Using Historical Cost Reports to Derive System Specific Factors

ICEAA Workshop June 2015

Author Biographies:

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Abstract:

Non-Recurring Engineering (NRE) is often a cost driver for new, complex systems and must be given high attention during Milestone B cost estimating. Our team developed an approach for developing system specific Cost Estimating Relationship (CER) using actual costs for from combat weapon systems with shared capabilities, resulting in a credible defensible, yet flexible approach that can be replicated for a wide range of estimates.

1. Background

Utilizing validated Cost Data Summary Reports (CDSR) to develop-system-specific factors is a versatile approach that will assist cost estimators to anchor an estimate using actual costs expenditures where none may be available. Likewise, the analyst must be open to investigating all available data sets to find potential relationships between cost elements that may be used to predict future costs on similar electronics and ordnance systems. The analyst should have an inquisitive approach to understand the nuances in data bookkeeping. This approach has a wide application and may improve the reliability of an estimate in the early stages of the acquisition timeline.

Leveraging cost data on historical programs is essential for developing a cost estimate for programs that are in the early stages of its lifecycle. The early stages of systems development are particularly important to cost estimating. Figure 1 shows that for a typical Department of Defense (DoD) weapon system, 80% of the future lifecycle costs are decided when only the first 20% of cost has been incurred. Therefore, an estimate prior to the development contract award is the point in the acquisition timeline where an accurate and credible cost estimate can have the greatest impact on programmatic costs. A Program Lifecycle Cost Estimate (PLCCE) at Milestone B can inform contract negotiation, drive competition, assist in design trade study discussions and thus help the DoD achieve meaningful cost savings. A PLCCE can also be the basis for budget requests to Congress regardless of Milestone designation to defend or explain any assets or shortfalls.

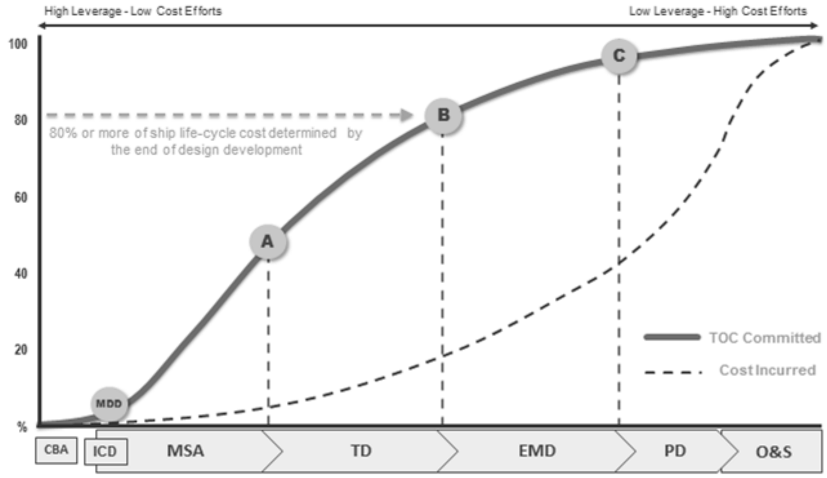

Figure 1: Costs Committed / Incurred over Program Lifecycle

There are many unknowns when developing a Milestone B cost estimate, which makes it very difficult to take an engineering build approach using actual costs. Actual costs include sunk costs, labor rates, contractor negotiated priced bill of materials, government labor expenditures, and other parameters. As a result, a common approach would be to identify analogous systems. An estimate that uses an analogous approach is not ideal for decision making due to the lack of accuracy, reliance on a single data point, source documentation, and fidelity that is more evident when taking an engineering build up approach.

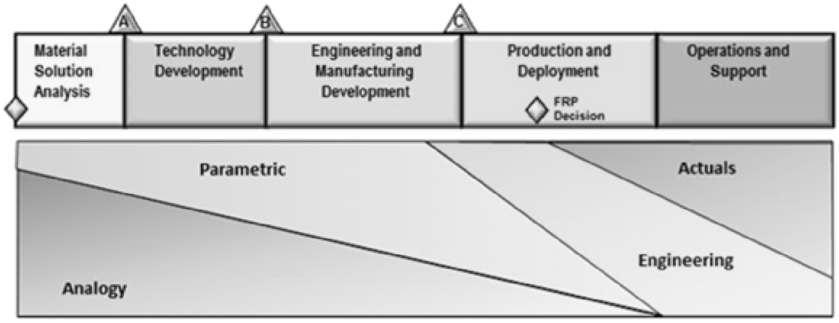

Figure 2: Cost Estimate Techniques

Although using an analogous approach is not the most accurate estimating method (see figure 2), it is nonetheless an improvement over estimating at the Rough Order Magnitude (ROM) level. Analogies allow an estimator to leverage historical cost data from the legacy system and apply adjustment factors as needed (e.g. inflation, complexity). An estimate using an analogous approach using a prior variant could likely be defended to support a Milestone A or B decision. A further challenge would occur if there is no legacy system or prior variant with similar capabilities. Rigorous analysis should be performed whenever possible to develop an accurate, defensible cost estimate rooted in credible methods, which is imperative to strategic decision making.

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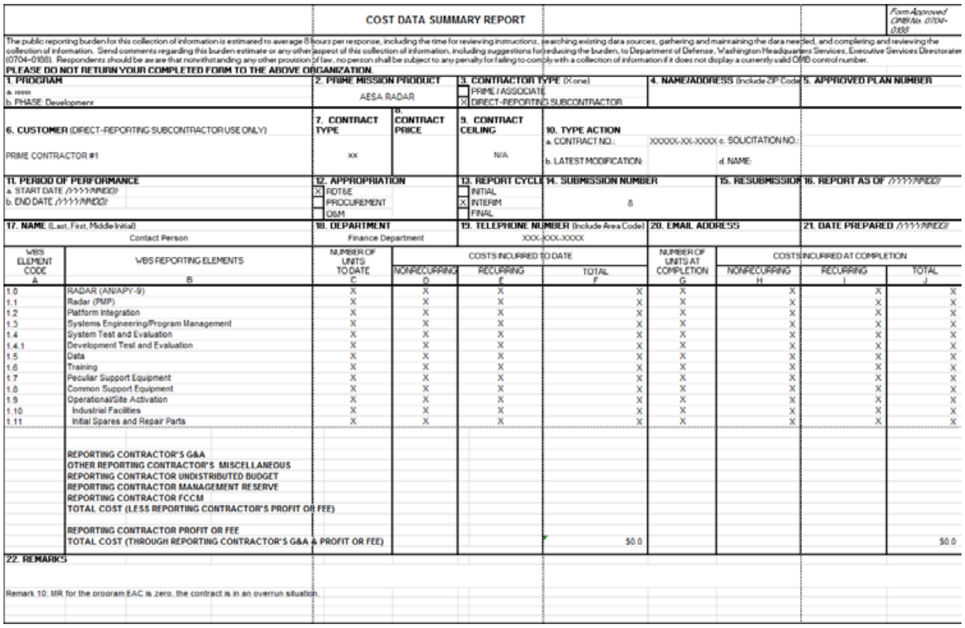
2. Cost Reporting

Programs in the DoD are categorized in order to facilitate decision making, program execution, and management compliance [ACQuipedia]. The various categories, as designated based on criteria in Department of Defense Instruction (DoDI) 5000.2, determine the level of decision authority, reporting requirements, programmatic reviews, acquisition documentation, and more [Department of Defense Instruction]. Programs that are of higher level Acquisition Category (ACAT) often require more detailed cost reporting information than non-ACAT programs. One reason is that these programs spend more money and are at a higher level of oversight by Navy, or other branch of DoD, leadership. ACAT I/II programs are often viewed to have higher levels of programmatic cost risk, as a 10% cost overrun in a $5 billon program is much more costly than a 10% cost overrun in a $5k program. However, the latest DoDI 5000.02 explicitly requires full cost reporting for all ACAT I, ACAT II and ACAT III programs, if the latter two are installed on an ACAT I end item [Department of Defense Instruction]. While this was implied in prior versions of the instructions, but it is now clearly specified.

Such cost reporting required for an ACAT I/II program is managed by the Defense Cost and Research Center (DCARC). DCARC follows a validation process where first, the contractor submits their draft report to DCARC who reviews the reports and compiles all errors and sends them back to the contractor. Then, the contractor makes corrections and resubmits the form, and DCARC decides on whether or not to validate the report. Afterward, the document is uploaded to the Defense Automated Cost Information Management Systems (DACIMS) database for use by government personnel within the DoD [CSDR Overview and Summary].This documented process helps to ensure that the forms are filled out correctly and the costs reported are reliable.

Cost Data Summary Reports (CDSR), or DD Forms 1921, for weapons systems were leveraged to develop the parametric CER for the electronic system. According to the DACIMS website, CDSRs are “used by contractors to submit (1) direct and indirect actual cost data on both a recurring and nonrecurring basis on Government contracts and (2) proposed cost data” [DI-FNCL-81565C]. This report tracks the sunk costs and cost at completion for all elements in the Work Breakdown Structure (WBS) for the contractor.



COST DATA SUMMARY REPORT

Form Approved OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 8 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Executive Services Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE ABOVE ORGANIZATION.

1. PROGRAM
a. xxxx
b. PHASE: Development

2. PRIME MISSION PRODUCT
AESA RADAR

3. CONTRACTOR TYPE (X one)
☐ PRIME / ASSOCIATE
☒ DIRECT-REPORTING SUBCONTRACTOR

4. NAME/ADDRESS (Include ZIP Code)

5. APPROVED PLAN NUMBER

6. CUSTOMER (DIRECT-REPORTING SUBCONTRACTOR USE ONLY)
PRIME CONTRACTOR #1

7. CONTRACT TYPE
xx

8. CONTRACT PRICE

9. CONTRACT CEILING
N/A

10. TYPE ACTION
a. CONTRACT NO.: XXXXX-XX-XXXX
b. LATEST MODIFICATION:
c. SOLICITATION NO.:
d. NAME:

11. PERIOD OF PERFORMANCE
a. START DATE (YYYYMMDD):
b. END DATE (YYYYMMDD):

12. APPROPRIATION
☒ RDT&E
☐ PROCUREMENT
☐ O&M

13. REPORT CYCLE
☐ INITIAL
☒ INTERIM
☐ FINAL

14. SUBMISSION NUMBER
8

15. RESUBMISSION

16. REPORT AS OF (YYYYMMDD)

17. NAME (Last, First, Middle Initial)
Contact Person

18. DEPARTMENT
Finance Department

19. TELEPHONE NUMBER (Include Area Code)
XXX-XXX-XXXX

20. EMAIL ADDRESS

21. DATE PREPARED (YYYYMMDD)

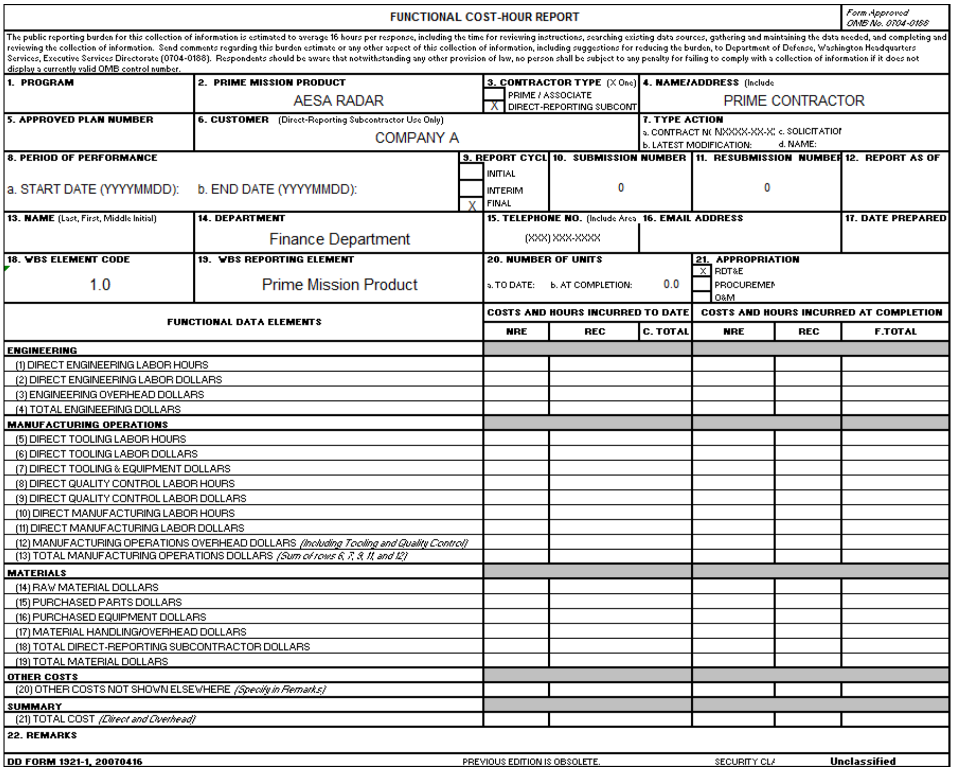
WBS ELEMENT CODE	WBS REPORTING ELEMENTS	NUMBER OF UNITS TO DATE	COSTS INCURRED TO DATE			NUMBER OF UNITS AT COMPLETION	COSTS INCURRED AT COMPLETION		
			NONRECURRING	RECURRING	TOTAL		NONRECURRING	RECURRING	TOTAL
A	B	C	D	E	F	G	H	I	J
1.0	RADAR (AN/APY-9)	X	X	X	X	X	X	X	X
1.1	Radar (PMP)	X	X	X	X	X	X	X	X
1.2	Platform Integration	X	X	X	X	X	X	X	X
1.3	Systems Engineering/Program Management	X	X	X	X	X	X	X	X
1.4	System Test and Evaluation	X	X	X	X	X	X	X	X
1.4.1	Development Test and Evaluation	X	X	X	X	X	X	X	X
1.5	Data	X	X	X	X	X	X	X	X
1.6	Training	X	X	X	X	X	X	X	X
1.7	Peculiar Support Equipment	X	X	X	X	X	X	X	X
1.8	Common Support Equipment	X	X	X	X	X	X	X	X
1.9	Operational/Site Activation	X	X	X	X	X	X	X	X
1.10	Industrial Facilities	X	X	X	X	X	X	X	X
1.11	Initial Spares and Repair Parts	X	X	X	X	X	X	X	X
	REPORTING CONTRACTOR'S G&A								
	OTHER REPORTING CONTRACTOR'S MISCELLANEOUS								
	REPORTING CONTRACTOR UNDISTRIBUTED BUDGET								
	REPORTING CONTRACTOR MANAGEMENT RESERVE								
	REPORTING CONTRACTOR FCCM								
	TOTAL COST (LESS REPORTING CONTRACTOR'S PROFIT OR FEE)								
	REPORTING CONTRACTOR PROFIT OR FEE								
	TOTAL COST (THROUGH REPORTING CONTRACTOR'S G&A & PROFIT OR FEE)				$0.0				$0.0

22. REMARKS

Remark 10: MR for the program EAC is zero, the contract is in an overrun situation.

Figure 3: CDSR or DD Form 1921 file

The Functional Cost-Hour Report, or DD Form, is “used by contractors to submit: (1) direct and indirect actual cost data on both a recurring and nonrecurring basis on Government contracts and (2) proposed direct and indirect cost data,” [DI-FNCL-81566C]. This type of report exists for every major element within the WBS and instead of providing insight to only cost, it also provides visibility to the number of hours charged by the contractor for a particular task. Such tasks include Engineering/Design, Material Handling, Touch Labor and Support Labor for the contractor. These labor hours, which are broken out by task, substantiate the total for the corresponding cost element in the CDSR, or DD Form 1921.



FUNCTIONAL COST-HOUR REPORT

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 16 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Executive Services Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. PROGRAM

2. PRIME MISSION PRODUCT AESA RADAR

3. CONTRACTOR TYPE (X One) ☐ PRIME / ASSOCIATE ☒ DIRECT-REPORTING SUBCONT

4. NAME/ADDRESS (Include PRIME CONTRACTOR

5. APPROVED PLAN NUMBER

6. CUSTOMER (Direct-Reporting Subcontractor Use Only) COMPANY A

7. TYPE ACTION
a. CONTRACT N(NXXXX-XX-X; c. SOLICITATIOI
b. LATEST MODIFICATION: d. NAME:

8. PERIOD OF PERFORMANCE
a. START DATE (YYYYMMDD): b. END DATE (YYYYMMDD):

9. REPORT CYCL ☐ INITIAL ☐ INTERIM ☒ FINAL

10. SUBMISSION NUMBER 0

11. RESUBMISSION NUMBEI 0

12. REPORT AS OF

13. NAME (Last, First, Middle Initial)

14. DEPARTMENT Finance Department

15. TELEPHONE NO. (Include Area (XXX) XXX-XXXX

16. EMAIL ADDRESS

17. DATE PREPARED

18. WBS ELEMENT CODE 1.0

19. WBS REPORTING ELEMENT Prime Mission Product

20. NUMBER OF UNITS a. TO DATE: b. AT COMPLETION: 0.0

21. APPROPRIATION ☒ RDT&E ☐ PROCUREMEI ☐ O&M

FUNCTIONAL DATA ELEMENTS	**COSTS AND HOURS INCURRED TO DATE**			**COSTS AND HOURS INCURRED AT COMPLETION**		
	NRE	**REC**	**C. TOTAL**	**NRE**	**REC**	**F.TOTAL**
ENGINEERING						
(1) DIRECT ENGINEERING LABOR HOURS						
(2) DIRECT ENGINEERING LABOR DOLLARS						
(3) ENGINEERING OVERHEAD DOLLARS						
(4) TOTAL ENGINEERING DOLLARS						
MANUFACTURING OPERATIONS						
(5) DIRECT TOOLING LABOR HOURS						
(6) DIRECT TOOLING LABOR DOLLARS						
(7) DIRECT TOOLING & EQUIPMENT DOLLARS						
(8) DIRECT QUALITY CONTROL LABOR HOURS						
(9) DIRECT QUALITY CONTROL LABOR DOLLARS						
(10) DIRECT MANUFACTURING LABOR HOURS						
(11) DIRECT MANUFACTURING LABOR DOLLARS						
(12) MANUFACTURING OPERATIONS OVERHEAD DOLLARS *(Including Tooling and Quality Control)*						
(13) TOTAL MANUFACTURING OPERATIONS DOLLARS *(Sum of rows 6, 7, 9, 11, and 12)*						
MATERIALS						
(14) RAW MATERIAL DOLLARS						
(15) PURCHASED PARTS DOLLARS						
(16) PURCHASED EQUIPMENT DOLLARS						
(17) MATERIAL HANDLING/OVERHEAD DOLLARS						
(18) TOTAL DIRECT-REPORTING SUBCONTRACTOR DOLLARS						
(19) TOTAL MATERIAL DOLLARS						
OTHER COSTS						
(20) OTHER COSTS NOT SHOWN ELSEWHERE *(Specify in Remarks)*						
SUMMARY						
(21) TOTAL COST *(Direct and Overhead)*						

22. REMARKS

DD FORM 1921-1, 20070416 PREVIOUS EDITION IS OBSOLETE. SECURITY CLA **Unclassified**

Figure 4: FCHR or DD Form 1921-1 file

3. Application to Non-Recurring Engineering

Consider the system used in an analysis to be called Radar A, which is a radar system with active Electronic Warfare (EW) capability. Even though Radar A's predecessor does not have analogous active capability, our team discovered that systems with Active Electronic Scanned Array (AESA) radars have transmit and receive capabilities that are comparable to Radar A's active EW. Defining this relationship was very valuable to the estimating team as AESA radars have a 30 year history as ground based and airborne systems. The team investigated these relationships further.

Development

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Non-Recurring Engineering (NRE) costs include one-time engineering efforts and are independent of the number of systems procured. For system hardware, these are often thought of as the costs associated with design and development costs. Development NRE occurs during the Engineering and Manufacturing Development (EMD) phase in the lifecycle. Because development NRE costs are typically sunk by the end of EMD, Milestone C cost estimates tend to focus on recurring cost drivers of the remaining production lots. Conversely, in a Milestone B estimate of a system that is not in a legacy series, NRE costs could potentially be one of the highest cost drivers. Engineering labor is expensive and design costs may increase exponentially according to the complexity of the system. Thus, the extra efforts related to developing an estimate for non-recurring engineering at Milestone B is pertinent to developing a credible, defensible lifecycle estimate.

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This method was developed using a parametric approach. The Radar A team of estimators pulled hardware dollars from 1921 files and NRE hours from 1921-1 files for all systems considered. The relationship between NRE hours and Engineering Development Models (EDMs) was examined with the fundamental assumption being made that EDM hardware cost is a proxy for system complexity.

During this methodology's first time application, the team experienced a few situations that required certain data points to be considered outliers. While Radar A was a shipboard radar, the data set included AESA radars that were airborne radars. The resulting ratios for NRE hours / EDM hardware cost were skewed; the airborne radars had higher values than the shipboard radars did, as shown in figure 3. The data anomaly was reasoned to be because airborne radars have additional constraints on system weight that are not as important to shipboard radars. Greater weight constraints require additional design, or NRE, work to fit the system capabilities within such constraints. Therefore, the airborne radars had a lopsided CER that was heavier with NRE hours than our shipboard radar would be. For this reason, the airborne radars were considered not to be representative of the desired data set, leaving both ship-based AESA and ground-based AESA radars in the data set.

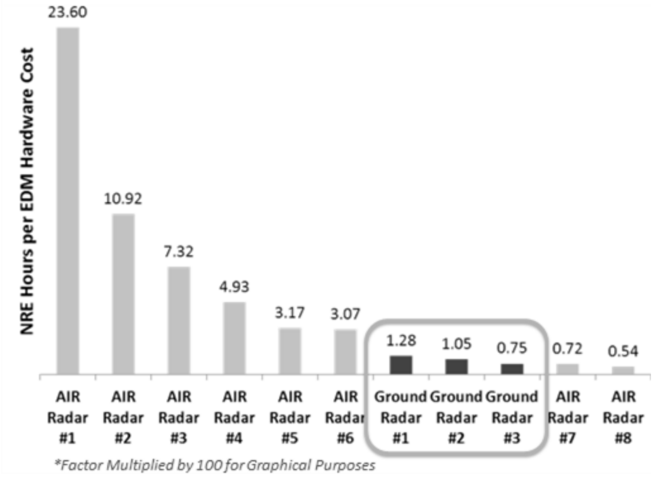

Figure 3: Pareto of results for NRE Hours / EDM Hardware Cost

Based on the data analysis, a ground based AESA radar CER and an airborne AESA radar CER would prove to be useful for determining total NRE development cost shown in the equation below:

$$NRE\ Development\ Cost = NRE\ Factor * 10^{-2} * Hours\ per\ Year * Labor\ Rate * EDM\ Cost$$

where: *NRE Factor = Number of NRE Hours* $*10^{2}$ *per EDM Cost ($) – (from CER in figure 3)*

$10^{-2} =$ *Graphical Scaling Factor Conversion back to hours from CER Developed in figure 3*

$Hours\ per\ Year = Number\ of\ \ annual\ Hours\ for\ a\ full\ time\ equivalent$ *(in Hours)*

Labor Rate = Fully burdened engineering Labor Rate at Site Location (in Dollars)

$EDM\ COST = Direct\ Material\ Unit\ Cost\ of\ Engineering\ Development\ Unit$ *(in Dollars)*

This implies that the more expensive the Engineering Design Manufacture (EDM) hardware of the system, the more engineering hours it would take to design and develop that hardware. Since EDM hardware cost was estimated using an engineering build up approach, the CER was applied to determine the NRE hours. A composite engineering labor rate, which was developed using the labor rates of likely contractors, was applied to the resulting number of hours.

4. Other Applications

Thus far, this method for estimating has been effective. It started with a complex, innovative non-legacy system prior to contract award, and now have actual cost documentation from systems with a similar capability. Of course, there must be a challenge with leveraging these cost reports - understanding the bucketing of costs and hours in these reports requires critical thinking throughout the process to develop a credible CER. Each data set has a story and throughout the data collection effort, estimators are required to use an inquisitive approach to learn the story behind the values reported.

Other data points that were determined as outliers were deemed so due to their report completeness. Contract progress on some systems at the time the cost report was issued was not close to being 90% complete, and therefore considered unusable data sources. Some reports were not incomplete, or to the required level of detail for this analysis. Consequently, those reports were not used in this analysis. This analysis required explicit identification of NRE hours for the prime mission product (PMP) and EDM cost. While NRE has been described using this methodology, it is significant to point out that the same methodology was used in other aspects of Radar A's estimate, as well as other for other system's estimates within NAVSEA's cost engineering department.

Major defense contractors typically have an accounting line called System Engineering and Program Management (SEPM). SEPM encompasses running the technical and management efforts of the program. According to the Mil-STD 881C definition of the standard work breakdown structure (WBS), SEPM also includes business and administrative planning, organizing, directing, coordinating, controlling, and approval actions designated to accomplish overall program objectives, which are not associated with specific hardware elements and are not included in systems engineering [Work Breakdown Structures for Defense Materiel Items].

Due to the uncertainties of SEPM cost during the EMD phase, a similar parametric method was chosen to determine SEPM Costs of Radar A. The collected data included 11 completed AESA radar cost reports. This included eight airborne AESA radars and three ground based AESA radars. Unlike the NRE and EDM hardware relationship, the airborne radar data sets were considered valid data points for SEPM. Weight was not a determining factor in production - once the design is set the systems were similar to Radar A. Overall, the data showed SEPM costs were on average 24% of total development contract costs, with an observed maximum of 40% and an observed minimum of 13%. The results are shown in figure 4, which also includes four missile programs. The SEPM for those four programs averaged 23%, with less variance than with the radar study results.

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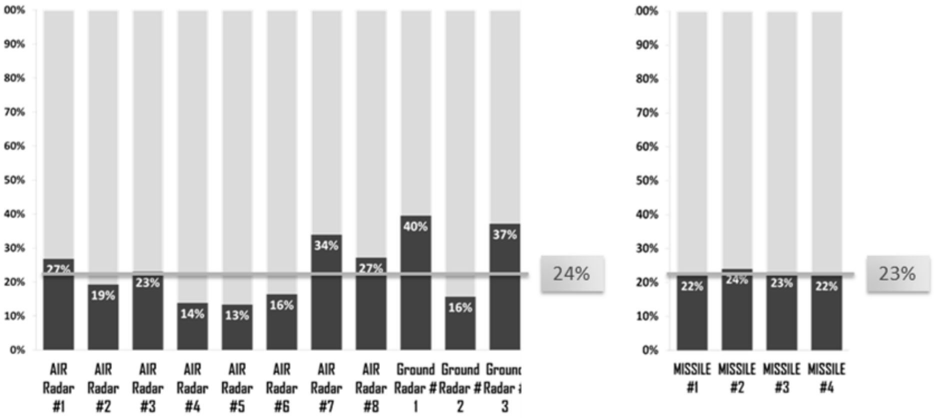

Figure 4: SEPM percentages for AESA Radars (left) and SEPM percentages for Missiles (right)

Based on the cost reports of the AESA radars, the following CER was determined for estimating SEPM costs during the EMD phase based on taking a simple average or of the data:

$$
\begin{aligned}
SEPM\ (AESA\ Radar\ Dev) &= 0.24 *\ Development\ Contract\ Cost \\
&= 0.32 * Development\ Contract\ Cost\ (Excl\ SEPM)
\end{aligned}
$$

If an estimator would prefer to select a specific data point from one of the 11 AESA radars above deemed to be truly analogous to their system, another CER could can be used. It is important to note that the same approach could be analyzed for production SEPM and other cost elements.

$$
\begin{aligned}
SEPM\ (AESA\ Radar\ Dev) &= X *\ Development\ Contract\ Cost \\
&= \frac{X}{1-X} * Development\ Contract\ Cost\ (Excl\ SEPM)
\end{aligned}
$$

where: $X = percent\ of\ SEPM\ observed$

Another application for this approach would be using learning curve on the production labor of radars. The general learning curve theory states that as the number of units produced doubles, the unit cost decreases in a predictable pattern. It is generally accepted that when a new task is started, learning occurs while actually performing the task. The more often the task is repeated, the more efficient you become at performing the task, and the time required to perform the task decreases. Whether considering time or money, this means that each unit costs less than the preceding unit, [Fundamentals of Cost Analysis].

There are two types of learning curve approaches:

(1) The Unit formulation states that if there is learning/improvement in the production process, with each doubling in cumulative quantity (e.g. 1, 2, 4, 8, and 16) the cost of the doubled unit (e.g. 8) equals the cost of the undoubled unit (e.g. 4) times the learning curve slope. Again, the cost of unit number 2(X) (where X is any unit number) is a constant percentage of the cost of unit number (X).

(2) The Cumulative Average formulation states that if there is learning in the production process, the cumulative average cost (CAC) of some doubled units equals the cumulative average cost of the undoubled units times the learning curve slope. As output doubles, the cumulative average cost of the doubled units is reduced by a constant percentage.

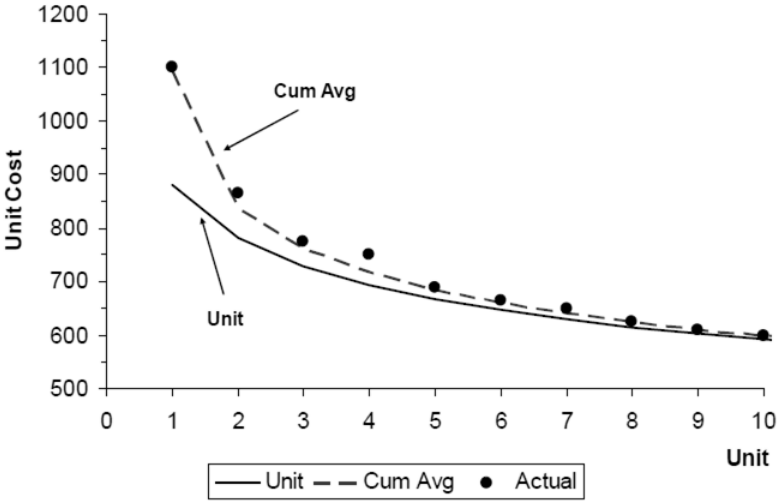

Figure 5: Typical Learning Curve

In order to understand rate of learning during the production phase, both the unit formulation and cumulative average approaches were regressed. Touch hours from the cost reports on five ground based AESA radars were collected on eight airborne AESA radars that had four or more production lots of historical cost data. Each data set was arranged in ascending order with no missing quantities to perform regression analysis with CO$TAT software and develop a learning curve slope with an equation of $y = Ax^{\mathbf{b}}$. Five of the eight AESA radars provided good fit statistics resulting in an observed range of 66% to 86% in learning with an average of 81.2% applied as a slope, with risk bounds. Results are shown in Table 1.

CO$TAT RUN	Data Points	Slope	F-stat - Prob not zero on Regression	T-stat - Prob not zero on Independent Variable	R^2 adj	R^2	Std Error (unit space)	Coef of Variation based on Std Error
AESA Radar # 1	5	86%	97%	97%	77%	83%	0.1069	10%
AESA Radar # 2	9	66%	100%	100%	93%	94%	0.1494	13%
AESA Radar # 3	9	84%	100%	100%	92%	93%	0.0688	8%
AESA Radar # 4	5	84%	98%	98%	85%	89%	0.1616	12%
AESA Radar # 5	5	86%	99%	99%	86%	90%	0.1015	8%

Table 1: CO$TAT Single Variant Regression Results for Learning Curve

“Cost advantages occur with an increased output of a product. Economies of scale arise because of the inverse relationship between the quantity produced and per-unit fixed costs. The greater the quantity of goods produced, the lower the per-unit fixed cost because these costs are shared over a larger number of goods,” [Economies of Scale].

In order to understand the cost advantage in AESA radars, direct material unit cost were collected on eight legacy AESA radar cost reports that had four or more production lots of historical cost data. The purpose of collecting unit costs was to try and understand the economies of scale and the rate effects that are realized during production to predict the future outcome of rate effects on direct material during production. Each data set was arranged in ascending order with no missing lot quantities to perform regression analysis in CO$TAT and develop a rate curve slope with an equation of $y = Q^r$. Four of the eight AESA radars provided good fit statistics resulting in an observed range of 82% to 94% in rate effect which an average of 88.7% applied as a slope, with risk bounds. Results are shown in Table 2.

CO$TAT RUN	Data Points	Slope	F-stat - Prob not zero on Regression	T-stat - Prob not zero on Independent Var	R squared adj	R squared	Std Error (unit space)	Coef of Variation based on Std Error
AESA Radar # 1	5	90%	100%	100%	96%	97%	0.0286	3%
AESA Radar # 2	9	82%	100%	100%	77%	80%	0.1402	19%
AESA Radar # 3	5	89%	99%	99%	86%	90%	0.1015	10%
AESA Radar #4	5	94%	98%	98%	83%	88%	0.0456	5%

Table 2: Single Variant CO$TAT Regression Results for Rate Slopes

5. Conclusion

Leveraging historical cost reports to develop cost factors and CERs was key in Radar A’s estimate, and many recognized the global nature of this approach for future applications. It may be useful for software estimating where the source lines of code (SLOC) count is not finalized, or the software requirements are still being developed. One would determine systems with similar capability, and pull Software Development hours and PMP dollars from historical cost reports. This approach could be used to inform an analysis of alternatives, or to cross check an engineering build up estimate. Cross checking is an important step in cost estimating and helps to give senior leadership confidence in the analysts' results. While the purpose of this analysis was done on an electronics system in the radar and active EW family, this flexible approach can be replicated and applied to a wide range of systems, including other branches of DoD and private industry. Estimators are encouraged to further explore additional avenues of application for future cost estimating. The following table displays the discrete cost elements that are called out in the CDSR or DD Form 1921 files that could be used to potentially develop a system specific cost factor or CER.

Commented [TG6]: DoD system? Weapons system? *ANY* system, including private industry?

Prime Mission Product (PMP) Hardware	Non-Recurring Engineering (NRE)	Facilities
Prime Mission Product (PMP) Software	Operational/Site Activation	Training
System Test and Evaluation	Support Equipment	Integration
Systems Engineering/ Program Management (SEPM)	Initial Spares and Repair Parts	Test and Checkout

Table 3: Potential WBS items for replicating approach

Ultimately, the defined process of leveraging validated cost reports for developing system specific factors and CERs demonstrated to be a versatile approach. It helped the Radar A team to anchor the estimate by utilizing actual costs from analogous programs, where it seemed that none were available. With consistency and patience, the cost estimators experienced a breakthrough – uncovering system specific factors to determine total development NRE costs. Similarly, the team was able to confidently estimate costs for SEPM and direct material (informed by learning and economies of scale). Overall, leveraging historical cost reports allowed the team to develop a quality Milestone B cost estimate.

Prior to contract award, Milestone B estimating during an ACAT I or high profile ACAT II program can seem to have an unclear path forward – especially prior for a new or first generation system. Typical Milestone B estimating can be improved in accuracy by leveraging historical costs available. Developing an accurate and credible estimate that can inform contract negotiation improves accuracy in this earlier stage of program acquisition. This can result in enormous benefits to the program office, Navy, and ultimately the taxpayer.

Acronyms

ACAT	Acquisition Category
AESA	Active Electronic Scanned Array
CER	Cost Estimating Relationship
CO$TAT	Cost Analysis Statistics Package
CDSR	Cost Data Summary Report / DD Form 1921
DACIMS	Defense Automated Cost Information Management Systems
DAU	Defense Acquisition University
DCARC	Defense Cost and Research Center
DoD	Department of Defense
DoDI	Department of Defense Instruction
EW	Electronic Warfare
EDMs	Engineering Development Model
EMD	Engineering Manufacture Development
FCHR	Functional Cost Hour Report / DD Form 1921-1
NAVSEA	Naval Sea Systems Command
NRE	Non Recurring Engineering
PLCCE	Program Lifecycle Cost Estimate
PMP	Prime Mission Product
RDTE	Research Development Test and Evaluation
ROM	Rough Order Magnitude
SEPM	Systems Engineering and Program Management
SLOC	Source Lines of Code
WBS	Work Breakdown Structure

References

ACQuipedia. 22 Jan 2008. *Defense Acquisition University*. Web. 12 March 2014. Retrived from https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=a896cb8a-92ad-41f1-b85a-dd1cb4abdc82

CSDR Overview and Summary. *Defense Cost and Resource Center*. n.d. Web. 12 March 2015. Retrieved from http://dcarc.cape.osd.mil/CSDR/FormsReporting.aspx

Department of Defense Instruction. 7 Jan 2015. *Operation of the Defense Acquisition System*. PDF file. Retrieved from http://www.acq.osd.mil/fo/docs/500002p.pdf

DI-FNCL-81565C. 18 May 2011. *Data Item Description*. PDF file. Retrieved from http://dcarc.cape.osd.mil/Files/Policy/2011-1921.pdf

DI-FNCL-81566C. 18 May 2011. *Data Item Description*. PDF file. Retrieved from http://dcarc.cape.osd.mil/Files/Policy/2011-1921.pdf

"Economies of Scale." *Investopedia.* n.d. Web. 26 Feb 2015. Retrieved from http://www.investopedia.com/terms/e/economiesofscale.asp

Fundamentals of Cost Analysis. Chapter 8. Learning Curves. n.d. *Defense Acquisition University*. PDF file. Retrieved from https://myclass.dau.mil/bbcswebdav/institution/Courses/Deployed/BCF/BCF106/Student_Materials/08%20Learning%20Curves/Learning%20Curves_Aug%2008.pdf

"Work Breakdown Structures for Defense Materiel Items." 3 Oct 2011. *Department of Defense Standard Practice.* PDF file. Retrieved from http://www.mcri.com/wp-content/uploads/2014/09/Military-Standard-881C-----Department-of-Defense-Standard-Practice-----Work-Breakdown-Structures-for-Defense-Materiel-Items-MIL-STD-881C-3-Oct-11.pdf