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The Royal United Services Institute

Whitehall Report 3-07

Beyond *Artful*: Government and Industry Roles in Britain's Future Submarine Design, Build and Support

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www.rusi.org

First Published 2007

Whitehall Report Series

ISSN 1750-9432

Series Editor: Dr Terence McNamee
Assistant Editor: Victoria Shin

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Back cover image: The Royal Navy SSN HMS *Trafalgar* sailing from Devonport. Photo by DML LW.

Printed in Great Britain by Stephen Austin & Sons Ltd. for the
Royal United Services Institute, Whitehall, London, SW1A 2ET, UK

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Comments pertaining to this report are invited and should be forwarded to Dr Lee Willett, Royal United Services Institute, Whitehall, London, SW1A 2ET, United Kingdom, or via email to dr.leewillett@rusi.org

List of Acronyms

ASMIPT	Attack Submarines Integrated Project Team
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATTAC	Availability Transformation, Tornado Aircraft Contract
BAES	BAE Systems
BNS	Babcock Naval Services
CFA	Contracting for Availability
COTS	Commercial-Off-The-Shelf
CVF	Carrier Vehicular Future (Future Aircraft Carrier)
DACP	Defence Acquisition Change Programme
DE&S	Defence Equipment and Support
DEC(UWE)	Director Equipment Capability (Underwater Effects)
DG Nuclear	Director General Nuclear
DG Sub	Director General Submarine
DIS	Defence Industrial Strategy
DLO	Defence Logistics Organization
DLoD	Defence Line of Development
DML	Devonport Management Limited
DPA	Defence Procurement Agency
DTI	Department of Trade and Industry
DTS	Defence Technology Strategy
EB	Electric Boat
EIPT	Equipment Integrated Project Team
FRPS	Flotilla Reactor Plant Support Contract
GIUK	Greenland-Iceland-United Kingdom
HCDC	House of Commons Defence Committee
HVAC&R	Heating, Ventilation, Air Conditioning and Refrigeration
IAW	Indicators and Warning
IPT	Integrated Project Team
ISR	Intelligence, Surveillance and Reconnaissance
JV	Joint Venture
KSF	Key Supplier Forum
LTCA	Long Term Collaboration Agreement
MARS	Maritime Afloat Reach and Sustainability
MIS	Maritime Industrial Strategy
MoD	Ministry of Defence
NSRP	Nuclear Steam-Raising Plant
PFG	Pricing and Forecasting Group
PPP	Public-Private Partnership
R&T	Research and Technology
RAMP	Revalidation and Assisted Maintenance Period
RC	Reactor Compartment

RCS	Replacement Combat System
SAM	Submarine Acquisition Modernization
SDR	Strategic Defence Review
SF	Special Forces
SIB	Submarine Industrial Base
SLoC	Sea Line of Communication
SME	Small/Medium Enterprise
SPO	Submarine Programme Offer
SSBN	Ship Submersible Ballistic Nuclear
SSBN-F	Ship Submersible Ballistic Nuclear – Future
SSK	Ship Submersible Conventional
SSMG	Submarine Support Management Group
SSN	Ship Submersible Nuclear
SUBIPT	Submarine Support Integrated Project Team
TLAM	Tomahawk Land Attack Missile
TLCM	Through-life Capability Management
TSS-D	Transforming Submarine Support - Design
UK	United Kingdom
US	United States
WHLS	Weapons Handling and Launch System

Acknowledgements

This *Whitehall Report* was written while the author was a full-time staff member, on secondment for seven months from October 2006 until May 2007, in the Military Sciences Department at the Royal United Services Institute for Defence and Security Studies. The author would like to thank Lee Willett (Head, Maritime Studies Programme) and Michael Codner (Director, Military Sciences) at RUSI, and Martin Pulford and Tim Chittenden at BAE Systems for making this Whitehall Report possible. The author also thanks Sandy Morris at ABN Amro, the UK Ministry of Defence, those across the submarine defence industrial base, and those from Government departments, whose professional and personal opinions contributed to this study.

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Introduction

On 8 June 2007, the nuclear powered attack submarine (SSN) HMS *Astute* was rolled out for launch. HMS *Astute* was the first British submarine to go in the water since 1998, when HMS *Vengeance*, the Vanguard class deterrent submarine was launched, and the first SSN since the Trafalgar class boat HMS *Triumph* was launched in 1991. HMS *Astute*'s launch, and the recent debate on the renewal of Britain's strategic nuclear deterrent, has focused public and political attention on the future of the UK Submarine Industrial Base (SIB). In terms of the UK's strategic deterrent, the Government policy – supported by Parliament following a vote on 14 March 2007 – approved concept work for the successor to the current fleet of Vanguard class nuclear powered ballistic missile submarines (SSBNs).[1] Often to the exclusion of wider policy debate, industrial issues formed a central point around which the discussion revolved, with focus ranging from the proposed seventeen year timescale for the production of a new SSBN (hereafter referred to as SSBN-F[2]), to the technical and regulatory challenges inherent in supporting the Vanguard class beyond a thirty year service life.[3] As one commentator observed, 'the future of Trident … becomes less a matter of pure strategy and more a sort of country dance in which tricky political and industrial steps must be made at precisely the right intervals.[4]

The decision to proceed with a successor to the Vanguard class was also important for the Royal Navy's continued operation of nuclear powered attack submarines (SSNs) as the build programmes for SSNs and SSBNs are mutually interdependent. Had the decision been taken to renounce a submarine-based nuclear deterrent, the maintenance of a nuclear submarine capability in the UK would most likely have become unviable[5] as an absence of future orders could have jeopardized the submarine build and support infrastructure. Whilst a fourth Astute class submarine could have been produced, the likely departure of key skilled workers from the doomed enterprise may have ensured that the third Astute class boat, HMS *Artful*, would be the last nuclear powered submarine to be built in the UK.

But of course the SSN does not exist solely to sustain industrial capacity. As this report discusses, the role of the SSN in Britain's execution of defence and security policy is uniquely important, but often underestimated. Furthermore, a wider

[1] Ministry of Defence (MoD) and Foreign & Commonwealth Office (FCO), *The Future of the United Kingdom's Nuclear Deterrent*. Presented to Parliament by The Secretary of State for Defence and The Secretary of State for Foreign and Commonwealth Affairs, by Command of Her Majesty. Command 6994, December 2006 (Norwich: The Stationery Office [TSO]).

[2] The acronym SSBN-F stands for 'Ship Submersible Ballistic Nuclear – Future'. At the time of writing, this identification has not been used officially by the Government. SSN stands for 'Ship Submersible Nuclear'.

[3] Garwin et al, 'Memorandum from Richard L. Garwin', in House of Commons Defence Committee (HCDC), *The Future of the United Kingdom's Strategic Nuclear Deterrent: The White Paper*, Ninth Report of Session 2006-07, HC 225-II, March 2007, Volume II Oral and Written Evidence, London, TSO, Ev.92.

[4] James Buchan, 'Trident', in *Granta 96: War Zones*, January 2007. p.189.

[5] Murray Easton (Managing Director, BAE Systems Submarine Solutions), HCDC, *The Future of the United Kingdom's Strategic Nuclear Deterrent: The Manufacturing and Skills Base*, Fourth Report of Session 2006-07, HC 59, December 2006, London, TSO, Ev.3.

appreciation of the linkage between operational requirements and industrial structure is essential.

With the collapse of the industry seemingly averted, a pressing short-term requirement is the decision on the fourth and subsequent boats of the Astute class submarine programme. Boats four onwards, in a class of up to seven hulls, are required to be substantially less costly to produce, requiring a fundamental shift in the performance of industry and the Ministry of Defence (MoD). This effort is led by what has become a much-needed, cohesive approach to the industry provided by the MoD's Defence Industrial Strategy (DIS), its maritime component the Maritime Industrial Strategy (MIS) and the cultural changes sought by the Defence Acquisition Change Programme (DACP). The MIS, at the time of writing still in development, is intended to be the 'routemap' for the implementation of the principles of DIS which relate to the maritime sector.

The challenges facing industry and MoD are considerable. Force levels for the UK nuclear submarine flotilla will have declined from twenty-one hulls in 1990 to twelve by 2008.[6] The low rate of production places pressure on the overheads of the build facilities. The new Astute class contains a reactor core that will last the full twenty-five year life of the submarine, drastically reducing the workload for the upkeep facilities at Devonport which conducts the refuelling of the current flotilla. The cost of procured parts, which constitute more than 50 per cent of the value of the Astute class,[7] is rising as specialist suppliers consider an exit from the submarine market due to infrequent orders and poor returns. Perhaps most importantly, the renewed emphasis on through-life cost has forced a dramatic shift in industry and MoD behaviour in order to secure both industrial sustainability and the future of the submarine as a key sovereign defence capability.

The December 2005 DIS affirmed the need to retain an indigenous capacity to 'deliver, operate and maintain [nuclear submarines] without significant reliance on unpredictable offshore expertise'.[8] This provided a clear statement of requirement for the industry to work towards. But DIS also suggested that without a dramatic reduction in through-life costs, the Royal Navy might not be able to afford to operate nuclear powered submarines in the future.

This carrot and stick approach – sheltering industry under the requirement for sovereign control whilst urging massive change – is a feature of MoD-industry relations that appears likely to continue over the coming decade. The relative size of the carrot and the stick is a matter for debate.

This report seeks to explore some of the challenges facing the organizations responsible for the design, build, support and disposal of Britain's nuclear powered submarines, the most complex weapons platform in the UK armed forces.[9] The report begins with an analysis of the role and importance of submarines in UK defence policy. Subsequently, the report will analyse MoD and industry approaches from a comprehensive and forward-looking perspective, taking into account the operational requirements for future submarines, industrial structure, developments in contracting strategy

[6] In 1990, there were four Resolution class SSBNs in service along with seventeen SSNs: seven Trafalgar class, six Swiftsure class, two Valiant class and two Churchill class. Additionally, the Royal Navy operated eleven conventionally-powered attack submarines (SSKs). At the time of writing, the flotilla comprises four Vanguard class SSBNs, seven Trafalgar class SSNs and two Swiftsure class SSNs. When HMS *Trafalgar* decommissions, SSN force levels will drop to the required level of eight.

[7] BAE Systems, 'Memorandum from BAE Systems', HCDC, *The Future of the United Kingdom's Strategic Nuclear Deterrent*, *Op. Cit.*, Ev.53.

[8] MoD, *Defence Industrial Strategy*, Defence White Paper, Cm. 6697, 2005, London, TSO, p.71.

[9] *Ibid*., p.60.

and questions of emerging technology.

The report will address the following questions:

- Are nuclear-powered submarines an essential UK defence capability, or merely desirable?
- Are current force levels and availability sufficient to meet operational requirements?
- Is the move to MoD-industry partnering, as sought by the DIS, the right way to secure a sustainable and efficient SIB?
- What level of capability is required for current and future submarine classes?
- What level of industrial infrastructure is required to support this?
- How are the sometimes conflicting demands of initial-build cost reduction and through-life cost reduction to be managed?
- What are the leadership challenges for MoD as it seeks to change the structure and culture of the SIB and its own submarine community?
- How can collaboration with the United States' submarine programme best be exploited?
- How are the demands of a new nuclear submarine programme to be reconciled with those of the civil nuclear industry?

From this analysis, the report concludes that:

- Nuclear powered submarines are a unique asset of vital importance to the implementation of UK defence policy across a broad spectrum of operations.
- The introduction of the Astute class SSN will ensure that the Royal Navy's submarines will continue to provide unrivalled flexibility no matter what the future environment demands of them.
- The partnering model outlined in DIS is the most appropriate long-term approach to this uniquely specialized, strategically important industry.
- The recent restructuring of the industry under BAE Systems and Babcock requires strong leadership from MoD to ensure that the aims of DIS are realized.
- Current force levels are already stretched to meet operational demands. Without substantial improvements in availability, a reduction to seven SSNs would risk the Royal Navy being unable to meet current and likely future operational requirements.
- A deeply self-critical view of submarine capability is required from MoD in order to establish the requirements for future classes. There is evidence that this is already underway.
- A broad view, encompassing industry's need for visibility of workload as well as the Royal Navy's operational requirements, must be adopted across Government, not just MoD.
- In general, MoD intervention in the supply chain should be minimized in order to foster a self-sustaining, competitive industrial base.
- Research and technology (R&T) investment in later Astute class boats will pay dividends for the SSBN-F programme by de-risking new design, technologies and practices.
- The seventeen year timescale for production of SSBN-F is challenging in a number of areas, and meeting it depends on establishing clear priorities in the concept and assessment phases.
- In some specific cases (such as high-grade castings and forgings, and US-sourced material for SSBN-F), government intervention should be considered in order to maintain security of supply.
- Just as submarine operations are unique, the industry that builds and supports them is unique. The successful future of UK submarine build and operation depends on government and industry continuing to find innovative solutions to unique challenges.

An Enterprise Transformed

Had this report been written three years ago, it would have been able to recommend a number of areas for urgent attention in the SIB. Many of these may have been impossible to implement at that time, given what was often a confrontational relationship between the major companies in the SIB, and between the SIB and its MoD customer. Since then, dramatic progress has been made by Government and industry, with the level of commitment and co-operation between the companies of the SIB being hailed as exemplary.

In evidence to the House of Commons Defence Committee (HCDC), representatives of several principal companies in the SIB presented a coherent view of the industry's outlook and agreed on the importance of the recent initiatives undertaken. The witnesses were particularly keen to emphasize the work performed by the Key Supplier Forum (KSF), initiated by BAE Systems in 2006. The KSF draws together the senior management of the principal companies currently engaged in the Astute class programme in order to develop a coherent approach to the submarine supply base and reduce the cost of supply into the Astute programme and future classes. The success of the KSF has spawned similar arrangements for the wider Astute supply base, as well as for suppliers local to BAE Systems' Barrow-in-Furness build facility. The KSF has reduced some of the uncertainty inherent in an industry where many firms are monopoly suppliers and where MoD is their sole submarine customer. By engaging the customer and the supply chain in the same forum, the fear in some quarters that the prime contractor might seek to take advantage of both is greatly reduced. This trust is increasingly important as the industrial model moves towards partnering and consolidation over competition.

However, as successful as the forums have been, there is a limit to what they can achieve; in evidence to the HCDC, the Managing Director of Weir, Strachan & Henshaw observed that, 'even with the good work we are doing on the Key Supplier Forum, still the main, by order of magnitude, focus of that is unit production costs rather than through-life costs… [T]here is

The Key Supplier Forum

The KSF is composed of the customer (MoD), the prime contractor (BAE Systems), the Department of Trade and Industry (DTI) and the ten Key Supplier Partners, who represent around 75 per cent of the Astute programme's material spend. The full KSF membership controls around 95 per cent of the total cost of the submarine programme, including through-life costs. The purpose of the KSF is to ensure a consistent understanding of current and future submarine programmes, and the affordability challenges to be addressed.

The Key Supplier Partners, and their main scope of work, are:
Alstom – Steam turbines and propulsion
L3 Communications – Platform Management System
McTaggart Scott – Non-hull penetrating masts
Rolls-Royce – Nuclear steam-raising plant
Sheffield Forgemasters Engineering – High-grade forgings and castings
Thales – Elements of the combat system, including Sonar 2076, above water surveillance and external communications
Ultra Electronics – System and sub-system integration
Weir, Strachan & Henshaw – Weapons Handling and Launch System (WHLS)
Wellman Defence – Air purification equipment
York – Heating, Ventilation, Air Conditioning and Refrigeration (HVAC&R)

still not enough attention paid to the full through-life costs of the programme'.[10]

The complexity of a nuclear submarine demands unique abilities from the industry that builds and supports them. Pipework, electrical cables and hydraulic lines are laced through the interior of the submarine, along with highly sensitive combat systems, machinery and a nuclear steam raising plant (NSRP). Therefore in a platform as densely integrated as a nuclear submarine, the penalties for neglecting through-life factors at initial design can be substantial, even more so than for surface ships. Accordingly, DIS recognised that a focus on through-life capability management in submarines may require industrial consolidation to occur as a prerequisite for managing successfully this complexity.

This consolidation was never going to be particularly straightforward, but important steps have been made over the past year towards long-term structural reform. Much depends on the approach taken by Babcock, the new owners of the Devonport submarine re-fit facility, but work is ongoing within the industry to define how future co-operation could best be structured. Arguably, what is required is a set of rigorous guidelines which will define the structure of the submarine industry over the next two decades. In April 2007, the Government detailed ongoing negotiations between MoD and the key industrial players towards '[developing] principles for collaboration and [defining] how, commercially, collaboration may operate to deliver reduced cost and … improved future performance'.[11] This is seen as a prelude to a Long Term Collaboration Agreement (LTCA) which would establish the industrial structure for the design and build of SSBN-F. The extent to which the funding for work on SSBN-F is tied to formalizing future collaboration remains unclear.

In its role as the customer, MoD is also making considerable progress in improving its approach. Having lost much of its submarine technical expertise since the early 1990s, MoD is now striving to reduce the cost of procuring and supporting nuclear submarines for the Royal Navy. The post of Director General Nuclear – or DG Nuclear – occupied by Rear Admiral Andrew Mathews, became in April 2006 the first dual-accountable Director General within what was until April this year the twin-agency MoD acquisition structure of the Defence Procurement Agency (DPA) and Defence Logistics Organization (DLO). With oversight of all submarine activity, DG Nuclear led the way in meeting the DIS aim of creating a single programme management organization within MoD. Since the DPA and DLO merged to form Defence Equipment and Support (DE&S) in April 2007, DG Nuclear has been replaced as an organization by Director General Submarines. Under the new arrangement, Rear Admiral Matthews has been freed of several other roles in order to concentrate fully on submarine related work, where his organization has full oversight of procurement, support and capability insertion.

The dramatic progress of the past three years has set the SIB largely on track to provide an environment where the constituent businesses can make sustainable profit and the customer can acquire and maintain an affordable submarine flotilla. Nonetheless, there is much work still to be done. The National Audit Office's Major Projects Report detailed an in-year cost increase of £164m on the Astute programme,[12] while the early years of the SSBN-F programme will

[10] Joe Oatley (Managing Director, Weir, Strachan & Henshaw), House of Commons Defence Committee, *The Future of the United Kingdom's Strategic Nuclear Deterrent*, *Op. Cit.*, Ev.3.

[11] HCDC, 'The Defence Industrial Strategy: Update. Government Reponse to the Committee's Sixth Report of Session 2006-07', Eighth Special Report of Session 2006-07, TSO, April 2007, HC 481, p.3.

[12] National Audit Office (NAO), 'Ministry of Defence Major Projects Report', HC 23-1 Session 2006-07, 24 November 2006, London: NAO. p.13.

need to be constructed with through-life costs as a high priority from the start.

The Affordability Imperative

Referring to the future cost of the Astute class in an October 2006 session of the HCDC, Liberal Democrat MP Mike Hancock commented that, 'There will come a time when [we cross] the line beyond what is reasonable to pay for a fourth and fifth boat'. He continued that, 'I think everyone has to understand that there is an enormous risk here, that if this price just goes on and on escalating, then there cannot be another order, the nation just cannot afford it'.[13]

While Mr Hancock's phrasing may be rather dramatic, the view that continued operation of nuclear-powered submarines may eventually prove to be unaffordable has come to be accepted across the SIB and MoD, but it extends beyond the build cost of Astute. Speaking in 2005, John Coles, then director of the DLO's Warship Support Agency, commented on the £1.35bn annual cost of supporting the UK's nuclear submarine capability, stating that '[t]here is immense pressure from the [MoD] centre to reduce this figure', adding that 'the UK submarine industry is unsustainable in the long term unless it restructures'.[14]

At the time of Mr Coles' comment, the Submarine Acquisition Modernization initiative (SAM) had been underway for a year. A joint MoD-industry study, SAM was an attempt to rationalize the UK industry and MoD's own infrastructure to reflect the reduced flotilla size since the 1998 Strategic Defence Review (SDR). Crucially, SAM revealed that the actual state of the industry was perilous and more poorly understood than had been assumed, specifically regarding major cost drivers and the fragility of the supply chain.[15]

SAM resulted in a proposal, the Submarine Programme Offer (SPO), from MoD to industry, in which industry would be required to meet stringent unit cost reduction targets across the remainder of the Astute class, with the order for the next boat being contingent on the cost of the last. The apparent limitation of the SPO was the lack of a structured commercial incentive for industry to undergo such dramatic change, with the demand for cost reductions seemingly being forced by an overly assertive MoD.

However, while the SPO may have failed to engage industry's support, its key tenet – that without major cost reductions there would be no further orders – was accepted by industry. The approach since the SPO has been characterized by co-operation rather than confrontation. Industry has largely accepted MoD's requirement for more control of submarine design authority, while MoD has accepted industry's need for profit as vital to a sustainable industrial base, rather than being a case of corporate greed.

Such co-operation built the foundations of reform in the SIB, but the renewal of the nuclear deterrent was arguably the true catalyst for change. In the months prior to the Government's White Paper on the deterrent, the SIB accepted that the assertion in DIS – 'For submarine-based options, it will be very important that MoD and industry are able to demonstrate an ability to drive down and control the costs of nuclear submarine programmes'[16] – was credible and that without substantial change, the industry would not be in a position to build a new class of SSBN within reasonable cost. Based on the Government's figures, it is apparent that the fleet of up to four SSBNs forms by far the

[13] HCDC, *Defence Procurement 2006*, First Report of Session 2006-07, HC 56, December 2006, London, TSO, Ev.25.
[14] Richard Scott, 'Can UK submarine industry retain critical mass?', *Jane's Defence Weekly*, 1 July 2006.
[15] Commodore Mark Anderson Royal Navy (formerly Director Equipment Capability for Underwater Effect, MoD), 'Delivering Flexible Effect from Underwater', *RUSI Defence Systems*, (Vol. 9 No. 2, Autumn 2006), p.39.
[16] MoD, *Defence Industrial Strategy*, *Op. Cit*. p.76.

largest component of the acquisition cost of the renewed deterrent. Had the SIB remained on its previous trajectory, the cost of replacing the Vanguard class could have increased sharply and placed the feasibility of renewal in doubt.[17]

Although the UK submarine industry is already providing good value relative to the United States and France, it must be accepted that nuclear powered submarines are a major cost to the UK. Therefore, there is a real need to establish the value of the capability that submarines provide. The value of the SSBN has been exhaustively discussed in the recent Trident renewal debate, principally in terms of its relative invulnerability and flexibility as the delivery platform for the strategic nuclear deterrent. These characteristics are enduring, and the role of the SSBN has changed little since the Resolution class entered service in 1968, although its capability and posture have undergone significant change over this period. It is the SSN which is the more numerous type and is the focus of current attention with the launch of HMS *Astute*. Moreover, the SSN's current and future roles are the subject of debate, particularly in light of current 'land-centric' UK operations, in which the Royal Navy risks being seen as irrelevant with the public, the media and much of Whitehall fixated on Iraq and Afghanistan, to the exclusion of considering the importance of naval forces to Britain's defence, foreign, economic and social interests.[18]

An unfortunate spin-off of the deterrent renewal debate is a perception in some quarters that SSNs exist for little other reason than to sustain industrial capacity. In the Spring 2007 edition of *RUSI Defence Systems*, the experienced individuals who form the RUSI Acquisition Focus produced their third paper entitled, *'The Underfunded Equipment*

Cost Comparison

Comparing the costs of national submarine programmes is an inherently imprecise task. Costing is complicated by differing levels of Government-furnished equipment such as the nuclear propulsion plant (the cost of which may not appear in the submarine builder's figures) and differing approaches to through-life support.

Published programme costs, including design and development, for the build of the first three Astute class submarines are £3.6bn, with a unit cost in the region of £900m. In the US, the Virginia class SSN programme cost is cited as $90bn for a thirty-boat class, with a unit funded cost of around $2.4bn dollars per hull.

The build of the French Barracuda class SSN, considerably smaller and likely to be less capable than Astute or Virginia, is due to commence in 2007. The expected six-boat programme cost is €7.9bn, an average of €1.32bn per hull. The accuracy of this initial contract cost, as well as the amount of Government furnished equipment, is unclear.

The UK SIB produces submarines to a very high standard, with greater capability than their French equivalents and at lower cost than their US equivalents in spite of much smaller production runs.

[17] Of the estimated £15-20bn acquisition cost, £11-14bn is assigned for replacement of the submarines, along with £2-3bn associated with the warhead and £2-3bn for supporting infrastructure. See MoD & FCO, *The Future of the United Kingdom's Nuclear Deterrent*, *Op. Cit.*, p.26.

[18] See Jeremy Blackham and Gwyn Prins, 'The Royal Navy at the Brink', *RUSI Journal*, (Vol. 152 No. 2, April 2007), pp.10-16.

Programme – Where Now?' Regarding the Astute class submarine, the panel asked, 'Do we need more than three or four Astute submarines except to retain onshore expertise? And if not, should onshore expertise be funded from the defence budget?'[19] Although the panel conceded that their recommendations 'would make the Defence Industrial Strategy no more easy to implement nor would [they] shore up the viability of a British onshore defence industry',[20] their difficult questions demand an answer. With the defence budget under severe strain in the coming years, there is every need to justify the cost of procuring and operating nuclear submarines in the context of their importance to UK defence and security.

Why Submarines?

The value of the SSN has been debated at length since the end of the Cold War. In the Cold War itself, the principal role of the Royal Navy's SSNs was clear – Anti-Submarine Warfare (ASW) operations conducted largely in the North Atlantic against the threat of Soviet SSNs and SSBNs. The SSN has long been considered peerless in the ASW role; with UK submarines being optimized for stealth and crewed to exacting standards, the Royal Navy's SSNs provided a formidable capability in this vital role. In a largely unsung additional role, SSNs also contributed to strategic surveillance of potential adversaries, a role which continues today across the globe.

By the time of the 1998 SDR, the role of the SSN was in transition. With the Russian submarine threat almost absent, a reduction from twelve to ten SSNs was deemed sufficient to meet future requirements. SDR also announced that all of the SSNs would be fitted with the Tomahawk Land Attack Missile (TLAM), rather than the seven boats that were previously planned to have that capability.[21] This marked the shift from the SSN as primarily an ASW asset, to a swing-role platform able to conduct strategic coercion with the most capable deep strike weapon system in the UK inventory. However, this expanded scope placed its own demand on force levels – the planning exercises behind SDR indicated a requirement for as many as fourteen boats, but economy dictated the lower number.

In addition to land attack, other long-standing capabilities of the SSN – principally Intelligence, Surveillance and Reconnaissance (ISR), but including delivery of Special Forces (SF), and Anti-Surface Warfare (ASuW) and other elements of sea control and denial – began to assume primacy in SSN operations. By 2003, and following MoD's publication of the White Paper *Delivering Security in a Changing World*, the SSN force was reduced to eight, even as the demands on the flotilla increased. Submarine operations in the Kosovo campaign of 1999, Afghanistan in 2001 and Iraq in 2003 demonstrated the versatility of the SSN, with boats involved in TLAM strikes, ISR duties and ASW. In the 2001 strikes on Afghanistan, one Tomahawk-equipped SSN was able to transit from exercises off Iceland to its firing position in the North Arabian Sea within twenty-one days, a journey of some 8,000 miles which no other type of vessel could have completed as quickly.

The official stance on the SSN force level remains that, subject to affordability, the force level may number up to eight hulls.[22] It is now widely assumed, however, that a maximum of seven Astute class boats only will be

[19] John Weston et al, 'The Underfunded Equipment Programme – Where Now?', *RUSI Defence Systems*, (Vol. 9, No. 3, Spring 2007), p.27.
[20] *Ibid.*, p.27.
[21] MoD, *Strategic Defence Review*, Presented to Parliament by the Secretary of State for Defence by Command of Her Majesty, July 1998, paragraph 141.
[22] MoD, *Defence Industrial Strategy*, *Op. Cit.* p.68.

built before the construction of SSBN-F.[23] As the Swiftsure and Trafalgar classes retire, the result would be seven Astute class boats to compose the SSN flotilla, the maintenance and support implications of which will be discussed in due course.

In sum, the capability requirement outlined in SDR has not fundamentally altered and has not been officially updated in subsequent defence White Papers. Bearing this in mind, the force level has decreased from twelve to eight, with seven likely to be the *de facto* force level in the near future. Under current policy assumptions of their use, this would most likely be the minimum sustainable level for the British SSN flotilla.

The vision for equipping the Royal Navy was outlined in DIS:

> *The force will have the ability to deliver and sustain a full range of missions: from small highly focussed interventions with Special Forces, to large, high intensity coalition operations, securing key influence in the process. This versatile maritime force will be capable of winning safe theatre entry for the deployment of joint forces.*[24]

The SSN is central to each of these missions. As a covert platform, the SSN is ideally suited for SF insertion and recovery, a capability that will be substantially improved with the introduction of the Astute class. The SSN also remains peerless in its ability to arrive on station long before other maritime units, operating independently of supporting forces and air cover, and providing options for covert or overt access and effect. It is this 'variable visibility poise' which makes the SSN so valuable to politicians in the early stages of a crisis and may even avert a crisis developing in the first place. In its intelligence gathering role, the SSN offers a wide range of options and can remain undetected on station for prolonged periods of time, unlike airborne or more visible surface assets. The ability to provide an indicators and warning (IAW) capability, in concert with the intrinsic ASW and ASuW ability of the SSN, provides assurance of theatre entry for the rest of the fleet.

Whilst there is no direct state competitor today, who can be identified as an overtly hostile submarine force, in any deployment of Royal Navy surface ships near a conventional submarine's area of operations, there is considerable risk to the surface fleet. It is not inaccurate to say that even a poorly handled submarine is a threat, as was seen in the Adriatic during NATO's 1999 Kosovo intervention, where the Serbs' solitary, decrepit Sava-class submarine was sufficient to keep most allied forces outside the Adriatic and required the tasking of Royal Navy and other coalition SSNs with ensuring it did not put to sea. The fact that ASW has been de-prioritized in the surface fleet makes the SSN all the more valuable as an integral part of fleet operations.

Twenty-five years ago, the Falklands conflict demonstrated the potency of the submarine, not just in the sinking of the *General Belgrano* by HMS *Conqueror* – an attack which precipitated the withdrawal of the Argentine fleet for the remainder of the conflict. The announcement, in the immediate aftermath of the Argentine invasion that British SSNs were on station prompted the Argentine command to re-supply their invasion force by air rather than sea, greatly slowing their progress.[25] A topical issue is the

[23] This was confirmed in a solicitation for supply of electro-optical visual systems by BAE Systems for later Astute class builds, reported in April 2007, which stated, 'The programme will include options for fixed support periods for each of the second batch of Astute class vessels (up to four new-build hulls)…'. Three Astute boats are already in build. (See: Richard Scott, 'BAE Systems Eyes Future Submarine Visuals', *Jane's Navy International*, 1 May 2007).

[24] MoD, *Defence Industrial Strategy*, *Op. Cit.*, p.68.

[25] The Government's announcement was supported by reports of HMS Superb sailing towards the South Atlantic. *Superb* actually sailed north from Gibraltar to Faslane, and British SSNs did not arrive on station in the South Atlantic until ten days after the invasion. However, the use of such effective disinformation was possible only because of the covert nature of the platform.

SSNs in Controlling – and Denying – the Use of the Sea

The use of the sea – and the benefits delivered by submarines as they use the sea – in support of national policy is not widely understood. The UK's Military Tasks are roles assigned by the Government to the UK's Armed Forces to ensure the peacetime security of the UK and its dependent territories, to ensure against major external threats, and to contribute to the UK's wider interests through the maintenance of international peace and stability. The use of maritime forces, and submarines in particular, to control the sea is fundamental to the execution of the Military Tasks.

Sea control is defined in *BR1806: British Maritime Doctrine* as 'the condition that exists when one has freedom of action to use an area of the sea for one's own purposes for a period of time and, if necessary, deny its use to an opponent. Sea control includes the airspace above the surface and the water volume and seabed below.' *BR1806* adds that '[t]here is likely to be a requirement for sea control across the spectrum of conflict.' Sea control also concerns denying the use – and control – of the sea to the other side.

Controlling and denying the use of the sea to an adversary enables operations at and from the sea. It generates freedom of action regardless of the wider security situation; permits access into theatre and onto target; allows the protection of forces, Sea Lines of Communication (SLoCs) and trade; and supports policy and other means of influence in both combat and non-combat contexts.

Today, the increasing use of the sea makes controlling and denying its use – and the role of submarines therein – remains fundamentally important for several reasons:

- Over 90 per cent of the world's trade moves by sea, and Britain remains a net importer of major energy resources. Access to – and protection of - SLoCs and maritime choke points remains necessary.
- The effective execution of most expeditionary military operations requires the control of the sea. Expeditionary military operations are likely to be vulnerable without sea control.
- Potential adversaries are using the sea more regularly as a means of moving personnel and material, and as a base from which to mount attacks ashore or as a target in its own right.

One major threat to effective sea control is the submarine. Submarines can deny the use of SLoCs or access to choke points. All elements of a maritime force contribute to offsetting this threat and to the securing of sea control. Surface forces, helicopters, maritime patrol aircraft and submarines come together to provide several layers of capability. A submarine, however, has particularly valuable uses because it is covert, agile, has great reach, and deploys a powerful set of weapons and sensors.

The ability to control the sea is a requirement for a navy and a nation which wishes to have a global presence. The simple decision to develop or retain a submarine capability is in itself a deterrent to others seeking a capability to challenge sea control, and to exploit decisive nodes of vulnerability which would otherwise exist in an expeditionary operational plan.

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assertion by some analysts that if the Falklands were invaded by Argentina today, Britain could not mount an operation to liberate them as it did in 1982. Largely neglected is the fact that the capability upgrades to the SSN flotilla ensure that a Royal Navy Task Force could prove extremely effective against Argentine naval forces, and could attack military targets on the Argentine mainland – a capability absent twenty-five years ago.

The persistent intelligence-gathering ability of a covertly-deployed SSN invisible to potential adversaries continues to be of direct relevance to UK defence and security. Without the capabilities of the submarine, the situational awareness, flexibility and offensive and defensive ability of a naval force would be severely reduced. Constraint of a naval force's operations may lead directly to constraints on defence, security and broader foreign policies. Without the SSN, the Royal Navy and the UK's maritime defence capability would be greatly diminished indeed.

Whither Submarines?

In spite of their versatility, the future of nuclear powered submarines within UK operations is by no means certain. While the roles currently performed by the SSN will endure and while others may return to prominence, the advance of technology – both in unmanned systems and non-nuclear propulsion – may eventually force some critical decisions on the future of naval nuclear power.

For the near to medium-term, nuclear power has significant advantages in terms of sustained operation, high transit speed and dived endurance. These qualities are particularly relevant in a variety of theatres, for example in Arctic operations, as seen in the recent ICEX 2007 exercise.[26] Indeed, the importance of UK submarines in that particular environment may be set to increase. A number of studies have concluded that the Arctic ice cap will be vastly reduced in scale over the next thirty to fifty years, introducing new opportunities for global trade to pass over the pole and avoid the lengthy diversions via the Suez and Panama canals, both of which are already struggling to match demand for transit of container and oil carrying vessels. Should the Arctic become a viable and desirable shipping route, the task of assuring sea control through the Arctic, across the Greenland-Iceland-UK (GIUK) gap and across the North Atlantic would return to prominence.

Expanding roles would develop alongside the existing roles of the SSN, but there is no guarantee that the SSN will endure in the face of increasingly advanced diesel-electric submarines (SSKs). Air independent propulsion and fuel cell technology have advanced greatly in the past decade and with the automotive industry increasingly focusing on the latter, it is possible that by the time HMS *Astute* decommissions in the late 2030s, her replacement may not be nuclear powered. In some quarters, the expectation is that fuel cell-equipped SSKs will soon be able to match SSNs in every performance area with the notable exceptions of sustained high-speed transit and dived endurance. However, the ability to combine reach, speed and endurance is unique to nuclear powered submarines and remains of high importance to the flexibility of the Royal Navy, particularly in light of a smaller flotilla. Any curtailment of this capability would have to be justified by a change in the doctrine of British submarine operations and a possible increase in force levels. There would almost inevitably be some compromise in capability, but this option demands consideration by industry

[26] ICEX 2007 was an Arctic warfare exercise conducted by HMS *Tireless* and the US Navy's Los Angeles class SSN USS *Alexandria* in March and April 2007. The main purpose of the exercise was to conduct 'joint classified testing on submarine operability and warfighting capabilities' as well as to enable scientific assessment of the polar ice cap.

and MoD, even though its realization may be decades away.

There is considerable merit in looking several decades hence given the development timescale for current submarines. Submarine programmes typically take a minimum of fifteen years from inception to in-service and, as discussed in due course, a seventeen year timescale for SSBN-F presents serious challenges for industry and MoD.

Returning to a near-term view, while SSBN-F remains the most significant programme for the future of the industry, intervening boats in the Astute class are intended to de-risk the technology and contracting practices to be used in the SSBN programme.

In seeking to reduce the costs of Astute Boats Four+, the necessarily rigorous studies by MoD and industry have tackled the question of performance, with questions being raised as to whether the level of performance built into UK SSNs could in any way be reduced without significant impairment of their mission. In some quarters, there is a perception that current submarines are to an extent 'gold plated', in that they encompass the highest of standards for capability, design, build and maintenance, and that this could in some cases be safely reduced in order to reduce cost without sacrificing operational utility.

There is considerable resistance to this suggestion on two principal grounds. The first is the role of UK submarines and the fact that they must potentially operate against highly advanced adversaries in the unforgiving underwater environment. British submarines are regarded as amongst the finest in any navy, and the demands placed on them are reflected in their level of performance. Measures to reduce cost may risk compromising the flexibility and performance of the boats at the time when they are arguably required to be more flexible, given reduced force levels and predicted emerging threats over their twenty-five to thirty year service lives.

The intrinsic overhead cost of building and supporting submarines also means that a reduction in performance would save a disproportionately small amount of money. The indications are that in consciously pursuing a smaller, cheaper SSN in the new Barracuda class, the French Navy have accepted certain compromises in the areas where an SSN holds its greatest advantages. At present, the MoD is not prepared to do the same and, similar to a potential move to SSKs, a cost-inspired reduction in performance would have to be preceded by a review of submarine doctrine and acceptance of the potential military and policy implications.

The second concern is centred on the idea of better technology taking the place of equipment redundancy. Safety on a nuclear submarine is paramount; the Devonshire Dock Hall where the Astute class is constructed is adorned with giant banners reminding the workforce that 'lives depend on us doing our jobs right'. This simple dictum is adhered to across the submarine enterprise and its value can be seen in the recent fatal accident onboard HMS *Tireless*, which could have escalated far beyond the tragic loss of two submariners. Commanding Officer Iain Breckenridge stated, 'It is a testament to the design, construction and maintenance that despite this event and the small fire that ensued, no serious damage was done'.[27] In some cases, improved equipment performance may not offer the same security as redundancy. Successfully resolving this difficult and highly emotive discussion will require close collaboration and cultural understanding between MoD, the Royal Navy and industry.

Whilst there is reluctance to significantly reduce the performance of UK submarines, there is a widely acknowledged

[27] 'Arctic submarine blast 'unique'', *BBC News*, 2 April 2007 <http://news.bbc.co.uk/1/hi/england/6517811.stm>, accessed April 2007.

need to at least preserve the main performance requirements whilst greatly reducing cost. To this end, much of the hitherto bespoke equipment on board the current flotilla is gradually being replaced by commercial off-the-shelf (COTS) equipment. Whilst industry and the wider supply chain can provide the innovation required to make extensive use of COTS in the submarine environment, leadership from MoD will be required to encourage the adoption of this technology. As discussed, much of the resistance to modifying the standards applied to submarine build and operation are based on valid concerns of safety and capability. Nonetheless, there are likely to be areas in which innovation can be introduced without compromising safety or performance. In some of these cases, the existing defence standards may need to be re-examined and modified. The indications are that this is accepted at the top-level of MoD's submarine community but ensuring agreement throughout the customer organization is just one of the leadership challenges facing MoD.

MoD Leadership

In 2005, the RAND Corporation produced a series of MoD-commissioned reports on the SIB, with the second report examining MoD roles and required technical resources.[28] The study began by acknowledging the drastic loss of MoD's submarine expertise during the 1990s, and posited ways in which the Government could maximize its assets in managing future submarine design, build and support.

The perceived need to reduce the overhead cost of MoD's technical bureaucracy was the driving factor in the loss of submarine technical expertise. Whilst the resultant haemorrhaging of talent is now acknowledged as a mistake, the desire to streamline MoD's procurement and support infrastructure and staff remains. The challenge now is to place MoD's assets at the points in the CADMID[29] cycle where they can effect the most positive influence on submarine procurement and support. Industry's view, as expressed to the HCDC in late November 2006, was that MoD 'has a leading role in a solution, which involves major rationalization of organizations, facilities, programmes and processes'.[30] In pursuit of a more efficient industrial base, there is a desire to reduce duplication of effort across industry and between industry and MoD and the prospect of through-life support increasingly being contracted to industry may prompt a reshaping of MoD's submarine community. The build sector has cited a need for greater MoD involvement at the initial design stage, which may provide substantive work to sustain MoD technical capacity whilst reducing acquisition and through-life costs.[31]

To this end, Director General Submarines now has oversight of MoD's Submarine Support, Attack Submarines, Nuclear Propulsion, Nuclear Weapons, Strategic Systems, NATO Submarine Rescue, Nuclear Movements and Strategic Options Integrated Project Teams (IPTs), as well as the safety and commercial aspects of submarine procurement and support. Further input is received from the Equipment IPTs (EIPTs), located within the Director General Ships organization, such as Marine Auxiliary Systems, Marine Electrical Systems and Naval Electronic Warfare. A significant struc-

[28] RAND Europe, *The United Kingdom's Nuclear Submarine Industrial Base, Volume 2: Ministry of Defence Roles and Required Technical Resources*, 2005, available from <http://www.rand.org/pubs/monographs/MG326.2/>, accessed April 2007.

[29] Introduced under the Smart Acquisition initiative, CADMID refers to the successive phases a defence programme moves through – Concept, Assessment, Demonstration, Manufacture, In-service and Disposal.

[30] HCDC, *The Future of the United Kingdom's Strategic Nuclear Deterrent*, *Op. Cit.*, p.26.

[31] *Ibid.*

tural change is occurring with the move to class-based support arrangements for the surface fleet, which is gradually moving surface-fleet staff out of the EIPTs. This depopulation may eventually result in the EIPTs being increasingly focused on submarine requirements.

The work on pricing of Astute Boats Two and Three was criticized by the HCDC for placing MoD at unlimited financial risk until pricing was completed.[32] Although the Committee's view was understandable and entirely appropriate given its remit, the HCDC did neglect the positive impact that the collaborative pricing has had on MoD-industry relations. Through the work conducted between the MoD's Pricing and Forecasting Group (PFG) and BAE Systems Submarine Solutions, MoD has gained visibility of the cost drivers and overheads of the prime contractor's business, while BAE Systems similarly has benefited from understanding MoD's funding constraints and the wider political context. It is of vital importance that this openness is sustained and expanded across the industry. If the reform of the industrial landscape sought by DIS is to be achieved, MoD will have to maintain a broad understanding of how the key suppliers interact, as well as the cost drivers which each supplier faces individually. The ideal result would be a consolidated view of the industrial base that accommodates the demands of each supplier within the broader requirement for reforms that prioritize long-term sustainability over short-term commercial gain.

In tackling the commercial challenges within the industry, it is vital that the Government understands some of the pressures facing the companies within the SIB. Rolls-Royce derives only £250m of its £7.3bn turnover from its submarine operations, while as recently as 2004 BAE Systems was considering the sale of its submarine business as non-core activity.[33] For companies whose business is expanding in other markets, there is a risk that the submarine-related business units will face growing pressure to increase margins and contribute more revenue to the group, a target somewhat at odds with the collaborative approach being sought in the SIB. Similarly, Alstom, manufacturer of the turbines for UK submarines, cite the submarine industry as non-core to their business.[34] In each of these cases, it is important for MoD (and wider Government) to understand the sometimes tense relationship between the overall corporate entities and their specialist business units who contribute to the SIB. Aside from providing a predictable workload for industry to plan towards, there is a need for ongoing engagement between MoD, wider Government (notably the Department of Trade and Industry [DTI] and the Treasury) and the corporate entities that contain the companies within the SIB.

Babcock's recent acquisition of DML has presented the MoD with challenges and opportunities as it seeks to implement the principles of DIS. The consolidation of submarine support and the management of the two current submarine base ports by one company is certainly in line with DIS and ought to achieve gains in efficiency. Although the division of the support sector under Babcock and build under BAE Systems would appear to contradict the DIS aim of a 'single industrial entity' covering build and support, cohesion may still be achieved if the long-term value of MoD-industry partnering can be firmly established. However, the risk of competition replacing collaboration remains, and MoD's role in managing the

[32] HCDC, *Defence Procurement 2006*, *Op. Cit.*, p.19.

[33] 'BAE shares rise after sales talk', *BBC News*, 26 April 2004, <http://news.bbc.co.uk/1/hi/business/3660139.stm>, accessed April 2007.

[34] Jim Morrison (Unit Managing Director, Alstom Power Steam Turbine Retrofits UK), HCDC, *The Future of the United Kingdom's Strategic Nuclear Deterrent*, *Op. Cit.* Ev.3.

ongoing relationship between the companies of the SIB will be of vital importance.

The Design and Build Sector

Every significant study on the SIB has sought to define how unique this particular trade is. Defence economist Professor Keith Hartley summarizes the SIB as:

> *a unique UK defence industry in that it produces one product for a single buyer (there are no exports) and it comprises a small number of highly specialized facilities … Critical skills and facilities needed for nuclear submarines comprise design staff with submarine expertise; nuclear site licenses for the [nuclear reactor] core facility, for construction and for re-fit; and highly specialized industrial facilities which have no alternative use … The need for nuclear site licences imposes major barriers to new entry, competition and international collaboration.*[35]

Although the complexity of nuclear submarine building was repeatedly emphasized during the Trident renewal debate, there remains a very poor understanding of what this means in practice, most prominent in one analyst's assessment that a 'copy' of the Vanguard class could be constructed in five years.[36] Within the build sector, there is already an awareness that seventeen years to design, build and commission a new class of SSBN – particularly one that is required to be substantially cheaper to support – is a stern challenge for an industry only recently recovered from the crisis days of the Astute programme up to 2003.

The submarine design and build sector is concentrated on BAE Systems' Barrow-in-Furness shipyard but encompasses the company's combat systems sites at Farnborough, Ash Vale and Weymouth as well as a supply base distributed across the United Kingdom, including the specialist design and manufacture conducted by a range of first tier suppliers. Foremost among these are Rolls-Royce Submarines (who produce and support the nuclear steam raising plant, or NSRP, from their facility in Derby), Weir, Strachan & Henshaw (who provide the weapons handling and launch systems, or WHLS) and MacTaggart Scott (suppliers of non-hull penetrating masts).

Whilst the future requirement of SSBN-F remains important, the immediate priority is cost reduction for the remaining Astute class boats. At the time of writing, the contract price for Astute Boats Two and Three is finally being agreed between the MoD and BAES. Once complete, this will enable orders for submarine hulls in due course. MoD's announcement, on 21st May 2007, of a contract for initial build work on Boat Four with final contracts expected in late 2008, underscores MoD's confidence in the nature and structure of its relations with SIB.[37] Whilst the current emphasis is being placed on reducing through-life costs, the remainder of the Astute programme will be subject to demanding unit cost reduction targets, cited as 30 per cent on Boat Four and 45 per cent by Boat Six, requiring continual improvement across the programme.[38]

The tiered approach to cost reduction is matched in certain areas by innovative approaches to spiral development. The MoD-industry combat systems 'rainbow team' at BAE Systems' Ash Vale facility is an example.[39] The thirty-strong team comprises the principal suppliers – BAE Systems, Thales, Insyte and Qinetiq – as well as a range of Small and Medium Enterprises (SMEs) and members of the Attack Submarines IPT (ASMIPT). The rainbow

[35] Keith Hartley, 'The Economics of UK Nuclear Weapons Policy', *International Affairs*, (Vol.82 No.4, July 2006), pp.682-683.
[36] Paul Ingram, 'Decisions over the future of British Nuclear Weapons', BASIC Green Paper, British American Security Information Council, December 2006, p.6.
[37] MoD. 'Royal Navy to get New Attack Submarine', Press Release 102/2007, 21 May 2007.
[38] 'Team aids affordable sub drive', *Wavelength – News for BAE Systems Naval Businesses*, Sep/Oct 2006, p.7.
[39] *Ibid.*

team approach has been able to identify cost savings which exceed the 30 per cent cost reduction target by 10 per cent. The re-design for Boat Four involves a COTS-based solution of common equipment cabinets, operator consoles and processing technology, with further advances into open-architecture systems planned for Boat Six onwards. The benefits are to be developed across the Astute build programme with some elements cascaded down to the first three boats in the class as well as the Trafalgar and Vanguard classes, with the end goal of a common flotilla-wide combat systems architecture. The collaborative approach is formalized by a team charter, binding the participants to technical data sharing and common goals.[40] Whilst the application of this principle to the wider industry is a more complex task, the rainbow team approach suggests that closer collaboration can increase affordability and guarantee future orders.

The pursuit of innovative ways of reducing cost and improving performance has a broader aim: to maintain the design skills necessary to integrate a product as complex as a nuclear submarine. Several commentators and industrialists have cited the problem of a 'skills gap', where a lack of challenging work leads to atrophy of design and manufacturing skills either through lack of practice or staff leaving the business. Recently there has been a tendency for this notion to be scoffed at as industrial lobbying for the sake of filling the order book. Whilst often discussed, what is the actual impact of a 'skills gap' and how can it be mitigated?

The submarine sector has recent experience of what a gap in design and build efforts can involve. A case in point is the Upholder class conventional submarine (SSK), now in service with Canada as the Victoria class. While the build of the first-of-class at Barrow went largely according to plan, Cammell-Laird, responsible for constructing the final three boats, had moved from construction of major surface vessels to building an SSK so advanced that it was likened to 'an SSN without the reactor'.[41] The gap from the Mersey yard's previous submarine build was some twenty years, apparently long enough for the tacit knowledge accumulated in the production workforce to have been lost. This was compounded when Cammell-Laird struggled to recruit experienced welders and accordingly suffered quality control problems. Having estimated a build time of four to four-and-a-half years, the Cammell-Laird boats ranged from five-and-a-half to over six years between contract award and delivery.[42]

More recently, Rolls-Royce Submarines has experienced the impact of a skills gap in its production workforce, one which took three years and £8m to bridge. Rolls-Royce's experience suggests that the crucial areas affected are manufacture and build, rather than concept and assessment. It is often the application of knowledge to physical production that poses the greatest challenge, in this case knowledge of materials and chemistry being particularly critical. Without sufficient quality in initial production of a nuclear submarine, very costly problems may arise many years later, meaning that quality from the outset is of vital importance. In turn, this requires a high level of technical skill that is difficult to maintain without substantive new work. Ultimately, the potential impact of a skills gap has to be quantified in terms of risk to the project. Quite simply, the longer a skills gap exists the greater the potential impact on schedule, cost and performance. If SSBN-F is assumed to be the next major design effort, it is apparent that the opera-

[40] *Ibid.*

[41] Comment received in author's conversations with individuals involved in the design and operation of the Upholder/Victoria class.

[42] Keith Hartley, *The UK Submarine Industrial Base: An Economics Perspective*, available from <http://www.york.ac.uk/depts/econ/documents/research/uksib.pdf>, accessed April 2007.

tional demands on the national nuclear deterrent cannot be compromised because a lack of design skills fifteen years previously built an unmanageable level of risk into the project.

At an operational level, the means of preventing a skills gap depends on maintaining a workload sufficient to exercise the abilities of engineering and production staff whilst planning for the succession of skilled individuals. The latter activity has long since been implemented in the industry, but it is contingent on sufficient new work so that designers can learn their skills throughout the whole development cycle of a product or system. To some extent, it could be argued that the problem is overstated, given that much of the equipment is only slightly evolved from one class of submarines to the next. This, however, would be to ignore the fact that the design of any new submarine is a challenging task by virtue of the density of equipment contained within the pressure hull. This is a space in which nearly 100 men must live and work alongside a highly advanced nuclear propulsion plant, several tons of high explosives – and, in the case of an SSBN, nuclear warheads – and surrounded by high-energy electrical and mechanical systems, all whilst submerged for months at a time. The complexity of the systems required to support this means that a change to one system can have a substantial impact on multiple separate systems across the boat, all of which demands a level of systems integration skill that can only be practiced by new design work.

Following Parliament's vote in support of retaining the nuclear deterrent, the concept phase for SSBN-F will extend over 2007 and 2008, indicating that a skills gap has been averted by the decision to renew the deterrent. However, the manner in which design progresses after the concept phase will be contingent upon MoD clearly establishing its priorities relating to the level of innovation required, the location of Design Authority between customer and prime contractor and the incentives for the build sector to design for through-life cost reduction. The means by which this is to be achieved are unclear at present, but may include a mechanism where savings realized by one principal company within the enterprise are distributed amongst all. The difficulty of establishing the boundaries of such an initiative are obvious in an industry as interdependent as this, but arguably the level of contractual risk (which may take into account aspects such as the maintenance of a nuclear site license) could be used as a yardstick to determine which companies fall within such a collaborative arrangement. The differing levels of profit margin across the principal companies also presents a challenge, particularly in the context of their contribution to wider corporate entities as discussed above. A recent report by PriceWaterhouseCoopers stated that, 'Our analysis shows that successful lower-tier suppliers can be significantly more profitable than the primes, due in part to their ability to capture the value of specific proprietary technology and, in some cases, the associated aftermarket'.[43] This is certainly the case in the SIB, where the unique technology and demands of sovereign supply lead to numerous companies being monopoly suppliers. On a larger scale, Babcock's acquisition of DML arguably has provided BAE Systems with a near-peer competitor in the submarine and ship support market. It remains to be seen whether these companies (the heads of the submarine build and support sectors) will agree an LTCA enabling a through life approach to delivering UK submarines. Whilst increasing profit margins makes business sense, the need for long-term collaboration in the SIB dictates that some commercial

[43] 'Flying High: Aerospace and Defence M&A', PriceWaterhouseCoopers, London, 2007, <http://www.pwc.com/extweb/pwcpublications.nsf/docid/ABA0DE44AF1CE2BA852572B2000E82B3/$File/flying_high.pdf>, accessed April 2007.

gain may have to be sacrificed by individual companies for the good of the industry. Developing a culture where this can occur is a long-term challenge for the Government and industry alike.

International Collaboration

Beyond domestic collaboration, the design and build sector has a real opportunity to benefit from international collaboration, almost entirely with the United States.[44] The US submarine build programme, devoted at present to the Virginia-class SSN, faces a similar long-term challenge to the UK SIB. The US programme is committed to reducing the build cost of the each Virginia-class boat to $2bn by 2012, from a current level of $2.4bn.[45] Although the US historically has been more willing to sell than collaborate in submarine technology (possibly because of political and economic reluctance to expose its indigenous industry to external competition), the pressures on each country's submarine programme may foster greater openness from the US. As with Astute, Virginia suffered early in its build from insufficiently mature design information, and the US Navy is already aware that such a situation must be avoided in future procurement. Aside from Virginia, the US expects to build a new SSBN in time for deployment around 2029, which means that US involvement in Britain's SSBN-F programme could progress the maturity of US design practices in advance of a firm order for their next SSBN. Assuming US willingness (strong in the Navy and industry, but potentially limited by Congressional opposition to technology transfer), it is up to Britain's SIB and MoD to decide the appropriate level of collaboration, particularly given that the UK programme must not become merely a de-risking exercise for its US counterpart.

Collaboration to maintain expertise, rather than direct supply of parts and systems, appears to offer the greatest potential benefit for the UK SIB, as identified in MoD's Defence Technology Strategy (DTS).[46] Despite the currently favourable exchange rate, past experience suggests that on a like-for-like basis, the US is a more expensive place to acquire material and technology than the UK or Europe. Collaboration could also hold great significance from the level of overall transatlantic relations, to the specific working practices and technologies involved in submarine construction. The US programme is well advanced in terms of reducing unit cost by innovative build strategy, developments which have aided the Astute programme since 2003 through industrial co-operation between BAE Systems and US submarine builders Electric Boat. Furthermore, the US approach to open-architecture combat systems offers a valuable reference point as MoD seeks a similar solution, and works with a part of the industry that has historically tended to develop complex, bespoke combat systems of closed-architecture. The willingness of the US to share their combat systems expertise has recently been demonstrated in the Replacement Combat System (RCS) programme for the Australian Collins class SSK which involved 'unprecedented access to US technology and capability'[47] through collaborative work since 2001. However, it must

[44] Whilst some measure of dialogue on supply chain fragility has occurred with France, further co-operation is precluded largely by the terms of US-UK co-operation defined by the 1958 Mutual Defence Agreement (MDA) on the use of nuclear technology for defence purposes, but also by both nations' broader desire to remain strategically independent of each other for their deterrent capability in particular. As one British official commented to the author, 'we can only be in bed with one partner at a time'.

[45] United States Government Accountability Office, Report to Congressional Committees, Defense Acquisitions: Assessments of Selected Weapons Programs, GAO-07-406SP, Washington, March 2007.

[46] MoD, *Defence Technology Strategy*, October 2006.

[47] Prime Minister of Australia Media Release, 'HMAS Waller – Replacement Combat System', 3 April 2007, <http://www.pm.gov.au/media/Release/2007/Media_Release24232.cfm>, Accessed April 2007.

be noted that there is a gap between US willingness to sell their systems and components and the truly collaborative sharing of expertise that would be beneficial to both countries.

With the UK SIB under pressure to deliver highly capable, yet affordable submarines, and with the US programme tasked with cost-reduction and de-risking of new technology, there is real potential in further collaboration on both the state-to-state and business-to-business levels.

The Support Sector

The balance between unit-cost and through-life cost reduction is perhaps the most pressing issue facing the submarine industry as it moves forward, but the results will not become fully apparent for a number of years. For the moment, the support sector has other challenges – rationalizing the facilities involved and ensuring that the Navy can generate the required force levels from a smaller flotilla.

The submarine support sector is centred on the re-fit and nuclear fuel handling facilities of the Devonport Royal Dockyard, now owned by Babcock, who also operate the Faslane submarine base in a partnering agreement with MoD. The business of submarine support is principally divided between Rolls-Royce, Babcock and BAE Systems, along with the Submarine Support Management Group (SSMG) (a joint venture between DML, BMT and SEA).

Structure

Babcock's recent acquisition of DML has dramatically re-shaped the support sector. When the bids for DML sale were invited, BAE Systems was widely expected to acquire DML and consolidate both build and support under one BAE-led construct, thereby rationalizing the SIB in line with the principles of DIS. Due to perceived concerns at the prospect of a BAES monopoly across the UK SIB, MoD sought to ensure that BAES partnered with another group, with possible partners being private equity firm Carlyle, Rolls-Royce and Babcock International. With the favoured route seemingly being a joint venture (JV) designed to place the Barrow-in-Furness build facility and Devonport support facility in one company, BAE Systems and its potential partners were unable to agree commercial terms. BAES subsequently declined to submit a final bid, leaving Babcock to finalize its winning bid.

Babcock already operates the Faslane submarine base under a £875m public-private partnership (PPP) contract with the MoD. The recent extension of this contract to 2013 was perhaps indicative of the disjointed approach taken by the DLO and DPA as they were at the time, but while this was seen in some quarters as miscommunication, the focus on consolidation being promoted by Director General Submarines should ensure that any further contracts for submarine support are let as part of a cohesive scheme in which Babcock will be the principal player. Although Babcock's capabilities will be expanded by the DML acquisition, the company will nonetheless need to engage its industrial partners in future support work. It remains to be seen just how collaborative this approach will be and, to a large extent, the sustainability of the SIB depends on its outcome.

Facilities

Babcock is well-placed to expand on its operations at Faslane, already set for development since being designated as the sole UK submarine base once the Devonport-based Trafalgar class retires in the late 2020s. Faslane is also likely to benefit from some of the £2-3bn earmarked for infrastructure modernization for the renewed nuclear deterrent, which is likely to encompass modernizing the centrepiece of the Faslane base, the shiplift capable of hauling the 16,000 ton Vanguard boats from the water for maintenance. The view from some financial analysts is that Faslane remains underutilised as

a facility, and that programmes such as the RAMP[48] of HMS Torbay at Faslane in 2007 should mark a shift towards Faslane as a submarine maintenance facility. However, whilst the expertise and facilities to conduct many aspects of maintenance exist at Faslane, the deep overhaul of submarines, as well as any fuel handling activity, can only be conducted at Devonport. Furthermore, the use of the shiplift is heavily prioritized for the SSBN flotilla due to the demands of maintaining one boat continuously at sea, which limits the use of the facility for SSN maintenance.

Regarding the facilities which support the flotilla, MoD commented in June 2006 that it is 'open to proposals for alternative sites where there are economic, or other, advantages [but] given that significant investment has already been sunk in various facilities around the country, it is difficult (but not impossible) to construct a persuasive case to re-site the associated activities'.[49] However, the terms of reference of the ongoing Naval Base Review all but specified that Devonport will remain the centre for nuclear submarine re-fit[50] and the anticipated savings from Babcock's operation of Rosyth, Devonport and Faslane should support this aim, although the expectation from financial analysts is that Devonport could see substantial rationalization of facilities, staff and working practices in order to improve the efficiency of submarine and surface ship support. Increased efficiency will be required to offset the decline in submarine refuelling work that will occur when the last of the Trafalgar and Vanguard Boats complete their major overhauls in the next decade. Clear decisions on the structure of the SIB also will influence the direction taken with regard to surface ship build and support, with Rosyth and Devonport likely to take an increasing amount of work from Portsmouth. Decisions on submarine-related infrastructure cannot be separated from wider questions of maritime industry rationalization that will need to be answered in the coming years. With the industrial workload expected to decline following construction of the Future Aircraft Carrier (CVF), the Military Afloat Reach and Sustainability (MARS) programme and the replacement of the Type 22 and 23 frigates, at least one shipyard in the UK is likely to cease operating in the next decade.

Contracting

The introduction of Contracting for Availability (CFA), effective in the fixed wing domain through initiatives such as the ATTAC Tornado support contract,[51] faces significant challenges in the submarine domain. While French shipbuilder DCN claims to operate its submarine support on a CFA basis, the actual operating structure appears little different from the way current Royal Navy submarines are supported, with availability being achieved in terms of timely completion of re-fit rather than the contractor being incentivized to achieve a certain level of availability or sea days per year.

The notion of providing a target level of availability would in theory be appealing to a flotilla that is under pressure to generate the required number of hulls from a smaller force. The reality, as so often with submarines, is rather more complicated. In comparison to surface ships, submarines spend a considerably greater portion of their support time in deep upkeep (as opposed to fleet time engineering), which greatly limits their state

[48] The acronym RAMP stands for 'Revalidation and Assisted Maintenance Period'. This is a nine- to twelve-month refit programme, part of which is conducted in dry dock, to conduct capability upgrades and certify the boat for continued operation. Although the RAMP habitually has been conducted at the submarine's home port, HMS *Torbay* will undergo her RAMP at Faslane rather than at Devonport, in order to spread the work load between the two bases.

[49] Richard Scott, 'Can UK Submarine Industrial Base Retain Critical Mass?', *Op. Cit*.

[50] MoD, *Naval Base Review Terms of Reference*, <http://www.mod.uk/NR/rdonlyres/B11F1691-A6BD-4973-97C2-44A2B9B8954D/0/20060803RNBRTLTORacq2Ver5_2_.pdf>, accessed April 2007.

[51] The acronym ATTAC stands for 'Availability Transformation, Tornado Aircraft Contract'.

of readiness. Furthermore, the overriding imperative of nuclear and platform safety introduces a higher level of caution than is the case with surface ships. The reactor faults discovered on HMS Tireless in 2000, which temporarily withdrew most of the flotilla from service, demonstrate the level of contractual risk involved in support of nuclear submarines, which could be an impediment to any privately financed CFA arrangement. Further to the safety aspects of the nuclear propulsion plant, a submarine depends on a high level of safety assurance and redundancy in order to safely operate. The demands this would place on a commercial CFA arrangement could be sufficiently onerous to discourage any contractor from taking on the inherent risk at an affordable price. A second major impediment to CFA is the availability of crews to man the submarine, as discussed below in the context of Through-life Capability Management.

The closest approximation of CFA in the UK SIB would appear to be Rolls-Royce's proposed Flotilla Reactor Plant Support (FRPS) contract, which is expected to be concluded in mid-2007. FRPS is an incentivized contract for the support of the reactor plants installed in the current flotilla and the forthcoming Astute class. Informed by Rolls-Royce's experience with the Vulcan shore test facility at Dounreay, the aim of FRPS is to reduce support costs and improve availability of the flotilla's reactor plants. Savings realized through the tiered incentives in the FRPS contract accrue to MoD and to Rolls-Royce. Whilst this would be expected in most industries, the complex interfaces between MoD, Rolls-Royce, BAE Systems and DML result in dispute over how the savings from incentivized contracts should be distributed. As discussed above in the context of the design and build sector, the relative level of profit made by the principal companies of the SIB remains a matter of contention within the industry.

Another important contract due to be concluded in 2007 is the BAE Systems-led Transforming Submarine Support - Design (TSS-D), due for Main Gate approval in late 2007. This contract will consolidate technical support for the Astute, Swiftsure, Trafalgar and Vanguard classes under a common arrangement. At present, the latter three classes fall within the remit of SSMG. The TSS-D contract is intended to replace SSMG from early 2008, and will implement a shift in culture from an 'input-led' system – as is the case with SSMG – to an 'output-led' approach where industry's technical authority is provided as a support service to MoD's Submarine Support Integrated Project Team (SUBIPT). The contract would see a BAE Systems-led group become the Technical Authority for the UK submarine classes, and targets a shift from the support contractor delivering set work packages in line with MoD orders to the support contractor providing qualitative technical analysis with a 'whole-boat' view. A perceived disadvantage of the current SSMG construct is that it separates materials supply from maintenance activity; suppliers interface with the EIPTs for the former, and SSMG for the latter. Although TSS-D is based on provision of technical advice, the contract seeks to align suppliers with the waterfront support in a more direct manner. Ultimately, the intent is for a supplier who provides materials and maintenance support to deal with one organization at all stages from initial design, through procurement, manufacture, installation and support.

While it may be accommodated within a flotilla-wide support arrangement, the Astute class requires an altogether different approach to support, which will place new demands on the sector. The principal difference between support of previous classes and Astute is that the new SSNs will not require refuelling of the reactor core during their lives. The Swiftsure, Trafalgar and Vanguard classes have all required refuelling around every twelve years of operation, whereas Astute's Core H will last for the twenty-five year design life of the boat.

Astute is still planned to undergo major re-fit twice in twenty-five years, but these refits are planned to be at one third and two-thirds of service life. Undoubtedly of benefit in cost, availability and environmental terms, this will place a premium on the nuclear safety skills and facilities at Devonport, as the boat will for the first time be undergoing an extensive re-fit with an active core onboard. Astute is also expected to achieve a significant improvement in availability over previous classes. The requirement for this was defined at the outset of the programme in the late 1990s, but has perhaps become even more significant given the smaller flotilla that the Astutes will operate within and eventually comprise. With a wide range of platform design changes, improved reactor performance and a programme of reliability-centred maintenance, the expected increase is from 69 per cent availability on the Trafalgar class to 75 per cent on the Astute class.[52]

The fragmented nature of the submarine support sector is due largely to the turbulent recent history of the UK's maritime industry, but contracts such as TSS-D and FRPS promise to revitalize the support sector and make more efficient use of industry and MoD's skills. Nonetheless, there appears to be greater conflict than the MoD would like within this sector of the SIB and it is unclear whether this will extend to renewed competition amongst the principal companies. Almost irrespective of the DML sale, the support sector is where progress on the culture and behaviour sought by DIS is perhaps the hardest to implement.

Bridging the Sector Gap – Through-Life Capability Management

In assessing the manufacturing and skills base required to support a renewed nuclear deterrent, the HCDC professed to being 'concerned that insufficient attention has been given to the costs of through-life support.' The report continued:

> *While we understand that DML is not a supplier to the Astute programme, it seems odd and regrettable that the company responsible for through-life support on the UK's nuclear-powered submarines has had so little input into the design of the class. If the affordability of the submarine programme is to improve, it is essential that through-life costs are taken into consideration at the initial design phase.*[53]

While the entire SIB accepts the imperative of reduced through-life cost, the trade-offs between unit cost and through-life support, due to a number of industrial and platform-specific factors, are uniquely challenging in the submarine context, as illustrated in the Astute programme.

Particular new build techniques such as modular build and vertical outfit,[54] which have accelerated the Astute build and helped bring the programme on track, may yet complicate the upkeep of the submarines once they are in service. The density of equipment within any submarine is such that removal and replacement is exceptionally difficult, and the use of large modular structures may introduce further challenges to major refit activity. On the other hand, access and removal of equipment has been prioritized in the Astute design, including enlarged hatches and direct access to the main machinery space via logistics and escape trunks.[55] Although the support sector is now gaining better visibility of the design (and is broadly content that such issues are manageable) as long as the structure of the industry and its contracting strategies continue to divide responsibility for build and support between separate and competing entities, the problems of building for through-life cost reduction appear likely to continue.

[52] HCDC, *Defence Procurement 2006*, *Op. Cit.*, Ev.55.
[53] HCDC, *The Future of the United Kingdom's Strategic Nuclear Deterrent*, *Op. Cit.*, p.27.
[54] See Murray Easton, 'Future Submarines', *RUSI Defence Systems*, (Vol. 9, No. 2, Autumn 2006), p.45.
[55] HCDC, *Defence Procurement 2006*, *Op. Cit.*, Ev55.

Whilst the competing demands of build and support are intrinsic to a through-life view, the TLCM concept goes much further, encompassing all of the Defence Lines of Development (DLoDs) – training, equipment, infrastructure, information, personnel, logistics, organization, and concepts and doctrine. Of particular relevance to a platform as technically advanced as a nuclear submarine is the performance of the crew, and their training and retention forms a key part of the TLCM approach to submarines. Several submarine crew roles have already been identified as 'pinch points' by the National Audit Office,[56] and the management of career progression and shore time for submarine crews is a critical activity for the Royal Navy. Although the SSBNs have two full crews each in order to maintain the required operating tempo, this is not yet the case with the SSNs. The deployment pattern for the Royal Navy's SSNs has changed greatly from the regular North Atlantic operations of the Cold War. SSNs increasingly are deployed on much longer cruises for a greater proportion of the year, leading the Navy to conduct rotations of certain key roles on the submarine at intermediate port calls. Beyond a certain point, the benefits of improved hull availability can only be realized if dual crews are adopted for the SSNs, but this prospect remains unlikely due to the even greater demand for recruitment and retention, as well as the increased through-life cost. Although improved hull availability potentially places greater strain on crewing, it does have the potential benefit of hulls being available for dedicated training purposes, which is vital if British submarines are to be crewed to the their normal high standard. Political consideration of the cost of operating submarines ought to take into account manning and training requirements, rather than just the technical matters of hull availability and capability.

For the design and build sector, there is a challenge to make submarines a more habitable environment for crews who, with reduced force levels and the resultant need for greater hull availability, will spend longer periods continually at sea. Surface ships such as the Type 45 destroyer place great emphasis on crew habitability, and while submariners are traditionally seen as more stoic than their surface counterparts, more space onboard will always be welcome. The training requirements of an increased use of COTS technology, particularly for combat systems, will also be carefully managed so as not to complicate operator and maintainer training across the flotilla.

COTS also presents a through-life challenge in terms of managing capability insertion, but working practices already in place give a high confidence that this aspect of TLCM will be managed successfully. The aforementioned combat systems rainbow team, the success of the Swiftsure and Trafalgar-class upgrade programme, and the unity provided under the DG Submarines organization should ensure that capability insertion maximizes the value derived from the flotilla. To an extent, the insertion of improved technology to the flotilla is dependent on a focused programme of R&T, also a consideration of the TLCM approach. Particularly important is the need to de-risk technology that may contribute to the success of the SSBN-F programme, which may yet include a new reactor plant designed for through-life cost reduction and improved safety, as well as increased use of electrical actuation in place of hydraulic systems. A truly funded and therefore focused approach to R&T has arguably been lacking since the start of the Astute programme, but the prospect of SSBN-F should rectify this situation. Central to the development of technology will be MoD's Director Equipment Capability (Underwater Effect) or DEC

[56] HCDC, 'Ministry of Defence Annual Report and Accounts 2005-06', Second Report of Session 2006-07, December 2006, HC 57, Ev 28.

(UWE), who will ensure that balanced decisions on future capability are made.

The final stage in the CADMID cycle, disposal, also presents unique challenges in the submarine context largely relating to the nuclear propulsion plant. Unlike the Royal Navy's surface ships, which may be refitted for sale to a foreign navy, a nuclear submarine becomes a liability as soon as it is decommissioned. The UK currently stores fourteen decommissioned nuclear submarines afloat at Rosyth and Devonport pending final disposal. The long-term intent, announced by Environment Minister David Miliband in 2006, is to store irradiated material from decommissioned submarines in deep geological storage between 200m and 1000m underground. Despite the fact that current decommissioning plans will exhaust the available afloat storage capacity over the next ten to fifteen years, confirmation of a final storage site is not anticipated for a number of years. An interim solution under the MoD's Project ISOLUS[57] would see the bulk of the submarine's structure dismantled for recycling and the sealed reactor compartments (RCs) stored or packaged as waste. This initial work may be conducted at the current storage sites and could help to alleviate the shortfall in refuelling work conducted at Devonport. The design and build sector is also placing greater emphasis on disposal at the design stage, seeking innovative approaches to reduce the amount of metal cutting involved in removing the irradiated RC.

Threats and Opportunities

The recent HCDC hearings highlighted that the prolonged technical effort of designing, building and supporting nuclear submarines was subject to the retention of key skills within the industry. The committee also considered the competing demands on the skilled resource that the SIB requires, most notably the civil nuclear industry over the coming decades. The nuclear submarine industrial base already contains a high proportion of the most skilled nuclear engineers in the country. As such, it is already the principal sector that the civil nuclear industry recruits experienced staff from. But the level of skilled engineers within the SIB also presents a considerable opportunity for the companies involved.

BAE Systems, Rolls-Royce, DML, Babcock, and Weir, Strachan & Henshaw have significant expertise in nuclear engineering and nuclear safety case delivery. Each recognizes the danger of losing key skills entirely to the civil sector, which is likely to be able to offer higher remuneration than a defence-related contractor, but each also recognizes that competing for work in the civil sector could deliver additional business and preserve their own nuclear engineering skills. The advantages of competing for civil work include the maintenance and development of skills, additional revenue and levelling of the demand that is involved even with the targeted production 'drumbeat' that would see a boat launched every twenty-two months.

In theory, the Government might be expected to have a role in mediating this demand, and to some extent it has supported efforts by Cogent, the Sector Skills Council,[58] to quantify and predict resource demand such that it does not impede either civil or military programmes. However, the companies within the SIB are largely content that by using their skills to compete for civil nuclear work, the requirements of each sector can be fulfilled by market demand, without need for

[57] Interim Storage of Laid-Up Submarines. See <http://www.isolus.org.uk>.

[58] Cogent is the Sector Skills Council (SSC) for the Chemicals and Pharmaceuticals, Oil and Gas, Nuclear, Petroleum and Polymer Industries. It is one of twenty-five SSCs which, together with the Sector Skills Development Agency (SSDA), form the Skills for Business Network (SfBN).Cogent is licensed by the Government to provide employers in its sector with the opportunity for coherent leadership and strategic action to meet their skills needs.

intervention from MoD or the DTI.

While nuclear engineering skills may be distributed by market dynamics, this approach may not succeed in other crucial aspects of submarine construction. Several areas of the submarine, particularly on an SSBN, depend upon large, high-grade castings and forgings, which are also in high demand worldwide for the construction of new civil nuclear power plants. The particular problem is that only two companies are in a position to supply these castings to the UK submarine programme. The potential for cost inflation or even a lack of availability may yet require a longer-term view from the UK Government, particularly in terms of authorizing funding sufficiently far in advance to ensure timely supply. The potential impact of delayed delivery is serious, and industry is simply not able to entirely mitigate the risk involved. In this case, as in many varied aspects of future submarine design, build and support, long-term partnering between Government and industry is vital to ensure that the UK can continue to field this uniquely capable platform.

Conclusion – Establishing an Affordable Minimum Capability

ICEX 2007 was an ideal showcase for the capability of the SSN: able to operate autonomously under-ice, having rapidly transited from its home port and performing a range of roles from arctic warfare exercises to scientific research under the polar ice cap. In the ensuing media coverage, it was heartening to see at least one article explaining the tasks performed by this most elusive and secretive of platforms, one whose roles and capability are rarely acknowledged in public.[59]

Ultimately, nuclear powered submarines provide a unique and highly relevant defence capability, but they do so at what is perceived to be an unsustainable level of cost. In comparison to other capability areas, nuclear submarines suffer criticism because their through-life costs cannot be absorbed or masked by other programmes as can be the case with fast jets or large standing land forces. Nonetheless, the Royal Navy can ill afford to lose its submarine service at a time when its unique capabilities are increasingly in demand. To postulate the loss of the submarine service is not an exaggeration and the fact that UK submarine operations could become unsustainable has undoubtedly catalysed the dramatic change in the submarine enterprise since 2005. But the drive to reduce costs across the enterprise must not be so aggressive as to constrain the future viability of the SIB, nor the submarines that it builds and supports.

For the SIB, the way forward detailed in the Defence Industrial Strategy had a clear purpose. Recognizing that competition in such a unique industry is not necessarily conducive to sustainability, DIS sought partnering within the SIB and between Government and industry. DIS was also correct to identify the need to work closely with the established companies at the head of the industry as well as the supply base that supports them. With Babcock's acquisition of DML rapidly reshaping the industrial landscape, there is perhaps a risk that competition will usurp collaboration within the SIB. Were this to occur, the DIS aim of a single industrial entity could be fulfilled in name only, and true cohesion would remain elusive. Accordingly, the principles of DIS will require constant reaffirmation if it is to succeed in the long-term.

The efficiency of the submarine enterprise must be balanced against the need to retain a viable level of industrial capacity and military capability. Those in MoD and industry responsible for the design, build, support and operation of the Royal Navy's nuclear

[59] Lucy Rodgers, 'Key Role of UK's Underwater Hunters', *BBC News*, 22 March 2007, <http://news.bbc.co.uk/1/hi/uk/6478915.stm>, accessed April 2007.

submarines face something of a capability quandary. On the one hand is the perception that with a flotilla of only seven or eight SSNs, the UK has reached the lowest possible level of capability in terms of the number of hulls available for operations worldwide and that each boat must offer greater advances in capability to account for fewer hulls. On the other, there is the perception that current boats are being built to an overly stringent set of requirements, that they are 'gold-plated'. The cost-capability trade-off will be accompanied by trading unit build cost against through-life support cost. It is this demand for a more integrated and balanced approach that has driven the Maritime Industrial Strategy and the subsequent restructuring of the industry. The optimization of submarine design for through-life cost will necessitate an occasional reappraisal of defence standards and accepted practices in submarine construction. The end result may prove to be a conservative, evolutionary design, but the more radical alternatives must at least be considered where appropriate.

Ultimately, MoD and industry must seek a mutually agreed minimum level of capability, both for new submarines and the industry that designs, builds and supports them. Without seeking refuge in the time-served maxim that the best is the enemy of the good, only a deeply self-critical approach to capability can ensure the continued operation of British-built nuclear submarines in the Royal Navy. It is encouraging that this has already started in industry, largely prompted by the impending work on SSBN-F, as well as in MoD's new DE&S structure. There remain some difficult decisions on both counts, including the level of advancement built into later Astute class boats and the new SSBN. Furthermore, the Naval Base review may not conclude the matter of surplus facilities, but Devonport, Barrow and Faslane may not be able to continue operating in their current format when the defence budget is desperately needed elsewhere. Decisions on submarine-related infrastructure cannot be separated from wider questions of maritime industry rationalization that will need to be answered in the near future.

Only a handful of countries in the world have the capacity to build nuclear submarines, and arguably none compete with the value and capability of the UK industrial base, even in spite of its recent turbulent history. If Government and industry fail to fulfil their roles in pursuit of a viable industrial base, the cost of re-establishing the SIB at a later date would most likely be prohibitive and the country would lose a key strategic industry and defence capability.

Although the enterprise is by no means at its optimum level, the recent success in an industry as technically and commercially complex as this is not to be underestimated. The challenge for Government and industry now is to sustain this effort long into the future. The ideal is that in 2024, a new British-built SSBN will depart on its first operational patrol. It might be escorted by the seventh Astute class SSN, the predecessors of which will have paved the way for the new SSBN to enter service on-time and to budget. Meanwhile, further SSNs, operating at availability levels unheard of two decades previously, may be deployed worldwide in support of UK defence policy. In roles as diverse as support of expeditionary strike groups led by the Queen Elizabeth class aircraft carriers, sea control in the emerging shipping lanes of the Arctic and the current choke points in the Mediterranean, the Persian Gulf and further afield, and ISR operations globally, the Royal Navy's submarines will provide unrivalled flexibility no matter what the future environment demands of them.

This ideal version of the future will only come to pass if Government and industry are able and willing to collaborate with an appropriately cohesive and long-term view.