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Executive Summary

The aim of the Submarine Dismantling Project (SDP) is to deliver a timely and cost-effective solution for the dismantling of the UK's defueled nuclear powered submarines. This document presents evidence for the relative cost-effectiveness of the 3 credible technical options for submarine radiological dismantling. Its purpose is to present initial conclusions and recommend where future work should be focused.

There are 3 credible options for radiological dismantling and interim storage:

- Option 1 - Reactor Compartment (RC) Storage.
- Option 2 - Reactor Pressure Vessel (RPV) Storage.
- Option 3 - Packaged Waste Storage.

These options have been assessed in terms of:

- Effectiveness – an assessment of the relative merits of the options developed through a Desk Officers' workshop, supported by a qualitative technical assessment.
- Whole Life Cost (WLC) – an assessment of the costs associated with each option, calculated against a range of confidence values.

Factors such as those relating to local and national acceptability have not been considered in the analysis as they are matters for public consultation at a later stage.

The results have been combined in a Combined Operational Effectiveness and Investment Appraisal (COEIA) plot. This COEIA is limited in its rigour by the maturity of the WLC model, a relative (rather than objective) assessment of effectiveness and the need to fully integrate the results with the methodology for site selection. Within these limits the following conclusions can be drawn from the COEIA:

- Option 3 (Packaged Waste) is strongly and positively differentiated from the others in terms of effectiveness.
- Option 1 (RC) is clearly and negatively differentiated from the others in terms of WLC.

These conclusions and supporting evidence were reviewed by a panel of Senior Officers charged with providing project assurance, and it was agreed that:

- SDP continues to plan on the basis of the assumption that Option 3 (Packaged Waste) will be the proposed approach.
- Further development of Options 1 (RC) and 2 (RPV) will be focused on demonstrating with sufficient rigour the parking of these options within formal analysis.

Providing that:

- Future work identified and discussed during the meeting was undertaken.
- Opportunities are fully investigated, although without delaying progress on the baseline Options.
- Underlying assumptions are challenged.

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1. Introduction

1.1. Overview

1.1.1. The aim of the Submarine Dismantling Project (SDP) is to deliver a timely and cost-effective solution for the dismantling of the UK's defueled nuclear powered submarines.

1.1.2. This document sets out evidence for the relative cost-effectiveness of the 3 credible technical options for submarine radiological dismantling. It presents:

- the results of analysis conducted to date,
- the critical review of the results by stakeholders, and
- conclusions and recommendations as to the prioritisation of further work to develop the options.

1.2. Background

1.2.1. SDP is a phased Category A project working towards an incremental Main Gate (MG) through 6 Phases. The project is currently in Phase 2, which will identify the recommended option for SDP, comprising the:

- site for initial dismantling,
- site for Intermediate Level Waste (ILW) storage,
- technical approach to radiological dismantling and storage of ILW, and the
- procurement strategy.

1.2.2. This document presents evidence for the third of these, the technical approach to radiological dismantling.

1.2.3. An earlier study, the Technical Options Study [Ref A], involved a range of MOD and external stakeholders in considering the same Options but was inconclusive, largely due to the maturity of the evidence available at that time. It was nevertheless instructive in the development of criteria and in understanding the breadth of stakeholder interests attached to the technical approach. Subsequent work, which has informed this paper, has involved a wide range of MOD stakeholders and Subject Matter Experts (SMEs), contractor support from the SDP Customer Friend and external observers from the SDP Advisory Group (AG).

1.3. Document Structure and Aims

1.3.1. The Concept of Analysis (CoA) [Ref B] sets out guiding principles for SDP options analysis, including how evidence should be gathered and managed to provide an audit trail to support decision making. The CoA has recently been submitted to D Scrutiny for endorsement.

1.3.2. The CoA also provides a roadmap leading to the creation of an Operational Analysis Supporting Paper (OASP) to accompany the Business Case (BC) for MG submission. The OASP will contain a Combined Operational Effectiveness and Investment Appraisal (COEIA), summarising the results of the options analysis.

1.3.3. The process of options analysis will include the development of a number of intermediate, indicative COEIA's to assess each major element of the project, to allow technical work to be prioritised and the range of options to be narrowed. This document is the first example of an intermediate COEIA, and is broadly structured in the same way as an OASP, setting out the 3 credible options for radiological dismantling and presenting evidence as to their cost-effectiveness.

2. Assumptions

2.1. Boundaries of the Analysis

2.1.1. This document summarises evidence relating to the technical approach to radiological submarine dismantling. It comprises:

- The results of Operational Effectiveness (OE) analysis, including:
  - The results of a structured Desk Officers' workshop (representing the Senior Officers who provide project assurance) to assess the relative effectiveness of the 3 candidate options.
  - The technical review of the 3 candidate options to identify advantages and disadvantages, based on the outcome of the above workshop.
- A current, initial view of the financial analysis.
- An introduction to the treatment of Other Contributory Factors (OCF) with a bearing on the 3 candidate options. The OCF are significant factors which cannot be quantified in terms of effectiveness or WLC.
- An indicative COEIA based upon the above analysis.
- The results of a review of the COEIA and underpinning evidence by the Senior Officers who provide project assurance, leading to conclusions and recommendations for further work.

2.2. Key Assumptions

2.2.1. SDP has a full Master Data and Assumptions List (MDAL), and where assumptions have been made they have been consistent with the MDAL. At top level, however:

- The *specific* potential sites for submarine dismantling and storage of radioactive waste have not been considered, although the *technical* requirements of dismantling, transport and storage have been assessed.
- The potential impact of the 3 candidate options on procurement strategy has not been considered.
- No OE analysis of the Do Minimum[1] option has been conducted, at this stage, as it does not involve a technical approach to submarine dismantling but continued afloat storage of whole submarines.
- Regardless of the technical approach adopted, the remaining non-radioactive submarine hulls will be dismantled using conventional techniques to enable the

[1] The Do Nothing option for SDP would not accord with policy commitments or legislative requirements. Instead a legally compliant Do Minimum approach of continued, and expanded, afloat storage is being considered as the SDP benchmark.

recycling of materials, wherever possible, after transfer to a suitable ship breaking facility.

3. Technical Options

3.1. Overview

3.1.1. There are currently 3 credible options for radiological dismantling and interim storage:

- Option 1 - Reactor Compartment (RC) Storage – also referred to as "Cut-out".
- Option 2 - Reactor Pressure Vessel (RPV) Storage.
- Option 3 - Packaged Waste Storage – also referred to as "Cut-up".

3.1.2. A full description of the credible options and their technical implications is included in the Data Report [Ref C]. A summary follows.

3.2. Option 1 – Storage of RC

3.2.1. This option requires the RC to be separated from the fore and aft sections of the submarine, resulting in a shielded container of up to 1000 tonnes in weight. It is then transported intact to an interim storage location and stored until the planned national Geological Disposal Facility (GDF) becomes available at some time after 2040. The RC will be used as the transport and interim storage container for the ILW contained within it. When the GDF is able to accept waste from submarine dismantling the RC will be transported to a suitable facility where it will be dismantled, the plant components cut up and the ILW packaged for disposal in the GDF. The Low Level Waste (LLW) contained within the reactor compartment will also be packaged and disposed of at the National Low Level Waste Repository (LLWR) at this time.

3.3. Option 2 – Storage of RPV

3.3.1. This option sees the RPV and any other ILW removed from the submarine. Any LLW remaining in the reactor compartment after removal of these components is immediately processed, stored and disposed of to the National LLWR. The RPV is then packaged and transported to an interim storage location for storage until the planned national GDF becomes available. At this time it is transported to a suitable dismantling facility, cut up, and the ILW separated and packaged for storage, then interred in the GDF.

3.4. Option 3 – Packaged Waste Storage

3.4.1. This involves early full dismantling of the RPV, segregating ILW and LLW, prior to interim storage. The ILW would then be suitably packaged, conditioned into compliant containers and stored on land before being transferred to the GDF for final disposal. It is very similar to Option 2 in that the RPV has to be removed from the RC, the essential difference being that the RPV is then immediately dismantled, the ILW is packaged into disposal containers and sent to an interim storage site, with the LLW being immediately processed, stored and disposed of to the National LLWR. It is assumed that these operations will be undertaken on the same dismantling site as the removal of the RPV from the submarine, meaning that no off-site transportation of the RPV is required.

3.5. Project Opportunities

3.5.1. It should be noted that a number of project opportunities (potential options that are not currently credible) exist which are being actively managed by the project. The opportunities which are being managed at present include:

- UK adoption of IAEA Waste Categorisation.
- Direct disposal of the whole RPV into GDF as ILW.
- Interim ILW Store for Demonstrator only.
- Storage of ILW at an NDA Facility.

3.5.2. These opportunities are described fully in files held by the project and are subject to change control until they are either admitted as credible options or closed out as not credible.

4. Operational Effectiveness Analysis

4.1. Overview

4.1.1. This section summarises the results of OE analysis, based around a summary of the Desk Officers' workshop, which convened to provide a quantitative assessment of the options. It is supported by a qualitative, technical interpretation of the advantages and disadvantages of each of the 3 options.

4.2. Desk Officers' Workshop

4.2.1. The Desk Officers' workshop was conducted on 12 May 2010 and included the desk officers themselves (representing the Senior Officers who provide project assurance) supported by SMEs, facilitators, recorders and representatives from D Scrutiny and the SDP AG (as observers). The conference used Multi-Criteria Decision Analysis (MCDA) to assess the relative effectiveness of each of the options. MCDA is a method for structuring and quantifying information where there are several – potentially competing – factors bearing on a decision. It allows decision makers to decide on the relative importance of these factors, and to apply their judgement as to how well each candidate option performs against them.

4.2.2. MCDA was applied as follows.

- A group of SMEs established a set of specific, measurable criteria able to discriminate between the options. This was done before the conference, and resulted in the generation of 15 criteria which included:
    - Criteria such as the *Interim Storage Area* (required to store ILW) relevant to each option. This type of criteria can be measured by a physical quantity (m^2 in this case).
    - Criteria such as *Technical Challenges* associated with the successful delivery of each option. This type of criteria is measured on a subjective scale, such as 0 to 9. Most of the criteria were of this type.
- At the conference the desk officers, supported by advice from SMEs, scored each of the options against each criteria. In the case of the subjective criteria this was done through judgement. In the case of criteria measured by a physical quantity the values were reaffirmed or adjusted by the desk officers.
- The desk officers then assigned a 'weight' to each criteria to allow the different criteria to be compared to one another.
- The scores and weights were combined for each option to produce values for the options, which give an overall *relative* score. This was done at the conference.
- Sensitivity analysis was then performed, after the conference, to test the robustness of the results (by, for example, varying weights) and to examine several technical variants discussed at the conference.

4.2.3. Ref D includes a full description of the MCDA process, and Ref E a description of its results. In summary, however, the criteria presented in the conference are shown in the table below, including their relationship to the SDP Key User Requirements (KUR's), which are described in the User Requirements Document (URD) [Ref F].

Criteria	Definition	KUR(s)
Intergenerational Equity	The endowment of cost and / or burden to future generations.	6 (Sufficient design flexibility for continued ILW storage)
Flexibility of Location	The number of potential sites available for most site-restricted part of the process.	5 (Sufficient design flexibility for future submarine classes)
Industrial Skill Set	The availability of the skills needed to undertake the work.	6 (Sufficient design flexibility for continued ILW storage)
Technical Challenges	A measure of the technical difficulty of carrying out each option.	
Worker Dose	The worst-case radiation dose expected in routine operations.	7 Compliance with legislation and safety)
Adaptability	The ability for future developments to provide a better solution.	5 (Sufficient design flexibility for future submarine classes); 6 (Sufficient design flexibility for continued ILW storage)
Interim Storage Area	The footprint required for an interim store.	2 (Interim storage of ILW)
Volume of ILW to GDF	The total volume of ILW anticipated to be transferred to the GDF after the interim storage period.	6 (Sufficient design flexibility for continued ILW storage); 9 (Decommissioning and disposal of facilities)
Volume of LLW to National LLW Repository	The total volume of LLW anticipated to be transferred to the National LLW	3 (Disposal of LLW); 9 (Decommissioning and disposal of facilities)
Accidental Radiological Discharges	The radiological discharges and emissions resulting from accidents and deliberate actions (a measure of passive safety).	2 (Interim storage of ILW)
Radioactive Discharges	The radioactive discharge in routine operations.	7 (Compliance with legislation and safety)
Vulnerability	The vulnerability of material to accidental or deliberate misuse	2 (Interim storage of ILW); 4 (Control of classified material)
Regulatory Compliance / Statutory Approvals	The relative difficulty of attaining regulatory / statutory approvals for the option.	2 (Interim storage of ILW); 3 (Disposal of LLW); 7 (Compliance with legislation and safety)
Other/Non-radiological Environmental Impacts	The statutory and non-statutory nuisances and other environmental impacts which differentiate between the options and are not captured elsewhere.	2 (Interim storage of ILW); 9 (Decommissioning and disposal of facilities)
Industrial Submarine Experience	The availability of the experience needed to undertake the work.	6 (Sufficient design flexibility for continued ILW storage)

4.2.4. The table below summarises the scores and weights generated at the Desk Officers' workshop. It shows whether each criteria was measured by a physical quantity or a subjective score, and records both the values for each option and the weights attributed by the conference panel.

Criteria	Scale	Option			Weight (%)
		1. RC	2. RPV	3. Pack-aged	

Criteria	Scale	Option			Weight (%)
		1. RC	2. RPV	3. Pack-aged	
Intergenerational Equity	1 to 9 (Subjective)	2	5	8	12.6%
Flexibility of Location	1 to 9 (Subjective)	3	5	9	9.9%
Industrial Skill Set	1 to 9 (Subjective)	7	7	7	3.6%
Technical Challenges	81 to 0 (Subjective)	12	14	8	10.9%
Worker Dose	Man mSv	9	47	50	3.3%
Adaptability	1 to 9 (Subjective)	8	5	3	7.6%
Interim Storage Area	m^2	3574	574	1084	3.6%
Volume of ILW to GDF	No of boxes	4	4	8	10.6%
Volume of LLW to National LLW Repository	m^3	11.35	11.35	8.95	10.6%
Accidental Radiological Discharges	9 to 0 (Subjective)	2	3	3	5.8%
Radioactive Discharges	20 to 0 (Subjective)	1	2	1	1.6%
Vulnerability	1 to 9 (Subjective)	4	5	6	0.3%
Regulatory Compliance / Statutory Approvals	1 to 9 (Subjective)	2	3	7	12.1%
Other/Non-radiological Environmental Impacts	1 to 5 (Subjective)	3	2	1	4.2%
Industrial Submarine Experience	1 to 9 (Subjective)	4	6	6	3.6%
Total		**32**	**35**	**69**	**100%**

4.2.5. Some of the criteria, whilst important in an absolute sense, were found to be less important in distinguishing between the options. For example, *Worker Dose* was given a relatively low weight of 3.3% because estimated doses were acceptably low for all options.

4.2.6. When the scores are normalised and combined with the weightings, the outcome is that Option 3 (Packaged Waste) emerges with the highest preference score of 69, compared to Option 2 (RPV) with 35 and Option 1 (RC) with 32 points. The major contributing criteria for Packaged Waste were:

- Intergenerational Equity;
- Flexibility of Location;
- Technical Challenges;
- Volume of LLW to the National LLWR; and
- Regulatory Compliance.

4.2.7. In interpreting this outcome, it is important to appreciate that the weighted scores have no absolute datum that would allow an objective measure of performance, since the approach deals only with the relative performance of the options. So they cannot be taken to infer, for instance, that Option 3 (Packaged Waste) is twice as good as Option 2 (RPV).

4.2.8. A number of sensitivity analyses were conducted on the scores and weights, to test the robustness of the outcomes to changes in weights and scores. The analyses concluded that the rankings and relative values were extremely robust. Some of these analyses were also conducted on the basis of variants discussed at the conference, such as changing the relative volume of ILW and LLW arising from each option. In all cases the ranking of the options did not alter.

4.2.9. The results of the conference are robust and represent a consensus view of the Desk Officers. Further work may usefully explore the limits of this consensus, and/or explore a more objective assessment of effectiveness, but Option 3 (Packaged Waste) emerges as significantly more effective than the alternatives.

4.3. Technical Assessment

4.3.1. Option 3 (Packaged Waste) was assessed to be the most effective option because it scored higher in more criteria than the other two options and also because it scored higher in the more heavily weighted criteria.

4.3.2. Under Option 3 (Packaged Waste), critical activities like cutting up the submarine and packaging and storing the ILW would be carried out within a shorter timescale and not be left to future generations. The only remaining task for future generations would be the transportation and disposal of the packaged waste to the GDF at some time after 2040 (the project requires interim storage for up to100 years to cater for potential delays in the GDF). The other options would leave significant elements of submarine dismantling and waste management activities to future generations. This *intergenerational equity* criterion aligns closely with the policy requirement that *decommissioning operations should be undertaken as soon as reasonably practicable*[2].

4.3.3. Compliance with regulatory requirements and obtaining necessary approvals was judged to be easier for Option 3 (Packaged Waste) because of the uncertainty over what the future may hold. It was judged that there was less risk associated with obtaining the necessary approvals in the near future, rather than in the far future.

4.3.4. The main technical challenges for Options 1 (RC) and 2 (RPV) relate to transportation issues. Under Option 1 the RC would need to be packaged and transported by sea to a suitable interim storage site. Under Option 2 the RPV would need to be transported by sea or road to a suitable storage site. Because such transportations have never been carried out in the UK, there is a large degree of technical and regulatory uncertainty (and hence risk) associated with the process. By size reducing, packaging and conditioning the waste, the transportation issues associated with Option 3 (Packaged Waste) become similar to those already being dealt with by the UK civil nuclear industry. The main technical challenge for Option 3 is judged to be the dismantling and size reduction of the RPV which, in itself, is a new activity but one which will draw on techniques already used in deep submarine maintenance and civil nuclear plant decommissioning.

4.3.5. Greater flexibility exists under Option 3 (Packaged Waste) for the use of existing ILW stores, most of which can only be reached by road transport. There is less flexibility for the other two options. The storage facility for a RC (and possibly the

[2] The Decommissioning of the UK Nuclear Industry's Facilities – Amendment to Command 2919, DTI Paper, September 2004

[redacted]

RPV) would require access by sea, which limits the choice of a site.

4.3.6. The primary argument against implementation of Option 3 (Packaged Waste) relates to worker dose where estimated Collective Doses for Option 3 (and Option 2) are around five times greater than those for Option 1 (RC) which allows for longer decay times. Nevertheless, because these estimates were acceptably low for all options[3], it was considered by the Desk Officers' conference that a case could be made, under any option, for reducing worker dose to levels which are as low as reasonably practicable (ALARP).

4.3.7. A secondary argument against implementation of Option 3 relates to the *adaptability* criterion as this Option forecloses, more rapidly, against the use of new and emerging techniques or processes.

4.3.8. A more detailed technical interpretation of the workshop results is included at Annex A. In conclusion, however, the technical assessment reinforces the outcome of the conference that Option 3 (Packaged Waste) is the strongest candidate for consideration by SDP.

[3] In terms of the MoD's through life management plan where the through life collective dose is a key consideration, the predicted levels of collective dose accrual associated with Option 3 (Packaged Waste) are < 1% of collective dose associated with maintaining and operating a Trafalgar Class submarine.

[redacted]

5. Whole Life Costing

5.1. Overview

5.1.1. This section summarises the current financial analysis and consequent ranking of the options. The information has been drawn from the SDP WLC Model which has being developed in house with support from the SDP Customer Friend. The cost information contained within this section has been redacted and differences between options have been described in terms of relative % differences from the 'costliest' option rather than absolute differences in terms of actual cash.

5.2. Context

5.2.1. The financial data and costed risks that underpin these results received an initial independent verification and validation by CAAS in April 2010 who confirmed that the WLC model was both professional and had the correct functionality. During its build the WLC model has followed guidance and best practice from JSP507, HM Treasury and involved meetings with DASA/DESA and CAAS. The financial data, initial risks and underlying estimates have been built up following extensive dialogue with MoD and Customer Friend SMEs.

5.2.2. Further development of the underlying financial data is planned so as to improve the maturity of the data and the robustness of the financial analysis. The WLC model is scheduled for a full V&V by CAAS in September 2010.

5.2.3. To enable fair comparison each option used the same key assumptions, which are found in the SDP MDAL and include:

- Dismantling of the 27 hulls is to be undertaken at one or more nuclear licensed dockyards.
- Submarines are to be dismantled at the rate of up to one per year.
- Resultant ILW is to be transferred and stored at a new MoD storage facility.
- Waste will be transferred from the storage facility to the GDF at an even rate.

5.3. High Level Costed Results

5.3.1. For ease of reporting and meaningful analysis, the costs incurred have been grouped into four categories. The costs within these categories take account of uncertainty boundaries within the costed data and are the breakdown of the 50% confidence limit from a Monte Carlo Simulation.

Sub Totals	Option 1 - RC Storage	Option 2 - RPV Storage	Option 3 - Packaged Waste	Comments
Capital	Costliest	(15%)	(43%)	RC storage is the most expensive due to the build requirements of the storage facility. The RPV storage is significantly more than the Packaged Waste option due to an additional capital build in the RPV packaging facility.

Sub Totals	Option 1 - RC Storage	Option 2 - RPV Storage	Option 3 - Packaged Waste	Comments
Operational	Costliest	(18%)	(20%)	RC Storage is the most expensive due to the labour intensive task of removing the RC from the boat hull and ensuring that parts are suitable for transportation. The RPV Storage costs are slightly greater than packaged waste due to the additional step of packaging the RPV.
Transport	Costliest	(3%)	(22%)	The cost of transportation is higher in the RC and RPV storage options due to the size/complexity of the cargo and the requirement of sea transportation. Packaged Waste can use existing transportation methods so would require limited additional investment.
Facilities Decommiss-oning	(39%)	Costliest	(19%)	The higher costs in the Packaged Waste and RPV Storage relate to the more substantial costs of decommissioning and de-licensing the storage facility. (This is the least material cost category)
Outturn Total	**Costliest**	**(15%)**	**(30%)**	
Risk	Highest Risk	(35%)	(38%)	The 'financial-risk' premium associated with RC Storage is the greatest due to PR risks in RC movement, contamination found on the RC and the GDF not being made available. The RPV storage has a number of distinct risks that differentiate it from the packaged waste namely the RPV buffer store required at the RPV packaging facility. However, all three options have associated and high levels of risk due to the lack of experience in submarine dismantling.
Risk Adjusted Total	**Costliest**	**(17%)**	**(26%)**	

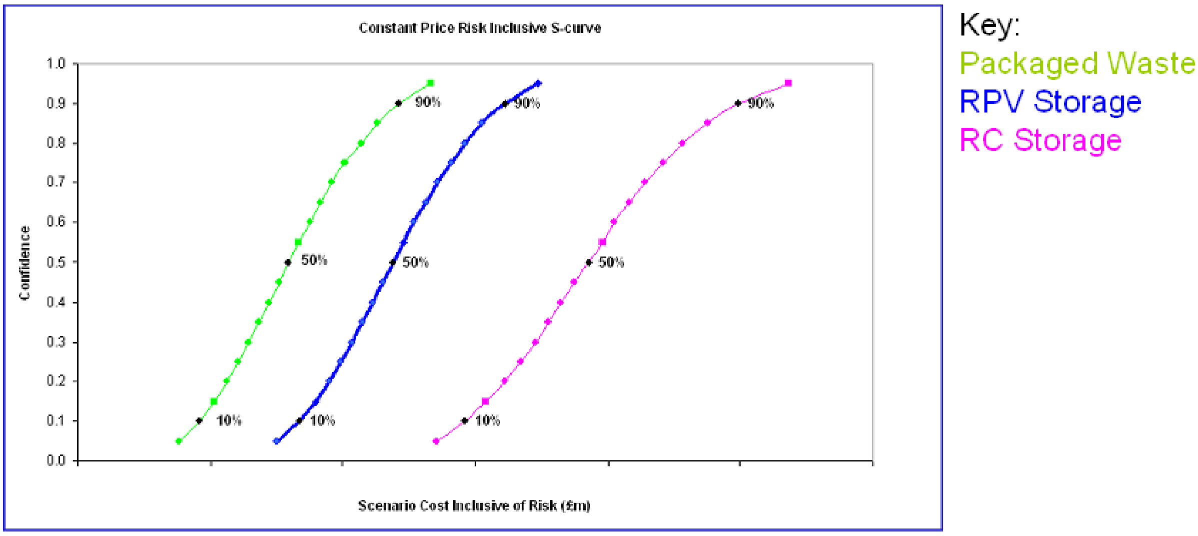
Table 1 – High level differences between the options

5.3.2. In terms of materiality, the operational costs represent between 56%-62% of the total costs within all options. Transport is the next most expensive cost category representing between 25%-28% of total costs, Capital costs between 11%-14% of the total costs and facilities decommissioning costs less than 2%. The cost of storage is included, and the estimates include GDF costs.

Sub Totals	Option 1 -RC Storage	Option 2 -RPV Storage	Option 3 - Packaged Waste
Capital	14%	14%	11%
Operational	59%	56%	62%
Transport	25%	28%	26%
Facilities Decommissioning	1%	2%	2%
Outturn Total			
Risk	19%	14%	15%
Risk Adjusted Total			

Table 2 – Apportionment of costs via cost category

5.3.3. The S-Curve graph below shows the confidence levels within each option.



5.3.4. The graph demonstrates that there is a significant cost difference between the Option 3 (Packaged Waste) and Option 1 (RC). There is no overlap between the 90% confidence in Option 3 (Packaged Waste) and the 10% confidence in Option 1 (RC). Option 3 (Packaged Waste) is also less costly than Option 2 (RPV) with the 90% confidence line of Option 3 crossing the 50% confidence line of Option 2. The S-Curve shape of Option 1 (RC) is caused by some large uncertainties and potentially huge costs associated with its storage.

5.4. Treatment of Risk

5.4.1. The WLC model has the functionality to show the costed profile of options both with and without risk. The initial risks, their potential costed impact, probability, and mitigation strategies were formulated through discussions with MoD and Customer Friend SMEs. Risk owners were asked to provide a minimum, most likely and maximum variable. This allowed a Monte Carlo simulation to be executed providing a 10:50:90 view of risks.

5.4.2. Table 1 shows that adjustment for risk impacts all options, increasing the overall cost of each. However, the impact of risk is greater for Option 1 (RC) and this increases the cost delta in comparison to the two other options both in absolute cost terms (adding a further 19% on top of total costs) and relative cost terms (38% higher than Packaged Waste and 35% higher than RPV). The primary reason for this impact in Option 1 is the inherent risks involved in transporting and finding a suitable storage facility for the RC.

5.4.3. The initial risk assessment consolidates the financial ranking status and highlights significant differences. Risk is an area that will undergo further development as more is known about the technical processes involved in dismantling and data quality improves.

5.5. Initial Sensitivity Analysis – Scenarios

5.5.1. To test the initial analysis that Option 1 (RC) represented the costliest option, followed by Option 2 (RPV) and then Option 3 (Packaged Waste), two key variables were altered to measure the sensitivity of cost.

5.5.2. Scenario 1 - The storage facility is at the same location as the initial dismantling facility. This reduces the need to move waste significant distances until the GDF is available. The financial implications of this scenario reduce the overall cost in Option 1 (RC) by 16% and Option 2 (RPV) by 10% with a negligible impact on cost in Option 3 (Packaged Waste). However, Option 1 (RC) still remains the costliest option but with a reduce variance against the other two options of 7% (Option 3) and 4% (Option 2) which is further increased once risks are accounted for to 11% and 9% respectively.

5.5.3. Scenario 2 - The GDF availability is delayed by twenty years. This increases the time 'waste' is held in storage. The financial implications of this that the overall costs within Option 2 (RPV) and Option 3 (Packaged Waste) increase by 6% whereas the cost impact for Option 1 (RC) is a smaller 1.5% increase in costs. However, Option 1 still remains the costliest option but with a reduced variance against the other two options of 20% (Option 3) and 10% (Option 2) which is further increased once risks are accounted for to 24% and 15% respectively.

5.6. WLC Conclusion

5.6.1. The underpinning knowledge, quality and robustness of financial data within the WLC model is being improved incrementally. In addition, risks and optimism bias workshops will be undertaken to improve this area of cost modelling and as a consequence impact the costing profiles.

5.6.2. In conclusion, however, these improvements are unlikely to change the overall financial ranking as the financial gaps are considerable even when taking into account scenario/sensitivity modelling.

6. COEIA

6.1. Overview

6.1.1. The assessment of the options uses a COEIA plot. This has been compiled as follows:

- The OE results have been derived from the results of the Desk Officers' workshop, as discussed in Section 4. These consist of a single value for each option.

- The WLC results have been derived from modelling as discussed in Section 5. These consist of three monetary values for each option, corresponding to 10%, 50% and 90% confidence levels. The WLC values are in terms of Net Present Value (NPV).

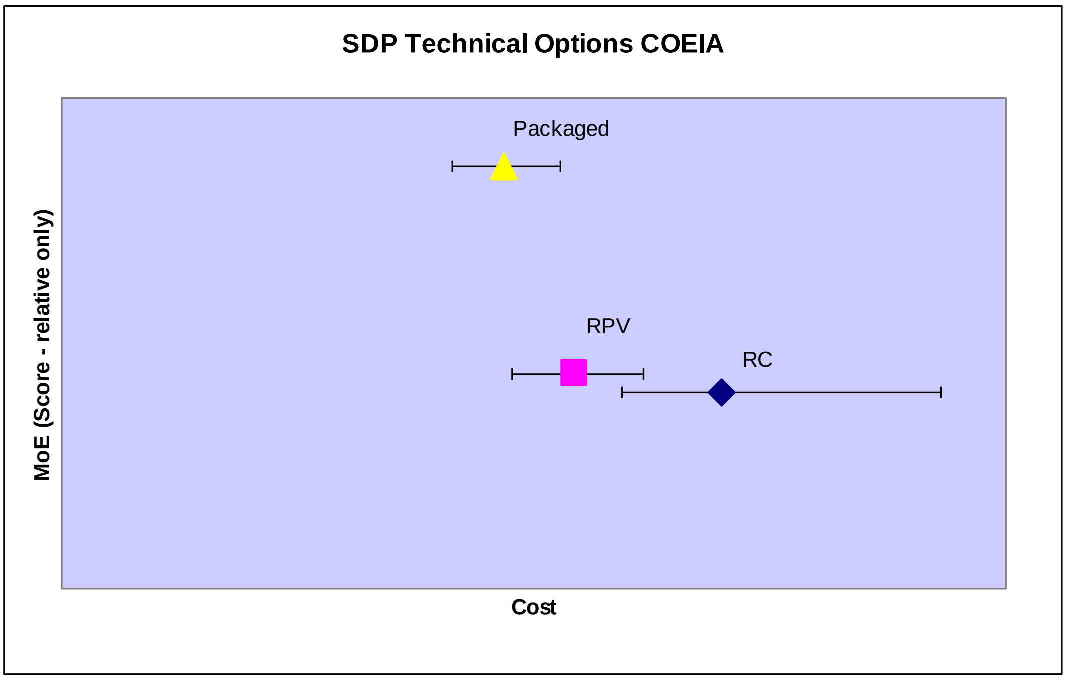
6.1.2. It is important to state that the OE values, measured against the y-axis, are *relative* and <u>not</u> objective. The values provide a comparative indication of the merits of the 3 options against one another, but cannot be used to develop an objective measure of cost-effectiveness.

6.2. Results

6.2.1. The results are summarised in the table below:

Option	**OE Result**	**WLC Result (Confidence)**		
		10%	**50%**	**90%**
1 – RC	32	REDACTED		
2 – RPV	35			
3 – Packaged Waste	69			

6.2.2. The plot below shows them graphically, with error bars corresponding to the spread of confidence levels for WLC:



6.3. Analysis

6.3.1. This COEIA is limited in its rigour by the maturity of the WLC model, the fact that the decision conference has provided relative, rather than objective, values of effectiveness, and the need to fully integrate the results with the methodology for site selection. These aspects will all need to be addressed prior to an IAB submission but the following conclusions can be drawn from the work to date:

- Option 3 (Packaged Waste) is strongly and positively differentiated from the others in terms of effectiveness.

- Option 1 (RC) is clearly and negatively differentiated from the others in terms of WLC, with the only overlap being between the 10% value for Option 1 (RC) and the 90% value for Option 2 (RPV).

6.4. Conclusions

6.4.1. In summary, therefore:

- Option 3 (Packaged Waste) has been identified as the most cost-effective option on the basis of the available evidence.

- Option 1 (RC) has been identified as the least cost-effective option on the basis of the available evidence. It offers similar effectiveness to Option 2 (RPV) but has a significantly greater WLC (50% confidence).

- Option 2 (RPV) is significantly, but not overwhelmingly, more costly than Option 3 (Packaged Waste), and provides comparably poor effectiveness to Option 1 (RC). Therefore, whilst demonstrating greater cost-effectiveness than Option 1 (RC), it is not comparable to Option 3 (Packaged Waste).

[redacted]

[redacted]

7. Other Contributory Factors (OCF)

7.1. Overview

7.1.1. The CoA sets out an approach to the analysis of SDP options based on a clear separation of:

- Measures of Effectiveness (MoE) which may be assessed through OE and/or IA; and

- Factors which may have a significant bearing on the options but are not measurable. These include factors more properly considered during public consultation, such as local or national acceptability or other political factors.

7.1.2. The latter have not, therefore, been considered in this analysis but the project is developing an understanding of such factors through engagement with Other Government Departments and Devolved Administrations, briefings to Elected Representatives, previous public consultation[4], the previous Technical Options Study [Ref A] and the advice of the SDP Advisory Group (AG).

7.1.3. It should be noted that previous public consultation reported a sceptical perception of early cut-up of RCs and indicated a preference for Option 1 (RC) over Option 3 (Packaged Waste). However, further public consultation on technical options is planned (and considered necessary) because of the extent to which the definition of the options and associated evidence has matured and the national and local context evolved since 2003.

[4] Front End Consultation (FEC) and Consultation on ISOLUS Outline Proposals conducted by Lancaster University in 2002 and 2003, respectively

8. Results of Senior Officer Review

8.1. Purpose of the Review

8.1.1. The results of the evidence gathered to date, as reported in Sections 4 to 7 above, were presented to a panel of Senior Officers, with the role of providing project assurance, on 16 June 2010. They were invited to review and critique the evidence, analysis and conclusions drawn from the COEIA. The panel were provided with an earlier version of this report [Ref G] and its contents were reported at length at the Conference.

8.1.2. The Senior Officers comprised:

- A Stirling, Head In-Service Submarines
- Dr P Hollinshead, Head Cap DUW
- [redacted], DES SM S-TL
- [redacted], DepHd Projects & Change
- [redacted], SDP AsstHd Demonstrator
- [redacted], Defence Estates (for [redacted])
- [redacted], CDR-DepHd, HMNB Clyde
- [redacted], Fin-AsstHd, ISM

8.1.3. In addition to the above, the Conference was attended by SMEs in the role of Informers, and a number of Observers including members of the AG.

8.2. Results of the Review

8.2.1. Detailed results of the review are recorded at [Ref H]. In summary, the panel agreed that on the basis of the evidence to date, Option 3 (Packaged Waste), was the most cost-effective approach to dismantling, and accordingly it was agreed that:

- SDP continues to plan on the basis of the assumption that Option 3 (Packaged Waste) will be the proposed approach.
- Further development of Options 1 (RC) and 2 (RPV) will be focused on demonstrating with sufficient rigour the parking of these options within formal analysis.

8.2.2. The following qualifications were, however, recorded:

- The technical options will be subject to further work and Options 1 (RC) and 2 (RPV) shall not be discounted completely at this stage.

- Assumptions underpinning the analysis will continue to be tested to ensure that the current positioning of Option 3 (Packaged Waste) as the clear front runner can be confirmed with sufficient rigour.

- Further work will be conducted to confirm Option 3 (Packaged Waste) has the least technical challenges of the three options.

- The WLC model will be subject to Validation and Verification (V&V).

- Sensitivities within the cost model will be explored as more information becomes available.

- Opportunity realisation work will continue, as stated, although it must be recognised that this should not delay work into identifying proposed options.

8.2.3. These qualifications were noted by the SDP Project team, although the need to prioritise work to reduce the number of options was re-iterated.

9. Conclusions and Recommendations

9.1. Conclusions

9.1.1. On the basis of the evidence to date, Option 3 (Packaged Waste) is the most cost-effective approach to dismantling, and it was agreed that:

- SDP continues to plan on the basis of the assumption that Option 3 (Packaged Waste) will be the proposed approach.
- Further development of Options 1 (RC) and 2 (RPV) will be focused on demonstrating with sufficient rigour the parking of these options within formal analysis.

9.1.2. Providing that:

- Future work identified and discussed during the meeting is undertaken.
- Opportunities are fully investigated but without delaying progress on the baseline Options.
- Underlying assumptions are challenged.

9.2. Actions Arising

9.2.1. The following specific actions were identified from the Senior Officers Conference:

- Successor could provide a precedent for whole RPV transport, and this should be managed as a new project opportunity.
- Sensitivity analysis should be applied to the stated best and worst case dose values.
- The cost deltas between the Options for the 4 and 10 year periods should be determined.
- The capitalised costs for ILW storage should be inputted into the WLC model.
- There should be a data refresh to reduce optimisation bias.

10. References

Ref	Title	Originator	Reference/ Version	Date	Classification
A	ISOLUS Technical Options Study	Frazer-Nash	FNC 35114/59269V Issue 1 Draft (final version to be issued)	January 2009	UNCLASSIFIED
B	SDP Concept of Analysis	ISM	DISM/SDP/420/3220/3279 Issue 0.6	June 2010	PROTECT - POLICY
C	MPOS Study Data Report	Nuvia	89330/PDT/TAF6/006	4 May 2010	UNCLASSIFIED
D	Briefing Pack for MPOS Desk Officers' Conference	Frazer-Nash	FNC 36995/63581V Draft	April 2010	UNCLASSIFIED
E	Desk Level MPOS Conference Report	Frazer-Nash	FNC 36995/36702 Draft	June 2010	UNCLASSIFIED
F	User Requirements Document	DISM	DISM/SDP/420	March 2009 Issue 1.0	Restricted, Management, Commercial
G	Technical Options Analysis Paper V1.0	DISM	V1.0	9 June 2010	PROTECT - POLICY
H	Notes & Actions of the SDP Senior Officers Conference	DISM	V1.0	TBD	UNCLASSIFIED

11. Glossary

Abbreviation	Meaning
AG	Advisory Group
ALARP	As Low As is Reasonably Practicable
BC	Business Case
CAAS	Cost Assurance and Analysis Service
CoA	Concept of Analysis
COEIA	Combined Operational Effectiveness and Investment Appraisal
DUWC	Deterrent & Underwater Capability
GDF	Geological Disposal Facility
IA	Investment Appraisal
IG	Initial Gate
ILW	Intermediate level Waste
KUR	Key User Requirement
IAEA	International Atomic Energy Agency
LLW	Low Level Waste
LLWR	Low Level Waste Repository
MCDA	Multi-Criteria Decision Analysis
MDAL	Master Data and Assumptions List
MG	Main Gate
MoD	Ministry of Defence
MoE	Measure of Effectiveness
MPOS	MOD Proposed Option Study
NPV	Net Present Value
OA	Operational Analysis
OASP	Operational Analysis Supporting Paper
OCF	Other Contributory Factors
OE	Operational Effectiveness
RAWLC	Risk Adjusted Whole Life Cost
RC	Reactor Compartment
RPV	Reactor Pressure Vessel
SDP	Submarine Dismantling Project
SEA	Strategic Environmental Assessment
SME	Subject Matter Expert
SSUN	Single Statement of User Need

Abbreviation	Meaning
VfM	Value for Money
V&V	Validation and Verification
WLC	Whole Life Cost

A Detailed Technical Assessment

A.1 Introduction

In the commentary which follows the term "scores highest" means that an option has achieved the best overall score (for some criteria a lower score was good), whereas "scores lowest" means that an option has achieved the worst overall score (for some criteria a higher score was poor). The same logic applies throughout to the terms "scores higher" and "scores lower".

A.2 Option 1 (RC)

The scoring profile from the Desk Officers' workshop for Option 1 (RC) is shown below, with focus on the most highly weighted criteria and on those which were judged to be the main discriminators.

- Option 1 had the lowest score on *Intergenerational Equity* (ranked 1st in the weightings), because critical activities would be left to future generations. This reflects the fact that there would be a significant time interval (possibly 50 to 100 years) before future generations could completely dismantle the submarine and deal with the waste arising.

- Option1 scored low on *Flexibility of Location* (ranked 6th in the weightings), because the reactor compartment needs to be transported by sea and then (for a short distance) by road and this will restrict the choice of the site.

- Option 1 had the median score on *Technical Challenges* (ranked 3rd in the weightings), mainly because of reactor compartment transportation issues. This reflects the perceived difficulties associated with the transportation of a reactor compartment by ship or barge to the interim storage site and difficulties in finding a suitable port where facilities can be constructed or modified to unload it. It also reflects the difficulties involved in the transportation of a reactor compartment, (which may have degraded during interim storage) to the dismantling site. The Desk Officers' workshop considered that transport is a key discriminator between options.

- Option 1 scored highest on *Adaptability* (ranked 7th in the weightings) because it could take account of future technical and/or regulatory developments, including ILW reclassification.

- Option 1 scored low with respect to the *Volume of LLW* (ranked 4th in the weightings), based on the perception that it would produce more LLW than Option 3. The Desk Officers' workshop considered that it would be difficult to discriminate between options based on the *Volume of LLW (and ILW)*.

- Option 1 had the lowest score on *Regulatory Compliance* (ranked 2nd in the weightings), because it involved a two stage planning process (unlike Option 3) and because of the uncertainties associated with future regulations and planning issues.

- Option 1 scored lowest on *Non Radiological Environmental Impacts* (ranked 9th in the weightings) because a larger and taller building will be required for interim storage and because dredging may be required in order to permit transport by sea.

Commentary:

- Option1 scored highest in only 1 out of 15 categories.

- The lowest worker dose is associated with Option 1, which therefore had the highest score. Worker dose was given a low weighting at the Officers' workshop. One of the benefits associated with Option 1 is the reduced operator dose, since dismantling operations will be carried out after 50 to 100 years, allowing the Co-60 to decay by factors of between 1000 and 1,000,000.

- The main technical and regulatory challenges associated with Option 1 relate to the transportation to and from the interim storage site and the restricted choice of the interim storage site.

- Inability to meet the relevant technical and regulatory transportation requirements would lead this to be considered the highest technical risk for Option 1.

- Other risks include ensuring that future generations have sufficient knowledge to size reduce the submarines.

A.3 Option 2 (RPV)

The scoring profile from the Desk Officers' workshop for Option 2 (RPV) is shown below, with focus on the most highly weighted criteria and on those which were judged to be the main discriminators.

- Option 2 scored lowest on *Technical Challenges* (ranked 3rd in the weightings), mainly because of reactor pressure vessel transportation issues. This reflects the perceived difficulties associated with the preparation of the RPV and its subsequent transportation by sea and (for a short distance) by road to the interim storage site. Such transportations have never been carried out in the UK and a significant amount of development work would be required. For example, a suitable overpack would need to be provided and it could be difficult to re-approve the reactor compartment as a transport container after a period of interim storage, if indeed this is required. The scoring of this option also reflects the difficulties involved in the transportation of a RPV (which may have degraded during interim storage) to the dismantling site. The Desk Officers' workshop considered that transport is a key discriminator between options.

- Option 2 had had the median score on *Worker Dose* (ranked 13th in the weightings). The assessed dose was similar to that for Option 3.

- Option 2 had joint highest score for *Volume of ILW to GDF* (ranked 5th in the weightings), Industrial Skill Set (ranked 11th in the weightings), and Industrial Submarine Experience (ranked 10th in the weightings).

Commentary:

- Option 2 had the joint highest scoring in only 3 out of 15 criteria.

- The second lowest worker dose is associated with Option 1, which therefore had the median score. The assessed value was in fact very similar to that for Option 1. Worker dose was given a low weighting at the Desk Officers' workshop

- The main technical and regulatory challenges associated with Option 2 relate to the transportation to and from the interim storage site and the restricted choice of the interim storage site.

- Inability to meet the relevant technical and regulatory transportation requirements is considered to be the highest technical risk for Option 2

A.4 Option 3 (Packaged Waste)

The scoring profile from the Desk Officers' workshop for Option 3 (Packaged Waste) is shown below, with focus on the most highly weighted criteria and on those which were judged to be the main discriminators.

- Option 3 had the highest score on *Intergenerational Equity* (ranked 1st in the weightings), because critical activities would not be left to future generations. This reflects the fact that the submarine ILW would be size reduced directly after dismantling and then packaged, conditioned and prepared for long term interim storage. The only remaining task for future generations would be the transportation and disposal of the packaged waste to the GDF.

- Option 3 scored highest on *Flexibility of Location* (ranked 6th in the weightings), because existing ILW stores (most of which can only be reached by road transport) could be used.

- Option 3 scored highest on *Technical Challenges* (ranked 3rd in the weightings). The main technical challenge was in the dismantling and size reduction of the RPV.

- Option 3 scored lowest on *Worker Dose* (ranked 13th in the weightings), but had a similar value to Option 2, reflecting the fact that both options involve removal of the RPV.

- Option 3 scored highest on *Regulatory Compliance* (ranked 2nd in the weightings), because there was less risk associated with obtaining the necessary approvals when compared to the other options.

Commentary:

- Option 3 had the highest scoring for most of the heavily weighted criteria and also in 7 out of 15 categories.

- The highest worker dose is associated with Option 3, which therefore had the lowest score. Worker dose was given a low weighting at the Desk Officers' workshop. One of the disadvantages associated with Option 3 is the increased operator dose, since dismantling operations will be carried out within a short timescale. The task remains to convince the regulatory authorities that reasonable measures, which are not unreasonably costly, will be taken to reduce doses to levels which are as low as reasonably practicable (ALARP).

- The main technical and regulatory challenges associated with Option 3 relate to the dismantling and size reduction of the RPV.

- Inability to meet the relevant technical and regulatory dismantling and size reduction requirements is considered to be the highest risk for Option 3.

- Other risks include:

    - Insufficiently definitive waste characterisation to meet the requirements of transportation, storage and disposal, which could lead to difficulties in obtaining statutory approvals.

    - Production of excess quantities of waste which can only be disposed of at the GDF. This could have an adverse impact on the waste disposal budget.