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Options for Initial Fuelling

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Prepared for the
United Kingdom’s Ministry of Defence
The research described in this report was prepared for the United Kingdom’s Ministry of Defence. The research was conducted jointly in RAND Europe and the RAND National Security Research Division.

Library of Congress Cataloging-in-Publication Data
The United Kingdom’s nuclear submarine industrial base.
   “MG-326/3.”
   Includes bibliographical references.
   ISBN 0-8330-3784-6 (pbk. vol 3)

359.9’383’0941—dc22
2005010735

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Cover design by Peter Soriano

Photo courtesy of DML

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Published 2005 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516
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Summary

In the United Kingdom, newly built submarines are fuelled where they are constructed: at the Barrow-in-Furness shipyard owned by BAE Systems. Devonport Management Limited (DML) currently refuels existing submarines once their initial fuel load is depleted\(^1\) (and defuels them at retirement). Sustaining separate fuelling and refuelling sites has meant sustaining two sets of nuclear fuel–handling licenses. This has proven increasingly costly in a regulatory regime that expects to see continuous improvement. Such cost increases have led the Ministry of Defence (MOD) to consider the possibility of consolidating its nuclear fuel-handling capabilities at the existing refuelling site at DML.\(^2\) If new submarines were fuelled at the DML dockyard, the Barrow yard could relinquish its nuclear fuel–handling license. Such a move could reduce expenditures on the current Astute-class attack submarine acquisition programme and future nuclear submarine projects.

Consolidation would, however, have complex implications for the Astute programme’s cost and schedule. The MOD’s Attack Submarines Integrated Project Team (ASM-IPT) thus asked the RAND

\(^1\) Beginning with the Astute class, future submarines are planned to be fuelled for life and therefore do not need refuelling at mid-life.

\(^2\) Nuclear refuelling activities for submarines have already been consolidated at DML. BAE Systems does not have the infrastructure or the regulatory approval to conduct refuelling at its Barrow-in-Furness shipyard. From a regulatory cost standpoint, refuelling is considerably more expensive than initial fuelling because of the nuclear hazards and consequences involved in handling spent, irradiated nuclear fuel compared with the lower risks associated with new, unused fuel.
Corporation to conduct an objective analysis of the full range of potential impacts that could result from consolidating dockyard nuclear fuel–handling capabilities at DML. The fuelling-refuelling consolidation problem was split into five components for analysis:

- Challenges to transporting an unfuelled submarine out of Barrow, through the Irish Sea, and on to Devonport
- Availability of DML facilities and the level of investment needed to make them suitable for fuelling the Astute boats
- Allocation of work between the two sites to produce an operational submarine
- Nuclear regulatory challenges at the two sites
- Contractual challenges that consolidation would have to meet, as well as public perceptions of consolidation-related impacts.

We assessed the consolidation-related savings (or costs) and the schedule risk (or potential for programme delay) associated with each of these sets of issues for three consolidation cases:

1. Fuelling all Astute-class boats at DML
2. Fuelling Astute 1 at Barrow and all subsequent boats at DML
3. Fuelling the first three Astute-class boats at Barrow and all the others at DML.

Case 2 is based on the recognition that, given the first boat’s advanced stage of construction, arranging for fuelling that boat at DML could cause delays. Case 3 is based on the possibility that the arrangements associated with consolidation would be easier to effect under a contract different to the current one, which covers the first three boats.

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3 These are compared with the current baseline strategy of fuelling all new boats at Barrow. Late in this project, after interaction with us regarding the DML fuelling alternatives, BAE Systems proposed a variant of the current baseline strategy (see “A New Proposal” below).
Transportation

The most problematic segment of the transportation route is the exit from Barrow-in-Furness. The passage from the dockyard to the open sea is through the twisting Walney Channel, over 7 nautical miles long. Typically there is not enough water in the channel to keep a submarine off the bottom long enough to make the exit. A high tide is required, and not all high tides are sufficient. Depending on the precise draught of the boat, it may be necessary to wait three weeks or more for a sufficient tide. Even then, the tide runs so rapidly in and out of the channel that the speed of exit becomes a key factor. A fuelled boat under its own power can move down the channel quickly enough to exit in one tide. However, if the boat has not been fuelled and is, for example, towed out of the channel, two consecutive high tides would be required for exit. A deepwater staging point would thus have to be dredged midway down the channel. More time (and more opportunities) would, however, be available for the tow if the submarine were placed on a floating transport cradle, a pontoon-like device that would effectively reduce the submarine’s draught. Less depth of water would then be required for exit. That is the arrangement we assume in the remainder of our analysis. It permits easier, less risky navigation than towing the boat without a cradle and would not cost as much as constructing the staging point required for a full-draught tow (£9 million vs. £20 million more than the baseline). There would also be more opportunities for exit than would be the case for either a fuelled submarine or a full-draught tow, so there would be less chance of delay.

Regardless of the exit option chosen, it would be most prudent if the MOD and BAE Systems reviewed the efforts leading to preparation of an Astute exit plan. A conservative plan similar to the one used for the Vanguard class in the past could result in unnecessary exit delays, even for a fuelled submarine. Safety can be assured through a more flexible plan that allows for the capabilities of modern technology to make precise sonar soundings of channel depth, predict swells at the channel mouth, and indicate the boat’s position.
However, work must begin promptly on a flexible plan if it is to be in place by the time the first of class is ready to depart.

**Facilities**

Facilities at DML are used to support in-service submarines. While there are periods during which a new boat could be fuelled, their occurrence is not convenient to the Astute programme schedule. The first of class either would have to wait many months or would have to be launched without some components that are most efficiently installed when the hull is still open. That installation would then have to be performed within the closed hull at DML, or the hull would have to be reopened there, both of which are costly and impractical alternatives.

Initial fuellings beyond the first of class may encounter conflicts with other submarines requiring docking periods for maintenance, but any delays on that account are likely to be minimal. Thus, only case 1 is seriously affected. For all cases, facility investments specific to fuelling Astute-class boats are difficult to judge. Although DML claims that these investments would be minimal, uncertainty will remain without having a detailed plan.

**Workload**

More production labour would not be required to fuel the boats at Devonport than to do so at Barrow under the fuelling procedures now in place. However, the work would be allocated differently, which has implications for schedule risk on the fuelling plan at Barrow. Additional oversight would be required if fuelling activities were consolidated at DML. This would entail DML personnel overseeing the manufacturing process at Barrow to ensure the submarine they fuel has met manufacturing standards, and BAE Systems personnel would serve as the design authority overseeing the fuelling and subsequent testing and commissioning at DML.
If fuelling were to occur at DML, construction work that would have been done in parallel with fuelling at Barrow would have to be finished at DML. Thus, construction processes required before launch and conducted in parallel with the core load would now be conducted in series with the core load. As a result, the construction schedule would be extended by the 15 weeks for the core load at DML, plus a few weeks for transport and preparing for fuelling.

This is an underestimate of the delay beyond the first two boats. By the time the third boat is built, BAE Systems expects to be taking a different approach to fuelling that is expected to save time (about one month) and labour (about 160,000 man-hours per submarine, subject to confirmation of feasibility of the construction change and satisfaction of security issues). Because, in that case, fuelling would become an integral part of constructing the hull, this approach could not be taken if fuelling were done at DML. Thus, relative to the Astute 3 baseline schedule, fuelling at DML would take the five months extra as for the first of class, plus the additional month. This applies to all three cases under consideration.

If a vessel is fuelled at DML, both BAE Systems and DML would need to have people stationed at each other’s site. BAE Systems personnel would be required for insights and input into post-launch activities, and DML personnel would want to monitor at least those aspects of construction associated with the nuclear steam-raising plant. This oversight workload is not required in the current plan to fuel at Barrow and would cost approximately £2.2 million per boat.

**Nuclear Regulation**

Two agencies regulate nuclear activities at the Barrow-in-Furness shipyard and DML: the MOD’s Naval Nuclear Regulatory Panel (NNRP) and the Health and Safety Executive’s Nuclear Installations Inspectorate (NII). At the time the last submarine was fuelled at Barrow, the NNRP’s jurisdiction was restricted to the submarine and the NII’s to the rest of the site. In 1996, the two organisations signed an agreement whereby the NII would attend also to the interface
between the submarine and the surrounding site, and there would be
greater joint attention to all nuclear-related activities on site. The
result has been, from the regulator’s viewpoint, a recognition that a
more modern approach to site safety cases and a greater coordination
between operating organisations and regulatory regimes are now
needed. Addressing this issue has seen a large increase in costs, which
has been regarded by the MOD’s contractors as directly attributable
to regulatory compliance, although the basic compliance require-
ments are long standing.

From the contractor’s viewpoint, the nonprescriptive environ-
ment fosters uncertainty in scope of work leading to cost growth. As a
result, our own discussion of regulatory compliance costs, which
draws from contractor perspectives and data, also has to be caveated
with an element of uncertainty.

About £20 million has already been spent at Barrow in this con-
nection and the expenditure of another £100 million in recurring and
nonrecurring expenses is anticipated for the first three boats. Of that
amount, £30 million is allocated for maintaining manufacturing
quality assurance standards sufficient for a nuclear-powered subma-
rine, which will have to be done regardless of where the submarine is
fuelled. The other £70 million is associated with fuelling and repres-
ts a potential saving at Barrow if the boat is fuelled at DML. The
compliance activities are, however, under way, so the longer a deci-
sion to fuel at DML is postponed, the more will be spent and the less
will be available for saving. Figure S.1 shows the potential savings
remaining over the next eight years. The break in the curve indicates
that by 2006, the fuel for the first of class will have arrived at Barrow
and no further savings can be realised (i.e., the costs must accrue)
until the boat leaves Barrow. Subsequent compliance savings (about
£21 million) can still be realised in case 2, in which the second boat
(and each one following) is fuelled at DML. None is realised in case
3, in which fuelling at DML awaits the next contract. In all cases,
however, the Barrow yard would save £7.3 million per year in recur-
ring nuclear regulatory compliance costs and nuclear-related overhead
for fuelling Astute 4 and beyond at DML, once the Barrow shipyard is decommissioned as a nuclear fuel–handling site for a one-time cost of £15 million.

Costs at DML have not been determined, but some fuelling-related activities and assets are already covered as part of the more stringently regulated refuelling and defuelling already done there. Nevertheless, a safety case would be required for the new fuelling process. It may take some time to satisfy regulators that DML can take full responsibility for fuelling, given its lack of involvement in the Astute programme to date. Presumably, regulatory issues will have been resolved by the time that boats under the next contract are to be fuelled; therefore, case 3 would not be affected.

It is important to note that the baseline programme, in which all Astutes are fuelled and delivered from Barrow, may itself be delayed by satisfying nuclear regulatory demands. The regulatory work left on
the Astute programme under the current fuelling plan could well be on the critical path to delivery of the first boat. It is also important to note that we account here only for nuclear regulatory compliance costs that can be anticipated in the current environment. Any future changes in standards required could result in further savings from fuelling at DML.

**Contractual Challenges and Other Issues**

Fuelling at DML would require the resolution of potentially challenging contractual issues. BAE Systems is the design authority for the Astute acquisition programme and is responsible for delivering an operational submarine to the MOD. Yet the important task of fuelling and all subsequent production and testing work would be done at DML. DML must convince nuclear regulators that it truly has full control over fuelling and nuclear plant testing. The contractual mechanisms that will allow the achievement of both these objectives are not obvious and would have to be developed. Presumably, each firm will try to position itself to minimise its ultimate contractual responsibility for a product for which it cannot be fully responsible. One possible solution, offered for exploration by ASM-IPT, is that the MOD might be able to take delivery of a partially completed submarine from BAE Systems and provide it as government-furnished equipment to DML. While this may go some way to solving the position for BAE Systems, it could complicate responsibility for existing and emergent defects at a later date and present substantial risks to the MOD.

Resolution of these issues could delay the first three boats in the class, thus impinging on cases 1 and 2. In addition to the cost of the labour required to resolve the contractual challenges, which is difficult to estimate, a further contractually related cost would accrue to the program from fuelling at DML because the company would require a fee for its work on the submarine. This cost would be in addition to the fee charged by BAE Systems for production of the
submarine as a whole. That DML fee could amount to half a million pounds per boat.

There are some other issues related to fuelling at DML that do not appear at this time to have the potential for affecting programme cost or schedule. Public perceptions of the MOD’s actions are likely to be adversely affected by consolidating fuel handling at DML. The loss of fuelling work at Barrow would translate into a decrement in economic opportunity in an area where alternative sources of production and employment are few. There could also be some increment in public concern over further nuclear activity in the Devonport area, although this seems less likely.

Summary of Savings and Schedule Effects

The savings (and costs) from consolidating all nuclear fuel–handling activities at DML accrue over a number of years in the future. To summarise them, then, we discount them to net present values (NPVs). Table S.1 shows the results for each case relative to the baseline.

In case 3, the long-term savings in annual nuclear regulatory compliance costs at the Barrow yard are offset by the costs of several activities: decommissioning the yard, the additional Barrow-DML oversight costs required, the inability to take advantage of the planned savings from fuelling the reactor before installation in the

<table>
<thead>
<tr>
<th>Case</th>
<th>Net Present Value (£ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>24–57</td>
</tr>
<tr>
<td>Case 2</td>
<td>9</td>
</tr>
<tr>
<td>Case 3</td>
<td>(2)</td>
</tr>
</tbody>
</table>

NOTE: See the list near the beginning of the summary for the definition of each case.
hull, and the procurement of a floating transport cradle. For cases 1 and 2, these costs still accrue to later boats, but the tally is dominated by the large savings in safety case preparation and other nonrecurring nuclear regulatory compliance costs accruing to the current contract at Barrow. These savings are considerably larger for case 1 than for case 2. It should be kept in mind that important elements of these savings are based on data from a single source, which we have not submitted to a thorough critical review. However, the difference between the savings for case 1 and those for the other cases appears unlikely to be reversed on closer examination.

Programme delays would total 14 months for the first of class, because of the need to wait for facility renovation at DML and the need to run fuelling and parallel processes at Barrow in series when shifting to DML (see Table S.2). That is a conservative estimate; it omits potential further delays related to nuclear regulatory demands and contractual matters that are difficult to quantify. Of these, only the running of parallel processes in series applies to subsequent boats, so the anticipated delays would be six months from currently planned delivery dates. Some further delay for contractual issues is possible for the second boat. Note that, in the table, a BAE Systems action item is prescribed to avert the possibility of schedule delays from failing to move promptly towards a flexible plan for moving ships from the Barrow dockyard to the open sea.

Table S.2
Schedule Risks from Fuelling New Submarines at DML

<table>
<thead>
<tr>
<th>Case</th>
<th>Transportation Facilities</th>
<th>Workload Impact</th>
<th>Nuclear Regulatory Issues</th>
<th>Contractual Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>No delay</td>
<td>No delay</td>
<td>Uncertain scope</td>
<td>No delay</td>
</tr>
<tr>
<td>Case 1</td>
<td>8-month delay for Astute 1</td>
<td>Up to 6-month delay</td>
<td>Nil concerns</td>
<td>Significant delay</td>
</tr>
<tr>
<td>Case 2</td>
<td>Minimal delay</td>
<td>Up to 6-month delay</td>
<td>No delay</td>
<td>Some delay</td>
</tr>
<tr>
<td>Case 3</td>
<td>Minimal delay</td>
<td>Up to 6-month delay</td>
<td>No delay</td>
<td>No delay</td>
</tr>
</tbody>
</table>

NOTE: See the list near the beginning of summary for the definition of each case.
In sum, case 1, for which the greatest savings accrue, would be severely affected (with respect to the first of class) by delays. Case 3 would be less affected by delays but realises no savings—and the potential for savings is what motivates the transfer of fuelling to DML. Case 2 affords modest savings and is subject to some delay. It is noteworthy, however, that we can account here only for currently anticipated costs. Should further tightening of the regulatory regime require future safety cases, those costs would be preempted at Barrow by consolidating nuclear fuel–handling at DML, and the savings from cases 2 and 3 could be dramatic.

**A New Proposal**

Towards the end of this study, BAE Systems proposed a new approach to fuelling that it believes would result in substantial savings to the Astute programme without the need to consolidate all fuelling activities at DML. The proposal includes measures to reduce risks of handling nuclear fuel and provides that activities necessary to complete the testing of the submarine be done at either Barrow or Faslane. BAE Systems estimates a savings of £18 million NPV in the first case (Barrow) and £50 million in the second (Faslane), since the reduction in nuclear hazards associated with such an approach would simplify the preparation of safety cases. To these costs must be added the cost of transporting the submarines to Faslane, which we estimate at £12 million NPV for the eight Astute-class boats.

We cannot independently validate the BAE Systems estimates. Furthermore, important uncertainties remain regarding

- the availability of berths, services, or testing equipment necessary for initial Astute power range testing (PRT) at Faslane
- the effort required to prepare a safety case for initial Astute PRT for Faslane
- any potential limitations on the number of days of critical operations that can be performed at Faslane
- issues of ownership of the untested submarine
availability of suitably qualified and experienced personnel.

Despite the uncertainties, this new proposal has to be regarded as promising. The savings achievable, if validated, are on the order of those attainable only through fuelling all Astute-class boats at DML, including the first of class, whose fuelling at DML would require a delivery delay of more than a year. BAE Systems claims no delays from planned delivery dates under its new proposal; further assessment is required to verify this claim. Meanwhile, BAE Systems is moving forward with the proposal.

Recommendations

Based on the analysis summarised here, we recommend that the MOD

- not consider fuelling the first Astute-class boat at DML
- take prompt action in analysing the latest proposal submitted by BAE Systems to reduce nuclear consequences of hazards at Barrow.

If upon further analysis the late BAE Systems proposal is found unlikely to produce the savings and risk reduction anticipated, a decision could be made at that time for the MOD to engage with the regulators in assessing options. It should look in detail at relevant aspects of the build programme, support facilities and options, and conduct a more detailed feasibility study for cases 2 and 3. The MOD should also consider the possibility that future nuclear regulatory requirements and restrictions could make both cases 2 and 3 seem advantageous, even with respect to the latest BAE Systems proposal. There is also the possibility, of course, that the current plan of fuelling all new boats at Barrow will emerge as preferable. Regardless, the MOD and BAE Systems need to
• review promptly the transportation challenges associated with moving Astute from Barrow to the open sea, regardless of whether the boat is fuelled or unfuelled, and produce a flexible exit plan that minimises potential schedule risk.