BEST BANG FOR THE BUCK

The Cost of
Technical Processes

NAVSO P-3691
October 2002

Office of the Assistant Secretary
of the Navy (RD&A)
Acquisition and Business Management

Forward

Forward

Navy and Marine Corps program managers and staffs for an acquisition program face a formidable task. They are responsible for balancing performance requirements against established cost and schedule targets, while continually making trade-off decisions to identify and manage high risk areas. To accomplish this they must have expertise in many areas, such as cost of technical processes (themselves early indicators of high risk areas), estimating techniques, the budget process and development cycle times.

One of ASN(RD&A)'s primary goals on any acquisition program is to reduce product development costs and cycle time. We continue to develop initiatives aimed at achieving this goal. This guide represents such an initiative by sharing information from Department of the Navy and Industry professionals on technical process costs, program budgeting highlights and knowledge resources. I urge our Navy and Marine Corps acquisition teams to familiarize themselves with this guide and share their experiences with us so that we can field the most cost effective, technically superior systems possible. The guide is posted on the ABM homepage www.abm.rda.hq.navy.mil and comments may be submitted there as well.

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Acknowledgements

The Deputy Assistant Secretary of the Navy (Research, Development and Acquisition) Acquisition and Business Management acknowledges the team of technical and financial experts responsible for developing this guide.

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Objective

Successful financial management of an acquisition program depends to a large degree on the initial selection and "should cost estimate" of critical technical processes, as well as the monitoring of any changes to those processes and their corresponding funding impacts. This is easier said than done. Program starts often overestimate technical performance and underestimate resource requirements. Consequently, the program is continually trying to catch up. In addition, the timeliness of cost performance reports often leaves program management with decisions after the fact.

The intent of this guide is to provide program managers and their staff with suggested trade-offs of specific and alternative technical processes and their respective comparative cost without compromising contract performance requirements.

This guide also provides a "quick look" reference to the program budgeting cycle, appropriations, financial contract considerations and resources for estimating cost.

Part I
Fundamentals

1. When appropriate, put financial incentives in the contract.
2. The acquisition strategy should consider the long-term contracting approach and corresponding appropriations to optimize total ownership costs.
3. Design iterations and cost are driven by performance requirements.
4. Contractor's past performance may be an indicator of cost risk.
5. The contractor's "basis for cost estimates" determines the reasonableness of the estimates.
6. Each program requirement is a potential cost driver.
7. Plan for contingencies by maintaining a management reserve.
8. The higher the reliability the lower the operational and supportability cost.
9. To control cost, manage technical risks.

Part II
The Cost of Technical Processes

Introduction

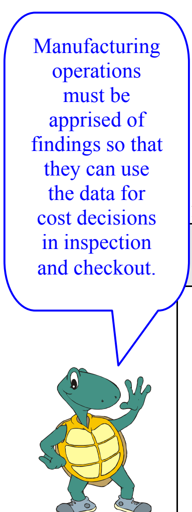
To financially manage a program, the program office must understand the costs involved with the technical processes of design, test and production of a system and be able to adjust those costs without jeopardizing the program. Often, a program needs to shift financial resources from one area to another due to budget decrements, unanticipated technical/engineering problems or schedule issues. Since there is often no other option but to redistribute program funds from within the program, the program needs to make cost adjustments based on sound engineering decisions so that the program does not fall into financial or technical trouble. The following tables address implementation options, associated cost considerations and decision factors for various technical processes. The estimated cost data below represents approximate mean and range values based on factors such as availability of system and part documentation, availability of failure mode/historic data, complexity of the system, software tools and experience level of the analyst. The technical processes discussed here include:

- Design Analyses
  - Reliability Prediction
  - Failure Modes, Effects and Criticality Analysis
  - Fault Tree Analysis
  - Sneak Circuit Analysis
  - Worst Case Circuit Analysis
  - Worst Case Tolerance Stack Up Analysis
  - Thermal Analysis
  - Stress Analysis
- Parts and Materials Selection
- Built-In-Test
- Accelerated Testing (Life/Reliability Growth)
- Environmental Stress Screening
- Qualification Test
- Failure Reporting, Analysis and Corrective Action
- Environmental Stress Screening

Reliability Prediction

This design analysis is conducted to evaluate alternative designs, assist in determining whether or not reliability requirements can be achieved and for detecting over-stressed parts and/or critical areas. The accuracy of the reliability prediction is important as it is also used as a primary source of data in several critical analyses such as Built In Test (BIT)/testability analyses, maintainability predictions, availability predictions, Failure Modes, Effects and Criticality Analysis (FMECA), fault tree analysis, logistics support analyses, maintenance planning, reliability centered maintenance, condition based maintenance, spares calculation, life cycle cost estimates, etc.

Implementation Options	Comparative Cost Data	Decision Factors
1. Prediction based on actual electrical, thermal and mechanical stresses.	0.5 mean hours of labor per part with a range of 0.2 to 1.0 hours.	• New design or state of art design. • All supporting detail design analyses must be completed and available. • Need for the most accurate reliability prediction.
2. Prediction based on parts count technique with assumed average electrical, thermal and mechanical stresses from previous (historical) contractor experiences.	0.15 mean hours of labor per part with a range of .07 to 0.3 hours.	• Use only when detailed design data is not available. • Otherwise, the actual prediction value may be significantly different, especially for specific parts and assemblies. • The prediction may be optimistic because some of the actual localized stresses may be significantly worse for specific critical parts. • May provide a less accurate prediction due to use of generic industry data.
3. Prediction based on similarity to other designs. (a) Under similar operating conditions. (b) Under different operating conditions.	(a) .05 mean hours of labor per part with a range of .03 to .08. (b) 0.35 mean hours of labor per part with a range of 0.15 to 0.8 hours.	• Use when the other designs and their applications are comparable in all aspects or the differences can be correlated from a reliability standpoint. • Commercial Off The Shelf/Non Developmental Items (COTS/NDI) prediction may not be accurate without design disclosure information.



Failure Modes Effects and Criticality Analysis

This design analysis is used to identify potential failure modes at the lowest system indenture level and assess their detectability and effects on performance throughout the system. This analysis is performed from the bottom up, from the lowest hardware indenture level (e.g., parts) to the system level. Criticality is assigned to each failure mode to assist in determining corrective actions. The FMECA provides essential information for other significant activities such as testability/BIT/performance monitoring analyses, maintenance planning, logistics support analyses, design improvements, etc.

Implementation Options	Comparative Cost Data	Decision Factors
1. FMECA performed starting at the parts level.	0.5 mean hours labor per part with a range of 0.3 to 0.9 hours plus the reliability prediction cost if not previously funded.	• Use when it is critical to identify all potential failure modes of a system, such as SUBSAFE, Safety of Flight, etc. • Use on Class I Engineering Change Proposals (ECP) or design changes involving critical parts. • Use when repairs will be performed at the parts level.
2. FMECA performed starting at the Lowest Replaceable Unit (LRU) level.	1.5 mean hours of labor per LRU with a range of 0.7 to 4.0 hours plus the reliability prediction cost if not previously funded.	• Applicable when LRUs are COTS/NDIs without design disclosure information. • Use when no performance monitoring/fault location, BIT or repairs performed below the LRU level. • Use on Class I ECPs or design changes to critical parts.

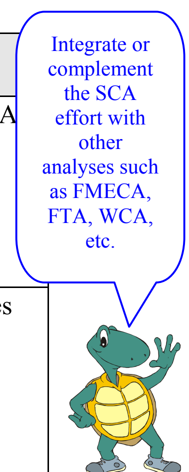
Fault Tree Analysis

This design analysis is similar to FMECA except that it is performed top-down, from the system level down to the lowest indenture part. Fault Tree Analysis (FTA) begins with the identification of system failures, analyzes the subsystem failure modes that can cause this failure and continues sequentially down to the lowest system indenture level. The FTA can identify failure causes that are not limited to hardware or software. FTA focuses on selected system failures and typically requires less effort compared to a FMECA that analyzes all possible part failure modes, regardless of its severity, to determine their impact on the system.

Implementation Options	Comparative Cost Data	Decision Factors
1. FTA performed down to the parts level.	0.5 mean hours of labor per part with a range of 0.3 to 0.9 plus the reliability prediction cost if not previously funded.	• Use as a design tool to identify causes of specific system failure modes, especially when safety related. • Update after major or critical design changes.
2. FTA performed down to the LRU level.	1.5 mean hours of labor per LRU with a range of 0.7 to 4.0 hours plus the reliability prediction cost if not previously funded.	• Applicable when LRUs are COTS/NDIs without design disclosure information.

Sneak Circuit Analysis

Sneak Circuit Analysis (SCA) identifies unexpected paths that may occur in the hardware and software that cause unwanted functions or inhibit wanted functions even though all components are operating properly. The first two options below are based on using the sneak path search technique originally developed for NASA. The third option is based on use of a computer software program to identify potential sneak paths supplemented with a functional FMECA.



Implementation Options	Comparative Cost Data	Decision Factors
1. Review all system functions and their interactions for sneak paths.	A system with a generalized component mix ranging from passive to large-scale integrated circuits cost approximately $200/part.	• Use on complex critical systems, as an SCA is a lengthy, thorough and costly analysis. • Typically performed in the latter stages of design. • Conduct on functions/paths with high occurrence of switching.
2. Conduct limited SCA on selected system functions and their interactions.	Same as option #1. Variability is in the parts count.	• Conduct on critical functions and interfaces such as those associated with ordnance, squib, switching elements, etc. • Conduct based on safety hazards. • Conduct on functions/paths with high occurrence of switching. • Typically performed in the latter stages of design.
3. Conduct analysis using computer software to identify potential sneak paths. This typically focuses on analog circuits and safety of a system containing ordnance/ squibs and is generally	SCA cost based on the combination of computer software to identify sneak paths: Approximately 1 man-month labor per drawing consisting of 5 standard “D” size sheets for SCA analysis that is focused on safety of a	• Use when acceptable to rely on software to identify potential high energy related sneak paths. • Use when trade-studies reflect reduced analysis with functional FMECA is acceptable and significant acquisition cost avoidance can be achieved.

Implementation Options	Comparative Cost Data	Decision Factors
performed in conjunction with a functional FMECA which is performed on the rest of the system. This functional FMECA is similar to an FMECA except that the analysis focuses on assessing whether or not the system operates properly when no failure occurs.	system containing ordnance/ squibs; plus a functional FMECA that costs the same as an FMECA starting at the part level (less if performed with the FMECA).	

Worst Case Circuit Analysis

This design analysis is conducted to evaluate the product's long-term performance under worst case operating and environmental conditions by accounting for variations in part tolerances and their stack-up in a circuit. Sources of product/circuit instability include part variations, drift of the parts' performance parameters due to aging, part quality, tolerance of other parts in the circuit, environmental stresses and electrical stresses.

Implementation Options	Comparative Cost Data	Decision Factors
1. Monte Carlo Simulation simulates system performance using techniques based on the actual part parameter distributions.	1.1 mean hours of labor/part with a range of 0.7 to 2.5 hours.	• Apply when most realistic estimate of worst-case performance is desired and the part parameter probability density functions are known. If not precisely known, the analysis precision is similar to root mean square analysis.
2. Root Mean Square Analysis simulates system performance by combining part parameter statistical distributions at the circuit level.	1.0 mean hours of labor/part with a range of 0.6 to 2.3 hours.	• Use when it is acceptable to assume that the part parameters are statistically normally distributed allowing use of standard deviations. Provides more accurate results than the extreme value analysis approach.
3. Extreme Value Analysis simulates system performance when the parts are simultaneously operating at their extreme worst-case values.	0.8 mean hours of labor/part with a range of 0.5 to 2.0 hours.	• Use when highest confidence in the analysis results in meeting operational requirements, which are not always precisely or accurately defined. • This is the most conservative analysis and does not require knowledge of the statistical distribution of the part parameter variations.
4. Selected Circuits - Conduct analysis only on mission and safety critical items, and high manufacturing cost items.	Cost is scaled using the above data for the number of parts in the selected circuits.	• Use when trade-studies reflect that reduced analysis is acceptable and significant acquisition cost avoidance can be achieved.

Worst Case Tolerance Stack-Up Analysis (non-electronic/electrical)

This design analysis is conducted to determine that dimensional tolerance stack ups will not compromise the products ability to be successfully manufactured, tested and operated. The analysis is performed using worst-case variations in dimensions and worst-case environmental conditions expected from manufacturing through its life cycle. Sources of worst-case dimensional variations include change in characteristics of the part due to stress and aging, part quality, worst-case tolerance of manufacturing fixtures, test and measurement equipment, gages and other interfacing parts.

Implementation Options	Comparative Cost Data	Decision Factors
1. Conduct analysis to the worst case environmental conditions of the: • Manufacturing facility and to the sources of worst-case dimensional variations. • Mission and life cycle profiles.	1.0 mean hours of labor/part with a range of 0.5 to 3.0 hours.	• Applicable to critical systems requiring high reliability and low maintenance with stressful mission and life cycle profiles. • Applicable to systems requiring high manufacturing quality and yields.
2. Conduct analysis only on mission and safety critical items, and high manufacturing cost items.	Cost is scaled using the above data for the parts in the selected items.	• Applicable for systems with mission and non-mission critical items as well as high manufacturing cost drivers.

Thermal Analysis

Performance and reliability are strongly affected by temperature. Thermal analysis is critical for successful implementation of thermal management for a product and is performed to achieve mission performance and reliability requirements by avoiding overstress conditions. Improper tailoring of the thermal analysis can result in costly redesign efforts and schedule delays. Thermal analysis results are a major determinant for the selection of parts and materials, placement of parts, cooling and heat dissipation requirements, storage requirements and test requirements. The approximate cost of thermal analyses of typical electronic equipment are listed in the table below. Factors affecting the amount of labor required to perform the analysis includes the experience of the analyst, complexity of the equipment and level of analysis to be performed.

Implementation Options	Comparative Cost Data	Decision Factors
1. Perform the thermal analysis on the system based on the mission and life cycle profiles. The thermal analysis model considers induced thermal loads such as from natural environments and other sources, as well as internally generated	The approximate cost per item (e.g., transformer, circuit board, cold plated mounted module, electronic cabinet etc.) is shown below.	• Use when thermal considerations may impact product reliability, life, maintenance and personnel safety.

<table>
<tr><th>Implementation Options</th><th>Comparative Cost Data</th><th>Decision Factors</th></tr>
<tr><td>heat. Thermal analysis is performed to lower levels of detail and preciseness as the design progresses (e.g., the initial analysis is based on worst case power dissipation of various items, final analysis based on actual application heat dissipation).</td><td colspan="2"><table><tr><th>Level of Analysis</th><th>Amount of Labor</th><th>Computer Cost</th></tr><tr><td>Preliminary</td><td>½ - 1 day</td><td>$20 - $40</td></tr><tr><td>Intermediate</td><td>3 days – 1 week</td><td>$100 - $200</td></tr><tr><td>Detailed</td><td>1 week – 2 weeks</td><td>$200 - $500</td></tr></table>Ref: Reliability Analysis Center Thermal Management Guidebook (RTMG).</td></tr>
<tr><td>2. Perform the thermal analyses on only critical heat sensitive or high heat dissipating parts.</td><td>Cost is scaled using option #1 for the parts in the selected items.</td><td>• Use if the product design is a low heat generator with very conservative parts derating and is used in a relatively benign environment.
• Use after a risk assessment is performed by a thermal engineer to select parts for analysis.</td></tr>
<tr><td>3. Conduct thermal survey.</td><td></td><td>• Use for short mission, unmanned, simple application where the expected heat loads are not critical to mission success.
• Validate thermal analysis model.</td></tr>
</table>

Stress Analysis

Electrical and mechanical stress analyses are conducted to determine or verify design integrity against conditional extremes or design behavior under various loads to assure material properties can withstand stresses in the intended environments. Stress analyses performed early in the design phase can significantly reduce test time and cost by providing a basis for a reliable design.

<table>
<tr><th>Implementation Options</th><th>Comparative Cost Data</th><th>Decision Factors</th></tr>
<tr><td>1. Conduct analysis to ensure successful performance under worst case conditions and minimize life cycle costs.</td><td>For electrical parts:
• 0.4 mean hours labor/part with a range of 0.25 to 0.75 hours based on manual calculations.
• 0.4 mean hours labor/part with a range of 0.15 to 0.80 hours based on a simulation model.
For mechanical parts (Finite Element Analysis):
• New development part: 2 to 3 analysis iterations.
• Modification or preliminary analysis of a part: 1 to 2 analysis iterations.</td><td>• Use on mission critical, safety critical and high cost non-redundant system.
• Need for earlier maturity in reliability.</td></tr>
</table>

Implementation Options	Comparative Cost Data	Decision Factors
	• 80 mean hours of labor/part, with a range of 40 to 200 hours*.	
2. Conduct on selected parts based on severity of stresses, mission criticality, safety criticality and high life cycle cost.	Cost is scaled using option #1 for the parts in the selected items.	• May result in late discovery of failures during testing.

* The analysis cost for a mechanical part can vary extensively depending on its complexity and application stresses. The analysis cost above is for a typical mechanical part such as a torroid shaped element and a hub on which it is placed.

System Level Design Analysis Cost Example

A system level cost can be derived from any combination of the methodologies and levels of detail contained in the tables in Part I "Cost of Technical Processes." A general expression to estimate the cost at the system level is contained in the following formula:

Cost at the Parts Level = P * CPP

Cost at the LRU Level = LRUs * CPL

Where:

- P = number of parts in the system for which the analysis will be performed.
- CPP = Mean Man Hour Per Part * Hourly Labor Rate.
- LRU = number of LRUs in the system for which the analysis will be performed.
- CPL = Mean Man Hours Per LRU * Hourly Labor Rate.

Example costs in Table 1 are based on a system assuming 10 LRUs with 150 parts each and a labor rate of $75 per hour.

Table 1: Design Analysis Cost for a Hypothetical System

Design Analysis	Implementation Options	Mean Man-Hours	Cost for Hypothetical System
Reliability Prediction*	Part Count	.15 per part	$16,875
	Part Stress	.50 per part	$56,250
	Similarity to an existing design, operates under same conditions	.05 per part	$5,625
	Similarity to an existing design, operates under different conditions	.35 per part	$39,375
Reliability Block Diagram/Model	Monte Carlo	0.8 per part	$90,000
Stress Analysis (electronics)	Manually Calculated	0.4 per part	$45,000
	Calculated based on a simulation model	0.4 per part	$45,000

Design Analysis	Implementation Options	Mean Man-Hours	Cost for Hypothetical System
Stress Analysis (mechanical)	Finite Element Analysis (FEA)	80 per part**	**
FMECA	Piece part level analysis	0.5 per part***	$56,250
	Functional (or LRU) level analysis	1.5 per LRU ***	$1,125
FTA	Piece part level	0.5 per part ***	$56,250
	Functional (or LRU) level analysis	1.5 per LRU ***	$1,125
Worst Case Analysis	Monte Carlo	1.1 per part	$123,750
	Root mean square	1.0 per part	$112,500
	Extreme value	0.8 per part	$90,000
Tolerance Stack-up	Mechanical	1.0 per part	$112,500
SCA	Review all System Functions	2.5 per part	$281,250
	Conduct Limited SCA	2.5 per part analyzed	Prorated by % parts analyzed
	Perform SCA with Software	0.5 per part	$56,250

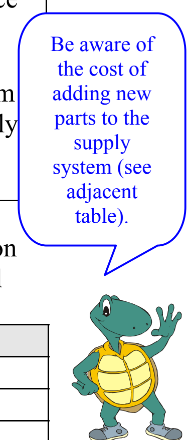
** Reliability prediction cost should include Reliability Block Diagram/Model*
*** The analysis cost for a mechanical part can vary extensively depending on its complexity and application stresses. The mean man-hour cost above is for a typical mechanical part such as a torroid shaped element and a hub on which it is placed.*
****Reliability prediction is required as source data, so that cost needs to be factored in to the final cost.*

Parts and Materials Selection

Parts and materials selection utilizes a disciplined design process to ensure that cost-effective selections are capable of withstanding the manufacturing environment and reliably meeting the mission and life cycle performance and storage requirements. The parts and materials program includes adherence to firm derating criteria and the establishment of a preferred parts list that focus on Qualified Manufacturers Lists (QML) parts and standardization of parts selection.

Implementation Options	Comparative Cost Data	Decision Factors
1. Qualified Manufacturers List (QML) parts are produced from a vendor's manufacturing processes and materials that are qualified and certified to a performance specification by a Government process.	QML parts include military, industrial and commercial grade parts. Purchase costs are generally 4 to 7 times more than their non-QML commercial counterparts.	• Use QML when obsolescence issues are a concern. • Use for systems that require consistent reliability, configuration control, standardization, long-term support, and increased availability of parts at lower life cycle cost. • Limited availability of selected QML parts, especially state-of-the art active parts, may require use of commercial parts that meet the system's mission requirements.

Implementation Options	Comparative Cost Data	Decision Factors
2. Industrial grade parts are commercially available and may require qualification testing to meet the application performance requirements.	Generally cost 25% - 85% less than their QML counterparts.	• Use for systems whose worst-case environmental (e.g., extreme temperatures ranges) requirements are less than worst-case Military specification requirements. • Obsolescence is an issue for long term support because of the part's relatively short availability *(See table below concerning supply support)*.
3. Commercial grade parts are parts whose reliability, quality and performance levels are less than military or idustrial grade parts.	Generally cost 75% - 90% less than their QML counterparts.	• Use for systems whose parts are exposed to worst-case environmental (e.g., extreme temperature ranges) requirements that are less severe than the worst-case industrial grade requirements. • Use for throwaway devices and one time buys for non-critical performance applications if long-term logistics support is not an issue. • Obsolescence is an issue for long term support because of the part's relatively short availability *(see table below concerning supply support)*.



The following table illustrates the average cost for adding a new part into the supply system. It reflects on the value of standardization and avoidance of introducing new parts into a system when considering total ownership costs.

Activity	**Cost**
Engineering & Design	$9,300
Testing*	$700
Manufacturing	$1,750
Purchasing	$3,800
Inventory	$875
Logistics Support	$3,750
Total	$20,175

**Each part needs to be evaluated. However, not all parts added to the inventory require testing.*
Ref: SD-19 Life Cycle Cost Savings Through Parts Management, Defense Standardization Office, June 2001

Built-In-Test (BIT)

Provides “built-in” monitoring, fault detection and isolation capabilities as integral features of the design. BIT results in reduced requirements for external test equipment, fewer interfaces between the system and the external world, less damage from invasive inputs, reduced skill level of maintenance personnel, rapid troubleshooting, reduced downtime, more accurate testing, improved status-monitoring and readiness and reduced life cycle cost.

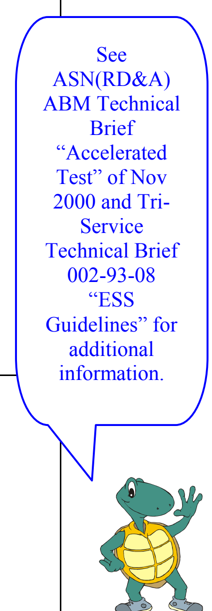
<table>
<tr><th>Implementation Options</th><th>Comparative Cost Data</th><th>Decision Factor</th></tr>
<tr>
<td>1. Design and Test Optimized BIT - includes detection of all failures, isolation to the lowest replaceable unit and low false alarm rates. Incorporates maximum BIT efficiency:
• Maximum probability of BIT detecting HW/SW failures.
• Maximum probability of isolation to lowest level of defective item.
• Minimize false alarm rate.
• Minimize the time needed to complete the test.</td>
<td>BIT implemented on digital electronics at the:

Component level
<table>
<tr><td>% Fault Isolation</td><td>Relative Cost</td></tr>
<tr><td>60</td><td>2.7</td></tr>
<tr><td>70</td><td>3.0</td></tr>
<tr><td>80</td><td>3.2</td></tr>
<tr><td>90</td><td>3.5</td></tr>
<tr><td>95</td><td>3.7</td></tr>
<tr><td>99</td><td>4.0</td></tr>
</table>
Circuit board/assembly level
<table>
<tr><td>% Fault Isolation</td><td>Relative Cost</td></tr>
<tr><td>60</td><td>3.4</td></tr>
<tr><td>70</td><td>3.7</td></tr>
<tr><td>80</td><td>3.9</td></tr>
<tr><td>90</td><td>4.2</td></tr>
<tr><td>95</td><td>4.5</td></tr>
<tr><td>99</td><td>4.8</td></tr>
</table>
System level
<table>
<tr><td>% Fault Isolation</td><td>Relative Cost</td></tr>
<tr><td>60</td><td>4.1</td></tr>
<tr><td>70</td><td>4.4</td></tr>
<tr><td>80</td><td>4.6</td></tr>
<tr><td>90</td><td>4.9</td></tr>
<tr><td>95</td><td>5.1</td></tr>
<tr><td>99</td><td>5.4</td></tr>
</table>
</td>
<td>• Use for systems that require high up-time or availability to meet mission objectives.
• Failure of the BIT circuitry must not precipitate other hardware or software failures.</td>
</tr>
<tr>
<td>2. Reduced operational BIT requirements and increased off-line testability.</td>
<td>See above for BIT. In addition, testability analysis cost is approximately the same as for a FMECA at the part level.</td>
<td>• Use when trade-studies reflect reduced requirements are acceptable and significant acquisition cost avoidance can be achieved.
• No BIT/testability analysis required.
• Use for COTS/NDI.
• Use when you can afford increased man-hours cost for troubleshooting.</td>
</tr>
</table>

Accelerated Testing (Life/Reliability Growth)

These tests are performed to estimate product life as well as to identify or confirm marginal design areas, assure design maturity and eliminate design weaknesses. They are often used to obtain more information during a given test time than normally would be possible by applying stresses beyond normal life cycle or usage conditions. The Reliability Growth Testing (RGT) process normally includes dedicated long term exposure of the equipment to simulated mission/life cycle environments, analyzing test failures to determine cause of failure, redesigning to remove the cause, implementing the new design, and retesting to verify that the failure cause has been removed.

Implementation Options	Comparative Cost Data	Decision Factors
1a. RGT Program results in achievement of the desired reliability with statistical confidence. It is performed under DRMP environments. **1b**. Accelerated Life Testing provides an estimate of normal life through the use of commonly accepted accelerated test models. Based on data obtained under conditions or stresses beyond normal life cycle or usage levels.	Outsourced Test Labs (representative data) • Lab # 1. $1,700/day plus $500 fixturing fee. Includes thermal chamber and shaker. • Lab # 2. $5000 analysis fee and $2,000 /day. Includes Electro Dynamic/ Electro Hydraulic (ED/EH) shaker. • Lab # 3. $2,500/day plus $350 for overtime hours. Includes ED/EH shaker. In House Equipment Cost (representative data): • $150K ± $25K for a multi-axis repetitive shock vibration system (30”x30” table low end/ 48”x 48”high end) and nitrogen chamber. In-house laboratory cost (facility and laboratory support) for testing two units for two months is typically $60-$80K per unit (representative data).	• Use when an adequate sample size is available for testing. • Use if the program schedule can accommodate the extensive test time required to achieve the mature reliability. • Use when an applicable model exists, or a new model for acceleration factors can be confidently developed using experimental test data to structure the model and validate the hypotheses. • It is very difficult to properly model the acceleration for complex assemblies and equipment and hence to quantitatively predict the item life under normal usage conditions.
2. Step Stress Testing achieves design maturity by accelerating the applied environmental and/or the system operating parameters, mission and environmental profiles. Step-stress test results cannot be extrapolated	See above.	• Use when test time is limited by the program schedule. • Achieves elimination of failure modes. • Results in growth in the reliability of the system with little statistical confidence in observed reliability. • Top management should review failure modes detected to determine need for additional testing due to lack of design maturity.



Implementation Options	Comparative Cost Data	Decision Factors
to long-term fatigue life.		• Time dependent failure modes may not be exposed.
3. Integrated Testing performed by tracking design problems found during other activities such as systems integration, subsystem/ component development testing, environmental qualification testing and operational/field testing.	No additional cost for test equipment or facilities. Some cost increase in the interpretation, analysis and assessment of the growth testing data.	• Use in deployment phase and when no other options are feasible. • Provides an engineering rough order of magnitude estimate of design maturity.

Environmental Stress Screening

Environmental Stress Screening (ESS) is a process for detecting in the factory, latent, intermittent or incipient defects or flaws introduced by the manufacturing process. It usually involves the application of one or more environmental stresses designed to stimulate the product but within product design stress limits.

Implementation Options	Comparative Cost Data	Decision Factors
1. Perform ESS on all product levels using a 3-axis vibration and full temperature cycle profile.	See "ESS Conditions/ Tradeoffs" table.	• First pass yields are < 90%. • Manufacturing processes are not mature.
2. Perform ESS on samples of the production units on all product levels to assess continuing maturity of the design, test and manufacturing processes.	See "ESS Conditions/ Tradeoffs" table.	• First pass yields are ≥ 90%. • Savings are primarily realized in reducing temperature cycling, as the reduction in vibration cycling cost are relatively small.
3. Perform ESS only at selected product levels: • End item level and selected critical subassemblies. • Selected critical subassemblies only.	See "ESS Conditions/ Tradeoffs" table.	• First pass yields are ≥ 98%. • Savings are realized since only selected items will be screened.
4. No ESS.	Monitor production yield rates and fleet failures to ensure weapon system quality remains high. If first pass yields are ≥ 99%, go to options #1, #2 or #3.	

ESS Conditions/Tradeoffs							
Level Of Assembly	Power Applied[1]		I/O[2]		Monitored[3]		**ESS Cost**
	Yes	No	Yes	No	Yes	No	
Temperature Cycling							
PWA		X		X		X	Low
	X			X		X	High
	X		X		X		Highest
Unit Box	X		X		X		Highest
	X			X	X		Lower
		X		X		X	Lowest
System	X		X		X		Highest
Random Vibration							
PWA	X		X		X		Highest
	X			X	X		High
		X		X		X	Lowest
Unit Box	X		X		X		Highest
	X			X	X		Low
		X		X		X	Lowest
System	X		X		X		Low
Notes: 1. Power applied at PWA level of assembly, power on during ESS is not always cost effective. 2. I/O equipment fully functional, with normal inputs and outputs. 3. Monitored – Monitoring key points during screen to assure proper equipment operation.							

Qualification Tests

These tests are designed to ensure that the system or subsystem design meet performance requirements when exposed to environmental conditions expected at the extremes of the operating envelope, the "worst case" environment of the DRMP. This test must be successfully completed to ensure the design requirements have been verified prior to start of production.

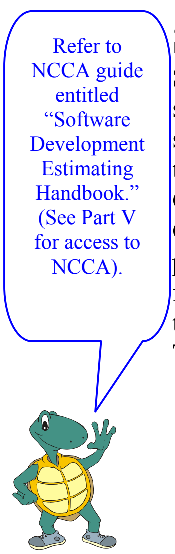
Implementation Options	Decision Factors
1. Qualification testing is conducted at all product levels from parts to system to the worst-case environments of the DRMP.	• Safety critical considerations (e.g., Safety of Flight, Subsafe). • New designs and major redesigns. • State of art design.
2. Qualification testing at end item level only and selected mission critical lower level items.	• Does not meet "Qualification Testing" decision factor criteria.
3. Qualification by similarity.	• Use if DRMP is compatible with previous DRMP's used in qualification of similar form, fit and function hardware items.

Failure Reporting, Analysis and Corrective Action

Failure Reporting and Corrective Action System (FRACAS) is a closed loop process in which all failures of both hardware and software are formally reported. Analyses are performed to determine the root cause of the failure, and corrective actions are implemented and verified to prevent recurrence during product development, production and deployment.

Implementation Options	Decision Factors
1. FRACAS includes all prime contractor and subcontractor failures. All failures	• Elimination of failure causes is essential to the program (such as space programs, safety of flight, etc.) for

Implementation Options	Decision Factors
require an engineering analysis and lab analysis if necessary to determine root cause.	achievement of program requirements from the development phase through the sustainment phase.
2. FRACAS includes all failures subsequent to systems integration at the prime contractor.	• Prime contractor past history reflects successful implementation of best design, test and manufacturing practices, and the risk to the program schedule is acceptable. • Subcontractors implement effective FRACAS. • Subcontract items are primarily mature NDI/COTS.
3. FRACAS analyses limited to pattern, repeat failures, failures at the prime contractor and subcontractors.	• Use for mature design and production processes. • Use FRACAS for: – Mission critical failures. – Safety critical failures. – Maintenance drivers. – High cost items. • Prime contractor past history reflects successful implementation of best design, test and manufacturing practices, and the risk to the program schedule is acceptable.
Representative FRACAS Cost Information	
Failure analysis cost can vary over a wide range. Representative costs for a typical laboratory failure analysis of a part, depending on the depth of the analysis performed, are provided in the column to the right. The more complex the part and the more unusual the failure mode (e.g., intermittents), the higher the cost.	1. Functional test and analysis of an electronic part to determine its condition as good or bad: Approximately 1-2 mandays. 2. Detail in-house laboratory analysis within the electronic part and applying additional environmental conditions: Approximately 4-6 mandays. 3. Detail laboratory analysis requiring the subcontractor specialized laboratory and engineering analyses for a mechanical part: 15-25 mandays.



Software Cost

Software costs are often responsible for large cost overruns. For instance, a 1995 Standish Group study showed that 53% of the software projects reviewed were overrun by more than 50% for both cost and schedule. Software cost control and estimation is an entire subject on its own and is too large to cover in this document. There are some good tools available to estimate software cost such as the Navy's Center for Cost Analysis (NCCA) Software Model (see sidebar) and the commercial software cost estimating model COCOMO II. COCOMO II is a model that allows one to estimate the cost, effort, and schedule when planning a new software development activity. It consists of three submodels, each one offering increased fidelity the further along one is in the project planning and design process. Listed in increasing fidelity, these submodels are called the Applications Composition, Early Design, and Post-architecture models. This model is available on the web at

www.sunset.usc.edu/research/COCOMOII/

Reference to commercial tools does not indicate endorsement

The following table provides some cost indicators associated with the design, test and production of software. They do not provide cost options and considerations, but provide indicators that let you know if your software system program may be in financial trouble.

Process	Indicators
• Schedule and Progress relates to the completion of major milestones and individual work units. A project that falls behind schedule can usually only meet its original schedule by eliminating functionality or sacrificing quality.	• A >10% cumulative, or >20% per period, actual deviation from planned progress (Once an actual progress trend line is established, it is difficult to change the rate of completion). • A 5% or greater build schedule variance for single builds or a 10% build schedule variance across two or more builds.
• Resources relates to the balance between the work to be performed and personnel resources assigned to the project. A project that exceeds the budgeted effort usually can recover only by reducing functionality or sacrificing quality.	• Voluntary staff turnover > 10% /year. • Large overruns during integration and test, which may indicate quality problems with the code and significant defects that may delay completion. • The addition of large numbers of people within a short period of time (this normally cannot be done effectively).
• Growth and Stability relates to the stability of the functionality or capability required of the software. It also relates to the volume of software delivered to provide the required capability. Stability includes changes in scope or quantity. An increase in software size usually requires increasing the applied resources or extending the project schedule.	• Total software size increases > 20% over original estimates. • Constantly changing requirements or a large number of additions after requirements reviews, which are leading indicators of schedule and budget problems later in the project.
• Quality relates to the ability of the delivered software product to support the user's needs without failure. Once a poor quality product is delivered, the burden of making it work usually falls on the sustaining engineering organization.	• Defect removal efficiency <85%. • Large gaps between the closure rate and the discovery rate, indicating that problem correction is being deferred, which could result in serious schedule, staffing and cost problems later in the project. • A horizontal problem discovery trend line during design, coding or testing. This may indicate that reviews and tests are not being performed and should be investigated.
• Development & Performance relates to the capability of the developer relative to project needs. A developer with a poor software development process or low productivity may have difficulty meeting aggressive schedule and cost objectives. More capable software developers are better able to deal with project changes.	• The developer has a poor software development process or low productivity, coupled with aggressive project schedule and cost objectives. • Unplanned rework, which is a frequent cause of low productivity. • Changes in assumptions concerning the use of COTS software or the amount of code that can be reused.

Part III
Program Budgeting "Quick Look Reference"

Introduction

The objective of this part is to provide a synopsis of the Planning, Programming and Budgeting System (PPBS), appropriations and the obligation process. It does not discuss the accounting requirements of financial management, as those are well documented and readily available.

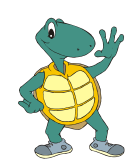
A key ingredient for success is the program's acquisition strategy relating to financial management. The acquisition strategy considers the restrictions on the various appropriations along with the contracting approach to make smart financial use of different appropriations to optimize total ownership costs and reduce program risk. Having the correct appropriations available during the program production and sustainment period requires financial management planning for the use of funds, especially operations and maintenance funds, their anticipated availability, and their expiration dates.

The acquisition strategy, for example, may reflect use of multiyear or annual procurements with program sustainment cost included in the production unit price using procurement appropriations. This long-term business strategy not only should reduce program cost, but also ensures higher likelihood of funding during the sustainment period. This is especially significant in reducing risks for programs that otherwise would require significant operations and maintenance funding that is in limited supply. In addition, it is recognized that a major portion of a program's life cycle cost is normally incurred in the sustainment phase.

Planning, Programming and Budgeting System

The PPBS is the primary resource allocation process of the Department of Defense (DoD). The PPBS is controlled by Office of the Secretary of Defense (OSD) assisted by the Defense Planning Resources Board (DPRB) that is chaired by Deputy Secretary of Defense (SECDEF). The objective of the DoD PPBS is to identify mission needs, match the needs with resource requirements and to translate the resource requirements into budget requests. At the DoD level, the system produces the Defense Planning Guidance (DPG), the Future Years Defense Program (FYDP), and the DoD portion of the President's Budget. The Department of the Navy (DoN) must operate within the guidelines of both the Federal budget process and the DoD PPBS. The DoN system is designed to meet the decision-making needs of the Department, while producing specific decisions and documentation that are forwarded to OSD and Office of Management and Budget (OMB) on a schedule set by those offices. Since the DoN consists of two separate Military Services, the Navy and the Marine Corps, planning and programming are essentially delegated to the two Services with staff offices consolidating a Departmental product for the Secretary of the Navy, who is the final decision-maker. Although the specific schedule for the various events involved in developing the DoN program and budget varies from year-to-year, the general schedule of the two-year biennial cycle does not vary much. The basis for the schedule is the requirement that the President must submit the budget to Congress by the first Monday in February. The schedule is developed to ensure compliance with that requirement. OMB sets the date for submission of the budget in the fall and OSD determines the date for

For an in-depth look at the PPBS cycle and other budget guidance, refer to the Budget Guidance Manual (BGM) on the ASN(FM&C) web site (see Part V).



submission of the Program Objectives Memorandum (POM) in the spring. PPBS is a biennial process with three distinct but interrelated phases, these are:

Planning

The objective of this phase is to identify mission needs and define a planned force that is fiscally attainable. This is primarily accomplished at the OSD level between the Joint Chiefs of Staff, Commanders in Chief, and the DPRB. This process results in the Defense Planning Guidance. The table below provides a description of activities and documents associated with this phase and their typical publication dates.

Activity/Document	Description
Draft Defense Planning Guidance (DPG) - issued in September of even-numbered years.	The draft DPG includes a statement of national objectives, a threat assessment, and force requirements. The Military Departments participate in preparation and review of the guidance. The Office of Program Appraisal coordinates the efforts of the Navy and Marine Corp's planning offices: • The two Deputy Chiefs of Naval Operations for Plans, Policy and Operations (N3/5). • The Marine Corps' Plans Division (MC-PL). These offices work with the OSD and JCS planning staffs during preparation and review of the draft DPG.
Defense Planning Guidance (DPG) - is the point of departure for the development phase of programming and is normally scheduled to be published in January of odd-numbered years.	The major output of the planning phase is the DPG, issued by the SECDEF following final decisions by the President on the budget. The DPG culminates the DoD planning process. The DPG serves as an authoritative statement of the fundamental strategy, issues and rationale underlying the defense program, as seen by the leadership of DoD. The DPG consists of the following: • Threat assessment and opportunities. • Policy and strategy guidance. • Force planning guidance. • Resource planning guidance. • Fiscal guidance. • Unresolved issues for further study.

Programming

The objective of this phase is to match program needs with available resources by assessing the status of programs as they have evolved from the previous PPBS cycle, for resolution of issues, and to achieve the DPG through the formulation of the POM. Responsibility for the Programming phase is assigned to the Director of the Navy Program Information Center (DoNPIC). Program planning and preparation of the two Services' (Navy/Marine Corps) POMs are conducted separately by the Chief of Naval Operations (CNO) Programming Division (N80) and by the Marine Corps Deputy Chief of Staff Programs and Resources (P&R), with a combined POM submitted to OSD by DoNPIC. The OSD response results in the Program Decision Memorandum (PDM). The table below provides a description of programming activities and documents.

Activity/Document	Description
Warfare Appraisal/Summary Readiness Appraisal - published in late December to summarize reviews such as investment strategies, warfare appraisals and assessments.	Programming in the Navy begins in September with reviews of strategy, warfare areas, and support tasks. These reviews examine the threat and the program levels provided by the previous cycle, and the requirements stated in draft OSD guidance. The reviews define funding needed to accomplish certain program levels or capabilities and make recommendations

Activity/Document	Description
	to the resource sponsors to use in preparing their program proposals.
CNO Program and Fiscal Guidance - issued in January.	Promulgates program development guidance to resource sponsors.
Sponsor Program Proposals (SPPs) - are developed from January until March and constitute the basic program building blocks for the POM.	Developed by resource sponsors, using the recommendations of the fall reviews, specific CNO guidance, and input from various offices, such as the Systems Commands for acquisition programs and Fleet Commands for readiness initiatives. These proposals are submitted to N80 in the form of changes to the Future Years Defense Program (FYDP), which is based on the previous President's Budget. Following review to ensure compliance with CNO guidance and to resolve issues, the program proposals are presented to the CNO, and then to the SECNAV. These proposals mark the beginning of final development of the POM and result in further CNO and SECNAV guidance.
"End Game" Phase of Programming - is conducted in April and early May.	This is the final development phase of the POM wherein outstanding issues are resolved by CMC, CNO, and SECNAV. It is during this phase that changes are made to ensure that the program submitted to OSD reflects their guidance. The results of CNO, CMC, and SECNAV decisions are incorporated into a database, and documentation is prepared to describe the program.
Program Objectives Memorandum (POM) - is submitted to OSD in late May or early June.	The DoN program is documented by the DoN POM. The DoN POM is the SECNAV's annual recommendation to the SECDEF for the detailed application of DoN resources. The POM documents changes to the FYDP proposed by DoN.
OSD staff reviews – conducted through July.	The OSD staff reviews the POM and prepares alternative proposals as necessary. The review takes the form of the preparation of a series of issue books. Each issue in these books is prepared by a working group that includes a DoN representative. Draft copies of these books are provided to the DoN for comment prior to their presentation to the DPRB.
Program Decision Memoranda (PDMs) - promulgated in August of even-numbered years.	Decisions made by the SECDEF and Deputy SECDEF, supported by the DPRB, during the program review process are documented by PDMs and signed by Deputy SECDEF. These documents form the programmatic basis for the subsequent submission of Military Departments' budget requests to the SECDEF.

Budgeting

The objective of this phase is to translate program resource requirements into a budget request that is executable, properly priced, and reflects OSD's decisions on the POM or PDM. This results in the Budget Estimate Submission (BES), which ultimately ends up in the DoD portion of the President's budget. The table below provides activities and documents associated with this phase.

Activity/Document	Description
Budget Call – issued by Office of Budget (FMB) in mid-May.	The Comptroller, through the Office of Budget (FMB), provides substantive guidance and technical direction for all stages of the budget formulation process. This guidance and direction is derived from several sources, such as congressional direction,

Activity/Document	Description
	OMB circulars, OSD guidance, as well as SECNAV policy, and is provided to all components in a single document known as the "budget call," promulgated as NAVCOMPT NOTICE 7111.
Budget Estimates - issued by SECDEF in July.	Initial budget guidance for the preparation and submission of the forthcoming fiscal year.
DoN Budget Review - markup/reclama process in July and August.	FMB reviews the budget submissions, conducts hearings and makes adjustments via the markup/reclama process.
Budget Submissions - are submitted to OSD by the Military Departments not later than 15 September.	Estimates should be consistent with the base programs described in the POM FYDP as modified by the budget guidance and the PDMs.
FYDP Update - is published in October.	OSD publishes the October update of the FYDP to document the DoD program as submitted in Military Department budget estimates.
OSD/OMB Budget Review - From September to January.	The OSD and OMB staffs conduct a joint review of the budget estimates. They hold hearings and recommend changes to the Department budget proposals. SECDEF decisions are documented by Program Budget Decisions (PBD). When major budget issues arise that are not satisfactorily resolved by the PBD process, the DPRB convenes to review the issue and provide recommendations to SECDEF for resolution.
Presidential Review – normally completed prior to mid-January.	The budget estimates are reviewed by the President and his decisions are finalized and communicated to DoN through OSD/OMB.
President's Budget - submitted to Congress in early February.	Detailed backup data which includes the Navy/Marine Corps budget schedules is prepared for the President's Budget and is submitted to Congress.

Execution

In this part of the process, Congress passes the appropriation act, the treasury department issues appropriation warrants, the OMB appropriates funds, OSD passes the apportionment to the Service with any additional SECDEF restrictions, ASN(FM&C) allocates appropriations to OPNAV, OPNAV allocates funding to the Navy System Commands, Direct Reporting Program Managers, Program Executive Officers and Program Managers. The table below provides a summary of activities associated with establishing a program's budget in preparation for budget execution.

Date	Action
March	• SYSCOM, PEO or DRPM issues statements of priorities. • Guidance and initial controls to PMs after coordination.
May	• In budget hearings, PMs present programs tailored to funding guidance. • PMs issue reclamas to initial controls.
July	• Reclamas considered and revised controls issued.
August	• Operating budget for upcoming FY briefed to PMs. • Final operating budget briefed to SYSCOM/PEO/DRPM.
September	• PMs complete obligation-phasing plan for each appropriation.
October	• Budget execution begins. • Budget adjusted based on applicable Congressional action.

Budget Cycle Timeline

The following timeline depicts major events in the Navy budget cycle over a three-year period, to illustrate the overlap of fiscal years versus calendar years. For example, the complete FY4 budget cycle, initiated in CY1 is shown, along with the initial phases of the FY5 and FY6 budget cycles.

CY	Month	FY4	FY5	FY6
CY1	SEP	Initiate program planning and POM preparation.		
	OCT			
	NOV			
	DEC	Warfare Appraisal/Summary Readiness Appraisal published.		
CY2	JAN	Develop Sponsor Program Proposals.		
	FEB			
	MAR			
	APR	Final development of POM.		
	MAY	Submit POM to OSD.		
	JUN	POM reviews by OSD.		
	JUL	Markup/reclama process.		
	AUG	PDMs signed by DEPSECDEF.		
	SEP	Budgets submited to OSD. OSD/OMB reviews.	Initiate program planning and POM preparation.	
	OCT	OSD/OMB reviews.		
	NOV			
	DEC		Warfare Appraisal/Summary Readiness Appraisal published.	
CY3	JAN	Pres. budget review.	Develop Sponsor Program Proposals.	
	FEB	Pres. budget submitted to Congress.		
	MAR			
	APR		Final development of POM.	
	MAY		Submit POM to OSD.	
	JUN	Congress approves budget.	POM reviews by OSD.	
	JUL		Markup/reclama process.	
	AUG		PDMs signed by DEPSECDEF.	
	SEP		Budgets submited to OSD. OSD/OMB reviews.	Initiate program planning and POM preparation.
	OCT	Begin execution.	OSD/OMB reviews.	
	NOV			

CY	Month	FY4	FY5	FY6
	DEC			Warfare Appraisal/Summary Readiness Appraisal published.
CY4	JAN		Pres. budget review.	Develop Sponsor Program Proposals.
	FEB		Pres. budget submitted to Congress.	
	MAR	Mid-Year review.		
	APR			Final development of POM.
	MAY			Submit POM to OSD.
	JUN		Congress approves budget.	POM reviews by OSD.
	JUL	Sweep up.		Markup/reclama process.
	AUG			

Appropriations

Prior to the beginning of the fiscal year, OSD provides to the Department of the Navy a schedule of financial authority (or operating budget for operations accounts), which establishes the control for each appropriation, including any controls at levels below the appropriation total and any other statutory or administrative limitations. Within those controls and limitations, the Comptroller establishes control levels by allocating funds for the types listed in the table below. Throughout the course of the fiscal year or the life of the appropriation, the Comptroller's staff conducts a continuous review of financial performance against budgetary plans and programs. If additional funds or other adjustments are required during execution, a request for the change is submitted to the Comptroller by the funds administrator. The Comptroller's office reviews the request and takes action as appropriate to adjust the allocation of resources. The following table provides a quick reference guide to the different types of appropriations and how they can be used.

Type	Purpose	Appropriation (Type/Policy/ How)	Available for Obligation	Available for Expenditure
Shipbuilding & Conversion, Navy (SCN)	• New Ship Construction to include: – Hull, mechanical/electrical – Guns, torpedo/missile launch systems – Communication systems • Existing ship conversion • Nuclear refueling/overhaul • Outfitting • Post delivery	• Investment • Full funding • Line item	Five years	Five years after obligation
Research, Development, Test & Evaluation, Navy (RDT&E, N) *And* OSD Research Development, Test and Evaluation	• Basic research • Exploratory development • Advanced development • Engineering development • Management & support • Ship contract design • Includes lease & operation of test facilities/ equipment	• Investment/ Expense • Incremental • Lump sum	Two years	Five years after obligation
Aircraft Procurement, Navy (AP,N)	• Aircraft purchase • Supporting programs, including: – Modifications/ installations – Spare parts – Ground support/training equipment • Industrial facilities/tools	• Investment • Full funding • Lump sum with some constraints	Three years	Five years after obligation
Weapon Procurement, Navy (WP,N)	• Missiles/torpedoes/guns • Air & ship launched ammunitions • Supporting equipment, including:	• Investment • Full funding • Lump sum with some constraints	Three years	Five years after obligation

Type	Purpose	Appropriation (Type/Policy/ How)	Available for Obligation	Available for Expenditure
	– Modifications/ installations – Targets – Hardware for satellites – Spare parts – Ground support/training equipment • Industrial facilities/tools			
Other Procurement, Navy (OP,N) *And* OSD Procurement Defense Wide (PROC, DW)	• Procurement modernization/ installations of equipment if not funded by Other Appropriations, i.e.: – Fire control systems – Electronic sensors – Training equipment – Spare parts – UAVs	• Investment • Full funding • Lump sum	Three years	Five years after obligation
Procurement, Marine Corps (PMC)	• Weapons/ ammunition • Tracked combat vehicles • Ground launched guided missiles • Communications/electrical equipment • Support vehicles • Engineering equipment • Modification installation • Spares/general purpose equipment	• Investment • Full funding • Lump sum	Three years	Five years after obligation
Operations & Maintenance, Navy/Marine Corps (O&M,N)/ (O&M, MC)	• Steaming hours • Aircraft/weapon system maintenance • Base operating support • Minor maintenance of real property • Supply systems operations	• Expense • Annual • Lump sum	One year	Five years after obligation
Operations & Maintenance, Navy Reserve/Marine Corps Reserve (O&M,NR)/ (O&M, MCR)	• Engineering support • Hardware/software maintenance • Field logistics support • Training • CIVPERS salaries • Housekeeping • Minor construction	• Expense • Annual • Lump sum	One year	Five years after obligation
Military Personnel, Navy/ Marine (MP,N)/(MP,MC)	• Military pay • Allowances • Clothing • Subsistence		One year	

Type	**Purpose**	**Appropriation (Type/Policy/ How)**	**Available for Obligation**	**Available for Expenditure**
	• Unemployment compensation			
Reserve Personnel, Navy/Marine (RPN)	• GI Bill • Retired pay accrual • Training		One year	
Military Construction Navy (MCN)	• Construction of military facilities • Land acquisition • Planning & design • Major maintenance of real property	• Investment • Full funding • Line item	Five years	Two years after obligation
Family Housing, Navy & Marine Corps (FH, N&MC)	• New housing construction • Housing improvements • Operation & maintenance of existing housing	• Investment • Full funding • Line item	Five years for construction One year for operational	Five years after obligation
Foreign Military Sales (FMS)	• Foreign Military Sales (FMS) program is the sale of US Government military tactical weapon systems to foreign governments. It is a total package approach, including government management support procurement, and operations and maintenance of deployed systems. • FMS must be sold, contracted and executed as if it were being done on behalf of the DoD implementing agency.	• Funded by direct cash outlays of the purchasing countries.		

Reprogramming

Reprogramming is shifting funds *within* an appropriation, from the original purpose for which those funds were to be used, to another purpose. Reprogramming applies to all appropriations in the annual DoD Appropriations Act. Reasons for reprogramming could include:

- Changes in operating conditions.
- New and urgent requirements.
- Wage rate adjustments.
- Price changes.
- Enactment of new legislation.

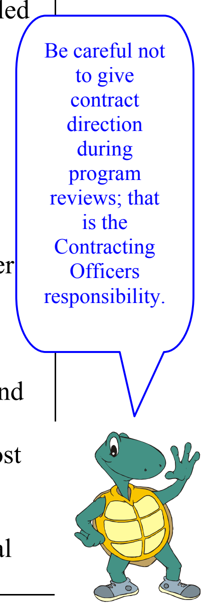
Considerable pressure is applied by the Congressional Committees to minimize reprogramming. The Committees and the DoD Comptroller establish approval and notification requirements for reprogramming. Dollar thresholds are established for each appropriation, and these amounts are on a cumulative basis. Reprogramming actions are often referred to as "below threshold" or "above threshold." For example, an "above threshold" reprogramming action (requiring notification of Congressional Committees) for Operations and Maintenance would be a cumulative increase of $20 million or more in a budget activity. For Military Personnel this threshold would be $10 million (current as of FY99). Amounts less than these amounts would be considered "below threshold" and only notification of USD(C) is required. Approval and notification requirements for Procurement and RDT&E are more complex. Dollar thresholds for all appropriation reprogramming actions can be found in a DoD Comptroller publication called “Budget Execution Flexibilities” and may change per the authorization bills. In addition to the approval and notification requirements, funds may only be reprogrammed from lower priority programs to higher priority programs and cannot be reprogrammed to items for which funding has previously been denied by Congress. A summary report of all reprogramming actions is submitted to the Congress semiannually.

Part IV Financial Considerations in Contracting

Introduction

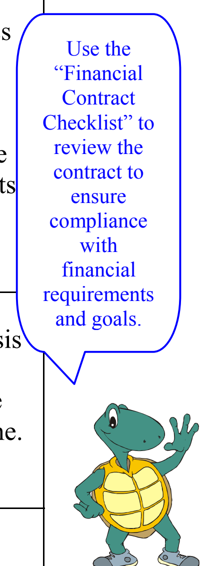
Just as major acquisition programs are built on sound engineering principles and performance objectives, the type of contract decision is based on many factors. Depending on the specific requirement, a contract type that includes financial considerations to incentivize performance may be selected. It is important to work with the contracting officer in determining the appropriate type of contract. This Part provides a discussion of some of the financial incentives and basic financial requirements that may be included in the contract, depending on contract type.

Contract Input	Guidance
Earned Value Management System (EVMS) – is a contractual requirement for monitoring the effectiveness of contractor performance in that it provides periodic comparisons of the actual work accomplished in terms of cost and schedule with the work planned and budgeted. This is accomplished through the Integrated Baseline Review (IBR) process. When variances in cost or schedule begin to appear in the work packages, the appropriate Integrated Product Teams can analyze the data to isolate the causes of the variances and gain insights into the need to modify risk-handling actions.	Detailed implementation guidance may be found in the "*Earned Value Management Implementation Guide*" NAVSO PAMPHLET 3627, Revision 1, of 3 Oct 97 and by accessing http://www.acq.osd.mil/pm/ or http://www.pmcl.com/pmwd/EVPM/policy.htm
Integrated Baseline Reviews – Effective management of acquisition programs and contracts requires proper control of cost, schedule, and technical performance, which depends on the establishment and maintenance of a reliable Performance Measurement Baseline (PMB). The IBR confirms that the PMB covers the entire technical scope of work; that the work is realistically and accurately scheduled; and that the proper amount and mix of resources are assigned to accomplish all contractual requirements. The IBR should be conducted no later than six months following a contract award, or a significant contract modification, on contracts with EVMS Criteria or Cost/Schedule Status Report (C/SSR). The government and the contractor conduct the IBR jointly. The IBR process is designed to: • Confirm the integrity of the PMB. • Foster the use of earned value as a means of communicating the cost implications of technical and schedule problems.	The following is a listing of typical documents required to support an IBR. Provisions should be made in the contract to ensure contractor controlled documentation is available to the Government. • Contract work breakdown structure (and dictionary, if any). • Program (project) organizational structure. • Responsibility assignment matrix or chart (dollarized). • Work authorization documents. • Program schedules, including contract master schedule and detail schedules that support control accounts. • Control account plans or equivalent. • Records documenting contractual changes and internal actions. • Current earned value performance report (cost performance reports or C/SSR and Contract Funds Status Report. • Earned value management system procedural documents.



Contract Input	Guidance
• Provide confidence in the validity of contractor cost/schedule reporting. • Identify areas of risk (cost, schedule, and technical performance) associated with the performance measurement baseline. • Involve technical specialists and contract analysts in the IBR process.	• List of major subcontractors and major vendors, including description of product, applicable contract work breakdown structure element, value of subcontracts/purchase orders, period of performance, and responsible control account manager. • Basic contract and modifications.
Program Reviews – As with IBRs, there are technical milestones at which the program should be formally reviewed to ensure cost data is understood prior to proceeding with the program. These are joint Government/contractor reviews which should be specified in the contract.	The statement of work should contain requirements for formal reviews and support to include: • Preliminary design review. • Critical design review. • Production readiness review/physical configuration audit. • Software readiness review.
Performance Based Incentives – Incentives can be monetary or non-monetary and should be positive or well balanced, when necessary, with remedies for missing specific program targets or objectives. Remember, monetary based incentives may result in unintended consequences and non-cost incentives often resemble commercial best practices.	There are a number of policies and tools for incentivizing contracts. Available tools include: • "DoD Guide to Incentive Strategies for DoD Acquisitions." It provides the necessary framework and tools with which to effectively structure contractual incentives. Access at http://www.acq.osd.mil/ar/resources.htm. or http://log.dau.mil/ • "Flexible Sustainment Guide." This focuses on the different types of contracts that can be employed, and the advantages and disadvantages of each. It can be accessed at http://lrc3.Monmouth.army.mil.
Non-Cost Incentives - One non-monetary incentive approach is award-term contracts. With these contracts, successful contractor performance results in a longer-term contract. This allows the contractor to make a long-term investment in the program as part of their business strategy. For example, a basic contract may have an initial period of six years, which may be reduced to 4 years or extended to 15 years, based on contract performance.	Determine desired outcomes and related criteria against which performance can be measured. Specify points at which decisions will be made to increase/decrease contract length along with interim review points.
Incentive Fees. Properly used, an incentive fee is a valuable tool for motivating contractors to improve performance while creating opportunities for improved Government – contractor communication, including ongoing feedback, thus permitting problems to be resolved sooner. Incentive fee discussions should be held on a regular basis; monthly or quarterly is usually recommended. The incentive fee process can be successfully implemented on a range of contract goals and elements, including financial management.	The guidelines below can help PMs establish a financial management program using incentive fee criteria. • Analyze the SOW and attendant requirements to determine which contract performance requirements should be subject to incentives. • Specify the criteria against which contractor performance will be measured. • From the total incentive fee amount to be made available, specify evaluation periods and the corresponding amount of incentive fee available each period.

Contract Input	Guidance
	• Explain the general procedures that will be used to determine the earned incentives for each evaluation period. • Specify what will be done with incentive fee which is not awarded. When analyzing the SOW and attendant requirements, an important first step is the identification of critical areas of program risk. As a general rule, historically high-risk processes and processes involved with new technologies are usually good candidates for consideration as incentive fee elements. Tailor the contract performance elements selected for incentive fees to key events, then assign them to appropriate incentive fee periods. The results become the basis of the request for information from potential bidders, as contained in the Instructions to Offerors, without having to ask for extraneous detail. A well thought out list of key cost factors or cost performance provides an excellent roadmap for the solicitation. Incentive fee contracts based on contractor process improvements normally require some objective measurements to use as a basis for evaluation and incentive fee percentage determination. Give the contractor regular, structured feedback to preclude great disparity between what the contractor expects as an incentive fee payment and what the Government actually pays.
Step Ladder Incentives for Fixed Price Incentive Contracts – These arrangements involve differing sharelines for over and under target performance. An example is a 50/50 shareline for overruns and a 40/60 shareline for underruns. More advanced versions of this involve multiple sharelines.	Breakpoints for the changes in sharelines can be based on historical performance or detailed analysis of anticipated performance against the proposed target cost. More challenging ceilings can also be used as a compliment to a more favorable shareline.
Financial management and cost accounting requirements – Any financial management and cost accounting requirements to be imposed on the contractor should be specified in the SOW and other pertinent contract sections such as the Contract Data Requirements List.	Examples are Cost Performance Reports and C/SSR. Formats can be tailored to obtain the required information at the lowest cost impact.



Financial Contract Checklist

The following provides guidance for the program office to review the contract to ensure compliance to financial contract and/or tasking documents requirements. 31 USC 1301(a) requires that appropriated funds be used only for the programs and purposes for which the appropriation is made. A checklist follows:

General:

- Correct appropriation.
- Correct fiscal year.
- In compliance with unique requirements of the cited appropriation.
- Procurement funds comply with the full funding policy.
- R&D funds comply with incremental funding policy.
- SCN funded performance stays within Obligation Work Limiting Date (OWLD) of ship(s) charged.
- Ensure appropriated funding is not used for gifts or personal items.

Statements of Work (SOW):

- If purchasing services:
  - Does SOW refer to the specific equipment the services pertain, and/or the specific service desired?
  - Are services a bona fide need of fiscal year being charged?
  - If services are not of a continuing nature: Are services defined by task, time, and place.
  - For services of a continuing nature: Are services defined by function?
  - Tasks provided to define various evolutions that will lead to a finished product: Are services depicted in the order in which they will be accomplished?
  - Standard Fair Share statements should be included where required.
  - Contractor Support Service statements should be included where required.
  - If Services are severable, ensure that either:
    - Performance does not carry over beyond funds expiration.
    - Section 801 approval included to allow up to 12 month carryover.
  - If Services are non-severable, ensure task fully funded to completion.
  - For procurement accounts (except SCN): should the services be annualized or fully funded.

- If purchasing hardware:
  - Ensure SOW adequately describes hardware to be procured either in words or by reference to specification.
  - Ensure that the following are avoided:
    - Unnecessarily general statements. General statements should be avoided, unless they are further defined by adding the phrase “That consists of...” or “consisting of...” and a specific list of those items contained within the tasking are stated.
    - Open-ended statements. Defining phrases like “including,” “such as,” “but not limited to,” etc. are open-ended and leave the work statement open to interpretation. It is recommended that words such as “contain,” “consist of” or “provided by the following” be used when listing tasks to be accomplished. Additionally, terms such as “provide support for” or “assist with” do not define the effort required. “Support” and “assist” are open-ended statements without a definition and should not be used.
    - Undefined abbreviations and acronyms. All abbreviations and acronyms used in the SOW need to be spelled out the first time they are used.

Intra/Inter Governmental Funding Documents:

- General
  - Is the proper funding document selected?
  - Is receiving activity in a position to begin performance promptly upon acceptance?
  - Does SOW provide receiving activity with enough information to commence performance?

- Transportation Account Code (TAC) cited and funded where required.
- When issuing an amendment (or revision on some documents) to an existing document and there is no change to the SOW and Standard, use the following statements only (do not repeat the SOW and Standard Statements on the amendment).
  - "There is no change to the previous provisions of this document. This amendment (or Revision if applicable) is issued to extend the work completion date/increase funds due to cost growth/issue incremental funding/other reason as required (pick one or more reasons as appropriate)."

- Work Request (WR)
  - Used for work of a continuing nature over a specific period of time (level of effort work).
  - Work Completion Date (WCD) cannot extend beyond funds expiration date.
  - 51% of work must be performed in-house by the receiving activity.
  - Cites Funds Expiration Date (FED) and WCD.
  - For SCN: Cite OWLD of ship(s) charged.
  - No use of Section 801 of P.L. 105-85 is approved unless specifically authorized by this document or an amendment to this document.

- Project Order (PO)
  - Used for specific, definite tasks (e.g. production, manufacturing).
  - Can carry over beyond funds expiration.
  - Must be fully funded.
  - 51% of work must be performed in-house by the receiving activity.
  - Cite WCD, but do not cite FED.
  - For SCN: Cite OWLD of ship(s) charged.
  - WCD cannot extend beyond the OWLD of the ship(s) charged.

- Request for Contractual Procurement (RCP)
  - Used for requesting contractual procurement (services or items).
  - 100% of work must be contracted out.
  - Contract must be in place before funds expire.
  - Cite FED, but do not cite WCD.
  - Must specifically state items to be procured.
  - For SCN: Cite OWLD of ship(s) charged.

- Military Interdepartmental Procurement Request (MIPR)
  - Issued to non-Navy DoD activities (similar to a WR or RCP).
  - Can be issued on a reimbursable economy act order or direct cite basis. The acceptance copy from the receiving activity specifies the amounts accepted on reimbursable/ direct cite basis.
  - Cite reference document in block 3 or under the line of accounting (Need to state FED and WCD in the SOW section).

- Inter Departmental Purchase Request (IPR)
  - Issued to non-DoD agencies (similar to a WR or RCP).
  - Uses the MIPR form with the following statement:
    - "This document is issued as an Inter Departmental Purchase Request (IPR) and must be accepted on a reimbursable basis, and when applicable, in accordance with 31 USC 1535."
  - A Determination and Finding (D&F) must be retained in the file. The D&F does not go with the document.

- Order for Work and Services/Direct Citation (WX/PX/RX)
  - Use only if authorized by your budget division, and authorized for use by field activity (see NAVCOMPINST 7600.30A).

- Letter of Obligational Authority (LOA)
  - Issued to any government owned or operated activity on a direct cite basis.
  - Used when other documents do not meet the need for the type of work authorized, or when requested by recipient.
  - Funds must be used before expiration.
  - FED should be cited where needed.

Supporting Documentation:

- For execution of customer funds: The SOW on fund usage documents that reference a customer's incoming document number must clearly tie back to the SOW on the customer's incoming fund usage or fund authorization document.
- Does a copy of any letter or document used as reference in the SOW accompany the document?

Contracts:

- Are there contingent liabilities arising during execution for which the program manager should be administratively reserving funds to preclude Anti-deficiency Act Violations? If yes, a contingency commitment should be established.
- TAC cited where required.
- Where multiple appropriations cited:
  - Separate CLIN/SLIN for each line of accounting cited?
  - Exceptions as authorized in Defense Federal Acquisition Regulation Supplement Part 204. For example, an R&D non-severable item paid for incrementally, or one SCN item paid for with multi-years SCN funds (e.g., advance procurement funding, full funding, and transfer accounts).
  - Does the SOW break work out adequately to ensure that only proper work is charged to each appropriation cited?
- Ensure the following are included where necessary:
  - Contractor Support Services - include proper major cost category code.
  - Standard fair share statements for common support.
  - Section 801 approvals.

Part V
Estimating Program Costs

Introduction

Often, a program is in financial trouble from the beginning because program costs were not realistically established or assessed. It is vital that the program costs are estimated realistically from program inception, and that all cost aspects be understood. This includes hardware and software costs, the processes to design, test and produce them, operational and support costs and all other program costs. The program office, working as an integrated team to include technical, contract, logistics and financial personnel is responsible for developing these program cost estimates. The Office of the Assistant Secretary of the Navy (Financial Management & Comptroller) ASN(FM&C) plays a significant role in supporting the program offices in developing these cost estimates. This Part provides a description of the resources and tools available for estimating program cost and financial management in general.

Organizations

ASN(RD&A)

ASN(RD&A) requires that certain cost information relating to technical progress and performance of the weapon system be presented at the quarterly program reviews. For programs that ASN(RD&A) is the Milestone Decision Authority, a standard format is required which requests technical information, program risk and cost information. It is beneficial for all Navy program offices to be able to translate their cost information into these formats in the event that information is requested. Since these reporting formats change as cost information is analyzed, they are not listed here. However, these charts can be accessed on-line after obtaining access information from DASN PP&R by calling:

703-697-1091

In brief, these cost charts require that the following information be presented.

- **Program Budget Chart**: Presents the entire budget for the program broken down in the way that it is managed, not the way it is budgeted. This should not be a replication of the DAES report, but should be a breakout of the functional distribution of spending. Solvency information should be provided which defines how well the Program Manager is able to cover the cost of the program within funds already allocated to the program.
- **"Bulls Eye Chart."** This chart uses acronyms/terms that are generally the definitions for DAES reporting and include reporting on CPI/SPI indices, as well as Contract Performance information for each prime contract, or significant subcontract.
- **Contract Rebaselining Charts**. Requests cost information regarding contract rebaselining if applicable to the program.
- **Earned Value Management Charts**. Provides earned value management information.
- **Special Initiatives**: Each special initiative (total operating cost reduction, reduced work, standard procurement system, paperwork reduction, etc) needs to be identified and discussed, as does any

initiative that has external budget visibility (SPS, COSSI, TOC, etc.) and internal to the program. It requests information for standard descriptive information and payback analysis.

ASN(FM&C)

All DoN comptroller functions, including budget, are assigned to the Assistant Secretary of the Navy (Financial Management and Comptroller (ASN(FM&C)). The budget functions of the Office of Assistant Secretary of the Navy (Financial Management and Comptroller) occur during all phases of the budget cycle. During the first phase, the ASN(FM&C), through the Director, Office of Budget (FMB), provides substantive guidance and technical direction with respect to preparation and submission of the budget. During the second phase, the ASN(FM&C), through FMB, reviews and justifies the budget for submission to OSD/OMB, the President, and finally to the Congress during the third phase. In the fourth phase, the ASN(FM&C), through the Director, Office of Budget (FMB), monitors budget execution and program performance. The Director of FMB is responsible to the Secretary of the Navy through the ASN(FM&C) for formulation, justification, and execution of the DoN budget. The Director is responsible to the ASN(FM&C) through the Principle Deputy ASN (PDASN) for the principles, policies and procedures for preparation and administration of the DoN budget as assigned by law, instruction, and regulations.

The Navy Headquarters Budget System contains the latest budget news, policy, guidance, decisions, and appropriations information required by Navy program offices. It contains information on the following and can be accessed at http://dbweb.secnav.navy.mil/nhbs.

Budget Formulation | Budget Justification | Budget Execution | Budget Guidance | Budget Office Information | NHBS Systems

Naval Center For Cost Analysis

The Naval Center for Cost Analysis is organized under the ASN(FM&C), and can be accessed at http://www.ncca.navy.mil. NCCA is responsible for the following:

- Advising the Secretary of the Navy and Chief of Naval Operations on matters relating to weapon system cost estimates and analysis for planning, financial management, and negotiation of major limited competition contracts.
- Leading the DoN cost community in issues of cost policy and policy implementation.
- Preparing Independent Cost Estimates for Acquisition Category IC/IA programs.
- Conducting economic analyses of weapon system, equipment, and Automated Information Systems acquisition, to include analysis and forecasting of labor, industrial, and technical trends as they impact the overall process.
- Managing the Navy's implementation of the Department of Defense (DoD) Visibility and Management of Operating and Support Costs (VAMOSC) Program.

Tools

Visibility and Management Operating Support Costs (VAMOSC) management information systems collect and report US Navy and US Marine Corps historical weapon system Operating and Support (O&S) costs. Reporting by fiscal year, VAMOSC provides the direct costs of weapon systems, linked indirect costs (e.g., ship depot overhead), and related non-cost information such as flying hour metrics, steaming hours, age of aircraft, people counts for ships, etc. Depending on the cost element, data for a particular commodity is available not only at the system level, but also at the subsystem and component levels. The cost data include expenditures or obligations collected annually from over 125 different sources. Cost analysts use VAMOSC data to develop the O&S portion of life cycle cost estimates for future weapon systems. VAMOSC also contributes to the Navy's efforts to reduce the Total Ownership Cost of legacy and future weapon systems. Like the Air Force's Total Ownership Cost (AFTOC) system, VAMOSC is being used to identify significant cost drivers that represent cost reduction opportunities. VAMOSC also supports special studies/analyses, cost research, modeling, and simulation. Recent VAMOSC improvements have increased the breadth (i.e., coverage of weapon systems and cost elements), depth (i.e., level of detail provided), and timeliness of VAMOSC reporting. The VAMOSC database is currently available to government and industry users by several means. Frequent users query the relational database directly using web browser software. There are approximately 500 users who access the database directly. Infrequent users prefer to request specific data directly from NCCA via the website. This avenue precludes the need for the user to have a working knowledge of how the aforementioned database query software operates. Government and contractor users are typically provided different levels of VAMOSC data access, as the database contains government proprietary information. Access VAMOSC at http://www.navyvamosc.com/.

OSCAMtools.com
Operating and Support Cost Analysis Model

Operating and Support Cost Analysis Model (OSCAM) is a Windows-based application designed to aid cost analysts, logisticians, and engineers in estimating weapon system Operating and Support (O&S) Costs. Using Powersim, a System-Dynamics based software engine, OSCAM effectively captures the real-world, inherent interactions and feedback relationships that other models simply cannot address. OSCAM simulates O&S costs by running through a series of time-steps and calculating the value of the cost and non-cost outputs following each step. After the completion of a run, a user-friendly, Windows-style output screen displays the calculated results. Access OSCAM at http://www.oscamtools.com/.

NAVY OBLIGATIONS DATA EXTRACTION SYSTEM

The ***Navy Obligations Data Extraction System*** (NODES) is an unclassified database of historical Navy operating and support obligations. It contains Operations and Maintenance, Navy (O&M,N) and Military Personnel, Navy (MP,N) cost detail for 1995 through 2000. NODES obtains data from budget and account sources and is updated annually. Data fields include Appropriation, Common Line Item (AG/SAG), Claimant, Unit Identification Code, Element of Expense, Special Interest Item and Inflation Cost Category. NODES improves understanding of VAMOSC data by relating it to budget and accounting data, and complements VAMOSC by capturing indirect and infrastructure costs that are not in VAMOSC. Access NODES at http://www.ncca.navy.mil/services/nodes.cfm.

The ***Cost of Manpower Estimating Tool*** (COMET) provides users with Navy manpower cost estimates of active, reserve and civilian components to provide the analyst with a tool to make decisions about manpower or hardware tradeoff comparisons. Access COMET at http://www.ncca.navy.mil/services/comet/index-frame.htm. COMET costs are:

- Customizable, allowing you to include only those costs pertinent to your cost analysis.
- Comprehensive, including both the direct costs (MP,N) of manning billets and the variable indirect costs (MP,N and O&M,N) associated with acquiring, training, locating and supporting those personnel.
- Granular, varying across skills, paygrade and geographic location (civilians).
- COMET incorporates parameters from NCCA's Cost of a Sailor studies in a PC-based, 32-bit (Windows) application that installs on your PC or network in minutes.

- Users can easily customize specifications to a particular cost exercise.
- Windows environment allows users to easily share data with other applications.
- Model outputs can be exported to spreadsheet applications or printed to hard copy.

Contractor Performance Assessment Reporting System or (CPARS) allows seamless access to data from other services for source selection. Past performance information is required to be used in the source selection process. The information in CPARS can be used to provide contractor strengths and weaknesses to Contracting Officers. CPARS is a web-enabled application that collects and manages the library of automated CPARS. A CPAR assesses a contractor's performance and provides a record, both positive and negative, on a contractor's performance. Each assessment is based on objective technical, performance and cost facts such as cost performance reports, financial solvency assessments, earned contract incentives. CPARS can be accessed at http://www.cpars.navy.mil.

Techniques

Cost Risk

Once the program baseline has been established, and key program cost drivers have been identified, cost estimates can be made for worst and best-case scenarios. One method is to perform Monte Carlo simulation to measure cost risk. A Monte Carlo simulation is an analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. A Monte Carlo Simulation Tool randomly selects values from the distribution specified at the element level and calculates total program costs and schedule. There are a number of Monte Carlo Simulation applications that can be integrated with Microsoft Project and can perform cost and schedule risk analyses. Three point triangular distributions are approximated from three data points provided by the cost accounting managers, IPT leads, personnel involved with cost estimating. The three points for each task element are: (1) the most likely cost and duration (schedule), (2) the pessimistic cost and duration, and (3) the optimistic cost and duration. The most likely cost and duration elements are normally what are loaded into Microsoft Project. The pessimistic and optimistic values are additional information that must be gathered from cost account personnel through interviews to support the cost and schedule risk assessment. The Monte Carlo simulation add-ons provide a place to load this additional information. Once 3 point distributions have been gathered and loaded for each task element, then the Monte Carlo Simulation is run. There are many software tools available for performing Monte Carlo Simulations. The results are your most likely project end dates and costs, and are not what your Project Scheduling Tool (i.e., Microsoft Project) estimated. Hence, there is some amount of cost and schedule risk of not meeting your estimated completion date or budget. The risk is quantified in terms of a probability or percentage of exceeding costs and schedule. For example, there is a 50% probability that the Project will not meet its estimated completion date. From here, the probabilities can be partitioned into levels that equate to Low, Moderate, High. There are several Monte Carlo simulation add-on tools for Microsoft products that allow you to perform Cost and Schedule Risk Analyses:

Crystal Ball (Cost Risk Analysis) add-on for Microsoft Excel.
www.decisioneering.com

Risk Plus (Schedule Risk Analysis) add-on for Microsoft Project
www.cs-solutions.com/products/products.html

@ Risk (Schedule Risk Analysis) add-on for Microsoft Project
www.palisade.com

Reference to commercial tools does not indicate endorsement

Parametric Cost Estimating

Parametric cost estimating is the application of equations that describe relationships between cost, schedule, and measurable attributes of a product or the system through its life cycle, from design, test, manufacturing and support to removal from service use. Parametric analysis is the process of determining the highly predictive equations necessary for parametric estimating. Together, parametric estimating and parametric analysis constitute parametric cost analysis.

From a mathematical perspective, parametric cost analysis is the set of processes by which appropriate characteristics of systems are mapped to appropriate ranges of cost. Given these mappings, one can then estimate cost, estimate the variability of cost, or design for cost with respect to the given system characteristics. The idea is find a value for the m parameters p = (p1 ... pm) such that the cost y can be predicted reasonably well by the equation y = f(x,p) + e where e is the prediction error and x = (x1 ... xm) is a set of measures of system characteristics which vary over n cases (yi,x1i ... xmi), different for each i. Given that f is linear in the parameters p, one such criteria for "predicted reasonably well" is least squares which minimizes the Euclidian distance between the predicted values (z1 ... zn) and the case values (y1 ... yn). The equation for calculating the values of these parameters is p = (X' X)^ X' y where X is a matrix with n rows (x1 ... xm), X' is its transpose, y is a vector with n rows yi, and (X' X)^ denotes the inverse of the matrix product X' X. Given an arbitrary x we can then predict the cost y reasonably well by z = f(x,p). Noting that response surface methodology (RSM) is the process of finding an equation of the form z = f(x,p) + e, then the analysis component of parametric cost analysis can be viewed an application of RSM with cost as the response surface. This perspective immediately suggests more powerful second and higher order equations, which should be considered for cost analysis. A second order equation will automatically capture the multicolinearity, which often plagues the linear equations typically used. If the cases have been chosen to represent a particular class of system, say a space launch vehicle, then p, the vector of parameters, is a label for that system class. The labels show up as numerical values in equations and are typically ignored. This has led to many misconceptions of cost. A scatter diagram of the labels is very revealing since it displays the clustering of classes. The parameters of the label are usually obtained by least squares, also called regression. The trick is to choose appropriate sets of measures (x1 ... xm) which reduce estimation error to a tolerable level. What level of estimation error is tolerable? From the typical American manager's perspective, the level desired is usually far smaller than is realistic. This creates a major problem for the estimator because:

- The predicted value is almost always far higher than management will allow.
- The cost z desired by the enterprise is typically much less than the estimated value x or the actualized value u.
- The estimator is often not allowed to treat x as the random variate it is, thus the very real cost of risk cannot be included.

Attempting to manage cost by managing the cost estimator and the cost estimate ultimately results in a far higher actual cost for the typical product. The increase comes from trying to do too much with too little. This often arises from price competition on cost plus fee, rather than fixed price, contracts, typically for major defense and NASA systems. The reality is, that, in this environment, the only thing being negotiated is the fee. The result is the typical large contract overrun predicted by parametric cost estimating prior to establishment of price by the enterprise plus the additional cost from unrealistic budget estimates. However, if it is understood how to design for cost, these overruns could become underruns. Given that the cost estimator and the estimate are not "managed," parametric cost analysis provides an excellent tool for estimating cost. Given an x which really represents the cost drivers, parametric cost analysis can be used to design for cost with Taguchi methods, response surface methodology, or multidisciplinary optimization. In fact, optimizing for cost illuminates a previously unrecognized form of cost driver, the constraint. In the past, these variables have typically been chosen to represent characteristics of the product to be estimated, such as weight for hardware, lines of code for software, or aircraft design variables for aircraft. Research indicates that more appropriate drivers come from the processes to design, test, manufacture, support and removal from service use of the product to be estimated. Binary variables which represent the use or non-use of Taguchi methods, response surface methodology, or multidisciplinary optimization during

conceptual design and design are appropriate. Other appropriate measures include the degree of enterprise use of activity based costing, concurrent engineering, design for ..., hoshin kanri, kaizen, quality function deployment, or systems engineering. The appropriate use of such tools tends to reduce cost. Another important aspect of parametric cost analysis is the depiction of cost uncertainty. If anything is uncertain in this world, it is cost. Parametric cost analysis invites the incorporation of probabilistic methods to simulate and estimate this cost uncertainty. In fact, if you use point estimates, instead of probabilistic methods, you will get a low estimate because you ignored the uncertainty. Cost risk is the degree by which a project could overrun the agreed upon price. The degree of risk is established by the location of the price on the cost axis of the cost uncertainty curve. For example, if the price has been established at the 0.2 probability point on this curve, then the odds are 4 to 1 that the cost will be more than the price. If, in this case, the price is fixed, then the project developer is at risk and will probably lose a substantial amount. The expected loss is the difference between the expected value of the cost uncertainty distribution and the price. For cost plus fee contracts, this difference is the expected cost overrun. It is, thus, the risk of the contracting organization. In the past, parametric cost analysis has been largely based upon unit costing. That means that the cost of one unit of a tangible product is estimated. It is then adjusted by a power law learning curve to estimate the total cost of all identical units purchased. It is known today that the unit cost accounting methods of the past did not represent the cost of a unit very well. Thus, parametric cost analysis based upon the old unit cost accounting techniques also contains these errors.
Taken from: "Parametric Cost Analysis," from the Perspective Competitive Advantage, by Edwin B. Dean.

The following **NASA *Handbook* on parametric cost estimating can be downloaded**. It is intended to be used as a general guide for implementing and evaluating parametric based estimating systems, and as the text material for a basic course in parametric estimating techniques. The information contained in this *Handbook* complements and enhances the guidance provided by DCAA Cost Audit Manual (CAM), FARs/DFARs, and other government regulations or public laws relating to cost estimating.

http://www.jsc.nasa.gov/bu2/PCEHHTML/pceh_t.htm