Diminishing Manufacturing Sources and Material Shortages

Cost Metrics

DEFENSE STANDARDIZATION PROGRAM OFFICE

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Executive Summary

Up-to-date cost metrics are crucial for ensuring that the Department of Defense uses the most cost-effective approach to resolving issues related to Diminishing Manufacturing Sources and Material Shortages (DMSMS). To update those metrics, the Defense Standardization Program Office undertook an analysis of responses to the 2014 DMSMS cost survey—Defense Industrial Base Assessment: Diminishing Manufacturing Sources and Material Shortages Cost Resolution Values Survey—conducted by the Department of Commerce's Bureau of Industry and Security.[1] The updated metrics will be incorporated into the latest version of SD-22, *Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program.*

The following table presents the updated cost metrics for DMSMS resolutions.

DMSMS Resolution Average Costs and Confidence Intervals

Solution	95% confidence (left limit)	Average cost (mean)	95% confidence (right limit)
Approved parts	$900	$1,028	$1,100
Life-of-need buy	$4,600	$5,234	$5,900
Simple substitute	$11,900	$12,579	$13,200
Complex substitute	$14,800	$25,410	$36,000
Extension of production or support	$14,000	$25,472	$36,900
Repair, refurbishment, or reclamation	$21,300	$65,015	$108,700
Development of a new item or source	$437,600	$655,411	$873,200
Redesign–NHA	$900,300	$1,092,856	$1,285,400
Redesign–complex/system replacement	$7,142,100	$10,287,964	$13,433,800

The average costs take into account all reported instances across the complexity spectrum of part type, commodity, and environment. The confidence intervals indicate a 95 percent certainty that the true average cost lies within the interval between the left and right limits.

This report outlines the analytical steps used to calculate the new DMSMS resolution costs, along with cross-tabulations that lend additional insights into the nature and characteristics of DMSMS resolutions. In addition, the report presents comprehensive information on the DMSMS cost survey, such as response rate and data characteristics.

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[1] See http://www.bis.doc.gov/dib.

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1. Background, Objectives, and Report Structure

Department of Defense (DoD) policy and obsolescence management guidance emphasize a cost-conscious approach to dealing with Diminishing Manufacturing Sources and Material Shortages (DMSMS) issues. Effective DMSMS management requires credible, up-to-date estimates of average resolution costs. Those costs are published by the Defense Standardization Program Office (DSPO) in *Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program* (SD-22).[2] Program managers and DMSMS management teams throughout the defense community use the cost data in SD-22 to meet cost avoidance and should-cost reporting needs.

The most recent cost metrics published in SD-22 were from September 2010[3] based on a 2009 survey.[4] To update those metrics, the Department of Commerce's Bureau of Industry and Security (BIS), in partnership with DSPO, conducted a cost survey of government and industry entities that support DMSMS resolutions within DoD programs and systems. The DMSMS cost survey—Defense Industrial Base Assessment: Diminishing Manufacturing Sources and Material Shortages Cost Resolution Values Survey—was conducted in early 2014.

LMI cost and survey experts processed and analyzed the data collected through that survey and calculated revised resolution average cost values and confidence intervals for use in updating SD-22.[5] A contemporary measure of DMSMS resolution costs is essential for programmatic budgeting and obsolescence management planning. Progressive emphasis on gaining detailed insights regarding engineering, design, and implementation costs needs to be sustained to better prepare the DMSMS practitioner community to mitigate adverse effects of DMSMS issues on material readiness and operational availability.

The remainder of this report is organized as follows:

- Section 2 provides information on cost survey administration, respondents, and specifics of the data collection instrument.

- Section 3 provides information on the characteristics of the data collected through the survey and the compiled data set.

- Section 4 presents the data analysis approach, specifics on the data cleaning process, and analytical findings on average costs of DMSMS resolutions.

- Section 5 presents an interpretation of the results and scope for improvement.

The appendixes contain additional detail.

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[2] Defense Standardization Program Office, SD-22, *Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program*, August 2012, http://quicksearch.dla.mil/, Search Parameter (Document ID = SD-22).

[3] Defense Standardization Program Office, *DMSMS NRE Resolution Cost Metric Update*, September 2010.

[4] Department of Commerce, *DMSMS Resolution Cost Survey*, 2009 (http://www.bis.doc.gov/dib).

[5] LMI provides contractual support to DSPO on DMSMS management.

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2. About the Survey

The goal of the DMSMS cost survey was to collect data from government and industry entities involved in DMSMS resolutions to generate an accurate, reliable, and valid data set that can be analyzed to compute updated average DMSMS resolution costs.[6]

The resolution cost survey conducted in 2009 limited our ability to estimate costs for contemporary DMSMS resolutions. For the 2014 survey, BIS made several significant changes to increase the scope and quality of data. It used recently developed renewed resolution categories[7] that vary in level and amount of research required to implement a resolution. The scope of the survey was changed to include commodity types other than just electronic components and systems. The survey requested solutions for mechanical components and assemblies, electrical components and assemblies, materials, and software. These additional commodity types are intended to cover the full range of DMSMS issues that both industry and government face. The quality of the survey was enhanced by adding the operating environment of the hardware affected by the DMSMS problem. The survey team assessed that each operating environment would have a unique cost profile based on engineering requirements and qualification costs. The quality of the survey was also enhanced by requesting a breakdown of the solution costs into specific categories, which were roughly based on the engineering change proposal (ECP) form (DD 1692).

Through this survey, government and industry respondents were requested to provide detailed costs for DMSMS solutions that they implemented in the last 2 years. They were requested to define and offer detailed cost breakdowns involved in implementing DMSMS solutions in sufficient detail to allow DoD to do the following:

- Estimate costs of solutions to emerging DMSMS issues.

- Develop budgets and Program Objective Memorandum information for resolving DMSMS issues in the future.

- Provide a basis for evaluating quotes for resolving DMSMS issues.

- Allow programs to provide accurate estimates of DMSMS cost avoidance.

The overall objective of the survey analysis was to generate a comprehensive, standardized inventory of DMSMS solutions, and their associated costs, that can be used for the warfighting tools supported by the DoD DMSMS Working Group. The standardized inventory will provide both the government and product manufacturers a common understanding of costs. The cost factors used by this survey were carefully selected to provide the detail needed for proper analysis. They are intended to include the total cost of the solution implemented.

2.1. Respondents

BIS, in cooperation with the DMSMS Working Group, solicited the participation in this survey of organizations involved in DMSMS resolutions. Organizations were identified as providing DMSMS-related support for DoD programs or systems and were contacted through a distribution

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[6] Department of Commerce, *Defense Industrial Base Assessment: Diminishing Manufacturing Sources and Material Shortages Cost Resolution Values Survey*, 2014.

[7] See Note 1, pp. 69–72.

letter explaining the survey data collection exercise, soliciting their participation, and assuring business confidentiality of the information furnished through the survey instrument.

The cost metrics survey was distributed in MS Excel format, along with instructions, to identified respondents. BIS provided technical and content support, making its support staff members accessible through email and telephone. The survey was administered over a 4-month period between March and June 2014. More than 50 organizations were contacted for participation in the survey, of which 35 furnished responses. A response rate of 70 percent is moderate for a mandatory data collection exercise.[8] Some timely responses were only partially complete due to the time intensity of calculating resolution costs, which resulted in a final set of 28 qualified responses. The inability of some preidentified respondents to calculate resolution costs within the specified time period contributed to responses in "working" or "partially complete" status. In addition, several entities were granted exemption from responding because either they did not deal with DMSMS issues in the recent past (within 2 years) or because they were primarily a research and development organization not directly involved in DMSMS resolutions. These two factors explain the moderate response rate. This iteration of the survey was a significant improvement in terms of planning, effective administration, and support provisions. Future iterations of the survey may benefit from better identification of eligible respondents along with successive notifications preceding the actual survey instrument. This may prove useful in generating interest and also allow for internal resource planning in respondent organizations, keeping in mind that DMSMS cost surveys have been perceived as time intensive.

2.2   Instrument

The survey instrument, complete with instructions and necessary definitions, was prepared collaboratively with participation of subject matter experts from the DMSMS Working Group, survey design experts from LMI, and the implementing/administering body, BIS. MS Excel format was chosen as the platform for the survey instrument given the complexity and large amount of data to be collected from each respondent organization. A secondary reason that informed the choice of this platform was the relative simplicity with which data, once collected, could be merged for analysis procedures.

Apart from definitions, instructions, and a table of contents, the survey instrument had 13 sections:

- Section 1 featured questions related to basic characteristics of the organization, such as name, location, and points of contact.

- Section 2 listed each DMSMS resolution category and oriented respondents about solution characteristics, e.g., part type, part commodity, and operating environment; Section 2 also provided explicit information on how to respond to Tabs 3 through 13 that correspond to individual resolution categories. A different solution tab needed to be filled out for each unique combination of solution type, solution characteristics (part type, part commodity, operating environment), and service. To allow for this reporting requirement, each tab had three worksheets (3a, 3b, 3c; 4a, 4b, 4c; etc.). Multiple solutions could be reported on a single tab only when they had the same combination of solution type, solution characteristics, and service.

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[8] Under 50 U.S.C. App. § 2155, entities participating in the data collection exercise were required to complete the survey within 30 calendar days of receipt of the distribution letter.

Furthermore, when reporting more than one solution per tab, for a set combination, respondents were required to report average costs.

- Sections 3–11 each contain three solution area tabs for each solution type.

- Section 12 was reserved for reporting certification type DMSMS resolutions.

- Section 13 was available for reporting additional DMSMS solutions.

Table 1 lists the sections of the survey instrument.

Table 1. Sections of the Survey Instrument

No.	Title
1	Company/Organization Information
2	DMSMS Solutions
3	Approved Part
4	Life-of-Need Buy
5	Repair, Refurbishment, or Reclamation
6	Extension of Production or Support
7	Simple Substitute
8	Complex Substitute
9	Development of a New Item or Source
10	Redesign–NHA
11	Redesign–Complex/System Replacement
12	Certification
13	Additional DMSMS Solution

In Sections 3 through 13, respondents were first given a definition of the applicable resolution type to orient their responses. They were then asked to explain the issue for which the reported solution was developed, along with program and problem context, and to indicate the characteristics of products/services and the applicable service that were supported through the resolution. Finally, respondents were requested to provide detailed cost breakdown information in two broad categories: (1) total engineering and design costs and (2) total implementation costs. Each category was further broken down into several cost factors.

Appendix A contains a sample extract from the survey instrument.

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3. Data Characteristics

The survey process yielded 34 MS Excel files from 28 organizations, covering both government and industry.[9] The structure of the survey file allowed for data to be captured in separate worksheets corresponding to separate resolution types. Data from all respondent organizations were merged into one consolidated file with the data variables shown in Table 2. Each row of data represents a particular resolution instance within an organization uniquely identified using a combination of resolution characteristics: part type, part commodity, and operating environment.

Table 2. Data Set Variables and Definitions

Variable	Definition
Org Name	Name of respondent organization.
Clean Business Unit/Division	Name of business unit/division.
Org Type	Type of organization: Department of Defense Program Office/Activity; Department of Defense Supply Activity; Prime Integrator; Second Tier/Lower Manufacturer; Other–Department of Defense Contractor; Other–Manufacturer/Supplier of Military Radios and Other Communications Equipment; Other–SDL, a University Affiliated Research Center.
Issue Tab	Alphanumeric sequence of worksheet, where numeric part (3-13) indicates resolution type and alphabet part indicates first, second, third, or later instance (3a, 3b, 3c, 4a, 4b, 4c…).
DMSMS Issue	Resolution type as indicated by the respondent organization: Approved Parts; Life-of-Need Buy; Repair, Refurbishment or Reclamation; Extension of Production or Support; Simple Substitute; Complex Substitute; Development of a New Item or Source; Redesign–NHA; Redesign–Complex/System Replacement.
Describe	Brief description of the resolution instance with information on program and problem context.
Army	Yes/No binary value indicating whether the DMSMS resolution supported Army.
Navy	Yes/No binary value indicating whether the DMSMS resolution supported Navy.
Air Force	Yes/No binary value indicating whether the DMSMS resolution supported Air Force.
Marines	Yes/No binary value indicating whether the DMSMS resolution supported Marine Corps.
Other DOD	Yes/No binary value indicating whether the DMSMS resolution supported other DoD.
Other Specify	Value indicating name if DMSMS resolution supported other non-DoD/armed forces agency.
Part Type	Type of part DMSMS issue is concerned with: assembly; component; raw material; software.
Commodity	Type of commodity DMSMS issue is concerned with: electrical; electronics; mechanical.
Environment	Operating environment in which DMSMS product/solution functions: aviation; ground; shipboard; space; undersea.
Number Reported	Number of DMSMS issues of a certain type reported per worksheet. A type of DMSMS issue is characterized by a combination of part type, part commodity, and operating environment.

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[9] In select instances, due to the inability of some respondents to report information in accordance with the required survey criteria, BIS received resolution cost data in non-survey Excel or PDF formatted documents.

Table 2. Data Set Variables and Definitions

Variable	Definition
Actual Est	Variable indicating whether cost value is estimate or actual.
Cost Type	Type of cost factor for which cost value is reported.[a] There are 17 values and other options: 1a Engineering/Engineering Data Revision; 1b Qualification of New Items; 1c Software Development/Modification; 1d Startup Costs; 1e Tooling/Equipment/Software; 1f Other; 1g Total Engineering/Design Cost; 2a Computer Programs/Documentation; 2b Interim Support; 2c Supply/Provisioning Data; 2d Support/Test Equipment; 2e Technical Manuals; 2f Training/Training Equipment; 2g Installation Costs; 2h Other; 2i Total Implementation Cost; Total Solution Costs.
Cost Value	Value of cost factor reported in previous variable. If Number Reported was greater than one, costs reported were average values.

[a] Defense Standardization Program Office, SD-22, Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program, August 2012, p. 72 (Table 6. Applicability of Cost Elements to DMSMS Resolution Options).

4. Analysis of Survey Data and Findings

4.1. Data Cleaning Process

Systematic data cleaning steps were applied to the data set after merging responses from individual organizations. The DMSMS Working Group, with support from LMI survey analysts, conducted a multistage review process to identify and correct data that were spurious, incomplete, or of low quality. In such instances, data elements were corrected or reclassified based on expert assessment; in some instances, incorrect or duplicate reporting data had to be deleted. At a high level, the following data cleaning protocol was used:

- The survey team evaluated the validity and plausibility of data elements, with particular focus on reported DMSMS issues, descriptions of the problem being addressed, solution characteristics, and cost values. Cumulatively, 85 data issues were identified, and a list was drawn up for further discussion and appropriate course of action.

- Group discussions began with the evaluation note documented by the original team member who had identified the issue. This evaluation note was primarily an indication of how the issues could be addressed or an assessment of its unsuitability for use in cost metrics analysis.

- Group members formally either agreed or disagreed with the proposed evaluation note and prescribed a resolution approach. Data issues with mutual agreement on an approach were cleared for cleaning. Those issues where mutual agreement was not reached were discussed individually to resolve disagreements and find a practical approach to render the data usable for cost metrics analysis.

At the conclusion of this process, all instances of data issues were resolved. The following major types of resolutions were achieved:

- Updated DMSMS resolution type when the problem did not match the resolution type and reported cost value. Determination was based on the nature of the DMSMS problem addressed.

- Updated number of issues reported (Number Reported) when the respondent had incorrectly entered a different value or unintentionally left this field blank. In some instances, this number was not supported by the description of the issue and was updated to match issue description.

- Updated part type, commodity type, and operating environment field values when the respondent had unintentionally left the field blank. In some instances, original solution characteristic values were based on expert assessment of the survey team (rarely used).

- Averaged costs if the respondent had unintentionally reported aggregate costs in place of average costs.

- Removed costs reported in "Other" cost category when reported costs were related to procurement or other non-implementation activities that were outside the scope of DMSMS costs.

- Deleted instances of issues found to be unrelated to obsolescence or for which no resolutions were reported.

4.2. Frequency of DMSMS Resolutions

At the conclusion of the data cleaning process, the resulting data set had 264 rows of data with a wide variation in the number of DMSMS issues reported. A total of 4,562 issues were reported with the number of issues per row ranging from 1 to 702. In terms of notational representation, all resolution types had at least 1 percent issues attributed to them. However, there is wide variability between resolution types, with about a third of all issues attributed to approved parts resolution (highest share) and about 1 percent each for two resolution types: repair, refurbishment, or reclamation and redesign of a complex/system replacement. This variability in attribution to resolution types is an important finding, because at an aggregate level, it reveals resolution types that are most frequently addressed and most prevalent based on industry and government experience over the past 2 years.

As shown in Figure 1, DMSMS resolutions fall into three broad categories: resolutions involving existing materials (logistics), resolutions involving substitutes (engineering), and resolutions involving redesign (engineering).

Figure 1. Broad Categorization of DMSMS Resolutions

- Resolutions Involving Existing Materials
- Resolutions Involving Substitutes
- Resolutions Involving Redesign
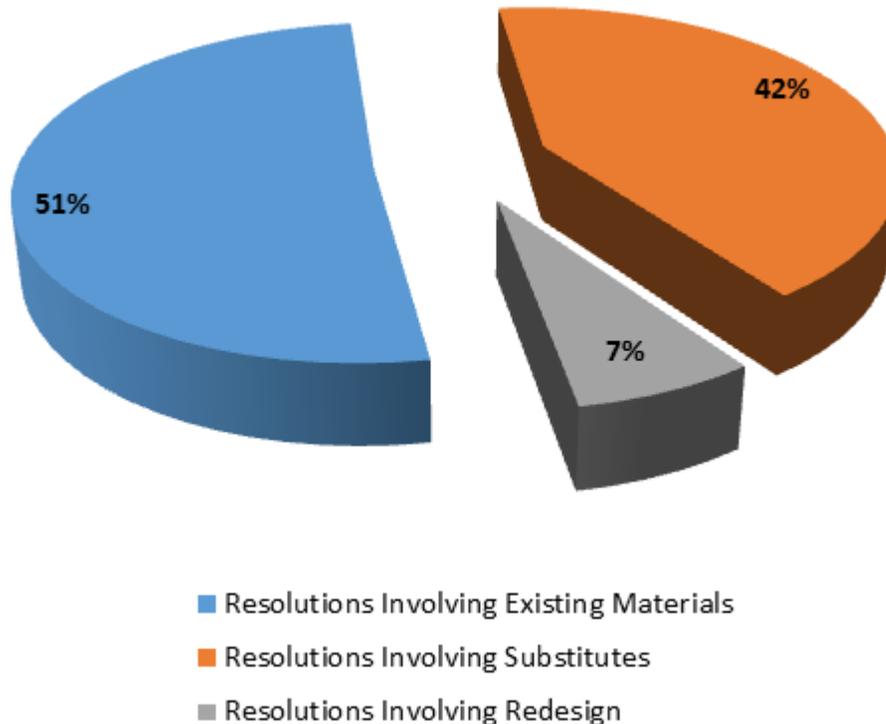
The broad categories indicate the level and amount of research required to implement a resolution. The amount of research and applicable cost elements required to implement a resolution also increase as the program progresses through resolution categories.[10] Cumulative percentage totals indicate that about half of all reported DMSMS issues belong to the first broad category of existing materials (logistics). About 40 percent of reported DMSMS issues can be attributed to the second broad category of substitutes (engineering). Only about 7 percent of DMSMS issues belong to the third category of redesign (engineering). Most frequently engaged solutions were

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[10] See Note 1, p. 69.

found to be approved parts and simple substitutes, commanding about a third share each of all resolutions. Life-of-need buys (15 percent) and complex substitutes (9 percent) are other categories that command sizable shares. Table 3 presents the number of DMSMS issues reported by resolution types, along with their respective percentages and cumulative percentage totals.

Table 3. Number of Issues Reported by Resolution Type

Solution	Sample size	Percent (rounded)	Cumulative percentage
Approved parts	1,539	34%	34%
Life-of-need buy	666	15%	48%
Simple substitute	1,500	33%	81%
Complex substitute	410	9%	90%
Extension of production or support	98	2%	92%
Repair, refurbishment, or reclamation	40	1%	93%
Development of a new item or source	127	3%	96%
Redesign–NHA	138	3%	99%
Redesign–complex/system replacement	44	1%	100%
Total	4,562	100%	—

Resolution types are intrinsically varied in research and cost elements, and a significant driver of this variation in resource intensity can be attributed to the type of part used to implement a resolution. Four standard part types are used in DMSMS resolutions: assembly, component, raw material, and software. (Appendix B defines them.) To illustrate the relative extent of the use of DMSMS resolutions differentiated by part type, Table 4 presents the frequency of DMSMS resolution types (rows) cross-tabulated with part types (columns). Component parts—base unit parts that may be used as part of an assembly—are the most frequently used solution, accounting for nearly 90 percent of all DMSMS issues. Assembly parts—grouping of parts that result in a final unit that is considered a distinct item—are the next most frequent solution, accounting for about 13 percent of DMSMS issues. The remaining part types (raw material and software) are seldom used to resolve obsolescence issues and constitute only about 1 percent of all DMSMS issues. These frequencies are derived from sample survey data; further comparative tests may be required to ascertain how well they represent population frequencies or distribution across part types.

Table 4. Frequency of DMSMS Solutions by Part Type

Solution	Assembly	Component	Raw material	Software	Total
Approved parts	133	1,398	8	0	1,539
Life-of-need buy	90	576	0	0	666
Simple substitute	94	1,403	3	0	1,500
Complex substitute	69	320	21	0	410
Extension of production or support	36	56	6	0	98
Repair, refurbishment, or reclamation	14	26	0	0	40
Development of a new item or source	38	88	1	0	127

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Table 4. Frequency of DMSMS Solutions by Part Type

Solution	Assembly	Component	Raw material	Software	Total
Redesign–NHA	59	75	0	4	138
Redesign–complex/system replacement	35	9	0	0	44
Total	568	3,951	39	4	4,562
Percentage share	12.5%	86.6%	0.9%	0.1%	100%

Another driver of variation in resource intensity of obsolescence resolutions is the type of commodity used to implement a solution. Three standard part commodities are used in DMSMS solutions: electrical, electronics, and mechanical. (Appendix B defines them.) To illustrate the relative extent of use of DMSMS solutions differentiated by part commodity, Table 5 presents the frequency of DMSMS solution types (rows) cross-tabulated with part commodity (columns). Electronics commodities—components, assemblies, or equipment built using electronic components or circuit cards—are the most frequently used solution, accounting for close to two-thirds of all DMSMS issues. Electrical commodities—equipment that generates electricity, transfers or controls electricity, or uses electricity as its prime energy source (excluding electronics)—are the next most frequent solution, accounting for about one-third of DMSMS issues. Mechanical commodities—parts, assemblies, or equipment that is neither electrical nor electronic—constitute about one-tenth of all DMSMS issues. These frequencies are derived from sample survey data; further comparative tests may be required to ascertain how well they represent population frequencies or distribution across part commodity.

Table 5. Frequency of DMSMS Solutions by Part Commodity

Solution	Electrical	Electronics	Mechanical	Total
Approved parts	987	316	236	1,539
Life-of-need buy	27	633	6	666
Simple substitute	190	1,233	77	1,500
Complex substitute	34	331	45	410
Extension of production or support	27	68	3	98
Repair, refurbishment, or reclamation	1	38	1	40
Development of a new item or source	14	103	10	127
Redesign–NHA	2	132	4	138
Redesign–complex/system replacement	12	31	1	44
Total	1,294	2,885	383	4,562
Percentage share	28.4%	63.2%	8.4%	100%

The characteristics of the operating environment in the context of obsolescence resolutions have a unique cost profile based on engineering requirements and qualification costs. DMSMS solutions classified by the operating environment are as follows: aviation, benign or non-tactical, ground, shipboard, space, and undersea. To illustrate the relative extent of use of DMSMS solutions differentiated by operating environment, Table 6 presents the frequency of DMSMS solu-

tion types (rows) cross-tabulated with operating environment (columns). Parts or equipment used in an aviation environment (in or on aircraft) are the most frequently used solution, accounting for close to 60 percent of all DMSMS issues. Parts or equipment used in a space environment are the next most frequent solution, accounting for about one-fifth of obsolescence issues. Parts or equipment used in ground or shipboard environments together constitute about 25 percent of DMSMS issues. The remaining operating environments (benign or non-tactical and undersea) are rarely served by obsolescence resolution and constitute less than 1 percent of all DMSMS issues. These frequencies are derived from sample survey data; further comparative tests may be required to ascertain how well they represent population frequencies or distribution across operational environments.

Table 6. Frequency of DMSMS Solutions by Operating Environment

Solution	Aviation	Benign or nontactical	Ground	Shipboard	Space	Undersea	Total
Approved parts	442	0	349	38	710	0	1,539
Life-of-need buy	438	0	96	100	32	0	666
Simple substitute	1,160	0	184	58	97	1	1,500
Complex substitute	310	0	38	61	0	1	410
Extension of production or support	93	0	3	2	0	0	98
Repair, refurbishment, or reclamation	4	0	4	26	0	6	40
Development of a new item or source	97	0	27	3	0	0	127
Redesign–NHA	46	0	41	51	0	0	138
Redesign–complex/ system replacement	30	0	6	8	0	0	44
Total	2,620	0	748	347	839	8	4,562
Percentage share	57.4%	0.0%	16.4%	7.6%	18.4%	0.2%	100%

As mentioned earlier, the 2014 iteration of the DMSMS cost survey featured several enhancements in terms of capturing additional solution characteristics, including part type, part commodity, and operating environment. The new data have been useful in offering additional insights into the nature of obsolescence issues faced by the DMSMS community, industry and government agencies. The discussion and cross-tabulations above present a more nuanced picture of obsolescence experience in the recent past. There is evidence that the most prevalent DMSMS resolutions involve electronic component parts in an aviation environment. Of 4,562 reported issues, 2,264 (50 percent) fit this solution profile, and of those 2,264 issues, more than half (60 percent) rely on substitute type resolutions, followed by about one-third resolutions based on existing materials (logistics). A broader cross-section of programs and organizations would likely produce different distributions across environments, commodities, and parts. Needless to say, the data can be sliced in several ways, and additional elements render this data set increasingly useful in understanding the landscape of contemporary DMSMS issues.

4.3. Cost of DMSMS Resolutions

The 2014 survey went a step forward in collecting detailed cost breakdowns (wherever available and feasible) for obsolescence resolutions. This builds upon previous efforts at increasing granularity in understanding solution costs.[11] This work posits that total solutions costs are composed of two broad categories of costs: engineering and design costs and implementation costs.[12] Table 7 lists the cost elements for the two cost categories.

Table 7. Composition of Total Solution Costs

Engineering and design costs	Implementation costs
Engineering/engineering data revision Qualification of new items Software development/modification Startup costs Tooling/equipment/software Other	Computer programs/documentation Interim support Supply/provisioning data Support/test equipment Technical manuals Training/training equipment Installation costs Other

Applicability and importance of cost elements are influenced by solution characteristics such as part type, commodity, and operating environment. This is driven by variation in the extent of design, degree of complexity, and resource intensity associated with resolution types. Operating environment, for instance, can impose burdens of testing and certification requirements for new parts.

Instructions in the survey requested respondents to enter costs associated with each applicable cost category in dollars to the best of their knowledge and to specify whether costs were actual or estimated. Definitions and examples of each cost category were also provided in the survey instrument. Respondents were asked to provide aggregate cost details (total engineering and design costs, total implementation costs) in the event that cost breakdowns at the requested level of detail were not available. The resulting data set shows that while some respondents were able to provide only total solution costs, some were able to report aggregate cost data categorized into total engineering and design costs and total implementation costs. At the same time, a sizable share of DMSMS issues has been reported with detailed cost breakdowns. The DMSMS survey's first attempt at increasing the granularity of cost data was partially successful. However, computation of average solution costs and confidence intervals requires consistency at the level of reporting costs. The following subsections elaborate on the computation method and present findings based on the survey data.

4.3.1. Computation Approach

Data collected using the DMSMS cost survey represents a sample of DMSMS obsolescence resolution issues within DoD programs and systems. The likelihood of results being representative increases with the share of the entire population that is represented by the sample. Respondents

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[11] See Note 1, p. 72, and DD 1692, Engineering Change Proposal (ECP).

[12] Material costs for purchasing parts are not included in cost calculations.

for the survey were identified based on the survey team's collaboration with the DMSMS Working Group,[13] which has information on organizational entities that are part of obsolescence management in the DoD community. The data collection process itself was uniform in its extent of outreach and follow-on support offered by BIS. Given these factors about selection of respondents and assistance in soliciting responses, it is safe to assume that the resulting data set is representative of the universe of DMSMS obsolescence issues.

Assuming the data are representative, one can infer that the average costs and confidence intervals computed using the data represent the universe of DMSMS issues faced by DoD. Average (arithmetic mean) is a measure of central tendency of a set of numbers, in this case, the costs associated with DMSMS resolutions. In this data set, respondents had the ability to report one or more DMSMS issues together for a set combination of DMSMS issues and solution characteristics. In those cases, the reported costs were averaged. Given this structure of data reporting, average costs must be weighted by the number of DMSMS issues they represent. In other words, costs of DMSMS issues/incidents must be weighted. For example, in a data set of k reported rows of cost data, average costs can be denoted as

$$\bar{x}_j = [(n_1 * \$c_1) + (n_2 * \$c_2) \ldots (n_k * \$c_k)] \div [(n_1 + n_2 + \ldots n_k)]$$

where

n_i = number of issues;

c_i = average cost of issues within a unique combination of solution characteristics;

k = number of rows of cost, each with its own reported number of n_i; and

$\bar{x}_j$ = average cost based on samples of resolution types j.

This computation approach must be applied for each DMSMS resolution type to generate respective average solution costs ($\bar{x}_j$). In addition to average costs for each resolution type, confidence intervals are important because they define the degree to which one can be certain the interval contains the true population mean. It specifies the confidence level that the population mean falls somewhere in the confidence interval.[14] Confidence intervals for average DMSMS resolution costs were computed based on the normal distribution for all resolution types, unless the sample size was small (<40), in which case confidence intervals would have been computed based on the student t-distribution. These are slightly different measurement techniques, because there are implications of sample size for confidence intervals. As the sample size gets bigger, the size of the confidence interval shrinks and, conversely, for smaller sample sizes, confidence intervals are generally wider. Widening of confidence intervals is not a desired attribute because it compromises the accuracy of the sample mean as an estimate of the true population mean.

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[13] The DMSMS working group comprises voting members (Air Force, Army, Navy, Marine Corps, DLA, OSD), advisory members, associate members, industry liaison, and members from the academic community. The establishing charter positioned the working group as the centralized focal point for DMSMS mitigation planning, policy, and guidance for DoD.

[14] Confidence intervals do not mean that 95 percent of the sample data points (costs) lie between the interval range or that the population mean will fall in this interval 95 percent of the time.

The generalized step-by-step approach to computing confidence intervals around resolution average costs is as follows:

- Compute frequency (n_i = number of issues) and mean ($\bar{x}_j$ = average cost based on samples of resolution types j) based on the weighting method outlined above.

- Compute margin of error using appropriate Z value, standard deviation, and sample size.

- Derive left and right confidence limits (confidence interval) by subtracting the margin of error from average cost and adding the margin of error to average cost respectively.

Confidence intervals for DMSMS resolutions based on the survey data set can be represented in notational format as

$$\bar{x}_j \pm \text{Margin of Error or } \bar{x}_j \pm (z * s_{j/\sqrt{n_j}})$$

where

$\bar{x}_j$ = average cost based on samples of resolution types (pronounced "x bar"),

$Z = 1.96$ at 95 percent confidence level,[15]

s_j = standard deviation of samples of resolution types j,[16] and

$\sqrt{n_j}$ = square root of sample size n for resolution type j.

4.3.2. Average Costs and Confidence Intervals

Data represent wide differences in coverage of DMSMS resolutions, with sample sizes representing more than a thousand solution instances for some categories and less than a hundred solution instances for others. As discussed earlier, sample size plays a major role in the width of confidence intervals, with tighter confidence bands being more useful for interpretation and planning.

Table 8 presents average costs (taking into account all instances across the complexity spectrum of part type, commodity, and environment) and confidence intervals for each resolution type. Confidence intervals are rounded to nearest $100 for simplicity. Values in the left and right confidence bounds indicate a 95 percent certainty that the true average cost lies within the interval. (Table 3 shows corresponding sample sizes.)

Table 8. DMSMS Resolution Average Costs and Confidence Intervals

Solution	95% confidence (left limit)	Average cost (mean)	95% confidence (right limit)
Approved parts	$900	$1,028	$1,100
Life-of-need buy	$4,600	$5,234	$5,900
Simple substitute	$11,900	$12,579	$13,200
Complex substitute	$14,800	$25,410	$36,000
Extension of production or support	$14,000	$25,472	$36,900
Repair, refurbishment, or reclamation	$21,300	$65,015	$108,700

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[15] Constant Z is number of standard deviations covered by the selected confidence level (95 percent) in a standard normal distribution.

[16] Square root of variance and indicates variation or dispersion from the average.

Table 8. DMSMS Resolution Average Costs and Confidence Intervals

Solution	95% confidence (left limit)	Average cost (mean)	95% confidence (right limit)
Development of a new item or source	$437,600	$655,411	$873,200
Redesign–NHA	$900,300	$1,092,856	$1,285,400
Redesign–complex/system replacement	$7,142,100	$10,287,964	$13,433,800

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5.   Interpretation of Results and Scope for Improvement

5.1.   Representation

As noted previously, survey respondents were identified based on DMSMS Working Group collective information on organizational entities that are part of obsolescence management in the DoD community. The collection process was uniform in its extent of outreach and follow-on support offered by BIS. Given these factors, we can reasonably assume that the resulting data set is representative of the universe of DMSMS obsolescence issues. The variability in reported resolution instances (ranging from <50 to >1,000) is simply attributed to the prevalence of resolution practices in the DMSMS universe. Considering this point, one can infer that the average costs and confidence intervals presented in Table 9 are statistically representative of obsolescence management and resolution practices. Data collected from a broader cross-section of programs and organizations is likely to be more representative and evenly distributed across environments, commodities, and parts.

5.2.   Data Collection

The survey exercise, with its emphasis on collecting accurate, systematic, and representative information on obsolescence management practices, highlights the need for a basis of estimating cost information for future resolution budgeting and planning. Although conducting a survey with a periodicity of 3–5 years may attain this goal, the survey process is difficult to design and execute and expensive to analyze. Specific information regarding the cost of DMSMS solutions could be gathered regularly by developing a reporting program and requiring DoD programs and commercial suppliers of DoD weapon systems to report annually on the cost of DMSMS solutions. The reports could be collated by a central DoD office and the compilation of the data could be used to update the solution cost estimates, look for trends in solution types, and refine DMSMS processes. This approach to DMSMS data would benefit the DMSMS community by providing a much more comprehensive data set regularly and would obviate the need to deal with small sample sizes and weak estimation basis related to small samples. This approach would obviate the need for a large survey research and analysis exercise every few years and offer insights on resolution approaches and costs more comprehensively.

DMSMS solution categories themselves undergo revisions over time due to evolving obsolescence management practices and available technological alternatives. This requires constant attention to updating metrics and their definition. This should be undertaken by a joint committee on DMSMS management that includes stakeholders from government, industry, and the research community.

5.3.   Granularity of Data

Future data collection efforts should not attempt to gather cost data at the same level that this survey attempted. The limited number of responses for the detailed cost elements in Section F of the survey instrument indicates that data are not collected and are not reportable at this level. Future data collection should limit the cost granularity to the summary level: engineering and design costs and solution implementation costs. Time involved in resolutions is another major fac-

tor in life-cycle management of DoD systems. In addition to the focus on resolution costs, future data collection efforts can consider including average time measurements of resolutions.

5.4.   Cost Avoidance

Analysis of the data resulted in a large gap in average costs between the solutions Repair, Refurbishment, or Reclamation ($65,015) and below and the solutions Development of a New Item or Source ($655,411) and above. While this gap is supported by the data in this survey as well as the preceding one, it poses a problem when calculating cost avoidance using the method prescribed in SD-22. That method calculates cost avoidance, when the survey's average values are used, by calculating the difference in cost between the solution used and the next more expensive viable or executable solution. When the solutions used for calculating cost avoidance span the referenced gap, the cost avoidance can be very large. The team recommends that the cost avoidance calculation method be evaluated to determine if another method would better serve the DMSMS community.

Appendix A. Survey Instrument (Sample Extract)

	Section 3.a: Approved Part I					
A	**Approved Part Definition:**	The obsolescence issue is resolved by the use of items already approved on the drawing and still in production.				
	If this product/solution was not used, please select "Not Applicable" to the right and proceed to the next section.					
B	Briefly explain the issue for which this solution was developed, including the applicable program and specific problem.					

C — Indicate which Armed Forces Services you provide this product/solution to. (Select all that apply)

Army	Navy	Air Force	Marines	Other Department of Defense	Specify Other

D — Identify your product/solution's application characteristics.

Part Type		Commodity		Environment	

E — How many DMSMS issues of this type will you be reporting on this tab? If greater than one, the costs reported should be the average cost of the items reported.

Note: A separate tab must be used for each unique combination of parts A, C, and D above.

F — Please enter the costs associated with each *applicable* category (in dollars) to the best of your knowledge and specify whether it is *actual* or *estimated*. Refer to the DMSMS Survey Definitions for examples of each category.

If you cannot provide cost breakdowns at the level of detail required below, please provide:
1.g: Total Engineering and Design Costs
2.i: Total Implementation Costs

Reported Costs Are (*actual* or *estimated*):

1. Solution Engineering and Design		2. Solution Implementation	
a. Engineering/Engineering Data Revision		a. Computer Programs/Documentation	
		b. Interim Support	
b. Qualification of New Items		c. Supply/ Provisioning Data	
c. Software Development or Modification		d. Support/Test Equipment	
		e. Technical Manuals	
d. Startup Costs		f. Training/Training Equipment	
e. Tooling/Equipment/Software		g. Installation Costs	
f. Other (specify)		h. Other (specify)	
g. Total Engineering and Design Costs		i. Total Implementation Costs	
Total Solution Costs (sum of 1.g and 2.i)			

G — Comments: Please provide some additional details about the product the DMSMS issue affected and the solution used. (This will allow us to better understand the nature of your solution).

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Appendix B. Definitions of DMSMS Concepts

This appendix presents, in Tables 9 through 12, definitions of DMSMS solution types, definitions of solution characteristics (part type, commodity type, operating environment), definitions and examples of solution engineering and design cost elements, and definitions and examples of solution implementation cost elements.

Table 9. Definitions of Solution Types

Solution type	Definition
Approved parts	The obsolescence issue is resolved by the use of items already approved on the drawing and still in production.
Life-of-need buy	A sufficient quantity of the item is purchased to sustain the product until its next technology refresh or the discontinuance of the host assembly. Because this solution uses an approved item, no testing or drawing changes are required. The source of supply can be residual stock from the original manufacturer, shelf stock from distributers, sponsor-owned material, etc. Costs for packaging, storage, and transportation should be considered in the business case analysis for selecting solutions.
Repair, refurbishment, or reclamation	The obsolescence issue is resolved by instituting a repair or refurbishment program for the existing item or assembly, whether a depot repair, a repair contract with the original manufacturer, or support from a third party.
Extension of production or support	The supplier is incentivized to continue providing the obsolete items. This may involve long-term agreements to procure specific quantities of parts. One-time costs may be associated with setting up this solution. Those costs should be included in any cost and cost avoidance calculations.
Simple substitute	The item is replaced with an existing item that meets all requirements without modification to either the item or its NHA and requires only minimal qualification. Associated costs are largely administrative.
Complex substitute	A replacement item that has different specifications, but requires no modification of the source product or the NHA, is researched and validated.
Development of a new item or source	A replacement product is developed that meets the requirements of the original product without affecting the NHA. Nonrecurring engineering (NRE) or other development-related activities will likely be required. The new product may be emulation, a reverse-engineered product, or a product developed as a replacement using a different manufacturer but the original manufacturing designs and processes.
Redesign–NHA	The affected item's NHA must be modified. Only the NHA is affected, and the new design will not affect anything at a higher level in the system.
Redesign–complex/ system replacement	A major assembly redesign affects assemblies beyond the obsolete item's NHA and may require that higher-level assemblies, software, and interfaces be changed.

Table 10. Definitions of Solution Characteristics

Solution characteristics		Definition
Part type	Assembly	Any grouping of parts that result in a final unit that is considered a distinct item. Examples: a network switch, a diesel engine, a starter.
	Component	A base unit part that may be used as part of an assembly. Examples: an integrated circuit, a piston, an electrical switch.
	Raw material	The substance or substances out of which a thing is or can be made. Examples: steel, fiberglass, halon, etc.
	Software	The programs or other code used by computers of other electronic components or assemblies. Examples: an operating system, anti-virus software.
Commodity	Electrical	Equipment that generates electricity, transfers or controls electricity, or which uses electricity as its prime energy source (excluding electronics, see below). Electronic controllers used by this equipment are categorized in the Electronics commodity. Examples: motors, switchboard, transformers.
	Electronics	Components, assemblies, or equipment that are built using electronic components and/or circuit card. Examples: computers, radios, radars, control circuitry.
	Mechanical	Parts, assemblies, or equipment that is neither electrical nor electronic in nature. Electronic controllers used by this equipment are categorized in the Electronics commodity. Examples: diesel engines, hydraulics, winches, pumps.
Operating environment	Aviation	The part or equipment is used in or on aircraft.
	Benign or non-tactical	Equipment not expected to be in a tactical environment, or equipment that is deployed in a tactical environment but not tactical in nature and not tested to the same standards as tactical equipment. Example: shipboard laundry equipment.
	Ground	The part or equipment is used in a tactical ground environment.
	Shipboard	The part or equipment is used on surface ships, boats, etc.
	Space	The part or equipment will be used in space.
	Undersea	The part or equipment will be used in submarines or other submerged equipment.

Table 11. Definitions and Examples of Solution Engineering and Design Cost Elements

Element	Definition	Example
Engineering/ engineering data revision	The one-time costs of research, design, and engineering work related to the solution selected (NRE). This could range from evaluation of a substitute to the development of a new design.	Research, design, prototype development, engineering/reverse engineering, white paper development, technical data, drawing changes, ECP development, ECP review, reliability and maintainability analysis
Qualification of new items	The one-time costs to determine if a new item is suitable for use in the application. These testing and associated costs could range from simple to complex depending on the solution selected, the type of equipment, and the operating environment.	Development/modification of test procedures, development/modification of test equipment, functional testing, unit environmental testing
Software development or modification	The one-time costs for any and all NRE-type software development or modification related to the selected solution. This could range from firmware revisions on a circuit card to the procurement of services to develop customized software.	Software procurement, application design, application development, application integration, beta test plan, software testing
Startup costs (aftermarket, etc.)	The one-time costs associated with getting production started or restarted.	Contract costs associated with production startup, costs to start an organic depot, procurement of production rights or intellectual property
Tooling, equipment, test equipment, or software	The one-time costs for equipment needed to design, test, evaluate, and qualify the new item for the solution. Items procured that are used both during evaluation and sustainment should be included in this category. Design, engineering, and development work to prepare this equipment for use are included in the engineering cost type.	Test equipment, prototyping tooling, software

Table 12. Definitions and Examples of Solution Implementation Cost Elements

Element	Definition	Example
Computer programs/ documentation	The costs for procuring and updating computer programs and documentation for use in the field/fleet. Does not include the costs for technical manuals and other nonsoftware documentation.	Software licenses, software media distribution, software documentation costs
Interim support	The costs for short-term measures that need to take place prior to full implementation of the solution. This could be contract maintenance or supply support until the solution is fully supported by organic systems. May include life-of-need (bridge buy) costs to extend product life until a redesign can be implemented.	Temporary contract support to sustain the item while a permanent depot is established, bridge buy to sustain item while the final solution is implemented
Supply/provisioning data	The costs associated with updating records and data with the new solution information.	Level of repair analysis, provisioning, generation of procurement documentation, supply support, development of a maintenance plan
Support/test equipment	The costs for modifying and/or buying support and test equipment for the new solution. Does not include the cost of equipment purchased for both development and sustainment.	Test equipment used to sustain the solution, handling equipment needed to sustain the solution
Technical manuals	The cost for updating technical manuals to reflect the new solution.	Technical documentation development, technical documentation distribution
Training/training equipment	The costs for purchasing new or updating existing training devices, training materials, and training to accommodate the solution.	Development of updates to existing training course, development/modification of training equipment
Installation cost	The costs to deploy the new equipment to the field/fleet. Applicable only if the new solution must be retrofitted into the field/fleet as a direct result of the original obsolescence. Does not include replacement by attrition.	Software media distribution, gathering of data and schedule installations, cost of installation (contractor), cost of installation (government), installation travel cost

Appendix C. Abbreviations

BIS   Bureau of Industry and Security

DMSMS   Diminishing Manufacturing Sources and Material Shortages

DoD   Department of Defense

DSPO   Defense Standardization Program Office

ECP   Engineering Change Proposal

NHA   Next Higher Assembly

NRE   Nonrecurring Engineering

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