



Final Report
Diminishing Manufacturing Sources and Material Shortages (DMSMS)
Non-Recurring Engineering (NRE) Cost Metric Update

Contract H94003-10-F-0109

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Executive Summary

There are eight requirements in this contract:

1. Analyze the 2009 Department of Commerce (DoC) DMSMS Cost Resolution survey results and calculate new non-recurring engineering (NRE) resolution cost metrics for the DoD DMSMS Guidebook of Best Practices (SD-22). This task was difficult because the survey results could not be used “as is” – the responses needed additional research and categorization. The table below is the updated Resolution Cost Metrics and reported time duration for the resolution costs. This table should replace Table 4 in the existing SD-22 guidebook.

Table 1. NRE Resolution Cost and Time Metrics (FY2011) from the 2009 DoC Survey

Resolution Type	90% Confidence (Left Limit)	Mean	90% Confidence (Rt Limit)	Weeks to Resolve (Avg)
Reclamation	\$1,000	\$20,000	\$39,000	12
Alternate Source ¹	\$0	\$41,000	\$92,000	11
Admin Substitute	\$1,000	\$3,000	\$5,000	4
Desktop Substitute	\$0	\$5,000	\$10,000	8
Normal Substitute	\$22,000	\$34,000	\$46,000	25
Complex Substitute	\$122,000	\$423,000	\$724,000	40
Emulation ²	\$29,000	\$73,000	\$117,000	26
Aftermarket Mfg	\$0	\$33,000	\$58,000	21
Redesign - COTS ³	\$82,000	\$1,118,000	\$2,154,000	42
Redesign - CP ⁴	\$542,000	\$1,094,000	\$1,646,000	61
Redesign - PNHA ⁵	\$654,000	\$1,010,000	\$1,366,000	64

¹ Alternate source includes parts from a different manufacturer (not already in the applicable technical data package) that meet the part specification.

² Emulation cost values provided by Defense Logistics Agency (DLA) are not from the DoC survey and represent the historical costs to DLA to emulate a part from the GEM¹ and GEM AME² programs; they do not include integration into the using next higher assembly or system.

³ Redesign – Commercial Off-the-Shelf

⁴ Redesign – Custom Part includes the development and validation in the application of new component-level parts

⁵ Redesign – Peculiar Next Higher Assembly

2. Generate “redlines” to update selected portions of the SD-22. Note: ARINC’s redlines to the SD-22 are provided separately from this report.

¹ GEM Generalized Emulation for Microcircuits Program

² GEM AME GEM Advanced Microcircuit Emulation

3. Compare the data from the 2009 DoC Survey results with previous surveys. No useful trends or inferences could be discerned from this comparison (because the resolution types surveyed were not the same).
4. Derive additional value from this survey for use in future surveys. ARINC recommends the use of the new ontology (Appendix B), the incorporation of the calibration methodology suggested by Dr Sandborn, and a new initiative to collect costs from selected organizations continuously (see paragraph 3.4).
5. Investigate the feasibility of using a “return on investment” (ROI) metric in lieu of the “cost avoidance” metric. Dr Sandborn, University of Maryland, investigated this and provided a preliminary methodology. ARINC believes that an ROI type of metric is possible but not practical (at least at the present time).
6. Perform an ontological review of the survey data and report on missing data, ambiguous data, and data replications. An ontology, as used in this study, is the common set of concepts (definitions and taxonomy) for use in shared understanding and consistent communication within the DMSMS domain. Generating a DMSMS ontology turned out to be a necessity in order to make use of the DoC survey data. The ontology defines DMSMS resolutions in three broad categories (logistics, engineering, and programmatic initiatives). ARINC has analyzed data from the DoC survey within the framework of the new ontology (see Appendix A).
7. Develop a best practice case study showing procedures for developing program-specific NRE cost resolution values. Appendix D is a “walk-through” illustration of how to use specific examples of DMSMS corrective action cost data (“actuals”) to adjust cost estimates for all other resolution types (that do not yet have actuals). This case study is incorporated into the suggested redlines to the SD-22.
8. Develop a second case study showing the proper application for resolution cost metrics in a DMSMS business case analysis (BCA). Appendix E shows how to apply the Office of Management and Budget guidelines for benefit-cost analysis to compare potential DMSMS solution alternatives. This case study is also incorporated into the suggested redlines to the SD-22.

Abbreviations and Acronyms

AMS	Aftermarket Source
BCA	Business Case Analysis
CAGE	Commercial and Government Entity
CCA	Circuit Card Assembly
COTS	Commercial Off-the-Shelf
CP	Custom Part
CY	Constant Year (\$)
DLA-L&M	Defense Logistics Agency – Land and Maritime
DMEA	Defense Microelectronics Activity
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DMT	DMSMS Management Team
DoC	Department of Commerce
DoD	Department of Defense
DSPO	Defense Standardization Program Office
DTO	Digitally Tuned Oscillator
F ³ I	Form, Fit, Function and Interface
FY	Fiscal Year (\$)
GEM	Generalized Emulation of Microcircuits
GEM AME	GEM Advanced Microcircuit Emulation
LCP	Life Cycle Phase
LRU	Line Replaceable Unit
LTB	Lifetime Buy
NCCA	Naval Center for Cost Analysis
NHA	Next Higher Assembly
NPV	Net Present Value
NRE	Nonrecurring Engineering
NSC	National Semiconductor Corporation
OMB	Office of Management and Budget
OSD/ATL	Office of Secretary of Defense, Acquisition, Technology, and Logistics
PBL	Performance-Based Logistics
PN	Part Number
PNHA	Peculiar Next Higher Assembly
QCI	Quality Conformance Inspection
RDT&E	Research, Development, Test and Evaluation
RIOS	Required Item of Supply
ROI	Return on Investment
SCD	Specification Control Drawing

SD-22	DMSMS Guidebook of Best Practices
SLEP	Service Life Extension Program
SMD	Standard Microcircuit Drawing
SoCD	Source Control Drawing
SOS	Source of Supply
SRU	Shop Replaceable Unit
TDP	Technical Data Package
TY	Then-Year
UK	United Kingdom
USAF	United States Air Force
WRA	Weapon Replaceable Assembly

Table of Contents

Abbreviations and Acronyms	v
Table of Contents.....	vii
List of Tables	vii
List of Figures.....	viii
1.0 Background.....	1
1.1 Contract Requirements.....	1
2.0 The Survey and the Analysis Procedures.....	2
3.0 Study Results	3
3.1 Requirement 1 – Calculate Revised NRE Cost Resolution Metrics.....	3
3.1.1 Projecting Resolution Cost Metrics to Future Years.....	4
3.2 Requirement 2 – Provide Redlines to the SD-22 Guidebook.....	5
3.3 Requirement 3 – Comparison of 2009 DoC Data with Previous Studies.....	5
3.4 Requirement 4 – Suggestions to Improve Future Surveys.....	7
3.5 Requirement 5 – Feasibility of Defining and Using an ROI Metric.....	8
3.6 Requirement 6 – Ontological Review of the Survey Data.....	10
3.7 Requirement 7 – Case Study: Program-specific NRE Cost Metrics.....	10
3.8 Requirement 8 – Case Study: Using Resolution Cost Metrics in a DMSMS BCA.....	11
4.0 Recommendations for Follow-Up.....	11
Appendix A – Analysis of Survey Responses	A1
Appendix B – Ontology of DMSMS Resolutions	B1
Appendix C – DMSMS Management Return on Investment (ROI) Analysis.....	C1
Appendix D – Case Study – Developing Program-Specific NRE Cost Metrics	D1
Appendix E – BCA Application Case Study	E1

List of Tables

Table 1. NRE Resolution Cost and Time Metrics from the 2009 DoC Survey Results.....	3
Table 2. NRE Resolution Mean Cost Value Comparison (FY2011).....	6
Table A1. Sample of Survey Data Analysis Worksheet (for Redesign PNHA).....	A1
Table A2. Resolution Type Definitions from the DoC Survey	A2
Table A3. Adjustments to the Survey Resolution Type Counts.....	A6
Table B1. Standard DMSMS Resolution Definitions, Properties, Relationships.....	B2
Table B2. Programmatic Initiatives that May Mitigate DMSMS.....	B7
Table C1. Conventional cost avoidance calculation.....	C6
Table C2. Additional Recurring Cost as a Result of DMSMS Management	C7
Table D1. Ratios of Type Average Cost to Cost of a Complex Sub	D2
Table D2. New NRE Resolution Type Metrics Based on Actual Cost of a Complex Sub	D2
Table D3. Ratios of Type Average Cost to Actual Cost of a Normal Sub	D2
Table D4. Estimates (Using Actual Values of Complex Sub and Normal Sub).....	D3

Table E1. Real Interest Rates on Treasury Notes and Bonds (in percent) (2011 Budget) E3
Table E2. Resolution Cost Metrics from the New SD-22 (FY2011)..... E2
Table E3. Computing Present NRE Cost of Alternative 1 (Mix of Solutions)..... E2
Table E4. Computing Present NRE Cost of Alternative 2 (SRU Redesign) E3

List of Figures

Figure A1. Input Survey Worksheet for “Existing Substitute- Normal” A2
Figure B1. DMSMS Resolution Taxonomy B1
Figure C1. ROI of the Unmanaged Case: Unmanaged System (Aegis DMSMS Program)..... C8

Final Report

Diminishing Manufacturing Sources and Material Shortages (DMSMS) NRE Resolution Cost Metric Update

1.0 Background. In 1999, ARINC Engineering Services LLC, under contract to the Defense Microelectronics Activity (DMEA), surveyed 31 major players in the defense microelectronics industry to produce a set of “standard” non-recurring engineering (NRE) resolution cost metrics for 9 defined types of DMSMS resolutions. The report of those NRE metrics³ has for the last 10 years been the definitive reference for calculating DMSMS costs and DMSMS cost avoidance estimates used by organizations that did not have their own DMSMS resolution cost data. DMEA and ARINC performed a supplemental update to the report in 2001, adding confidence boundaries and cost inflation factors (using DoD Weighted Inflation Indices where appropriate)⁴, but there was no new survey data in the 2001 update. (In this report, we will only refer to the 2001 DMEA Study, with the awareness that the resolution cost data were generated in 1999.)

After a decade of use, the DMSMS resolution type cost metrics needed updating. In 2009, the US Department of Commerce (DoC) sent surveys to 249 organizations to refresh the DMSMS NRE resolution costs. Data from the returned surveys are the foundation for this analysis; the principal objective of the analysis is to update the NRE Cost Metrics table (Table 4 in the current version of the SD-22 that has become Table 5 in the suggested redline version) in the next issue of the DMSMS Guidebook of Best Practices (SD-22) published by the Defense Standardization Program Office (DSPO).

1.1 Contract Requirements. Since the primary users of the SD-22 and the Resolution Cost Metrics are members of various DoD DMSMS Management Teams (DMTs), we kept that audience in mind as we satisfied contract requirements. There are eight requirements stated in Contract H94003-10-F-0109 (DMSMS Resolution Cost Factors Update):

1. Analyze the 2009 DoC DMSMS Resolution Cost Survey results and calculate revised NRE cost values (with 90% confidence bands) for the resolution types for inclusion in the SD-22 guidebook update (see paragraph 3.1).
2. Produce “redlines” to update the SD-22 section on “Measuring DMSMS Program Effectiveness” to be consistent with the results of the DoC survey and the revised NRE resolution costs. Develop SD-22 glossary entries for the NRE resolution types. ARINC

³ Resolution Cost Factors for Diminishing Manufacturing Sources and Material Shortages, February 1999, prepared for the Defense Microelectronics Activity, ARINC

⁴ Weighted Inflation Index - An index used to convert from a base fiscal year to budget (then-year) dollars and vice versa. This is calculated by multiplying the raw inflation index by the outlay profile factors to account for the inflation that occurs during the expenditure years. The outlay profile is the rate at which dollars in each appropriation are expended over time, displayed in percentage per year of expenditure.

generated redlines to the entire SD-22 – not just the two areas mentioned (see paragraph 3.2). (Note: those SD-22 redlines are being provided separately from this report.)

3. Compare the data from the 2009 DoC Survey results with the 2001 DMEA US Cost Metrics and the 2004 United Kingdom (UK) Cost Metrics Report (see paragraph 3.3).
4. Discern trends from this comparison (3 above) and derive additional value from this survey for use in future surveys (see paragraph 3.4).
5. Investigate the feasibility of using a “return on investment” metric in lieu of the “cost avoidance” metric that has been used for many years (see paragraph 3.5).
6. Perform an ontological⁵ review of the survey data and report on missing data, ambiguous data, and data replications (see paragraph 3.6).
7. Develop a best practice case study showing procedures for developing program-specific NRE resolution type cost values (see paragraph 3.7).
8. Develop a case study showing the proper application for resolution cost metrics in a DMSMS business case analysis (BCA) (see paragraph 3.8).

2.0 The Survey and the Analysis Procedures

The DoC survey resulted in two large Excel™ data files: one for platforms (e.g., an aircraft) and one for systems (e.g., a RADAR set). ARINC merged the files and eliminated the rows with no entries (much of the spreadsheet was blank) to make it easier to use the data. The process sequence for each DMSMS resolution type was as follows (the details can be found in Appendix A):

- Examine the response data population to identify the questionable or “outlier” resolution cost values.
- Match respondents’ comments (which were in a separate file) with the data instances to help identify questionable responses.
- Contact the respondents to clarify their comments and information on the questionable entries or outliers.
- Unplanned – create a set of new definitions of DMSMS resolution types to better match the survey responses (this is included in Appendix B).
- Exclude or re-categorize data as necessary from the follow-up contacts.

As detailed in Appendix A, the survey respondents often mis-categorized their resolution types (mostly due to difficulty applying the resolution type definitions). This required ARINC to adjust the survey data. For example, we excluded all responses from one organization because they reported cost avoidance values based on the existing cost resolution data (not the incurred

⁵ Ontology, as used in this report, is a set of defined concepts for use in shared understanding and consistent communication within the domain of DMSMS resolutions. The concepts are defined using: vocabulary, subclass hierarchy (taxonomy), and assignment and definition of properties, relationships, and constraints.

cost of completed projects). Many of the reported major redesign resolution types did not fit the definitions in the survey.

ARINC re-wrote the resolution type definitions and contacted 23 organizations to verify their answers and re-categorize the answers into the new definition set (the new ontology). There were major adjustments to the reported data and the new resolution cost metrics are based on those adjusted data. Detailed observations about the quality of the survey data, the results of further investigating the responses, and ARINC’s methods and assumptions in processing the data can be found in Appendix A.

3.0 Study Results

3.1 Requirement 1 – Calculate Revised NRE Cost Resolution Metrics. The 2009 DoC survey went out in November 2009 and requested data “for the past 36 months” (FY2007 through FY2009). Data returned from this survey were very difficult to analyze and ARINC expended considerable effort to correct data deficiencies (see details in Appendix A). Table 1 is the result of our analysis of the DoC survey data and should replace Table 4 in the SD-22 guidebook. These derived cost metrics are for NRE only (i.e., no procurement, production, or administrative costs, and no DMSMS program infrastructure costs).

We considered that the data represent FY2008 (mid-point of the collection range). All costs from the survey were then escalated (inflated) to FY2011 using the DoD raw inflation indices (FY2008 Constant Year to FY2011 Constant Year: value of 1.0354). Table 1 represents FY2011 resolution cost metrics and time duration (rounded to the nearest thousand dollars).

Table 1. NRE Resolution Cost and Time Metrics (FY2011) from the 2009 DoC Survey

Resolution Type	90% Confidence (Left Limit)	Mean	90% Confidence (Rt Limit)	Weeks to Resolve (Avg)
Reclamation	\$1,000	\$20,000	\$39,000	12
Alternate Source ¹	\$0	\$41,000	\$92,000	11
Admin Substitute	\$1,000	\$3,000	\$5,000	4
Desktop Substitute	\$0	\$5,000	\$10,000	8
Normal Substitute	\$22,000	\$34,000	\$46,000	25
Complex Substitute	\$122,000	\$423,000	\$724,000	40
Emulation ²	\$29,000	\$73,000	\$117,000	26
Aftermarket Mfg	\$0	\$33,000	\$58,000	21
Redesign - COTS ³	\$82,000	\$1,118,000	\$2,154,000	42
Redesign - CP ⁴	\$542,000	\$1,094,000	\$1,646,000	61
Redesign - PNHA ⁵	\$654,000	\$1,010,000	\$1,366,000	64

¹ Alternate source includes parts from a different manufacturer (not already in the applicable technical data package) that meet the part specification.

² Emulation cost values provided by Defense Logistics Agency (DLA) are not from the DoC survey and represent the historical costs to DLA to emulate a part from the GEM and GEM AME programs; they do not include integration into the using next higher assembly or system.

³ Redesign – Commercial Off-the-Shelf

⁴ Redesign – Custom Part includes the development and validation in the application of new component-level parts

⁵ Redesign – Peculiar Next Higher Assembly

The cost values from the “Mean” column from Table 1 should be used. Table 1 also includes the left and right 90% confidence limits for the resolution cost. These values provide a 90% assurance that the true mean cost lies within that interval range. A wider confidence range indicates a lower precision of measurement. Some left limit values in Table 1 are zero because of the small sample size and the wide range of values in that sample.

As noted in paragraph 3.3, these 2011 resolution cost metrics are significantly different from the metrics found in previous studies. Table 1 also includes the time to resolve (for each resolution type) as reported by the respondents to the DoC survey.

3.1.1 Projecting Resolution Cost Metrics to Future Years. A cost value for any given year (e.g., FY2011) must be escalated to be used for future years. ARINC has added suggested coverage of escalation procedures in the SD-22 redlines (after the updated Cost Metric table in the SD-22) as follows:

The resolution cost metrics presented in Table 4 (of the current SD-22) are in FY2011 dollars. When projecting resolution costs into the future, the effects of inflation must be taken into account. The term “then-year” (AKA “budget-year”) describes future year costs that include the effects of inflation, and should be used for budgeting purposes.

The Government provides weighted inflation factors that are updated each year. Weighted inflation factors should be used to inflate constant dollars (i.e., FY2011) to budget-year/then-year dollars (i.e., FY2012 and beyond). Weighted inflation factors are used to account for the time lag between budgeting of funds (congressional appropriations), contracting (for goods and services), and their receipt (completion). The weighted factor is calculated by multiplying the raw inflation index by the outlay profile factors to account for the inflation that occurs during the expenditure years. The DoD, each service, and each major appropriation category (e.g., RDT&E or Military Construction) have distinct weighted inflation factors, but generally the differences are at the third decimal point.

The Naval Center for Cost Analysis (NCCA) has an on-line inflation calculator that includes DoD-wide, Navy, Marine Corps, and Army weighted inflation factors (<http://www.ncca.navy.mil/services/inflation.cfm>). The USAF has a similar tool, but it has restricted access.

For example, the metric for a complex substitute resolution in 2011 is \$423,000 (from Table 1 of this report). From the NCCA Tool, the DoD-wide weighted index to escalate the cost from 2011 to 2012 is 1.0295. Therefore, the value to use in 2012 is: $\$423,000 * 1.0295 = \$435,000$ (rounded).

3.2 Requirement 2 – Provide Redlines to the SD-22 Guidebook. ARINC generated redlines for the entire SD-22 (provided separately). There are six substantive changes (the rest were editorial improvements) as follows:

- A new DMSMS Resolution hierarchy to replace the old Table 3 in SD-22 (Alternative Risk Mitigation Actions, by Life-Cycle Phase), based on the new resolution ontology. The new resolution definitions in the ontology match the definitions in the new NRE Cost Metrics table (old Table 4) in SD-22.
- Replacement of Table 4 (FY2011 NRE Cost Metrics) and the associated narrative, including the procedure for escalating the FY2011 cost values to future years. Also, the time duration values for each resolution type as reported from the DoC survey have been included in the replacement table.
- A case study to illustrate the application of BCA methodology to a DMSMS scenario that is suggested to become Appendix K in the SD-22.
- The BCA coverage of how to justify a complete proactive DMSMS program is suggested to be moved to the front of the SD-22 under the “Basis for DMSMS Mitigation.” That coverage summarizes the B-2 BCA that ARINC briefed to the Office of the Secretary of Defense Acquisition, Technology, and Logistics (OSD/ATL) in 2003. The outcome of that briefing was an affirmation by OSD/ATL that the proactive case is preferred and that other programs need not replicate the B-2 BCA to arrive at a justification for their proactive DMSMS programs. Therefore this material belongs in the front of the SD-22.
- A new appendix – an expanded DMSMS Resolution Ontology providing resolution taxonomy and associated data elements.
- A new appendix – an illustration of how to adjust the resolution type cost metrics based on program-specific actual costs.

3.3 Requirement 3 – Comparison of 2009 DoC Data with Previous Studies. The third contract requirement was to “discern trends and derive additional value” from the data. Table 2 compares the mean resolution cost metric values by resolution type from the 2009 DoC survey resulting from our analysis, the 2001 DMEA survey, and the 2004 United Kingdom (UK) survey, all adjusted to FY2011. The DoC values were adjusted for categories and counts as described in Appendix A.

Table 2. NRE Resolution Mean Cost Value Comparison (Adjusted to FY2011)

Resolution Type	2009 DoC Study	2001 DMEA Study	2004 UK Study
Reclamation	\$20,000	\$2,300	\$2,700
Alternate Source	\$41,000	\$7,900	\$10,900
Admin Substitute	\$3,000	\$22,000	\$27,900
Desktop Substitute	\$5,000		
Normal Substitute	\$34,000		
Complex Substitute	\$423,000		
Aftermarket Mfg	\$33,000	\$58,600	\$32,800
Emulation ¹	\$73,000	\$84,100	\$150,800
Redesign COTS	\$1,118,000	N/A	
Redesign - CP	\$1,094,000		
Redesign - PNHA	\$1,010,000		
Redesign - Minor	N/A	\$137,000	\$153,700
Redesign - Major		\$507,000	\$631,900

¹ 2009 emulation cost (\$73,000) from DLA historical data (not from the DoC Survey)

In Table 2, the costs from the 2001 DMEA study were inflated to FY2011 then-year dollars using the DoD-wide raw inflation factor (from the NCCA site) of 1.2371 (1999 to 2011). The UK values were converted from Great Britain pounds to US dollars using the factor 1.79 (1 pound = \$1.79 as of September 2004) and then inflated from FY2004 to FY2011 using the DoD-wide raw inflation factor of 1.1541 (FY 2004 to FY2011). Thus the Table 2 data have the same currency and time frame basis. Yet as seen in Table 2, the data from these three studies did not use the same resolution types; it is therefore not possible to discern meaningful conclusions from this comparison. There are three reasons why this is so:

- There were seven sub-types of redesign (A, B, C, D, E, F1, and F2) in the 2009 DoC survey that were not in the 2001 DMEA study. These sub-types were in the UK study, but the final value reported (by the UK) was only for minor and major redesign types (not the seven sub-types). For reasons presented in Appendix A, ARINC converted these seven sub-types in the DoC study into three redesign types (COTS, CP, and PNHA) and reclassified the DoC survey responses. The 2001 DMEA survey and the 2004 UK survey used different redesign type definitions (for both minor and major redesign).⁶
- There were four sub-types of substitute solutions (Administrative, Desktop, Normal, and Complex) in the 2009 DoC survey that were not in the other two studies.

⁶ From the 2001 DMEA study: major and minor redesign applies to “circuit boards (SRUs) and includes engineering, program management, integration, testing, and upgrade of technical data package (TDP).”

From the 2004 UK study: Redesign is “Designing an obsolete item out of the system. Usually used as a last resort because of the cost implications. Redesign typically has the goal of enhancing system performance and improving reliability and maintainability. The NRE cost for redesign of a circuit board (LRU) includes engineering, program management, integration and testing. Redesign can be further broken down into categories, i.e. minor (board re-layout) and major (board replacement). Redesign costs may attract system qualification and extensive testing such as flight tests.”

- Because of the wide variability of cost values reported for ostensibly similar resolution types and miss-classifications (see Appendix A) in the 2009 DoC survey, ARINC adjusted many responses to re-categorize them. That degree of follow-up adjustment was not done for the 2001 DMEA Study (and we don't know if there was an extensive data scrub for the 2004 UK study).

Conclusion on Comparisons: For those resolution types where the definitions were the same, the cost metrics from the 2009 DoC study are much higher (except for the Aftermarket Manufacturing category and DLA Emulation). In the follow-up contacts with the survey respondents, some stated their opinion that “the old metrics were unrealistically low.” Also, ARINC found it could not use the old DMEA metrics on the B-2 DMSMS Program because they were too low in every category. For example, in 2007, the cost to find a commercial off-the-shelf microcircuit and verify its suitability as a substitute for use in a B-2 LRU was \$1.2 M. The DMEA and UK study values for a substitute solution were both tiny fractions (about 2%) of this “actual” \$1.2M cost.

Recommendation: It is ARINC’s recommendation that future cost studies should use the same definitions as the “adjusted” 2009 DoC study; it would then be possible to meaningfully project cost trends.

3.4 Requirement 4 – Suggestions to Improve Future Surveys. As mentioned above, the first problem noted in the 2009 DoC survey returns stemmed from the respondents’ difficulty in matching their completed corrective action projects to the resolution type definitions in the survey. Of first importance – definitions of the resolution types must make it easy for the respondents to match the types with their experience. Using the resolution ontology in Appendix B would accomplish that aim. There is also a companion need for a software tool such as a “wizard” to help DMSMS practitioners in the field select among standardized resolution definitions.

The second problem with the 2009 DoC survey results is that the cost elements used by different survey respondents to arrive at costs for specific solutions may not be directly comparable for several reasons. Our study consultant, Dr Peter Sandborn of the University of Maryland, notes: “Each respondent has reported different cost elements. Even when respondents report their costs in the same resolution types, it is very likely that they do not represent the same activities. For example, it is possible that respondent A has included the cost of DMSMS management infrastructure (software licenses, training, etc.) within their reported costs and respondent B has not.”⁷ Rather than attempt to ask respondents for more detailed cost breakdowns, he suggests development of:

“An approach to normalize the reported costs between the future survey respondents. Each respondent would submit a cost and time estimate for a DMSMS benchmark exercise problem (scenario) with a very tightly prescribed set of actions. This “calibration” exercise

⁷ Dr. Peter Sandborn’s comments are from an unpublished manuscript, written specifically for this study effort, entitled, *Cost Normalization*, June 16, 2010.

would be required of respondents in addition to reporting on their actual completed DMSMS projects.” Dr Sandborn’s example of such a benchmark scenario:

“The impending obsolescence of part ABC is to be resolved using a complex substitute part. The substitute part is from a non-qualified supplier. The part will require form, fit, function, and interface (F³I) testing, compatibility testing, and performance testing at the next higher assembly (NHA). Assuming that the supplier and the substitute part both survive their qualification processes without any special actions, and that the appropriate resources are available without delay (people and test equipment), please estimate and show the buildup of your organization’s expected (budgeted) time and resources (costs) to complete this DMSMS resolution case.

“The data collected might look like:

	Respondent A	Respondent B
Total calendar time to resolve this case	60 days	30 days
Total budget to resolve this case	\$45,000	\$61,000

“If a nominal time and cost (used for all the data from all the respondents) is set at: 30 days and \$30,000, then the scaling factors (to be used) for the two respondents become:

	Respondent A	Respondent B
Calendar time scaling factor	0.5	1.0
Cost scaling factor	0.667	0.492

“All of respondent A’s reported times in the survey will be multiplied by 0.5 and all of their costs multiplied by 0.667. This approach will produce valid relative costs and times for the various resolution approaches.

“As presented here, this benchmark scenario is most likely too simple and would need to be augmented with additional detail. It is possible that the scaling could be a function of time as well. A follow-on activity that develops and field tests a benchmark scenario with one or more willing respondents is advised.”⁸

Recommendation on Improving Future Surveys: Surveying the field for resolution type cost data will always be difficult. If a new survey is undertaken, ARINC recommends the use of the new ontology and the incorporation of the calibration methodology suggested above.

Another approach might be to start collecting real costs from selected organizations continuously, methodically scrubbing the data, and making it available on a web site (similar to how the DoD inflation factors are updated and disseminated).

3.5 Requirement 5 – Feasibility of Defining and Using a Return on Investment (ROI) Metric.

Dr Sandborn investigated this feasibility and prepared a study on a DMSMS

⁸ Same reference as footnote 6.

Management ROI Analysis (see details in Appendix C to this report). His summary of the study and its suggested feasibility of using an ROI follow:

“The economic case for DMSMS management is conventionally based on calculating the cost avoidance that results from various management activities. Cost avoidance is a generally well understood concept, but understanding it does not mean that it is sellable to program management. An important attribute of most business cases is the development of an economic justification in the form of an ROI. ROI could be a useful means of gauging the relative economic merits of different DMSMS management approaches.

“Although ROI is a relatively simple concept that is widely applied to investments, it is not trivial to formulate correctly when the return on the investment is cost avoidance (i.e., a reduction in costs that have to be paid in the future to maintain the system).

“A new approach to the generation of cost avoidance (and associated ROI or DMSMS management efforts) has been postulated. The new approach postulates the determination of an ROI for DMSMS management as a function of the system sustainment cost of the unmanaged system. It contrasts with ROIs found using the conventional cost avoidance analysis (i.e., [the] difference between the cost of your solution and the next most expensive one), which produce cost avoidance numbers that are commonly used as a metric to measure the value of DMSMS management groups, but do not represent real dollars, and ROIs created using them are largely meaningless since they are not measured relative to any fixed solution.”⁹

Dr Sandborn’s new formulation (described in Appendix C) was offered as a possible means to resolve such concerns.

Conclusion on Feasibility of an ROI Metric: ARINC believes that an ROI metric is theoretically feasible and possibly could be developed for use by DMSMS management organizations. However, for the general DMSMS practitioner, the metric will remain academic until there is a method to collect the additional data needed to make the computations – both for systems proactively managed (for DMSMS) and for those that are not. Fundamentally, DMSMS is and always will be undertaken not to reap an economic or quantitative return – but to correct a supportability problem.

Recommendation – ROI Metric: We advise the implementation of a follow-on activity that:

- Includes an in-depth review of potential ROI alternatives by the Common Use Tools Committee of the DoD DMSMS Working Group.
- Engages with a specific DMSMS management organization (governmental or non-governmental) to understand their costs and develops ROIs for them in order to articulate or identify an end-to-end process for ROI analysis. This process could be characterized by a template with which organizations could generate valid and consistent ROI estimates.

⁹ Extracted from Dr Sandborn’s paper DMSMS Management Return on Investment (ROI) Analysis, July 17, 2010.

3.6 Requirement 6 – Ontological Review of the Survey Data. Developing a DMSMS ontology was inherently part of requirement 1 (made necessary by the survey responses not matching the resolution type definitions). The lack of standard definitions and understanding of resolution types within the DMSMS discipline has been a long-recognized deficiency. ARINC believes that the reporting problems with the 2009 DoC survey were largely due to this problem. The DMSMS discipline needs an ontology – a common set of well-defined concepts for use in shared understanding and consistent communication within a particular domain (DMSMS resolution types). The concepts are defined using:

Vocabulary (definitions)

Subclass hierarchy (taxonomy)

Assignment and definition of properties, relationships, and constraints

A suggested Ontology of DMSMS Resolution Types, resulting from collaboration between ARINC and Dr Sandborn, can be found in Appendix B. This same ontology has been proposed for incorporation into the SD-22.

3.7 Requirement 7 – A Case Study on Developing Program-specific NRE Cost Metrics. The SD-22 DMSMS Resolution Cost Metrics (Table 1 in this report, proposed Table 5 for SD-22) will suffice for estimating purposes when there are no actual program-specific cost data available. Assume that at some future time, the program initiates a DMSMS corrective action project. Cost data from that “actual” project can be used to generate program-specific metrics. Obviously, an average actual cost of the specific resolution type will be the best estimate for future examples of that same type. But what can be done to generate better estimates of the other resolution types? In Appendix D, we illustrate how to use the actual data to arrive at a program-specific estimate.

The technique described in Appendix D can be used to revise the set of resolution cost estimates each time a new actual cost (for any resolution type) is incurred. The values in the set of resolution cost metrics that came from previous actuals would not be changed, but all others would be. If other instances of the same resolution type occur, the cost metric of that type would be changed to the new average of the occurrences.

For this technique to work, each program DMT must keep track of solutions and the associated costs. The value is in the validity of cost estimates for future project corrective action budgets for the program.

3.8 Requirement 8 – Develop a Case Study Showing Application of Resolution Cost Metrics in a DMSMS BCA. Benefit-cost analysis (one outcome of a BCA, along with other econometric measures such as break-even point) is the technique to use in a formal economic analysis of a government program. The standard criterion for deciding whether a government program (or in our case, a DMSMS resolution alternative) can be justified on economic principles is net present value (NPV) -- the discounted monetized value of expected net benefits (i.e., benefits minus costs). NPV is computed by assigning monetary values to benefits and costs over time, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits.

In considering any two DMSMS resolution alternatives, the one with the least present cost is preferred. We assume that the benefit of mitigating a given DMSMS condition is the same for each alternative, namely to sustain the system and its operational availability; hence, present cost is as good as NPV in choosing among alternatives. To compute present cost, you must “discount” future costs using the Office of Management and Budget (OMB) discount rate to account for the time value of money. A cost has a higher value in the present if it is experienced sooner (delay is economical). The higher the discount rate, the lower the present cost of a future cash outlay.

Every BCA requires alternatives. In Appendix E, we illustrate the computation of the present cost values of two alternative ways of solving a DMSMS condition:

1. Funding and initiating a set of individual substitute projects in a 7-year time period.
2. Redesigning the SRU immediately (starting in FY11) and completing in the first three years of that seven year period.

The Case Study in Appendix E demonstrates how to calculate the present cost value of these two alternatives over 10 years. The sequence is 1) generate a cost stream (over time) for each alternative, 2) compute the Then-Year cost for each cost stream, and 2) discount those costs to the present year (FY11).

This technique has merit in making DMSMS decisions – ARINC has incorporated it into the redline version of the SD-22.

4.0 Recommendations for Follow-Up

There are several possibilities for continuing the progress made on this contract:

1. In order to implement an ROI metric in a practical way, a methodology must be developed to estimate the sustainment costs of a system that is unmanaged (with respect to DMSMS). A valid estimate of such costs is needed. Without guidance and procedures, the DMSMS practitioners in the field could not uniformly determine such costs, so clearly needed as the basis for an ROI for DMSMS management of their projects.
2. Determining the proper DMSMS resolution type for actual cases has been a long-standing problem. The ontology presented in Appendix B can help address this

problem. It is also possible and recommended that a software tool such as a “wizard” be developed and made available to aid in the determination of the proper resolution type for categorizing a particular actual case.

3. As part of this effort, ARINC is providing redline comments to the existing SD-22. The document can be improved by further investigating and confirming all the references, resources, and methodologies (and perhaps adding new resources).

Appendix A – Analysis of Survey Responses

About the Survey and the Survey Responses. The DoC survey resulted in two large Excel™ data files: one for platforms (e.g., an aircraft) and one for systems (e.g., a RADAR set). ARINC merged the files and eliminated the rows with no entries (much of the survey file was blank) to make it easier to use the data. Table A1 shows a portion of the analysis data file (from the population of Redesign – PNHA resolutions). Note: here the original resolution types (e.g., Minor A and Minor B) have been classified into the Redesign – PNHA type and the reported costs have been escalated to FY2011.

Table A1. Sample of Survey Data Analysis Worksheet (for Redesign PNHA)

Platform	Resolution Type (Was)	Resolution Type (is)	Reported Cost	2011 Cost (escalated)	Count	Total Cost
Tomahawk	Minor A	Redesign - PNHA	\$116,700	\$120,831	1	\$120,831
Bradley	Minor A	Redesign - PNHA	\$185,000	\$191,549	1	\$191,549
JDAM Seeker	Minor A	Redesign - PNHA	\$300,000	\$310,620	1	\$310,620
V22	Minor A	Redesign - PNHA	\$185,000	\$191,549	1	\$191,549
Not specified	Minor B	Redesign - PNHA	\$123,000	\$127,354	1	\$127,354
Not specified	Minor B	Redesign - PNHA	\$115,000	\$119,071	1	\$119,071
Not specified	Minor B	Redesign - PNHA	\$132,000	\$136,673	1	\$136,673
F-22	Minor B	Redesign - PNHA	\$406,533	\$420,924	1	\$420,924
F-22	Minor B	Redesign - PNHA	\$125,538	\$129,982	1	\$129,982
F-22	Minor B	Redesign - PNHA	\$423,176	\$438,156	1	\$438,156

The process sequence for each DMSMS resolution type was as follows:

- Examine the data population to identify the questionable or outlier resolution cost and time duration values.
- Match respondents’ comments (in a separate file) with the data instances (helped to identify questionable responses).
- Contact the respondents to clarify their comments and information on the outliers.
- Unplanned step – define a new set of resolution types (included as part of Appendix B).
- Exclude or re-categorize data as necessary from the follow-up contacts.

The DoC survey form sent to the field for data was a multi-sheet Excel file with a worksheet for each resolution type. Figure A1 shows a typical DoC input sheet, this one for the Normal Substitute resolution type.

Section 4.c		Existing Substitute - Normal			
Definition:	Existing substitute items may perform fully (in terms of form, fit, and function) in place of the DMSMS item. Substitute items may be further broken down to (from lower anticipated cost to higher anticipated cost). A normal substitute involves validating a known part candidate that requires engineering investigation, testing and update of TDP.				
A.	Provide the average cost and number of incidents common to all platforms for the following cost elements, if applicable.			Include all resolution incidents completed in the past 36 months.	
				Average Cost	# of Incidents
	Engineering Evaluation				
	Testing				
	Technical Data Package Update				
	Other cost (specify)				
	Other cost (specify)				
	Other cost (specify)				
Other cost (specify)					
Other cost (specify)					
Total			\$ -	0	
B.	Provide average additional cost elements that pertain to a particular platform , if applicable.				
	Description of Cost	Platform Type	Platform(s)	Include all resolution incidents completed in the past 36 months.	
				Average Cost	# of Incidents
C.	Indicate the average duration time for resolution (in weeks):				
Comments:					

Figure A1. Input Survey Worksheet for “Existing Substitute- Normal”

The input sheet included the definition and fields to report on the average cost for an associated number of incidents (with cost breakouts) for the previous 36 months (2007 through 2009). Multiple incidents of the same resolution type had no population of individual cost values (average costs only).

Altogether there were 15 defined resolution types in the DoC survey as shown in Table A2 below. Survey respondents had particular difficulty in assigning their DMSMS corrective action projects to the seven redesign types (A through F2).

Table A2. Resolution Type Definitions from the DoC Survey

Type & Sub-Type	Definition/Scope
Reclamation	Removal of DMSMS parts from available marginal or out-of-service equipment or, when economical, from equipment that is in a long or potential excess inventory position.
Alternate source	Procurement from a different company that can and will produce parts that are no longer available from the original company. The buyer must ensure that the alternate source is providing certified parts.
Substitute	Use of an existing different part from the DMSMS part in the original configuration that will perform acceptably (in terms of form, fit, and function) in place of the DMSMS item.
Admin Sub	Clerical changes to the technical data package (TDP) only (i.e., company name, CAGE code).

Type & Sub-Type	Definition/Scope
Desktop Sub	An engineering evaluation of the TDP to determine sufficiency (i.e., use the hi-reliability version of the same part).
Normal Sub	Validating a known candidate part through engineering investigation and testing; includes TDP update.
Complex Sub	Selecting and validating a new candidate part that requires engineering investigation, F ³ I part testing, system testing, Quality Conformance Inspection (QCI) testing, and update of the TDP.
Aftermarket Mfg	Seeks an aftermarket producer to obtain and maintain the design, equipment, and process rights to manufacture the component after the original manufacturer either has ceased production or ceases production in the future. Ensure the manufacturer is qualified, by appropriate service authorities, to produce the part.
Emulation	A manufacturing process that produces a substitute F ³ I item for the DMSMS item. Through microcircuit emulation, inventory reduction can be achieved because obsolete items can be replaced with state-of-the-art devices that emulate the original and can be manufactured and supplied on demand.
Redesign	Involves designing a DMSMS item out of the system.
Minor “A”	Involves adding a wire or discrete component to an existing circuit card assembly (CCA) (e.g., adding a resistor to adjust the bias for an alternate component).
Minor “B”	A re-layout of an existing CCA to accommodate a different package type or size.
Minor “C”	Re-manufacturing an exact F ³ I replacement card using the same design but more than 10% substitute components.
Minor “D”	Design and development of a new (replacement) F ³ I CCA using state-of-the-art technology (e.g., using a system on a chip to build a F ³ I replacement, thus reducing the original component count).
Minor “E”	Involves design of a new F ³ I CCA that could be used in multiple applications within the same system.
Major “F1”	Redesign or technology refreshment using commercial off-the-shelf (COTS) technology. Type F1 involves COTS replacement using existing host system interfaces (databus) and architectures.
Major “F2”	Type F2 involves COTS replacement that requires modification to the host system interfaces or architecture.

ARINC’s examination of the survey cost data disclosed some problems:

- Comments associated with a respondent’s identified resolution type conflicted with the generally accepted definition of that type.
- The same DMSMS part incident was reported by two organizations (potentially skewing results).
- The raw data responses indicated that a complex substitute resolution was less costly than a normal substitute.
- Major Redesign (Types F1 and F2) were reported when there was no COTS involved (those definitions are exclusively for COTS per Table A1). However, ARINC has experience on programs that performed non-COTS major redesigns. The definitions for these two resolution types were too restrictive. Upon investigation, we found that most F1 and F2 redesigns were for CCAs (not COTS).

- After discussion with DLA authorities, all reported instances of emulation from the survey data were reclassified as “Redesign – Custom Part.”
- DLA provided the emulation cost data; it is the cost to DLA to develop a GEM or GEM AME part.
- Major projects emanating from technical refresh programmatic initiatives were reported as DMSMS projects (i.e., non-DMSMS projects reported as DMSMS).
- The costs of operating a DMSMS Management program were included (the survey requested NRE costs only).
- The cost of buying quantities of the new part were included (should have been NRE only).
- Many “outlier” values were found; for example, there were 54 reported instances of a Major “F1” redesign resolution with an average cost of \$2,400 (obviously too low).
- The organization reporting the most incidents could not possibly have completed that many solutions (numbering in the thousands). After investigating, we found that they reported recommended solutions and the reported cost was actually potential cost avoidance based on the 2001 DMEA study.
- The survey required average costs for the reported incidents in lieu of individual costs. This would tend to dilute the validity of the conclusions, since estimating the average for a number of average values is not the same as establishing the overall average cost from a large number of individual instances.
- It is expected that the average cost metric for successively complex resolution types would rise – this was not found to be the case for all reported responses. For example, the reported mean cost of the complex substitute was found to be less than that of the normal substitute resolution; also, the reported mean cost of a Major F2 redesign was less than for a Major F1 redesign. Surprisingly, the average emulated solution was the most expensive, according to respondents.
- Five of the redesign categories had very small sample sizes (i.e., few responses), and that fact could adversely skew the accuracy of the overall results for those categories.
- The adjustments shown in Table A3 below were investigated and resolved. The survey average cost values for the outlier-only incidents reported by certain respondents were significantly different from those of other respondents for the same resolution type. After investigation (by ARINC), many incidents were re-categorized based on the respondent clarifying the description of the incident.

Each resolution cost has an associated time duration value that in many cases was zero. ARINC computed the mean time for the each resolution type based on the respondent’s data. Zero entries for the time duration were not counted in the average; also any outlier time durations were not counted. The time duration data is included with the resolution cost metrics in Table 1 (suggested Table 5 in the redline SD-22).

Conclusion: Because of the above, ARINC considered that the survey data could not be used “as is.” As stated, the underlying problem was that the resolution type definitions were confusing and did not provide enough guidance in selecting the type (particularly true for the

seven redesign types). Therefore, ARINC developed a new ontology of resolution types (see Appendix B) that could be used to salvage this survey and to improve any future surveys. ARINC then identified a subset of responses within each original category for further investigation, and interrogated 23 respondents to clarify their answers and to re-categorize if indicated.

There are two different statistical methods for processing the adjusted data responses to compute the mean and confidence bounds for the resolution cost metrics:

- **Method 1:** weight the costs of all the incidents equally (n_1 counts of the solution type S from organization A at \$X average and n_2 counts from organization B at \$Y average).
Thus Mean Cost of S = $((n_1 * \$X) + (n_2 * \$Y)) / (n_1 + n_2)$
- **Method 2:** weight the average cost from each respondent equally (one value from organization A and one value from organization B) for solution S.
Thus Mean Cost of S = $(\$X + \$Y) / (1+1)$

Dr Sandborn believes that it is more correct to weight all the respondents equally (Method 2) based on his argument as follows:

“If one assumes that all respondents are providing accurate and complete (apples-to-apples) cost numbers, then weighting all incidents equally is the best approach. However, if one assumes that the reported costs are a significant source of error (i.e., no two respondents are including the same elements in their reported costs), then there is merit to weighting all respondents the same. In other words, weighting all incidents the same gives a greater weight to the cost errors of the respondents that reported the most incidents, rather than giving an equal weight to cost errors reported by all respondents. Method 1 effectively assumes that the respondents that reported the most incidents also reported the most accurate costs – we have no reason to believe this. Method 2 assumes that the accuracy of the reported costs is independent of the number of incidents a respondent reports.”¹⁰

After examining the range of variability in the respondents’ cost elements, ARINC agrees that it is likely there was less-than-desired uniformity in the cost element breakouts by the various respondents. Therefore, Method 2 would be the better choice to smooth out the reporting differences and a better way to infer average costs from the reported data. The values in Table 1 of this report (Table 5 of the SD-22 Redlines) were computed using Method 2.

Adjustments to the resolution type counts from the survey are summarized in Table A3.

¹⁰ Manuscript from Dr. Peter Sandborn, *Cost Normalization*, June 16, 2010

Table A3. Adjustments to the Survey Resolution Type Counts

Resolution Type	Orig Count	Adjusted Count	Explanation (Source of the Adjustment)
Reclamation	195	5	Note ¹
Alternate Source	713	10	Most incidents reported were cost avoidance (from Hill AFB)
Admin Substitute	132	16	Note ¹
Desktop Substitute	662	21	Note ¹
Normal Substitute	140	10	Note ¹
Complex Substitute	42	9	Note ¹
Aftermarket Mfg	38	4	Mostly recategorization
Emulation	18	0	All reported emulations recategorized to Redesign - CP (per DLA input)
Survey Redesign Types²			
Redesign Minor Type A	11	N/A	Exclude 3, "CP" 4, "PNHA" 4
Redesign Minor Type B	29	N/A	Exclude 3, complex sub 1, "PNHA" 25
Redesign Minor Type C	12	N/A	"CP" 2, DT Sub 6, "PNHA" 2
Redesign Minor Type D	3	N/A	"PNHA" 3
Redesign Minor Type E	8	N/A	Exclude 5, "PNHA" 3
Redesign Major Type F1	81	N/A	Exclude 12, DT subs 54, "PNHA" 5, "COTS" 5, Other 5
Redesign Major Type F2	12	N/A	Exclude 1, "PNHA" 5, "COTS" 4, "CP" 1, Other 1
New Redesign Types			
Redesign - COTS	N/A	9	From "F1" (5) and "F2" (4)
Redesign - CP	N/A	12	From "A" (2), "C" (2), "F2" (1) Alt Source (1) emulation (5), and Complex Sub (1)
Redesign - PNHA	N/A	49	From "A" (4), "B" (25), "C" (4), "D" (3), "E" (3), "F1" (5), "F2" (5)

¹ The reduction in adjusted count comes from calculating the values based on number of respondents versus number of incidents (method 2 above). For example, if respondent A reported 10 incidents of reclamation at \$200 average cost and respondent B reported 5 incidents of reclamation at \$500 average cost, the adjusted count is 2 (not 15) and the average cost = $(\$200 + \$500)/2 = \$350$.

² See Table A2 for original survey definitions.

The following example from Table A3 serves to explain the adjustments for the redesign types in Table A3:

Of the 11 incidents of Redesign Minor Type "A," 3 were excluded as errors, 4 became Redesign "CP," and 4 became Redesign "PNHA."

ARINC processed the data to obtain the mean and $\pm 90\%$ confidence bands for the average costs for all respondents for each resolution type, with results shown in Table 1 of this report. For the small data sets (i.e., <50 incidents) for a particular resolution type, we based the confidence bands on the Student T Distribution, and used the Normal Distribution to calculate confidence bands for larger data sets.

The procedure for computing the confidence bands from a small sample is as follows: For a population with unknown mean and unknown standard deviation, a confidence interval for the population mean, based on a simple random sample of size n, is

$$\bar{x} \pm t \frac{s}{\sqrt{n}}$$

where t is the upper (1-C)/2 critical value for the "t" distribution with (n-1) degrees of freedom and C is the confidence interval (90%)

For example, the input data and computation of the upper and lower confidence band for the reclamation resolution type was:

- Adjusted sample size $n = 5$, degrees of freedom $= (n-1) = (5-1) = 4$
- Average cost $\bar{x} = \$20,000$
- Standard Deviation of the sample $s = \$20,341$
- $t = 2.13185$ (from the Student T Table with $C = 90\%$ and 4 degrees of freedom)
- The 90% high value $= \$20,000 + (2.13185 * (\$20,341 / \sqrt{5})) = \$39,000$ (rounded to nearest \$1000)
- The mean is $\$20,000$
- The 90% low value $= \$20,000 - 2.13185 * (\$20,341 / \sqrt{5}) = \$1,000$ (rounded)

The above values are in Table 1 of this report. Table 1 is recommended to replace the current Table 4 in the SD-22 and will be provided in the redlines to that document.

Appendix B – Ontology of DMSMS Resolutions

An ontology is a common set of well-defined concepts for use in shared understanding and consistent communication within a particular domain (DMSMS resolution types in this case). The concepts are defined using:

- Subclass hierarchy (Taxonomy of Standard Resolutions) (Figure B1)
- Vocabulary (definitions) (Table B1)
- Assignment and definition of properties, relationships, and constraints (Table B1)

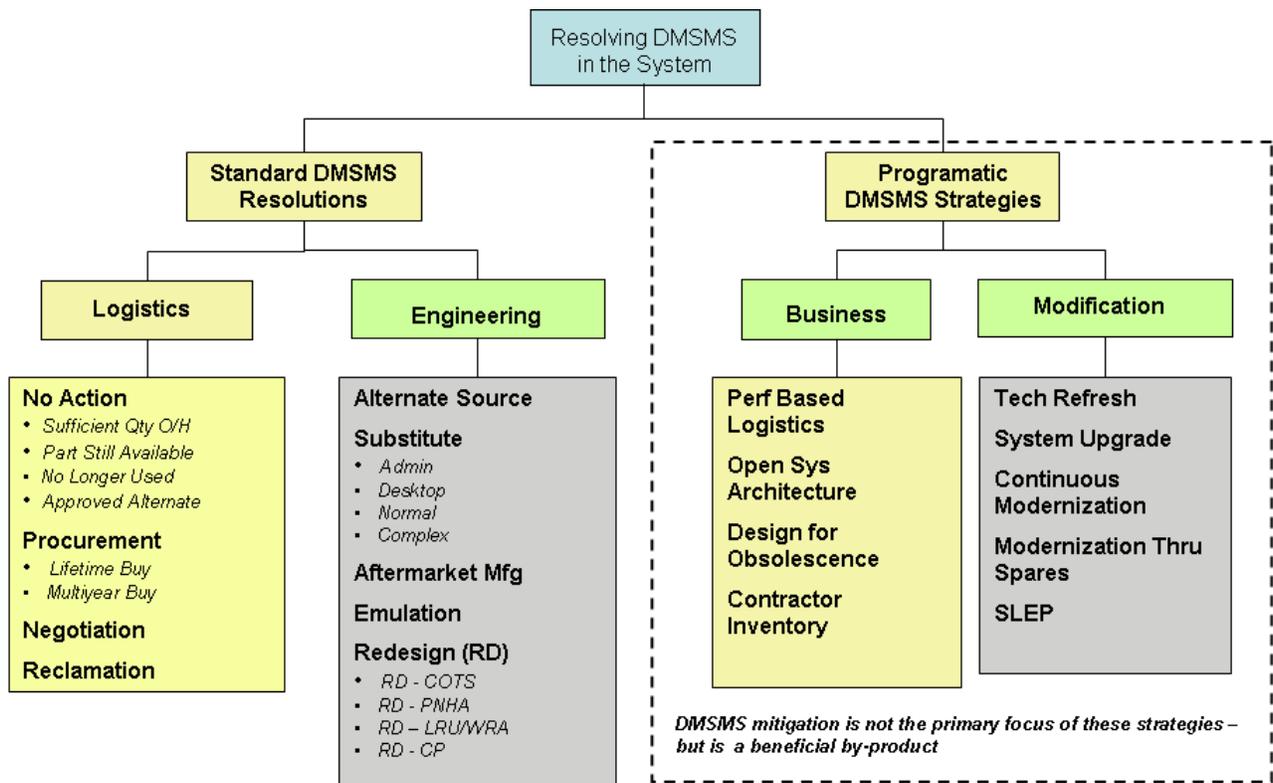


Figure B1. DMSMS Resolution Taxonomy

The associated data elements to build the ontology of DMSMS Resolution types are consolidated in Table B1.

Table B1. Standard DMSMS Resolution Definitions, Properties, Relationships

Resolution Type (Category)	Definitions, Properties, Examples	Objective
Logistics Actions	<p>Definition: Acting to lay-in or secure the availability of the existing Required Item of Supply (RIOS). There are four sub-types of logistics actions below:</p>	
No Corrective Action Required (Logistics)	<p>Definition: determination, based on findings of a) sufficient quantity on-hand in controlled inventory, b) item is still available (existing stock), c) item no longer used in the system; d) an approved alternate is available.</p> <p>Life Cycle Phase (LCP): Sustainment</p> <p>Scope: Examine the part sources, inventories, and installations in the configuration.</p> <p>Example: A 15 year supply exists in the contractor’s depot</p>	Inventory of the RIOS.
Procurement (Logistics)	<p>Definition: Lifetime buy or Multi-year buy – Purchasing a quantity (e.g., a 20-year supply) of the obsolete item while it is still available (Distributor or Aftermarket) and maintaining a controlled inventory of the item.</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Determining a safe quantity, procuring, verifying the traceability of the items (Certificate of Conformance), storing, and issuing as required.</p> <p>Example: Procuring finished parts from an Aftermarket source</p>	Inventory of the RIOS.
Negotiation (Logistics)	<p>Definition: Entering into an agreement with a source to continue supplying the item.</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: A contract or other document specifying intent to procure a quantity over a future time. This solution type would be used by contractors to ensure future production of SRUs.</p> <p>Example: Contractor X strikes an agreement with a specialty RF vendor for four RF hybrids for the next two years.</p>	Continuing Source.
Reclamation/ Salvage (Logistics)	<p>Definition: Salvaging obsolete parts from unserviceable or surplus NHAs</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Acquiring the NHA, removing (de-soldering), cleaning, inspecting, testing, verifying the traceability of the items, and packaging the parts. No Tech Data Package (TDP) changes.</p> <p>Example: Hybrids salvaged from an earlier configuration of the NHA.</p>	Inventory of the RIOS.

Resolution Type (Category)	Definitions, Properties, Examples	Objective
Engineering Actions	<p>Definition: DMSMS Corrective actions requiring engineering involvement (requirements, evaluation, design, testing, and documentation). There are 12 sub-types of engineering actions below (including 4 types of substitutes):</p>	
Alternate Source (Engineering)	<p>Definition: Procuring the <i>same</i> part from a different source not designated in the spec control drawing (SCD) or source control drawing (SoCD).</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Small project with no development. Engineering review, (possibly) part testing, TDP and cataloging changes are required. Procuring <u>finished</u> product from a different qualified SOS (e.g., Rochester Electronics) or an <u>existing</u> emulated part is an alternate source solution.</p> <p>Example: The SoCD called out a Motorola 2N2222A transistor (discontinued in 1995). The 2N2222A is available from Microsemi Corp. The project is to evaluate the Microsemi equivalent and change the SoCD if approved.</p>	An approved part source.
Substitute (Engineering)	<p>Definition: Authorizing a different existing part with an acceptable degree of nonconformance (more or less stringent electrical or environmental requirements from the original). We further segregate substitutes into four sub-types below.</p>	
Admin Sub (Engineering)	<p>Definition: Editing the TDP for non-performance (i.e., administrative or clerical) corrections.</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Changes in the TDP to Source of Supply (SOS) name, address, PN, Commercial and Government Entity (CAGE) code. Manufacturing and performance are unaffected.</p> <p>Example: National Semiconductor (NSC) purchased Fairchild, kept their military product lines, and changed PNs to NSC nomenclature (e.g., UA111HMQB to LM111H/883).</p>	An alternate part called out in the TDP.
Desktop Sub (Engineering)	<p>Definition: Evaluating the TDP of an intrinsically suitable (but different) part (i.e., a higher-reliability version [JANTXV versus JANTX] or an existing GEM or GEM AME part).</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: TDP changes that are more than clerical, but no testing or source evaluation required to validate the use of the part in the application.</p> <p>Example: Resistor RWR xxxx with a $\pm 1\%$ tolerance can be replaced by a different one with a $\pm 0.01\%$ tolerance (a higher reliability component). In a second example, a TDP calls out a Standard Microcircuit Drawing (SMD) but part is now only available as a MIL-M-38510 version.</p>	An alternate part called out in the TDP.

Resolution Type (Category)	Definitions, Properties, Examples	Objective
Normal Sub (Engineering)	<p>Definition: Validating one known (identified) existing candidate part.</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Engineering review, F³I part testing, compatibility testing and performance tests at the NHA level resulting in TDP changes. May require an engineering waiver or deviation since the substitute may lack some original spec requirement.</p> <p>Example: Test results for a linear amp from same SOS with same package and same temp level (but with lower response time) are fully satisfactory (slower response time is acceptable). The TDP package is changed to allow the slower time and the new part is listed in the Table of Recommended Sources.</p>	An alternate part called out in the TDP.
Complex Sub (Engineering)	<p>Definition: Seeking, selecting, and validating a new part from several potential candidates.</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Engineering investigation to find acceptable candidates, F³I part tests, compatibility testing, and performance testing at the NHA level, QCI testing, and perhaps environmental testing (e.g., for radiation hardness). A waiver or deviation may be required. Note: the investigation is not always successful. If not, a more expensive resolution must be pursued.</p> <p>Example: Optical coupler approved in the SCD is no longer made – an engineering search found four couplers with similar characteristics. After testing, two are approved for the application. The suggested sources table in the SCD is changed to authorize the new parts.</p>	An alternate part called out in the TDP.
Aftermarket Manufacturing (Engineering)	<p>Definition: An aftermarket source (AMS) (e.g., Austin Semi, Lansdale, QP Semi, or Rochester) has the resources to fabricate, package, and test products that have been discontinued by the original SOS.</p> <p>There are two ways AMS suppliers produce parts: 1) “Part Finishing,” where the AMS packages the original semiconductor die, and 2) “Full Part Manufacturing,” where the AMS both produces and packages the die.</p> <p>LCP: Sustainment</p> <p>Scope: Review of aftermarket SOS testing data, compatibility testing in the NHA, changing the TDP to cite the new SOS and PN.</p> <p>Example: NSC sold off all product including die for military logic to Arrow/QP Semi. Arrow became the sole source for these former NSC parts. If a program needs a part available only in die, they must contract with Arrow for aftermarket manufacturing.</p>	An alternate part called out in the TDP.

Resolution Type (Category)	Definitions, Properties, Examples	Objective
Emulation (Engineering)	<p>Definition: Contracting with an emulation SOS (e.g., Sarnoff Corp) to develop a F³I microcircuit replica from a mask-configurable gate-array. The internal configuration of the part is different from the original part but the input/output characteristics are identical.</p> <p>LCP: Sustainment</p> <p>Scope: If a suitable alternate source or substitute is not available, emulation is a method of replacing an obsolete (component-level) part. It is pursued after an investigation shows it to be an economical tradeoff. In some cases, emulation requires a contracting process to develop the new emulated replacement part followed by testing in the application and changes to the TDP.</p> <p>Note: Using a previously existing emulated product is an <i>alternate source</i>.</p> <p>Example: A transmitter has 5 circuit cards that each hosts 20 obsolete microcircuits (same PN). There is no alternate, substitute, or aftermarket source. There is a high repair demand for the obsolete microcircuit. An engineering study of alternatives concludes that contracting with Sarnoff to develop a new emulated part is the preferred solution.</p>	An alternate part called out in the TDP.
Redesign (Engineering)	<p>Definition: Designing and developing a new or modified module, or circuit card assembly, or a new component, necessitated by obsolescence. We further segregate redesign into three sub-types below.</p>	
Redesign – with COTS (Engineering)	<p>Definition: Major engineering project to insert new COTS equipment into a system made necessary from obsolescence of the existing COTS.</p> <p>LCP: Pre – Acquisition, Acquisition and Sustainment</p> <p>Scope: Contracting, design, system integration and testing.</p> <p>Example: The control computer for a ground radar system is no longer supported by the original source. The computer and software must be replaced.</p>	An alternate COTS NHA – in the TDP.
Redesign – Custom Part (AKA Reverse Engineering) (Engineering)	<p>Definition: Major DMSMS engineering project, may involve contracts with specialty (niche) parts suppliers to develop or re-create a replacement for an obsolete custom part (e.g., RF component, ASIC or hybrid) (possible performance improvements).</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Contracting, design, development, 1st article testing, qualification testing, subsystem and system testing. Typically a multi-year project.</p> <p>Example: A digitally-tuned oscillator (DTO) used in only one weapon system had extremely tight performance specs and the</p>	An alternate custom component in the TDP.

Resolution Type (Category)	Definitions, Properties, Examples	Objective
	original design data were missing. Only two companies worldwide could develop such devices. A source selection was performed and a contract was written.	
Redesign –Peculiar NHA (Engineering)	<p>Definition: Major DMSMS engineering project to design and develop a F³I replacement NHA (circuit card or module).</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: Contracting, design, development, 1st article testing, qualification testing, subsystem and system testing. May include technology insertion to reduce part count and improve reliability. Typically a multi-year project.</p> <p>Example: An RF Receiver module was non-supportable due to having eight obsolete custom parts. The module was redesigned by a different source (original designer out of business), resulting in a producible NHA with a complete TDP for use in reprocurement.</p>	An alternate NHA in the TDP.
Redesign – LRU/WRA Level (Engineering Type)	<p>Definition: Major system engineering project to design and develop a new subsystem to upgrade performance and meet new mission requirements. It would be very unusual to undertake such a project solely due to DMSMS.</p> <p>LCP: Acquisition and Sustainment</p> <p>Scope: This is a major engineering effort – as a by-product, DMSMS issues in the old configuration would be resolved.</p> <p>Example: An aircraft radar was replaced to use a different operating frequency. Many obsolescence issues were eliminated in the new design.</p>	A new LRU/WRA.

The programmatic initiatives listed below in Table B2 and Fig B1 are not the normal purview of the DMSMS practitioner. Clearly, the DMSMS Manager of a program would not implement Performance-Based Life-Cycle Product Support (sometimes known as performance-based logistics [PBL]) to solve the DMSMS problems in the program. However, DMSMS mitigation may be a by-product of such programmatic initiatives which are undertaken at the highest command level of decision-making.

Table B2. Programmatic Initiatives that May Mitigate DMSMS

Programmatic Initiatives – DMSMS issues may be examined and resolved as a by-product (secondary objective) of the following initiatives/actions.

Initiative/Action Type	Life Cycle Phase
Performance-Based Life-Cycle Product Support (or PBL)	Acquisition, Sustainment
Continuous modernization	Acquisition, Sustainment
System upgrade	Sustainment
Service Life Extension Program	Sustainment
Technology refresh	Acquisition, Sustainment
Modernization through spares	Pre-Acq, Acquisition, Sustainment
Open systems architecture	Pre-Acquisition, Acquisition
Design for obsolescence	Pre-Acquisition
Contractor-maintained inventory	Acquisition, Sustainment

Appendix C – DMSMS Management Return on Investment (ROI) Analysis

This paper was written by Dr Peter Sandborn of the University of Maryland

Cost avoidance is a “metric” that results from a “spend” that is lower than the spend that would have otherwise been required if the cost avoidance exercise had not been undertaken¹¹. While management can (with a bit of effort) understand cost avoidance, it is not necessarily “sellable.” Requesting resources to create cost avoidance is not as persuasive as making a return on investment (ROI) argument.

ROI is a useful quantitative means of gauging the economic merits of a decision. ROI measures the cost savings, profit, or cost avoidance that result from a given use of money.¹² At the enterprise level, ROI may reflect how well an organization is managed with regard to specific objectives such as gaining market share, retaining more customers, or improving availability. The ROI may be measured in terms of how a change in practice or strategy results in meeting these goals. The ROI allows for enhanced decision-making by enabling comparisons of alternatives. However, the factors used to calculate the ROI must be accurate and inclusive in order for the calculation to be meaningful.

In general, ROI is the ratio of gain to investment. An ROI computed over a product’s life cycle is given by:

$$ROI = \frac{V_f - V_i}{V_i} = \frac{\text{Cost Avoidance} - \text{Investment}}{\text{Investment}} \quad (1)$$

where V_f is the final value of the investment and V_i is the initial value of the investment. $ROI > 0$ indicates that there is a cost benefit.

Equation (1) is the classic ROI definition (also called arithmetic return). When investments are made to enhance the maintainability of a product, e.g., investments in DMSMS management. The return V_f is a “cost avoidance,” i.e., a reduction in costs that have to be paid in the future to sustain the system.

Constructing a business case for a product does not necessarily require that the ROI be greater than zero; in some cases, the value of a product is not fully quantifiable in monetary terms, or the product is necessary in order to meet a system requirement that could not otherwise be attained, such as an availability requirement.

¹¹ B. Ashenbaum, *Defining Cost Reduction and Cost Avoidance*, CAPS Research, March 2006.

¹² G. T. Friedlob and F. J. Plewa Jr., *Understanding Return on Investment*, John Wiley and Sons, New York, NY, 1996.

Formulating an ROI for DMSMS Management

The first challenge in formulating an ROI for DMSMS management is to determine what it is compared to. ROI has to be relative to something. Ideally, one wants to compare to the no DMSMS management case, but what is this case? If you are comparing to a case where the system becomes non-sustainable, what is the life cycle cost of a non-sustainable system? If you compare to a case where the system remains operational but at a higher cost, cost of what? Whatever case you choose to measure from will almost certainly be ambiguous (no two organizations will define it the same way).

One possible solution to this dilemma is to select the “perfect world” case, which represents the sustainment of the system if nothing ever went obsolete. This is not a real case, but, it is a clearly definable point to measure everything from. We postulate that it is definable without ambiguity. However, the downside to selecting this reference point is that it will require some manipulation of the final ROI to create a useful/meaningful number.

The next problem with ROI formulation is separating the life cycle costs when DMSMS is managed from life cycle costs when DMSMS is unmanaged. In general, this may be impossible to explicitly achieve; however, with careful formulation it is possible to compute the ROI in terms of life cycle cost differences. Consider the ROI relative to the “perfect world” case (ROI_0), which can be expressed from (1) as:¹³

$$ROI_0 = \frac{C_0 - C_m}{I_m - I_0} \quad (2)$$

where,

C_0 = total life cycle cost of the system if nothing ever went obsolete (i.e., the perfect world)

C_m = total life cycle cost of the real system with DMSMS management

I_0 = investment cost in DMSMS management if nothing ever went obsolete (i.e., the perfect world)

I_m = investment cost in DMSMS management in the real system

Note, C_0 and C_m are total life cycle costs that include their respective investment costs, I_0 and I_m . The denominator is the investment (relative to the perfect world case). By definition, $I_0 = 0$ (contains no investment in DMSMS management because there is no DMSMS to manage), therefore, (2) simplifies to,

$$ROI_0 = \frac{C_0 - C_m}{I_m} \quad (3)$$

In (3) $C_0 - C_m$ excludes all the costs that are a “wash” (i.e., the same whether parts go obsolete or not) – this solves the problem of splitting up the costs. In (3), if $C_0 = C_m$ the ROI = 0 implying that the cost avoidance that results from DMSMS management exactly equals the investment

¹³ Equation (2) is derived from (1) by replacing $V_f - V_i$ with $C_0 - C_m$ (which assumes $C_0 > C_m$) and V_i with $I_m - I_0$.

made (which is correct, again note that C_m includes I_m within it). In (2) and (3) the investment cost is given by,

$$I_m = C_{NRE} + C_{INF} \quad (4)$$

where,

C_{NRE} = DMSMS management non-recurring costs

C_{INF} = DMSMS management infrastructure costs

DMSMS management NRE costs are the costs of identifying and putting in place specific resolutions for specific parts – generally these are the costs reported in the DMEA survey. DMSMS infrastructure cost are the costs of acquiring and keeping DMSMS management resources in place (people, training, software, databases, plan development, etc.). These are not explicitly collected in the DMEA surveys, but included by some respondents.

One question that arises is, is I_m complete? Are there other investment costs that are not captured in (4)? This is a difficult question to answer. For example:

- What if my DMSMS solution is to buy an emulated part and that costs 20 times the original part cost from the original manufacturer. Is the increase in the recurring cost per part an investment cost (i.e., part of I_m)?
- What if my managed DMSMS program ends up buying more parts than an unmanaged program (lifetime buys that include buffers would do this)? Is the cost of the extra parts accounted for as part of the investment (I_m)?
- What if (for simplicity) my DMSMS management approach resulted in buying the exact same number of parts for exactly the same price per part as my unmanaged approach, but I buy them at different times. Due to the cost of money (non-zero discount rate), this does not end up costing the same. Is the cost of money part of I_m ?

The costs in the examples above would not be included in the investment cost because they are the result of the DMSMS management approach (i.e., the result of the investment) and are reflected in the life cycle cost C_m .

The quantity $C_0 - C_m$ represents the life cycle obsolescence management cost (C_{DMSMS}):¹⁴

¹⁴ As a standalone measure, the ratio below is actually a better metric because it is independent of the money year index; while the cost in (5) is not,

$$\text{Obsolescence Management Cost Ratio} = \frac{C_m}{C_0}$$

$$C_{DMSMS} = C_m - C_0$$

= Actual total life cycle cost - Life cycle cost if no parts had gone obsolete (5)

The actual total life cycle cost includes: all recurring costs (manufacturing and part procurement), all non-recurring design refresh and re-qualification costs, all lifetime buy and bridge buy costs, and all inventory costs. The life cycle cost if no parts had gone obsolete includes: all recurring costs (manufacturing and part procurement), no obsolescence events, no design refreshes (for obsolescence management), no lifetime buy or bridge buy costs, and no inventory costs (for extra parts).

Using the obsolescence management cost defined in (5), (3) becomes,

$$ROI_0 = \frac{C_0 - C_m}{I_m} = \frac{-C_{DMSMS}}{I_m} \quad (6)$$

As defined in (6), ROI_0 is always a negative number. In this form, the closer to zero the ROI is, the higher the value of your DMSMS management, i.e., you are closer to the life cycle cost of the no obsolescence case (the best possible case would be an ROI_0 of zero. Re-writing the ROI relative to a no management case (rather than a perfect world case), where $I_N=0$, we get,

$$ROI_N = \frac{C_N - C_m}{I_m} = \frac{C_0 + C_S - C_m}{I_m} = ROI_0 + \frac{C_S}{I_m} \quad (7)$$

Where the life cycle cost of a real unmanaged system be $C_N = C_0 + C_S$, where C_S is the sustainment cost of the unmanaged system. Why write the ROI this way? ROI_N is the sellable quantity (it has a real meaning and a clear interpretation to management). ROI_0 is a calculatable quantity (people could keep track of it or predict it). C_S is the “mapping” between ROI_N and ROI_0 .

So, how does this correlate to the survey findings? ROI_0 could be determined from the survey data (in theory):

- Note C_{DMSMS} requires recurring costs that result from the DMSMS resolutions to be known
- One would probably want to collect data slightly differently to enable ROI_0 calculation, but fundamentally, it appears to be within the scope of the present data collection
- Although ROI_0 is not “sellable” it is a valid way to compare things

If a C_S (sustainment cost of the unmanaged system) could be established (or estimated) for a system, then a real (meaningful) ROI for the DMSMS management effort could be found. Alternatively, the breakeven C_S for a system could be found (the C_S for which the investment in DMSMS management exactly matches the cost avoidance achieved).

The formulation of an ROI resolves another key issue that the conventional cost avoidance calculation cannot handle. Namely, how is a design refresh that concurrently resolves multiple current and future DMSMS problems valued? Using the ROI approach:

- I_m includes the NRE costs associated with the design refresh (true for both the conventional cost avoidance analysis and ROI methods).
- In the ROI approaches, the life cycle cost value (or possibly lack of value) of the design refresh is captured in C_m (the actual life cycle cost of the system) – so all current and future impacts on the system of doing a refresh are accounted for correctly.
- In the conventional cost avoidance calculation, the value of the design refresh is calculated for the resolution of a single current DMSMS event (possibly multiple current events) – no accounting for future DMSMS resolutions avoided is possible; however, for the ROI approach, all future value is accounted for.

Finally, the calculation of an ROI relative to an alternative DMSMS management approach can be found using,

$$ROI = \frac{C_{m1} - C_{m2}}{I_{m2} - I_{m1}} \quad (8)$$

Where m_1 and m_2 represent the two different obsolescence management approaches and (8) gives the ROI of management approach m_2 relative to m_1 .

Cost Avoidance and ROI Estimations from Survey Data. In this section, we present an example that uses existing survey data, supplemented with additional data detail where necessary, to calculate the cost avoidance using the conventional approach and the ROI approach proposed in this Appendix. Consider all the resolutions from Company X's (for this example, we have ignored the redesigns).¹⁵

Conventional Cost Avoidance Calculation: The conventional cost avoidance calculation is shown in Table C1.¹⁶

¹⁵ Note this is a simplified example that does not account for many other real cost impacts such as cost of money, cost of part storage and handling, uncertainties in future part demand, constraints on how resolutions must be performed, etc. These additional details could, however, be incorporated within the general approach by using detailed cost models.

¹⁶ The conventional cost avoidance calculation assumes that for whatever mitigation solution is chosen, one can consider the associated cost avoidance equal to the difference between the cost of the preferred or selected solution and the next most expensive resolution approach.

Table C1. Conventional Cost Avoidance Calculation (Cost Avoidance Data from the 2004 Survey)

Resolution	Number of Occurrences	Cost Avoidance	Total Cost Avoidance
Existing Stock	79	\$2000	\$158,000
Reclamation	0	\$5000	0
Alternate	15	\$13,000	\$195,000
Substitute	40	\$32,000	\$1,280,000
Aftermarket	30	\$23,000	\$690,000
Redesign-Minor	-	\$328,000	-
Redesign-Major	-	0	-
Total	164		\$2,323,000

As a result of the conventional cost avoidance calculation, Company X would report a cost avoidance of \$2,323,000 to their management as the value of their DMSMS management efforts.

The question is, what does the \$2,323,000 mean? Is this real money? Would the life cycle cost of the system actually have been \$2,323,000 higher if the DMSMS management organization had not existed? For that matter, is \$2M in Lockheed Martin’s Aegis Program valued the same as \$2M in Lockheed Martin’s C-130 Program?

Let’s take one more step with the conventional approach. Assume that all the survey costs for Lockheed Martin’s Aegis Weapons System are Non-Recurring Engineering costs, in the survey Lockheed Martin reported $C_{NRE} = \$471,648$ (ignoring redesigns) and that DMSMS infrastructure costs are given by $C_{INF} = \$200,000$ for the period of time covered by the data (this infrastructure cost was made up for this example). The infrastructure costs include software licenses, training, etc. With these values, Lockheed Martin could compute an ROI for their DMSMS management efforts for Aegis using (1) as,

$$ROI = \frac{\text{Cost Avoidance} - \text{Investment}}{\text{Investment}} = \frac{\$2,323,000 - (\$471,648 + \$200,000)}{\$471,648 + \$200,000} = 2.46 \quad (9)$$

Calculating an ROI solves value of money problems (i.e., since it is a ratio, differences in value of money in different programs are divided out), but, this ROI is relative to what? The only thing that can be said is that it is relative to the “next most expensive resolution,” which isn’t a fixed point (it’s different for each resolution that was performed). So this ROI doesn’t really tell us anything.

An Actual ROI Calculation: To perform the actual ROI calculation for Lockheed Martin’s Aegis Weapons System, we need to determine the recurring cost (C_{REC}) in addition to the survey numbers and assumptions made for the conventional cost avoidance calculation. In order to do this, several additional assumptions are necessary, plus we need recurring cost multipliers corresponding to the various mitigation approaches used. Table C2 shows the recurring part price multipliers (from the 2001 DMEA Cost Resolution Metrics survey), the number of instances of

each resolution type (the same as for the conventional analysis), and the resulting additional recurring cost caused by DMSMS management activities.

Table C2. – Additional Recurring Cost as a Result of DMSMS Management

Resolution	Recurring Part Price multipliers (P_{REC})	Number of Instances (N)	Additional Recurring Cost ¹
Alternate-Source	2.5	15	\$225,000
Substitute-Desktop	1.6	23	\$138,000
Substitute-Normal	5.8	8	\$384,000
Substitute-Complex	10	9	\$810,000
Aftermarket Mfg	7.5	30	\$1,950,000
Lifetime Buy	1	120	\$300,000
Total (C_{REC})			\$3,807,000

¹ Due to DMSMS management

The additional recurring cost due to DMSMS management is computed for the j th resolution type using,

$$\text{Additional Recurring Cost}_j = (P_{REC_j} - 1) \sum_{i=1}^{N_j} Q_i P_i \quad (10)$$

where:

P_{REC_j} = the recurring cost multiplier for the j th resolution type

Q_i = quantity of the i th part that has to be purchased after (or as a result of) the resolution

P_i = original price of the i th part

N_j = number of different parts resolved with the j th resolution type.

Note the additional recurring cost computed by (10) is only the cost over and above the original part cost for the original number of parts. In the case of the lifetime buy (LTB), $P_{REC} = 1$, so (10) would evaluate to 0. However, we have assumed that there is a 25% buffer on the lifetime buys, i.e., 25% more parts than needed are purchased at the LTBs to account for loss in inventory, etc. Therefore, in the special case of LTBs, the additional recurring cost becomes,

$$\text{Additional Recurring Cost}_{LTB} = P_{REC_{LTB}} \sum_{i=1}^{N_{LTB}} Q_i P_i B_i + (P_{REC_{LTB}} - 1) \sum_{i=1}^{N_{LTB}} Q_i P_i \quad (11)$$

where,

B_i = buffer size for the i th part (as a fraction)

N_{LTB} = number of parts resolved with a LTB.

In (11), the second term is the same term as in (10) – it evaluates to zero if $P_{REC} = 1$; the first term accounts for the extra parts purchased, i.e., the buffer – it evaluates to zero if $B = 0$.

For purposes of the example calculation, the following data was assumed for all parts:

- $Q = 1000$ (average demand for each part at obsolescence)
- $P = \$10/\text{part}$ (average price per part at obsolescence)
- $B = 25\%$ (average lifetime buy buffer size when LTB is made).

Using the assumptions above, the “Additional Recurring Cost” column of Table C2 was computed resulting in a total C_{REC} of \$3,807,000. For this example, the total investment cost is the same as it was for the conventional cost avoidance calculation in (9), $I_m = C_{NRE} + C_{INF} = \$471,648 + \$200,000 = \$671,648$. The total cost of DMSMS management is $C_{DMSMS} = C_{REC} + I_m = \$4,478,648$. Using (6), the ROI relative to the perfect world case (no obsolescence) is given by,

$$ROI_0 = \frac{-C_{DMSMS}}{I_m} = \frac{-\$4,478,648}{\$671,648} = -6.67 \quad (12)$$

The result from (12) above is a valid meaningful metric; however, it is calculated relative to a non-realistic case. The ROI relative to the unmanaged case, written in terms of the remaining unknown, is C_S (the sustainment cost of the unmanaged system) using (7) as,

$$ROI_N = ROI_0 + \frac{C_S}{I_m} = -6.67 + \frac{C_S}{\$671,648} \quad (13)$$

The resulting ROI_N plotted as a function of C_S is shown in Figure C1.

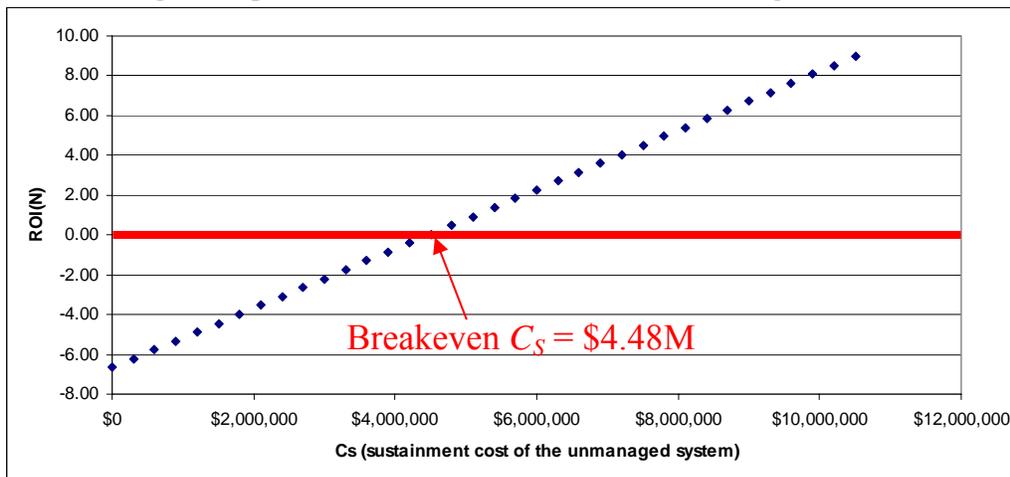


Figure C1. – Notional ROI of the Unmanaged Case based on Sustainment Cost of the Unmanaged System (Aegis DMSMS Program).

The result in Figure C1 indicates that the ROI of the DMSMS management program will be greater than zero if the sustainment cost of the unmanaged system is \$4.48M or higher. In the example shown in Figure C1, if $C_S = \$8M$, from the graph the ROI of this DMSMS management program relative to an unmanaged program will be 5.24. Alternatively, from (1), the result can be cast in terms of cost avoidance,

$$\text{Cost Avoidance} = (ROI_N + 1)I_m \quad (14)$$

What can we conclude from this example?

1. If sustaining this program without DMSMS management costs less than \$4.48M (the breakeven point shown on Figure C1), then there is no economic advantage to having a DMSMS management program. Possibly, calculating breakeven values could be used to measure program value.
2. If the sustainment cost of the unmanaged program can be estimated, an actual ROI can be found.
3. The meaning of the \$2,323,000 cost avoidance found using the conventional approach is unknown.

Critique of the Conventional Cost Avoidance Calculation

The conventional cost avoidance calculation assumes that for whatever mitigation solution is chosen, one can consider the associated cost avoidance equal to the difference between the cost of the preferred or selected solution and the next most expensive resolution approach.

Cost avoidance calculated using the conventional approach is neither the minimum nor the maximum cost avoidance possible. It is the cost avoidance associated with the DMSMS program if not having a DMSMS program resulted in the resolution of each individual DMSMS case using the “next most expensive” resolution approach. The conventional approach assumes that the role of the DMSMS program is to move each individual part resolution to the next less expensive resolution. So, the cost avoidance calculated the conventional way is relative to some less sophisticated DMSMS management program that would have resolved each DMSMS case using the “next most expensive resolution.”

Observations on the conventional cost avoidance calculation:

- Interpretation and comparison of conventionally calculated cost avoidances is nebulous. The correlation of conventionally computed cost avoidances to real costs is questionable.
- ROI calculations incorporating the conventional cost avoidance are measures are relative to a complex (and indeterminate) moving scale associated with the “next most expensive resolution approach.”
- The conventional calculation has no mechanism to accommodate resolution actions that have either no effect or a negative effect, i.e., every resolved case results in positive cost avoidance, which is probably not true.
- The conventional cost avoidance calculation approach captures how hard a DMSMS management group is working, but not how smart, i.e., the greater the quantity of individual resolutions the faster the cost avoidance accumulates. In general, the conventional cost avoidance calculation approach rewards only reactive management.
- The conventional cost avoidance calculation has the potential to significantly undervalue design refreshes because it cannot see future DMSMS resolutions that have been avoided by the refresh. The conventional cost avoidance calculation has no way of valuing strategic DMSMS management approaches (i.e., refreshes or other actions that solve

future problems); therefore DMSMS management groups who are measured or justified based on their conventionally calculated cost avoidance have no incentive to consider these solutions.

Summary

This appendix outlines a proposed ROI approach to assessing the value of DMSMS management. ROI_0 (the return on investment relative to a case where nothing goes obsolete) can possibly be determined from data collected by DMSMS management organizations, and is a valid quantification of DMSMS management value, but probably not a “sellable” number. Differing value of money problems (\$1 at Boeing \neq \$1 at Raytheon) are resolved by ROI since it is a ratio. If a C_S (sustainment cost of the unmanaged system) can be established (or estimated) for a system, then a real ROI for the DMSMS management effort can be found; alternatively, an application-specific breakeven C_S can be calculated.

Appendix D – Case Study – Developing Program-Specific NRE Cost Metrics

The SD-22 DMSMS Resolution Cost Metrics (Table 1 in this report, suggested as Table 5 in the SD-22 rewrite) will suffice as average costs when there are no actual cost data for your program. Assume that at some future time, a program initiates a DMSMS corrective action project. Cost data from that “actual” project should be used where possible to generate program-specific metrics. Obviously, an actual cost of a specific resolution type would be the best estimate for future occurrences of that same type. But what can be done to generate better estimates of the other resolution types? We will illustrate how to use the actual data to arrive at a program-specific estimate.

Scenario: In 2008, a microcircuit specified in a Company Y Spec Control Drawing had become a top DMSMS concern. Some 5 years earlier, a multi-year buy of 12 units of the part had been purchased and stored in a program-dedicated inventory. However, in the last two years, nine of those units had been consumed (on the Company Y LRU and on two other LRUs). The program office awarded a contract to Company Z, the prime contractor, who in-turn subcontracted to Company Y the scope of the contract was to find a suitable solution (which was categorized as a complex substitute).

The outcome of the project was to identify the most promising candidate and validate a commercially available component (the definition of a complex substitute). There was testing at the part level (radiation hardness) and at the NHA level (acceptance test procedures on three different NHAs) along with the technical documentation, quality oversight, and management oversight. The contract cost was \$850,000; any future complex substitution on this weapon system program would be expected to cost about the same. How could this data point be used to update the other costs on this program?

Cost estimates for other resolution types could be based on that experience: using the SD-22 Resolution Cost Metrics, one can compute the ratios of the resolution type cost metrics. Assigning the average cost of the complex substitute as the base value, for the other resolution types, we would simply compute the ratio of the average cost of each type to the average cost of a complex sub (i.e., express each type as a fraction of the complex sub). Thus from, the mean values in Table 1, the ratios would be:

Table D1. Ratios of Type Average NRE Cost Metrics to Cost of a Complex Sub

Resolution Type	Cost Estimate (from 2011 SD-22)	Ratio of Type \$ /Complex Sub \$	Value of Ratio
Reclamation	\$20,000	= 20,000 /423,000	0.047
Alternate Source	\$41,000	= 41,000/423,000	0.097
Admin Substitute	\$3,000	= 3,000/423,000	0.007
Desktop Substitute	\$5,000	= 5,000/423,000	0.012
Normal Substitute	\$34,000	= 34,000/423,000	0.080
Complex Substitute	\$423,000	= 423,000/423,000	1.000
Emulation	\$73,000	= 73,000/423,000	0.173
Aftermarket Mfg	\$33,000	= 33,000/423,000	0.078
Redesign COTS	\$1,118,000	= 1,118,000/423,000	2.643
Redesign - CP	\$1,094,000	= 1094000/423,000	2.586
Redesign - PNHA	\$1,010,000	= 1,010,000/423,000	2.388

By using the new actual cost of the complex sub (\$850,000) as the base (instead of the \$423,000 from this survey), revised estimates of the average resolution costs can be projected as seen in Table D2 below:

Table D2. New NRE Cost Metrics Based on Actual Cost of a Complex Sub

Resolution Type	Type \$/Complex Sub \$ (from Table D1)	Ratio * \$850K (New Base)	Revised Program Estimate 1
Reclamation	0.047	= 0.047 * \$850,000	\$40,189
Alternate Source	0.097	= 0.097 * \$850,000	\$82,388
Admin Substitute	0.007	= 0.007 * \$850,000	\$6,028
Desktop Substitute	0.012	= 0.012 * \$850,000	\$10,047
Normal Substitute	0.080	= 0.080 * \$850,000	\$68,322
Complex Substitute	1.000	= 1.000 * \$850,000	\$850,000
Emulation	0.173	= 0.173 * \$850,000	\$146,690
Aftermarket Mfg	0.078	= 0.078 * \$850,000	\$66,312
Redesign COTS	2.643	= 2.643 * \$850,000	\$2,246,572
Redesign - CP	2.586	= 2.213 * \$850,000	\$2,198,345
Redesign - PNHA	2.388	= 2.388 * \$850,000	\$2,029,551

If another actual cost is incurred (e.g., a normal substitute that costs \$90,000), the cost estimates can be refined further by making the new “actual” type cost base to be that of the previous normal substitute (\$68,322 from Table D2) and re-calculating the ratios as seen in Table D3 below. Since the complex sub value of \$850,000 was an actual cost, it is not adjusted (leave the ratio blank).

Table D3. Ratios of Type Average NRE Cost Metrics to Actual Cost of a Normal Sub

Resolution Type	Revised Estimate (from Table D2)	Ratio of Type \$ /Normal Sub \$	Value of Ratio
Reclamation	\$40,189	= 40,189 ÷ 68,322	0.588
Alternate Source	\$82,388	= 82,388 ÷ 68,322	1.206
Admin Substitute	\$6,028	= 6,028 ÷ 68,322	0.088
Desktop Substitute	\$10,047	= 10,047 ÷ 68,322	0.147
Normal Substitute	\$68,322	= 68,322 ÷ 68,322	1.000
Complex Substitute	\$850,000 ¹		
Aftermarket Mfg	\$66,312	= 66,312 ÷ 66,322	0.971
Emulation	\$146,690	= 146,690 ÷ 66,323	2.147
Redesign COTS	\$2,246,572	= 2,358,065 ÷ 66,322	32.882
Redesign - CP	\$2,198,345	= 1,880,851 ÷ 66,322	32.176
Redesign - PNHA	\$2,029,551	= 2,130,173 ÷ 66,322	29.706

¹ leaving as is since based on an actual cost

As before, by using the Table D3 ratios and the new known cost of a normal sub (\$90,000), new revised estimates of the resolution costs can be projected as seen in Table D4 below (the value for the known complex sub would remain unchanged):

Table D4. Revised NRE Cost Metrics (Using Actual Values of Complex Sub and Normal Sub)

Resolution Type	Type \$/Normal Sub \$ (from Table D3)	Ratio * \$90K (New Base)	Revised Program Estimate 2
Reclamation	0.588	= 0.588 * \$90,000	\$52,941
Alternate Source	1.206	= 1.206 * \$90,000	\$108,529
Admin Substitute	0.088	= 0.088 * \$90,000	\$7,941
Desktop Substitute	0.147	= 0.147 * \$90,000	\$13,235
Normal Substitute	1.000	= 1.000 * \$90,000	\$90,000
Complex Substitute	\$850,000 ¹		\$850,000
Aftermarket Mfg	0.971	= 0.971 * \$90,000	\$87,353
Emulation	2.147	= 2.147 * \$90,000	\$193,230
Redesign COTS	32.882	= 32.882 * \$90,000	\$2,959,412
Redesign - CP	32.176	= 27.529 * \$90,000	\$2,895,882
Redesign - PNHA	29.706	= 29.706 * \$90,000	\$2,673,529

¹ leaving as is since based on an actual cost

This technique assumes that the most recent “actual” cost is the best estimate for any type. A possible variation on that assumption is to use an average of all recomputations. This technique would be performed each time a new “actual” cost (of any of the resolution types) is incurred. Those values in the table that came from previous actuals would not be changed, but all others would be. If other examples of the same resolution type occur, the cost of that type would be changed to the average of the occurrences.

For this to work, the DMT must keep track of solutions and their associated costs.

ARINC proposes to include this technique in the redlines to the SD-22.

Appendix E – BCA Application Case Study

Background. From the Office of Management and Budget (OMB) Circular A94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs – “benefit-cost analysis is the technique to use in a formal economic analysis of government programs. The standard criterion for deciding whether a government program [or in our case, DMSMS resolution alternatives] can be justified on economic principles is net present value (NPV) -- the discounted monetized value of expected net benefits (i.e., benefits minus costs). NPV is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits.”

For DMSMS alternatives, the one with the least present cost is preferred. We assume that the benefit of mitigating a given DMSMS condition is the same for each alternative; hence, present cost is as good as net present value in choosing among alternatives. To compute present cost, you must “discount” future costs using the OMB discount rate (accounts for the time value of money). Costs are worth more if they are experienced sooner (delay is economical). The higher the discount rate, the lower the present cost of future cash outlays.

The discount rate is actually the forecasted interest rate as reported by the OMB¹⁷. Table E1 (from OMB, A94) is the real interest forecast from the 2011 Budget. These rates are used for discounting constant-dollar flows, as is required in cost-effectiveness analysis.

Table E1. Real Interest Rates on Treasury Notes and Bonds of Specified Maturities (in percent) (2011 Budget)

3-Year	5-Year	7-Year	10-Year	20-Year	30-Year
0.9	1.6	1.9	2.2	2.7	2.7

The discount factor is calculated as $1/(1 + i)^t$ where i is the interest rate and t is the year (current year is year 0, next year is year 1). Here are two example computations using the 7-year interest rate of 1.9% (0.019) (seven years is the time horizon in the following illustration):

$$\text{Discount Rate for year 2 (FY13)} = 1/(1+0.019)^2 = 0.963$$

$$\text{And Discount Rate for year 6 (FY17)} = 1/(1+0.019)^6 = 0.893$$

BCA Application to a DMSMS Scenario. In 2008, a particular SRU in the fuel management system of the B-2 had become a top DMSMS concern with six serious DMSMS issues. The approved problem part reports (PPRs) recommended individual solutions (with costs coming from the SD-22 Resolution Cost Metrics) as follows:

- A complex substitute project (FY14 thru FY15) and another complex substitute project (FY15 thru FY16)

¹⁷ <http://www.whitehouse.gov/omb/circulars/a094>

- Two normal substitute projects (FY16) and two other normal substitute projects (FY17)

Every BCA requires alternatives – in this case:

- Alternative 1 – funding and initiating six individual projects in the time periods indicated.
- Alternative 2 – redesign the SRU immediately (start in FY11) and completing in three years (FY11 cost of \$1,010,000, allocated 40% the first year [\$404,000], 40% the second year, and 20% the third year [\$202,000]).

To calculate the present value of these alternatives over 7 years (in this illustration, the projects are executed over a seven year period); we must generate a cost stream for each by: 1) computing the Then-Year cost for the set of corrective actions and 2) discounting those costs to the present year (FY11). We use the following data inputs:

- FY11 mean cost values from the SD-22 Resolution Cost Factors (as computed in this study) as seen in Table E2.
- DoD Weighted Inflation Factors from the Naval Center for Cost Analysis (NCCA) (FY11 Constant Year to seven future “Then-Years”)¹⁸
- 7 year real interest rate of 1.9% from the OMB A-94 from Table E1.

Table E2. Resolution NRE Cost Metrics from New SD-22 (FY2011 \$)

Resolution Type	90% Confidence (Left Limit)	Mean	90% Confidence (Rt Limit)	Weeks to Resolve (Avg)
Reclamation	\$1,000	\$20,000	\$39,000	12
Alternate Source ¹	\$0	\$41,000	\$92,000	11
Admin Substitute	\$1,000	\$3,000	\$5,000	4
Desktop Substitute	\$0	\$5,000	\$10,000	8
Normal Substitute	\$22,000	\$34,000	\$46,000	25
Complex Substitute	\$122,000	\$423,000	\$724,000	40
Emulation ²	\$29,000	\$73,000	\$117,000	26
Aftermarket Mfg	\$0	\$33,000	\$58,000	21
Redesign - COTS ³	\$82,000	\$1,118,000	\$2,154,000	42
Redesign - CP ⁴	\$542,000	\$1,094,000	\$1,646,000	61
Redesign - PNHA ⁵	\$654,000	\$1,010,000	\$1,366,000	64

¹ Alternate source includes parts from a different manufacturer (not already in the applicable technical data package) that meet the part specification.

² Emulation cost values provided by Defense Logistics Agency (DLA) are not from the DoC survey and represent the historical costs to DLA to emulate a part from the GEM and GEM AME programs; they do not include integration into the using next higher assembly or system

³ Redesign – Commercial Off-the-Shelf

¹⁸ <http://www.ncca.navy.mil/services/inflation.cfm>.

⁴ Redesign – Custom Part includes the development and validation in the application of new component-level parts

⁵ Redesign – Peculiar Next Higher Assembly

Table E3 shows the computation of the Present Cost of Alternative 1 (considering rounding). The solution costs are distributed over two years for the complex substitutes. We do not attempt to compute a benefit since it will be the same as for Alternative 2 (the benefit is DMSMS mitigation). Here, the present cost of spending the money in the future years is \$986,000 (rounded). This value would then be compared to the computation of present value for Alternative 2 (\$1,021,000 rounded) which is in Table E4 below.

Table E3. Computing Present NRE Cost of Alternative 1 (Mix of Solutions)

FY	Yr No.	FY11 Cost Complex Sub	FY11 Cost Normal Sub	Total	DoD Weighted Inflation	OMB Discount ¹	Present Cost
11	0			\$0	1.030	1.000	\$0
12	1			\$0	1.029	0.981	\$0
13	2			\$0	1.047	0.963	\$0
14	3	\$211,500		\$211,500	1.065	0.945	\$212,881
15	4	\$423,000		\$423,000	1.083	0.927	\$424,886
16	5	\$211,500	\$68,000	\$279,500	1.101	0.910	\$280,090
17	6		\$68,000	\$68,000	1.120	0.893	\$68,027
Present Cost of Alternative 1							\$985,884

¹ Based on 7-year real interest rate of 0.019 from Table E1

Table E4. Computing Present NRE Cost of Alternative 2 (SRU Redesign)

FY	Yr No.	FY11 Cost Redesign SRU	DoD Weighted Inflation	OMB Discount	Present Cost
11	0	\$404,000	1.013	1.000	\$409,142
12	1	\$404,000	1.029	0.981	\$408,161
13	2	\$202,000	1.047	0.963	\$203,680
Present Cost of Alternative 2					\$1,020,983

In this case, the more economical choice is to pursue the individual solutions. If there were more individual solutions, or if they must be started in earlier years, the outcome would have favored the SRU redesign. Of course, the economics of the decision must be tempered with other logistics and technical considerations, such as the more expensive production cost of the redesigned SRUs and the possibility of the SRU redesign incurring a cost and schedule overrun. Also, the timing for project initiation must be sound (as documented in the PPRs).

Whenever alternatives exist, the decision-maker will expect to know all the rationale for the recommendation – this present value basis is one such compelling reason.