-class submarines is also listed, and the MOD is also liable for damage to HMS Vanguard during its deep maintenance period.[257] Selected liabilities relevant to the programme are listed in Figure 12. These liabilities have not been included in our calculations as they cannot be quantified.

Figure 11. Costs not included

Full costs of the Astute programme
Cost of other conventional support assets
Additional costs arising from the review of Core Production funding
Unquantified liabilities listed in the MOD accounts
Cost of supporting civil nuclear power in the UK
Cost of manufacturing additional fuel cores if needed

Support for civil nuclear power

One unresolved question is the extent to which government enthusiasm for civil nuclear power is motivated by the desire to build up capacity and infrastructure that can support the UK's military nuclear programme. In the past the nominally civilian power sector has supported the nuclear weapons programme but there are fewer links now.

However, analysis by Phil Johnstone and Andrew Stirling of Sussex University suggests that the UK's enthusiasm for nuclear power is out of kilter with its benefits as an energy source. There was an unexpected change in energy policy in the Blair government shortly before the White Paper on beginning the Dreadnought programme, which resurrected the prospects for civilian nuclear power in the UK,[258] and questions remain about the high level of government support for Hinkley Point C, reportedly the most expensive power station in the world.[259]

It is clear that a thriving civil nuclear sector would help to support the programme in terms of shared supply chains, and business opportunities for suppliers. Stephen Lovegrove, Permanent Secretary to the MOD, has spoken of the "great opportunity" to build up the nuclear skills base, but noted that it will require concerted government action,[260] and in 2005 the MOD funded a RAND report on the UK's nuclear submarine industrial base which highlighted the links with civil nuclear.[261]

As mentioned above[262] Rolls-Royce have publicly advocated for the government to support Small Modular Reactors (SMR) so that they can diversify their reactor building business. Rolls-Royce literature explicitly states that the supply chain benefit from SMRs would help support the nuclear weapons programme.[263]

The MOD is actively involved in the Nuclear Skills Strategy Group, which is part of a broader strategy of government support for the civil nuclear sector, with the express aim of building up a workforce that would support the nuclear weapons programme.[264]

While there is no direct evidence that the needs of the programme are driving energy policy, it seems obvious that both government and industry are aware of the linkages and are keen to maximise the ways in which the nuclear power industry can support the nuclear weapons programme.

Whatever the motivations behind government support for the civil nuclear sector, it is clear that the military nuclear supply chain is likely to need financial support beyond the current financial commitments of the Enterprise if it is to remain in operation after the Dreadnought submarines are launched. In the absence of a buoyant civil nuclear sector, the level of support required is likely to be greater. However, due to the uncertainties surrounding this issue no additional costs have been included into the calculations.

What is the overall cost of the UK's nuclear weapons programme?

Using the above figures, assumptions and methodology provides a figure of £3.4bn/year for the programme averaged over the lifetime of each element. As mentioned above, while this figure takes into account known and quantifiable public spending associated with the programme, it is almost certainly a low estimate. The breakdown of the costings is shown in Figure 13.

Figure 12. Selected unquantifiable Enterprise liabilities[268]

Indemnities to AWE Management Ltd for nuclear and non-nuclear risks
Indemnities to Rolls-Royce and BAE Systems for risks associated with the handling of fissile materials
Indemnity to Rolls Royce for redundancy costs in the event of the termination of the nuclear submarine construction programme
Indemnities to the Babcock Group in respect of nuclear risks under the Nuclear Installations Act 1965
Indemnities to the Babcock Group in respect of non-nuclear risks resulting from claims for damage to property or death and personal injury to a third party
Indemnity in respect of nuclear risk in support of framework contracts under Next Generation Estate Contracts
Standard shipbuilding indemnity in respect of Astute class submarines
Indemnity to Rolls-Royce Power for the non-insurance of the Rolls-Royce Core Factory and the Neptune Test Reactor facility for death and personal injury to a third party
Overall cap on contractor liability within the future submarine design phase contract with Devonport Royal Dockyard Limited
Cap on contractor liability for inadequate performance within the future submarine design phase contract with BAE Systems Ltd
Strategic Weapons System Activities Future Delivery Project indemnity – outsourced contract includes an indemnity for non-nuclear events and unintended detonation of explosives

Most of the problems discussed in Chapter 3 have the potential to drive up costs within the programme, as does the MOD's tactic of managing in-year funding gaps by delaying work. The calculations assume that once the NWCSP is complete spending at AWE will return to its pre-2005 level, aside from the cost of producing a new warhead. If infrastructure upgrades planned as part of the NWCSP have been deferred, or other infrastructure upgrades are needed in the future, capital spending at AWE would almost certainly be higher than assumed in our costings. The MOD is reportedly also considering 44 infrastructure projects across the programme which would all represent additional costs if approved.[265]

In a recent speech the Secretary of State for Defence spoke of an annual spend of £4bn on nuclear weapons to guarantee the UK's security for 50 years. It is not clear how this figure was derived or over what timescale that level of spending would be maintained, but it is further evidence that £3.4bn a year is likely to be a low estimate for long-term costs.[266]

Estimating spending on the programme up to 2070 using this £3.4bn annual figure gives a total cost of £172bn at 2019 prices, which again should be regarded as a conservative estimate. This is within the range of other independent estimates which have been made.[267] It is also more than four times the MOD's predicted cost of the Dreadnought programme and contingency combined, underlining the need to consider all the costs of the programme together.

Figure 13. Per-year costings for each element of the programme

Programme element	Current annual cost (millions)	Total budget (millions)	In-service length (years)	Per-year cost (millions)
Dreadnought	£1,249	£41,498	35	£1,186
Core Production Capability	£187	£1,585	40	£40
AWE (baseline running costs)	–	–	–	£494
NWCSP (capital costs)	£1,025	£8,576	40	£214
NWCSP (non-capital, non-running costs)	–	£2,080	52	£40
Astute	£563	£9,942	35	£81
Trident D5 Missiles (original purchase)	–	£4,257	48	£89
Trident D5 Missiles (storage contribution)	£12	–	–	£12
Trident D5 Missiles (life extension contribution)	£158	£352	48	£7
Other submarine equipment and support costs	£94	–	–	£52
Navy support programmes	£630	–	–	£347
Announced Faslane base upgrades	–	£1,300	40	£33
Potential future Faslane upgrades	–	£4,000	40	£100
Nuclear programme decommissioning	–	£2,999	67	£45
Submarine programme decommissioning	Unknown	£6,201	56	£111
Policing	£80	–	–	£80
Devonport upgrades	–	£1,000	40	£25
New replacement warhead	–	£9,820	52	£189
SDA running costs	£165	–	–	£165
DNO running costs	£55	–	–	£55
Navy command running costs	£1	–	–	£1
Total per-year cost of the programme				**£3,367**
Total cost to 2070				**£171,694**

5. IMPLICATIONS FOR POLICY

Can the MOD achieve planned savings within the programme?

While this report has identified numerous possibilities for cost increases, the possibility that the MOD will make savings in the nuclear weapons programme should not be dismissed. The MOD is well aware of the political sensitivities around cost escalations, and is actively trying to make savings in the submarine programme.

In the 2010 Strategic Defence and Security Review (SDSR) the MOD identified aspirational savings of £879m it would like to make in the submarine programme. A contract to share efficiency savings with BAE Systems was signed in July 2013, and £92.8m of savings were reported between then and March 2015.[269] This model of incentivising savings through payments to contractors was broadened into a partnership with the main submarine project contractors, which is considerably more involved than a traditional customer-supplier relationship.[270]

Savings of £40m were reported for 2015/16 under the initiative known as the Submarine Enterprise Performance Programme (SEPP),[271] but the goals of the joint working project are wider than simply achieving savings, and include sustaining the capacity to continue to design, build and support nuclear submarines in the UK.[272] A joint management team for the Dreadnought programme, known as the 'Dreadnought Alliance', has been set up by the Submarine Delivery Agency (SDA), Rolls-Royce and BAE Systems, and is now responsible for delivery of the Dreadnought project, reporting to the SDA.[273]

It is an open question whether the divergent aims of the SEPP can be resolved in such a way as to deliver the savings that the MOD hopes for. A large proportion of the Enterprise costs are for long-term equipment procurement and support projects which cannot be competitively tendered because there is only one possible supplier. As a consequence the usual method of achieving best value in public sector procurement through tendering contracts is not possible.[274]

The interest of these contractors in maximising the profitability of their work is in direct conflict with the MOD's desire to make savings, as long as costs don't escalate so far they cause the programme to be cancelled. While the SEPP introduces incentive payments to contractors to minimise costs and incorporates contractors in the management of the programme, it is hard to see how it can fully compensate for this basic divergence of interests.

Even if the contractors did wish to deliver their projects as cheaply as possible, rather than fulfil their obligation to maximise profits for their shareholders, to do so might be beyond their capabilities. It is extremely rare for any civil nuclear plant to be delivered on time and to budget.[275] Why should we expect a different outcome from the Dreadnought programme, which is trying to deliver not only a new reactor model, but numerous other systems, all of them integrated in a new submarine design?

The SEPP originally planned to make savings of £900m between 2011 and 2021,[276] and current projections include a savings target of £982m through the SEPP. However, only £602m of those savings are expected to be realised. The prospects for a further planned £669m of savings at AWE being realised are unclear.[277] Increased spending in the early stages of the Dreadnought programme is also partly offset by spending in the two final years being forecast below the budget, but as mentioned above[278] this may be difficult to achieve.

The NAO have been critical of the MOD's approach to anticipated savings in the equipment plan. The 2018–28 plan incorporated £7.3bn of savings the MOD believes it is likely achieve.[279] However, a further £2.2bn of savings are included in the equipment plan costings, even though the MOD is less confident that these can be achieved. The NAO said the MOD was unable to provide a clear picture of its progress in achieving savings and the data on efficiencies contained inconsistencies they could not explain.[280]

CREDIT: MOD

Astute-class submarine HMS Ambush alongside a support vessel at Faslane, 2013.

The equipment plan factors in risks deemed likely to occur, but those the MOD deems less than likely are not included, resulting in only half of the risks identified in nuclear-related projects being currently factored into the plan costings. Over the 10-year period of the plan the MOD has calculated the value of these less likely risks to be £19.7bn.[281]

Given the MOD's past record and their propensity to manage short term budgetary problems by delaying work, increasing the risk of higher long-term costs, it would be imprudent to assume that the MOD will be able to achieve the savings it is aiming for.

Is the MOD capable of addressing rising costs in the programme?

As discussed above, the current MOD equipment plan is not affordable, with the MOD's own figures putting the funding gap at £7bn and the NAO warning that the true figure could be more than twice as large.[282] In total, nuclear spending accounts for about 25% of the MOD's equipment spend and the NAO has warned that the Enterprise projects are so expensive and complex that their failure could render the MOD's entire equipment plan unaffordable.[283] The increase of £941m in the Astute and Dreadnought programmes in January 2018 was responsible for 52% of the increases in the overall equipment budget for the period 2017–27, compared to the 2016–26 equipment plan published the previous year.[284]

As well as efficiency savings which may be optimistic, the equipment plan also anticipates savings from projects being delayed, known as an 'adjustment for realism'. Savings of £6.7bn are expected to be made this way over the 10 years of the current equipment plan. In other words, if all projects within the equipment plan met expectations, the funding hole would increase by £6.7bn, making the total almost double the current estimate.[285]

Options for dealing with the funding gap appear limited. The equipment plan is a substantial proportion of the overall MOD budget and is expected

"There seems little prospect of the MOD taking control of its equipment budget under the current Secretary of State for Defence, and it remains an open question whether it is an organisation that is institutionally capable of doing so."

to rise to 48% of the entire departmental budget in 2021/22.[286] Pressures exist in other areas of the MOD budget, with the NAO having identified a £30bn shortfall over the next 30 years in planned MOD spending on the property that it owns.[287]

These financial pressures are being keenly felt in the MOD's conventional military projects. In November 2017 the NAO reported that the Navy was increasingly resorting to cannibalising some of its vessels for spare parts in order to keep others in service, with such incidents increasing by 50% in the previous 5 years.[288]

For several years the MOD has recognised that the procurement ambitions of the 2015 SDSR exceeded the available budget and has been trying to align the two. This process was originally undertaken through the National Security Capability Review (NSCR) under the auspices of the National Security Council, but when the current Secretary of State for Defence came into post, the defence aspects of the review were taken over by the MOD with an expanded scope, becoming known as the Modernising Defence Programme (MDP).[289]

For the financial year 2018–19 the MOD has focussed on keeping within its budget for the year, rather than addressing the shortfall in subsequent years, in anticipation of the MDP outcomes. The treasury agreed a budget which was £1.2bn above the available funds on the understanding that spending would be adjusted within the year. This has been done through delaying work on the Astute programme and other measures, which the NAO warns could actually lead to greater costs in the long run.[290]

Under the current Secretary of State the purpose of the MDP has changed from attempting to find a way to allow the MOD to live within its means, to an exercise designed to make the case for an increase to the MOD budget. This attempt has yielded piecemeal increases in budget for the financial years 2018–19 and 2019–20,[291] but not sufficient funding to bridge the gap in the equipment budget, and the NSCR/MDP process gained the dubious distinction of becoming the "longest defence review in modern history".[292]

When the MOD announced what it called the "headline findings" of the MDP to Parliament in July 2018 instead of publishing a finished report it was variously described as an "anodyne…holding document"[293] that "outline[d] a series of important issues on which decisions still need to be taken".[294] The final report, released in late December 2018, failed to provide any concrete deliverables[295] or substantive savings proposals, although it did express a hope that the Treasury would provide £340m extra for a 'Transformation Fund' in the forthcoming spending review.[296]

As discussed above, the MOD has conceded that current equipment spending plans are not viable without a fundamental change in their financial settlement[297] There seems little prospect of the MOD taking control of its equipment budget under the current Secretary of State for Defence, and it remains an open question whether it is an organisation that is institutionally capable of doing so.

The nuclear weapons programme trilemma

Assuming that the £600m of Dreadnought contingency money that has been approved by the

treasury is all spent in the current financial year, the MOD has a further £9.4bn of contingency that it can request for the Dreadnought programme while staying within the official spending envelope. However, accessing this money will require agreement from the Treasury and would be an addition to the MOD's overall budget.[298]

The MOD also has a nuclear contingency, which is money that it currently holds and is included in its current funding settlement with the Treasury. This can be spent on any part of the nuclear programme at the MOD's discretion. £580m has already been allocated to the Defence Nuclear Organisation for the 3 years up to 2019–20, leaving a further £1.1bn remaining.[299]

The 2018–28 equipment plan anticipates that this nuclear contingency will all be spent, as well as a further £5.1bn of other contingency money. A further £4.3bn of departmental contingency is also available,[300] giving the MOD some leeway in mitigating cost overruns and unanticipated spending. However it is smaller than the various items of spending identified in this report which are not included in current plans – the estimated infrastructure spending at Devonport and Faslane alone comes to £5bn.

Even if some of the potential areas for cost increases identified in this report do not materialise, it seems inevitable that the nuclear weapons programme is going to cost more than planned for in the current MOD Treasury settlement.

The trilemma

Any future government will almost certainly face a trilemma in the next few years and will need to either:

- increase the overall MOD budget, with likely implications for government spending on other priorities
- allow nuclear weapons programme spending to increase at the expense of conventional defence spending or
- find a way to reduce costs in the nuclear weapons programme.

Risks to Continuous At Sea Deterrence (CASD)

As well as the potential for problems in the nuclear weapons programme to increase its overall costs, there is a serious potential for delays to impact on the ability of the submarine fleet to maintain continuous deployment of one submarine at sea at all times. As mentioned above,[301] a recent report published by BASIC makes the case that current policy is not sufficient to prevent a break in CASD, which will be difficult to maintain in the early 2030s.[302]

The disproportionate cost that would be attached to further extensions to the life of the Vanguard fleet, the decision not to refuel the younger Vanguard submarines during their final period of deep maintenance,[303] and the potential for delays in the Dreadnought programme all increase the risk of interruptions to CASD. If the likelihood of an interruption increases, a considered change to a nuclear posture that best aligns the UK's security needs and ambitions with the available funds and technical realities would be far preferable than one forced by circumstances that should have been anticipated.[304]

How could programme costs be reduced?

Given the cost pressures and the difficult policy decisions which future governments will almost certainly face, what are the options for reducing the cost of the nuclear weapons programme? If the trilemma on future nuclear spending is not to be reduced to a choice between cutting conventional military spending and increasing the MOD budget, it is essential to have an open public debate about possible UK nuclear postures and their cost implications.[305]

Using the costings figures for the different programme elements used in Chapter 4 it is possible to come up with indicative figures for the savings that could be made by cutting the nuclear weapons programme in different ways. The MOD has not published projected spending for the separate elements in the nuclear

CREDIT: LEWIS CLARKE

Laid-up submarines in Devonport awaiting dismantling.

weapons programme and firm projections only exist for the next 10 financial years. Details of government contracts are not released to the public, so it is not possible to be precise about the savings which could be made from cancelling various elements of the programme. These estimates are educated guesses, based on information currently in the public domain, rather than firm figures. However, they can be considered a reliable indication of the order of magnitude of possible savings.

The calculations themselves and the assumptions that underpin them are listed in Annexe B. What they demonstrate is that two divergent savings paths emerge, with the choices becoming more stark as contracts continue to be signed and funds continue to be committed to the Dreadnought programme. The first path involves retaining a similar but slightly reduced nuclear capability and includes measures such as moving from CASD to a less active posture and reducing the Dreadnought fleet to 3 boats, which could save around £15bn between now and 2070.

The second path would yield larger savings and involves cancelling the Dreadnought programme and moving away from a submarine-based weapons system. However, as the time to develop any alternative cheaper platform would take longer than the remaining lifespan of the Vanguard submarines, achieving savings through this path necessarily involves at least a temporary period where nuclear weapons could not be deployed, but would need to be either kept in storage or disarmed outright.[306] This would yield savings of around £70bn between now and 2070, or around £50bn if a plane-launched nuclear warhead was built as replacement.

Official rationale for the programme

The 2015 Strategic Defence and Security Review sets out the Government's official position that there is "a risk that states might use their nuclear capability to threaten us, try to constrain our decision making in a crisis or sponsor nuclear terrorism." No estimate of the likelihood of such an event occurring is given, but the review says it would be "irresponsible to assume that

the UK will not in the foreseeable future be confronted with the kinds of extreme threat to our security or way of life which nuclear weapons seek to deter."[307]

Two questions arise from this official position. Firstly, is the money that will be spent on nuclear weapons justified by the likelihood of this category of threat emerging in the future? Secondly, how do the sums involved compare to spending on other threats? For example, government spending on nuclear weapons and climate change do not seem to match their relative likelihood of threatening our way of life. Why is one possible future threat prioritised so highly that it warrants so much political attention and public funds, but the same funds and attention are apparently so limited for a threat which is already manifest?

Given the cost pressures on the programme and the risks to maintaining CASD, there is clearly a need for thorough review of the programme which evaluates the official rationale for the programme and the contribution it makes to the UK's security alongside its full costs.

Position of the main political parties

The two largest political parties are resistant to changes in nuclear weapons policy. The Conservative Party, currently in government, tends to consider support for nuclear weapons an article of faith, and seems likely to avoid admitting to rising costs and problems for as long as possible before providing piecemeal budget increases when this stance becomes unsustainable.

The position of the opposition Labour Party is less straightforward, with an apparent tension between the personal position of the Leader, who is a long-standing advocate of disarmament, and the current party policy to retain nuclear weapons. Whether these different positions can be reconciled into a policy which successfully tackles the problems within the nuclear weapons programme remains to be seen.

The Liberal Democrats currently have a policy to reduce the number of Dreadnought submarines, but currently only have 12 MPs. Similarly, the Scottish National Party and Plaid Cymru, with 35 and four MPs respectively, have a pro-disarmament stance. However, two of the last three general elections have resulted in no party having an overall majority in Parliament, providing rare opportunities for smaller parties to influence government policy. Despite the resistance in the two larger parties to fresh thinking on nuclear weapons policy, future coalition negotiations may nonetheless require some movement on this issue in the event of a similar electoral outcome.

6. CONCLUSION & RECOMMENDATIONS

CREDIT: MOD

Devonport Naval Base, with the submarine maintenance docks top right

This report has given an overview of the nuclear weapons programme and highlighted the problems occurring in the upgrade projects for the different elements, including the difficulties in extending the life of the Vanguard submarines, the risk of reactor problems and the potential for delays across the programme. A new method for providing a reliable estimate of the overall cost of the UK's nuclear weapons programme suggests that it will cost at least £172bn between now and 2070. Given the quantity and nature of the problems and risks within the programme, further cost rises seem very likely.

As the Dreadnought submarine construction project progresses, the possibilities for achieving savings whilst maintaining the existing submarine-based nuclear force will dwindle. The savings which the MOD has already priced into its equipment plan are unlikely to all materialise, and the recent history of MOD procurement suggests that as an institution it will struggle to close the large hole in its equipment plan budget, increasing the pressures on the programme. Eventually, policy options will narrow to a choice between paying the full cost of the upgrade projects at the expense of conventional defence or other public spending priorities or abandoning the submarine-based weapons system altogether. Delays in the upgrade projects may make an interruption to Continuous At Sea Deterrence unavoidable in any case.

Given the current situation and the potential for future problems, a non-dogmatic reappraisal of the UK's nuclear weapons programme is long overdue. It makes sense to properly re-examine the assumptions underpinning the case for the UK's nuclear weapons possession, rather than simply continue to pursue upgrade projects intended to maintain a posture that it may be unable to achieve. The recommendations below set out how this could be done and suggest further measures to enhance the transparency and democratic accountability of the programme.

Recommendations

1. Parliament should hold a review of the UK's nuclear weapons programme to re-examine the role of nuclear weapons in the UK's defence and security posture. The review should consider the full costs and risks of the UK's possession of nuclear weapons and their perceived benefits. The recommendations should include the best way to fulfil the UK's international nuclear disarmament obligations and achieve its goal of a nuclear free world. The review panel should include MOD and treasury representatives but it should be independent of both departments, and answerable to Parliament.

2. The MOD should publish full-life costings of all long-term elements of the nuclear weapons programme, providing figures which are as robust as those which are used to project 10-year equipment plan spending. Predictions of future savings should only be included in costings if concrete measures to achieve them have been identified and the potential savings have been conservatively calculated.

3. The MOD should publish annual figures for spending on the nuclear weapons programme, including all related and support costs, broken down into the separate elements. These figures should include a range of values where uncertainties exist, with risks and assumptions explicitly identified.

4. The MOD should develop a plan to reduce its equipment plan spending in order to bring it within the available budget from the next financial year onwards, using real reductions in spending rather than deferring plans.

5. The National Audit Office should work with the Infrastructure and Projects Authority to ensure that detailed assessments of progress on MOD projects is released alongside the current data, as was done in the past.

6. Parliamentarians should hold those responsible to account in order to ensure that the above steps are taken.

7. All political parties should re-examine their policy on nuclear weapons in the light of this report's findings and adopt a policy which appropriately addresses the range of security threats faced by the population of the UK and fulfils the UK's disarmament commitments under the NPT.

8. As part of this policy reappraisal, all political parties should set out a clear position on nuclear weapons spending that identifies how they would make savings or change budgets in light of the current situation.

ANNEXE A. DETAILS OF TOTAL PROGRAMME COST ASSUMPTIONS

- The per-year figure for the cost of the **Dreadnought** programme uses the total projected cost of the project from the most recent Infrastructure and Projects Authority (IPA) data, plus the £10bn contingency. This is divided by the planned 35 year life of the submarines.[308]
- The per-year figure for the **Core Production Capability** project uses the total budget of the project from the most recent IPA data, divided by an estimated 40 year life for the buildings at Raynesway.
- Per-year costings for **AWE** are difficult to derive, because all current funding for AWE is allocated through the Nuclear Warhead Capability Sustainment Programme (NWCSP), which includes general running costs alongside the costs of building infrastructure, production of the Mark 4A warhead and preparatory work for a new replacement warhead to succeed the Mark 4A. A per-year figure for the general running costs of AWE has been calculated from the mean annual cost of operations at AWE from the financial years 2000–01 to 2004–05, before the NWCSP began.
- Costs for the **NWCSP** have been split into capital costs and non-capital, non-running costs. The total cost of the project is taken from the most recent IPA data. Of this total, 43% is assumed to be capital spending on infrastructure and equipment, as this is the mean proportion of capital spending at AWE between 2005 and 2022.[309] The annual figure divides this total NWCSP capital spending by an estimated 40 year life for the facilities being constructed at AWE under the NWCSP (see below).
- The figure for **non-capital, non-running costs** under the **NWCSP** is an estimate of the costs of production of the Mark 4A and preparatory work for a new warhead. This figure is estimated at 11% of the total NWCSP, as this is the mean proportion of non-capital spending above the estimate for general running costs between 2005 and 2022. This total figure for non-capital, non-running costs under the NWCSP is divided by an approximately 52 year life-cycle for the current warhead to give the per-year cost.[310]
- The 40 year estimate for the lifetime of **capital spending** under the **NWCSP** is based on the known service life of some key buildings at AWE which are being upgraded or replaced as part of the project. For example the A90 plutonium facility that came into service in the early 1990s has been refurbished as part of the NWCSP, probably in the late 2000s, and was due to be replaced in the late 2020s[311] – about a 30 year life. Some facilities have a considerably longer life: the Mensa warhead assembly facility in AWE Burghfield is replacing buildings thought to have been built in the 1950s,[312] so they are likely to have had a 70-year life by the time they are replaced, but this is likely to be an outlier. Project Orion, the laser research facility at AWE, came into service in 2013, 34 years after its predecessor HELEN was opened. Other facilities, such as high performance computers and servers will have a much shorter life-span, so 40 years has been chosen as representing a reasonable estimate of the life-span of buildings. In the absence of detailed information about other planned infrastructure upgrades, this 40 year figure is used as the estimated life-span for all infrastructure projects in the programme.
- It is assumed that all spending on research for a future warhead has been included in the **NWCSP** budget, so no separate costs have been included.
- The **Astute** programme costs included in the nuclear weapons programme are calculated on the basis of a counterfactual scenario under which only two Astute-class submarines were built. If the build time for each submarine was slightly extended beyond the current timetable, and only one submarine was built at a time, two Astute submarines could have provided steady work for the workforce at Barrow-in-Furness, the first being built between 2001 and 2008 and the second between 2008 and 2016. This fleet of two submarines would also be sufficient to carry out delousing operations for the SSBN fleet. For this reason 2/7 (28.6%) of the cost of the Astute programme (based on the most recent IPA data) is included within the calculations. The per-year figure assumes that the Astute fleet will have their service life extended to 35 years.
- The **purchasing cost** used for the **Trident D5** missiles is the £1bn cost announced in the 1980s[313] adjusted

to today's values and divided by the 48 years between the first UK Trident test firing in 1994,[314] when they first came into service, and 2042 when they are due to leave service.[315]

- The annual contribution towards **Trident D5 storage** facilities is taken from the NAO nuclear landscape report.[316]
- The per-year figure for the UK's contribution towards the **Trident D5 Life Extension** project uses the total cost given in the NAO nuclear landscape report divided by the presumed 48 year life-cycle of the missiles, including the life extension period.
- The annual **'other submarines' equipment and support costs** are taken from the figures for 2018–19 in the NAO nuclear landscape report. It is assumed that these are support costs for the in-service SSBN and SSN fleets. The total cost is divided by 6/11 (55%) as there would be 6 submarines under the counterfactual scenario described above (2 SSN and 4 SSBN), compared to 11 at present.
- The figure for **Navy support programmes** is taken from the NAO nuclear landscape report.
- The figure for **upgrades to Faslane** is taken from official MOD announcements.[317] It is assumed that these upgrades would still be required even under the counterfactual scenario mentioned above, so the full cost of the upgrades have been included. The per-year figure is given by the total cost divided by an estimated 40 year life for the facilities.
- The figure for **potential upgrades to Faslane** is taken from the NAO nuclear landscape report. The per-year figure is given by the total cost divided by an estimated 40 year life for the facilities.
- The MOD lists **nuclear decommissioning** costs in its accounts. A full breakdown of these costs is not given, but several significant provisions are listed. In the calculations the figure used for nuclear decommissioning is the total undiscounted cost given in the 2018 MOD annual accounts, less the proportions relating to the listed provisions connected with the submarine fleet (the costs of managing nuclear fuel and costs associated with storing and dismantling old nuclear submarines).[318] These nuclear decommissioning liabilities are assumed to have built up over the whole life of the programme, so the per-year figure is the total divided by the 67 years since 1952, when the UK first detonated a domestically produced nuclear device.[319]
- The total figure for **submarine decommissioning** is the proportion of the total undiscounted cost for nuclear decommissioning relating to the three significant provisions connected to the submarine fleet.[320] To get the per-year figure this total is divided by the 56 years since the first nuclear submarine came into service.[321]
- The annual cost of **policing** the UK's nuclear weapon sites is taken from the Ministry of Defence Police 2016–17 policing plan.[322]
- The total cost of **Devonport upgrades** is taken from the NAO nuclear landscape report. The per-year figure is given by the total cost divided by an estimated 40 year life for the facilities.
- The figures assume that the MOD will decide to fully upgrade the existing nuclear warhead in 2022. Estimating the cost of delivering this **new warhead** is difficult. The per-year cost uses the current estimated $12.5bn cost for the US IW-1 interoperable warhead, which will replace one of the US Trident warheads: the W78. The UK warhead is closer in design to a different US warhead, the W76, which is also planned to be replaced with a different interoperable warhead, but there do not appear to be firm figures for the cost of this second warhead as yet.[323] This figure is significantly higher than the £2–3bn estimate for a replacement warhead in the 2007 White Paper[324] and the £4bn estimate in the 2013 Trident Alternatives Review,[325] but given the cost rises in the Dreadnought programme since those estimates were produced, it may well be more accurate. The IW-1 cost estimate has been converted into pounds and the per-year figure is the total cost divided by the in-service life of the current warhead, again assuming its replacement comes into service in 2039.
- The annual figures for the **running costs** of the **SDA**, **DNO** and **Navy Command** are taken from the NAO nuclear landscape report.

ANNEXE B. POSSIBLE SAVINGS SCENARIOS FOR THE PROGRAMME

Below are several possible scenarios which could reduce costs in the nuclear weapons programme, along with the assumptions used to calculate approximate savings for each scenario. The aim of these scenarios is to stimulate debate and to provide a basis for estimated costings.[326] Most of the figures quoted have been rounded for the sake of clarity. All figures are based on the costs used in Chapter 4.

The most relevant government publication for discussing programme savings is the Trident Alternatives Review, which was published in 2013 as a condition of the Coalition Agreement between the Liberal Democrat and Conservative parties.[327] The review showed that most other ways of deploying nuclear weapons would be cheaper than submarines, but the length of time to develop these alternative platforms meant that some new submarines would have to be built in order to maintain continuous deployment of nuclear weapons. The review concluded that building some submarines as well as the alternative platform would be more costly than the Dreadnought programme.

Five years after the review was published, the Vanguard submarines are closer to the end of their service life and any transition to an alternative platform would be even further in the future. The length of time needed to be covered by new submarines while an alternative nuclear weapon delivery programme were developed would be greater than envisaged in 2013, and the costs involved would be even higher.

As such, attempts to save money at this stage need to follow one of two paths. The first path involves continuing with a submarine-based weapons system and the second entails abandoning the submarine-based system and either accepting a hiatus in the ability to deploy nuclear weapons until a new platform was available or abandoning nuclear weapons altogether.

Scenario 1: Three Dreadnought submarines, ending CASD

This scenario assumes that the fourth Dreadnought submarine is cancelled. If this was done before the third control point in the Dreadnought programme in 2022 it is assumed that the contract for the main build would not have been signed, and the vast majority of the cost of that submarine could be saved.[328] The support costs for one submarine would also be saved. A proportionate reduction in support costs has been included in the scenario.[329]

A three-boat submarine fleet would be unlikely to be able to support a continuous deployment posture indefinitely, although it could be maintained for shorter periods of time if required. This is because while one submarine was in deep maintenance, it would be difficult to carry out any routine maintenance on the two other submarines if continuous deployment were maintained. One submarine would be deployed and the other would need to be in a state of readiness to deploy at all times, in case the submarine on deployment was forced to return to base unexpectedly.

For this reason it is assumed that one of the less active postures would be adopted.[330] No figures exist for the potential savings from ending continuous deployment, so a nominal 5% saving of support costs has been included in the scenario to represent reduced staff, maintenance, and equipment savings. This is on top of the assumed support cost savings from reducing the fleet by one submarine.

This scenario also assumes that the Vanguard fleet would be reduced to three while they were still in service, and as such the cost of one deep maintenance project would be saved.

This scenario would save around £15bn between now and 2070.

It would also be possible to go further than this scenario and reduce the SSBN fleet to fewer than three boats. This would be unlikely to provide the same proportionate level of savings achieved by cancelling the fourth boat, due to contracts having already been signed and relatively more of the cost already being committed. Conversely, it would also be possible to make more modest savings through operational changes, for example by ending continuous submarine deployment.

Figure 14. Scenario 1

		Savings to 2070
One quarter of Dreadnought programme costs minus lead-in costs	£9,608	£9,608
1/11 of annual submarine support costs	£57 / year	£2,921
10% of remaining support costs due to CASD ending	£57 / year	£2,921
One less refuelling/deep maintenance job	£270	£270
Total savings under this scenario		**£15,720**

All figures are millions

Scenario 2A: No submarines but warheads retained

In this scenario the Dreadnought programme is cancelled outright and the Vanguard fleet decommissioned, but some nuclear warheads are retained by the UK, either to be eliminated in a multilateral disarmament agreement or stockpiled for future deployment if required. This is arguably justified by the current government position that no threat requiring nuclear weapons currently exists but one may develop in the future. However, it is unlikely to be a politically popular option and it is chiefly included here as a baseline for two scenarios that follow.

In this scenario £33bn is saved from the outright cancellation of the Dreadnought programme.[331] It is assumed that no savings would be made on the CPC project, which is well advanced.

Support costs would wind down: a nominal figure of two years of full costs has been chosen to represent this, though in reality these costs would likely be spread over a longer period. After that it is assumed that long-term Navy support costs would be reduced in proportion to the reduction in submarine numbers.[332]

The scenario assumes that, accounting for the cost overruns and contracts which have already been signed, the budget for the NWCSP would still be spent, but after the NWCSP had finished the cost of the AWE contract would revert to pre-2005 spending levels. However, £10bn would not be spent on developing a new warhead.

Similarly, the scenario assumes that the UK would continue to pay the upkeep costs for the Trident missile facility in the US and its contribution to the D5LE as a good-will gesture to the US until the 2060s when the D5 will go out of service.

Figure 15. Scenario 2A

		Savings to 2070
Total Dreadnought cost minus approved spending up to 2020–21	£32,949	£32,949
36% of annual Navy support costs (after 2 years at current rate)	£227 / year	£11,113
No new warhead	£9,820	£9,820
No annual Trident facility contributions between 2060 and 2070	£12 / year	£120
Devonport upgrades cancelled	£1,000	£1,000
Saving 50% of potential future Faslane upgrades cost	£2,000	£2,000
Annual cost of policing nuclear weapon sites	£70 / year	£3,576
Minus defence diversification costs to mitigate 20,000 job losses	-£1,500	-£1,500
Total savings under this scenario		**£59,078**

All figures are millions

It is also assumed that the money for the upgrade projects at Devonport[333] would be saved and that the SSN fleet could be serviced with the existing facilities. The scenario also assumes that the Faslane upgrade plans which have already been announced[334] are already under contract and the costs can't be recovered. It is not known what projects are included in the further £4bn upgrade the MOD is considering spending at Faslane,[335] so it is difficult to assess how much would still be necessary to service an SSN fleet. A nominal 50% saving has been included in the scenario to reflect fewer upgrades being required and the site given a lower priority due to it no longer hosting the UK's nuclear weapons platform.

Policing costs are estimated to be reduced by £70m. The full cost of policing has not been deducted as Faslane and Devonport would still be used by the SSN fleet.[336]

This scenario would involve substantial job losses at Barrow-in-Furness and Raynesway. It is assumed that the government would provide 'defence diversification' funding to those areas to ease the transition away from military manufacturing, so an estimated £1.5bn fund for this has been included in the scenario.[337]

When all these factors are taken into account the estimated overall savings in this scenario would be around £60bn between now and 2070.

Scenario 2B: No submarines, nuclear gravity bomb developed

A variant of scenario 2 could involve producing a new nuclear gravity bomb warhead which could be fielded by the UK's F35 aircraft, meaning that the UK still had a platform which would allow it to use nuclear weapons in the future.[338]

A similar scenario was considered as part of the Trident Alternatives Review, which said a replacement warhead would cost up to £10bn and take 24 years to develop,[339] so it recommended that a replacement submarine be built to bridge the gap between the end of the Vanguard submarine lifetime and the new warhead being ready to deploy.

This would be more expensive than continuing with the full Dreadnought programme, so the cost of this 'stop-gap' submarine has not been factored into this scenario. Instead it is assumed that CASD will not be maintained, the Vanguard fleet would be decommissioned in the near future and there will be a time period where UK nuclear weapons would not be able to be used.[340]

With the estimate from the Trident Alternatives Review adjusted to current prices, scrapping the SSBN fleet and developing a nuclear gravity bomb would save an estimated £50bn.

Figure 16. Scenario 2B

	Savings to 2070
Savings under scenario 2A	£59,078
Minus new warhead cost	-£11,380
Total savings under this scenario	**£47,698**

All figures are millions

Scenario 2C : Full cancellation of the nuclear weapons programme

In this scenario variant the UK completely eliminates its nuclear weapons programme alongside the SSBN fleet. As well as steps under scenario 2A, AWE would be converted to civilian use.[341] The full process could take up to 80 years. Nominal costs equivalent to 3 years at ordinary funding levels (approximately £450m a year), followed by 15 years at 50% of ordinary funding levels, have been included in the scenario to reflect the costs of running AWE during that time. An additional £500m of defence diversification costs are also included in this scenario.[342]

The £211m cost of decommissioning the UK's nuclear warheads and the £4.9bn cost of decommissioning AWE (at 2019 prices)[343] have been subtracted from the savings in this scenario. Although economic and fiscal benefits would likely result from repurposing AWE to civilian usage,[344] these have not been included in the calculations as no solid figures exist. In this scenario the estimated savings between now and 2070 would be around £70bn.

The relatively small difference in savings between this scenario and 2A is due to the costs of decommissioning AWE and winding down operations there. These costs are of course inevitable if the UK is to fulfil its international disarmament obligations, but they only fall before 2070 in this scenario and offset much of the savings in that time period. In the years following 2070 the savings from full disarmament would accumulate faster than scenario 2A, which would also need to incorporate the costs of warhead and AWE decommissioning at some point in the future when the UK delivers on its international disarmament commitments.

Figure 17. Scenario 2C

	Savings to 2070
Savings under scenario 2A	£59,078
Running AWE at 50% costs for 15 years from 2022	£3,705
No AWE running costs from 2037 to 2070	£16,302
Minus defence diversification costs to mitigate 5,000 job losses	-£500
Minus cost of warhead decommissioning	-£211
Minus cost of decommissioning AWE	-£4,877
Total savings under this scenario	**£73,497**

All figures are millions

GLOSSARY

9 Dock – The dock in Devonport where deep maintenance of the UK's SSBN fleet takes place
Astute – The most modern class of UK attack submarine, currently in production.
AWE – Atomic Weapons Establishment. The organisation which produces the UK's nuclear warheads
AWEML – AWE Management Limited. Private consortium running AWE, comprised of Lockheed Martin, Serco and Jacobs Engineering
BAE Systems – Arms manufacturer whose maritime-submarine division is responsible for building the UK's Astute and Dreadnought submarines
Babcock – Corporation whose Marine Systems division owns Devonport Royal Dockyard and is responsible for deep maintenance of the UK's submarine fleet
Barrow-in-Furness – Shipyard where BAE Systems builds the UK's submarines
BASIC – British American Security Information Council
CASD – Continuous At Sea Deterrence. Permanent deployment of the UK's nuclear-armed submarines
CMC – Common Missile Compartment. The section of Dreadnought and Columbia submarines that will hold their ballistic missiles in launch tubes
Columbia – Class of US SSBN
CPC – Core Production Capability. Project to upgrade the core production factory at Raynesway and produce reactor cores for Astute and Dreadnought submarines
D5 – Trident II D5. Ballistic missile used by US and UK nuclear-armed submarines
Devonport – Devonport Royal Dockyard where submarine deep maintenance takes place
DNSR – Defence Nuclear Safety Regulator.
Dreadnought – The most modern class of UK nuclear-armed submarine. Currently in the early stages of production
DNO – Defence Nuclear Organisation. Internal agency of the MOD that oversees the Defence Nuclear Enterprise
Enterprise – Defence Nuclear Enterprise. The nuclear weapons programme and SSN fleet, including all supporting activities, institutions and infrastructure
Faslane – Naval base on the Clyde estuary. Home port to the UK's SSBN fleet
H core – Most modern core designed for the PWR2 reactor
HMNB Clyde – Her Majesty's Naval Base Clyde. Commonly known as Faslane
IPA – Infrastructure and Projects Authority.
J core – Core designed for the PWR3 reactor
Mark 4A – Upgraded UK nuclear warhead design. Currently in production
MDP – Modernising Defence Programme
MOD – Ministry of Defence
MUFC – Marine Underwater Future Capability. Project to deliver a successor to the Astute-class submarines
NAO – National Audit Office
NPT – Nuclear Non-Proliferation Treaty
NSCR – National Security Capability Review. Precursor to the MDP
NSQEP – Nuclear Suitably Qualified and Experienced Personnel
NWCSP – Nuclear Warhead Capability Sustainment Programme
ONR – Office For Nuclear Regulation
PAC – House of Commons Public Accounts Committee
Polaris – Ballistic missile system used in the UK's first generation of SSBN
Programme – The UK's nuclear weapons programme
PWR2 – Reactor design used in Vanguard and Astute submarines. PWR stands for Pressurised Water reactor
PWR3 – Reactor design used in Dreadnought submarines. PWR stands for Pressurised Water reactor
RAND – RAND Corporation. A US think tank
Raynesway – Site of Rolls-Royce factory in Derby where nuclear reactors and cores are produced for the UK's submarine fleet
Resolution – First generation UK nuclear armed submarine class. Armed with Polaris missiles
Rosyth – Dockyard on the Forth estuary housing several out-of-service nuclear submarines
SDA – Submarine Delivery Agency. Internal MOD agency responsible for delivering the submarine programme
SDSR – Strategic Defence and Security Review

SEPP – Submarine Enterprise Performance Programme
SSBN – Ship Submersible Ballistic Nuclear. NATO designation for a nuclear-armed, nuclear-powered submarine
SSN – Ship Submersible Nuclear. NATO designation for a nuclear-powered submarine
SMR – Small Modular Reactor
Submarine Dismantling Project – MOD project to dispose of its out-of-service service submarines
Trafalgar – Class of UK attack submarine. Currently being replaced by the Astute class
Trident – Ballistic missile system used on the Vanguard and Dreadnought class submarines
Vanguard – Second generation UK nuclear-armed submarine. Currently in service
W76 – US nuclear warhead design upon which the current UK warhead is based

ENDNOTES

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304. See Toby Fenwick,. '(Dis)Continuous Deterrence. Op. Cit. p23-28 for some options for how this could be done.
305. For more detailed discussion of the range of potential options see Dr Nick Ritchie. 2009. 'Stepping down the Nuclear Ladder: Options for Trident on a Path to Zero'. Bradford Disarmament Research Centre https://www.brad.ac.uk/acad/bdrc/nuclear/trident/Trident_Options.pdf and Tim Street, ORG Submission Part II Op. Cit. p17-20.
306. Maintaining continual deployment would require some of the Dreadnought class to be built in order to cover the time period until an alternative platform could be brought into service. With the cost of the alternative platform, this would be more expensive than the cost of the current plans. See: Cabinet Office, Trident Alternatives Review. Op. Cit.
307. National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom. London: Her Majesty's Stationery Office, 2015. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/555607/2015_Strategic_Defence_and_Security_Review.pdf.
308. Claire Mills. 'Replacing the UK's Strategic Nuclear Deterrent: Progress of the Dreadnought Class'. London: House of Commons Library, 22 May 2018. http://researchbriefings.files.parliament.uk/documents/CBP-8010/CBP-8010.pdf. p14.
309. Firm figures up to 2013, and planned spending from 2013 to 2022. Taken from Peter Burt, Britain's Nuclear Weapons Factory. Op. Cit. p19.
310. The current warhead came into service in 1994 with HMS Vanguard, with the Mark 4A version being brought into service around 2016, a service life of 22 years. If a decision on a replacement is taken in 2022 and the warhead itself comes into service in 2039, 17 years later, the full life of the warhead will have been 52 years.
311. Peter Burt, Britain's Nuclear Weapons Factory. Op. Cit. p16-17.
312. See AWE. 'Regulatory Response'. AWE. Accessed 9 December 2018. http://www.awe.co.uk/2018/06/regulatory-response-2/.
313. David Fairhall. '£5 Billion Trident Deal Is Agreed'. The Guardian, 16 July 1980. https://www.theguardian.com/century/1980-1989/Story/0,,108170,00.html.
314. 'HMS Vanguard (S28) | Royal Navy'. Accessed 23 March 2019. https://www.royalnavy.mod.uk/our-organisation/the-fighting-arms/submarine-service/ballistic-submarines/hms-vanguard.
315. Office of the Under Secretary of Defence (Comptroller)/Chief Financial Officer. 'Program Acquisition Cost By Weapon System: Fiscal Year 2019 Budget Request'. United States Department of Defense, February 2018. https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2019/FY2019_Weapons.pdf. p5-14.
316. Comptroller and Auditor General, The Defence Nuclear Enterprise. Op. Cit. p20.
317. See 'Defence Secretary Michael Fallon at Faslane'. GOV.UK. Accessed 13 March 2019. https://www.gov.uk/government/speeches/defence-secretary-michael-fallon-at-faslane and '£500 Million for Faslane Announced by Chancellor'. GOV.UK. Accessed 9 December 2018. https://www.gov.uk/government/news/500-million-for-faslane-announced-by-chancellor.
318. Ministry of Defence, Annual Report and Accounts 2017-18. Op. Cit. p190-194. The costs of managing nuclear fuel and the storage and dismantling costs for old submarines are listed as 41.4% of 16.2% and 10.3% of the current decommissioning costs. These proportions have been used to estimate the undiscounted proportion of each provision. It is assumed that the unlisted provisions all relate to the nuclear programme as a whole, rather than the submarine programme.

319. Although the programme began before this date, 1952 has been selected as the point at which the programme began full production of nuclear weapons and to reflect the fact some sites used in the early years of the programme, such as Fort Halstead, have already been decommissioned (see 'Sevenoaks Council Back Fort Halstead Development Plans'. Accessed 22 March 2019. https://www.kentonline.co.uk/sevenoaks/news/council-planners-back-controversial-plans-42619/.)
320. Ministry of Defence, Annual Report and Accounts 2017-18. Op. Cit. p190-194. Also see endnote 318.
321. Although some of these costs will relate so the SSN fleet, the full costs have been included due to the lack of a reliable methodology to isolate the costs relating solely to the SSBN fleet.
322. See ''Policing Plan 2016-2017'. Ministry of Defence Police, 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/537105/Policing_Plan_16-17_for_web.pdf. The total £73.7m cost of the nuclear policing categories has been adjusted to 2019 prices at http://www.in2013dollars.com.
323. 'Nuclear Warhead Costs Rise | Arms Control Association'. Accessed 9 December 2018. https://www.armscontrol.org/act/2018-12/news/nuclear-warhead-costs-rise.
324. Her Majesty's Stationery Office, The Future of the United Kingdom's Nuclear Deterrent. Op. Cit. p26.
325. Cabinet Office, Trident Alternatives Review. Op. Cit. p8.
326. See endnote 305.
327. Cabinet Office, Trident Alternatives Review. Op. Cit.
328. Costings for long-lead items have been included in the calculations. Taken from: Ministry of Defence, The Submarine Initial Gate Parliamentary Report, Op. Cit. Updated to 2019 values using http://www.in2013dollars.com. Although the cumulative costs across the three submarines have been used in order to give a conservative estimate of funds already committed, these costs are relatively low compared to the overall savings in this scenario.
329. The current fleet of 11 submarines (4 SSBN and 7 SSN) would be reduced by 1, so savings have been estimated as 1/11 or 9% of Navy support costs.
330. A detailed discussion of potential postures can be found in the two reports referenced in footnote 305 and Cabinet Office, Trident Alternatives Review. Op. Cit.
331. Approved spending up to 2020–11 is £8,051m. The scenario assumes that the rest of the £31bn and £10bn contingency would be saved in full, giving a total savings of just under £33bn. See: Ministry of Defence, Defence Equipment Plan 2018. Op. Cit.
332. The current fleet of 11 submarines would be reduced by 4, so savings have been estimated at 4/11 or 36% of Navy support costs.
333. See Comptroller and Auditor General, The Defence Nuclear Enterprise. Op. Cit. p47.
334. 'UK Marks 350th UK Deterrent Patrol'. GOV.UK. Accessed 15 January 2019. https://www.gov.uk/government/news/uk-marks-350th-uk-deterrent-patrol.
335. See Comptroller and Auditor General, The Defence Nuclear Enterprise. Op. Cit. p21.
336. See Ministry of Defence Police, Policing Plan 2016 2017. Op. Cit. p15. Costs for 'Nuclear Armed Policing', 'Nuclear Convoys' and 'Nuclear Tactical Support' have been included. The cost of 'Nuclear Marine Policing' has not been included to represent the ongoing cost of policing Faslane and Devonport with an SSN fleet. Costs have been normalised to 2019 figures using http://www.in2013dollars.com.
337. According to Comptroller and Auditor General, The Defence Nuclear Enterprise. Op. Cit. p21, 30,000 people are employed in the Enterprise. Some of these would still be employed to work on the SSN programme and AWE in this scenario, so it is assumed that a nominal 15,000 job losses would occur. Using figures of £100,000 per job cited in Barnaby Pace. 'Defence Diversification: International Learning for Trident Jobs'. Nuclear Education Trust, June 2018. http://www.nuclearedu cationtrust.org/sites/default/files/NET%20Defence%20Diversification%20Report.pdf, it is assumed that a fund of £2bn would be needed.
338. For discussion of a proposal along these lines see 'Trident Advocates Target the Air-Launched Option – BASIC (British American Security Information Council)'. Accessed 25 March 2019. http://www.basicint.org/blogs/paul-ingram-executive-director/04/2016/trident-advocates-target-air-launched-option.
339. Cabinet Office, Trident Alternatives Review. Op. Cit. The figure used in the calculations has been adjusted to 2019 values.
340. With CASD suspended, it might be possible to extend the life of the Vanguard submarines far enough that they would be available for deployment until the gravity bomb was available. Given the timescales, this would probably only be possible if they were used very infrequently – for example only put to sea for the minimum necessary training exercises to ensure they were still operational. This would be highly complex and costings for this have not been included in the scenario.
341. See Peter Burt, Britain's Nuclear Weapons Factory. Op. Cit. for a detailed description of how this might occur.
342. See endnote 337. This additional £500m would cover equivalent funding for the almost 5,000 employees of AWE.
343. See Peter Burt, Britain's Nuclear Weapons Factory. Op. Cit. p45-46.
344. Ibid. p43-51.

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