



PSM UG Conference Workshop #7 – Software Maintenance Cost Estimating Relationships

Facilitators: Brad Clark (SMI) & Christopher Miller (QSM)

***Office of the Deputy Assistant Secretary of the Army for Cost and Economics (ODASA-CE)
July 2012***

Workshop Overview

- **Prerequisites:**
 - ***This workshop will build on the results of the current DoD, Army, Air Force, and Navy initiatives and the 2009 and 2010 PSM Conference Workshops by focusing on software maintenance:***
 - *Work Breakdown Structure (WBS) as a basis of estimates and*
 - *Preliminary Cost Estimation Relationships (CER).*
- **Discussion:**
 - ***Participants should come to the workshop prepared discuss their experiences with software maintenance estimation and if possible bring practical applications for estimating software maintenance.***
- **Goals/Products:**
 - ***As stated in the Software Maintenance Study Objective, improve the accuracy of software maintenance cost estimates which should drive budgeting, allocating and justification of maintenance funds.***
 - ***Therefore we are seeking participant input on:***
 - *Relative costs in different areas of the WBS segmented by Operating Environment and Application Super-Domain*
 - *How cost in different areas in the WBS might be estimated*
 - *Our approach to integrating CERs to produce an overall estimate of next year's maintenance cost.*

Attendees

*Brad Clark**

*Chris Miller**

Joe Dean

Paul Below

Cheryl Jones

Marc Gutleber

Cari Pullen

Sue Koolmanojwong

Jack McGarry

Bob Charotte

Francine Bis

Corinne Wallshein

Don Beckett

Michal Bohn

Larry Osiecki

Bob Ferguson

Denton Tarbet

Rich Mabe

** Moderators*

Agenda

1330 – 1340	Introductions
1345 – 1400	Overview & Objectives
1400 – 1430	Session #1: Basis of Estimate Set-up
1430 – 1530	Working Session #1
1530 - 1545	* Break *
1545 – 1600	Session #2: CER Examples Set-up
1600 – 1645	Working Session #2
1645 -1700	Wrap-up

Relative WBS Costs

#	WBS Element	Sensor Processing	Ground Sys Space	C4 Sys	AC Avionics	Spacecraft
1	Software Maintenance	H	H	H	H	M-H
2	Software Licenses		M	M-H	M-H	0
3	Information Assurance		L	M	L	M
4	Certifications & Accreditation		L	L	L	M
5	Sustaining Engineering	H	H	L-M	L	M
6	Facilities & Infrastructure		M-H	0	H	H
7	Management	H	M	L-M	M-H	H

Working Session #2 Objective: Generate a list of CERs which have been used in practice and discuss practical applications based on attendees experiences

WBS	Title	Variability	CER Examples	Experiences / Practical Applications
1.1	Software Release (N)		Roll-Up	
1.1.1	Planning and Management	Variable	Defects by priority; SLOC; Requirements, Use Cases, Enhancements, HW/SW obsel., External interfaces, Language type, Release frequency	Parametric models as in SW Development; Ratio: LOC/FTE LOC/Time; LOE from last year
1.1.2	Software Requirements			
1.1.3	Architecture and Design			
1.1.4	Change Implementation			
1.1.5	Integration and Test			
1.1.6	Acceptance Test			
1.1.7	Rework		Historical quality from previous releases; Defects	
1.1.8	Emergency Repairs	Semi-Variable		Drive by new capability; operational usage
1.1.9	Hardware Updates		?	Vendor Catalogue
2	Licenses		Roll-up	Vendor Catalogue
2.1	Licenses - Deployed Systems	Semi-Variable	Cost of license x Number of licenses	Vendor Catalogue; consider discounts
2.2	Licenses - Facility systems	Fixed	Cost of license x Number of licenses	Vendor Catalogue
3	Information Assurance		Roll-up	
3.1	IAVA	Semi-Variable	Average cost/yr; number of IAVAs/yr; cost/IAVA	Number of vendor alerts

Software Maintenance, Sustaining Engineering, and Operational Support

WBS	Title	Variability	CER Examples	Experiences / Practical Applications
4	Certifications & Accreditations		Roll-up	
4.1	Certifications & Accreditations - Non information assurance related	Fixed	Average cost for a specific C&A	External organization
4.2	DIACAP	Fixed	Average cost for a specific C&A	Set schedule
5	SW Sustaining Engineering		Roll-up	
5.1	Analysis and Studies	Variable	Number of Analysis Studies	Captured under SE/PM or just PM
5.2	Test Support	Semi-Variable	Depends on # of test events	
5.3	Delivery	Semi-Variable	Number of Docs	
5.4	User Training	Variable	Number of locations, users, user experience level	Painful
5.5	User Support	Variable	Number of locations, users, user experience level	
5.6	Field Support	Variable	Number of system configurations, locations, Op-Tempo	Perform training, installation, trouble shooting
6	Software Facilities & Infrastructure			
6.0	Software Facilities and Infrastructure	Fixed	# of components & # of people to support them	Security, SCIF
6.1	Development Facilities			
6.2	Integration and Test Facilities			
6.4	Tactical Equipment			
6.5	Test Equipment and Tools			
7	Management			
7.1	Program Management	Variable	Based on "Size" of software system; system criticality; system location	
7.1.1	Project Release Management			
7.1.2	Risk Management			
7.1.3	Measurement/ Analysis			
7.2	Contract Management			
7.3	Change Management			
7.4	Data Management			
7.5	Quality Assurance			
7.6	Process Management			
7.7	Personnel Management			

Workshop Summary

- ***Thank you to the attendees for your active and insightful participation***
- ***The Basis of Estimate working session was successful in highlighting nuances between domains and super domains***
- ***The CER working session was successful in identifying actual (and potential) cost estimating relationships for each of the Software Maintenance WBS elements***
- ***The Army Software Maintenance Study is ongoing... stay tuned for more results next year***

Contact Information

Dr. Brad Clark

**Software Metrics, Inc.
4345 High Ridge Road
Haymarket, Va. 20169
(703) 754-0115**

brad@software-metrics.com

Dr. Christopher Miller

**Quantitative Software Management (QSM)
2000 Corporate Ridge
Suite 700
McLean, VA 22102
(703) 749-3521**

Chris.miller@qsm.com

Army Software Maintenance Study

- ***Sponsored by U.S. Army Office of the Deputy Assistant Secretary of the Army for Cost & Economics (ODASA-CE)***
- ***Collaborative environment - diverse perspectives***
- ***Army, Air Force, Navy, OSD, Industry participation***
- ***Initial focus on ACAT-1 weapons system software maintenance costs***
- ***Technical approach based on measurement and estimation best practices***

SMSEOS WBS Ver 2.82 with Definitions

WBS	Title	Description	Notes
1.0	Software Maintenance	Those products and activities directly associated with modifying an operational software product or system	Includes software components Definition assumes software product delivery to one or more users
1.1	Software Release (N)	Summary of all software maintenance products and activities associated with a specific software maintenance release (N)	"Release" may be defined as a software system, product, or component depending on the program planning structure
1.1.1	Planning and Management	Those products and activities associated with developing plans, budgets and schedules for software maintenance releases and managing the development of the planned release	"Release" may be defined as a software system, product, or component depending on the program planning structure
1.1.2	Software Requirements	Those products and activities associated with defining the requirements to be included in a planned software release	The requirements profile for a planned release is generally defined by multiple change drivers, including defect correction, enhancements, perfective changes, information assurance mandates, and others
1.1.3	Architecture and Design	Those products and activities associated with analysis of the baseline software system architecture and software design and the identification and documentation of architecture and design modifications required	The products and activities in this cost element capture the costs associated with required architecture and design changes based on the requirements for the planned release. This element includes both preliminary and detailed design efforts
1.1.4	Change Implementation	Those products and activities associated with generating new code or changing existing baseline software to incorporate the requirements of a planned release	This element includes baseline code modifications, development of new code, integration of new and modified code into the existing software component, and associated unit testing. This element represents code and unit test.
1.1.4.1	Change Development	Those products and activities associated with baseline code modifications, development of new code, and integration of new and modified code into the existing software component	The actual changes implemented for a planned release is defined by multiple change drivers, including defect correction, enhancements, perfective changes, information assurance mandates, and others. The results of the architecture and design effort dictates how the requirements will be implemented
1.1.4.2	Unit Testing	Those products and activities associated with unit testing of new and modified software components	The unit testing performed for a planned release is dictated by the nature of the software changes implemented into the existing software baseline
1.1.5	Integration and Test	Those products and activities associated with the integration of new and modified software components into the baseline software system and integration testing of the revised functional software baseline	This element includes software subsystem and system integration activities as defined by the program integration process and costs associated with integration test planning and conduct. Integration testing may be conducted in a dedicated System Integration Test (SIT) facility
1.1.5.1	Test Planning	Those products and activities associated with preparing and reviewing software system integration test plans	This element focuses on development of the integration test plan

SMSEOS WBS Ver 2.82 with Definitions

WBS	Title	Description	Notes
1.1.5.2	Test Scenario and Test Case Development	Those products and activities associated with developing test cases and test scenarios required for integration testing	This element focuses on the development of integration test scenarios and test cases in accordance with the product-system requirements
1.1.5.3	Test Tool Development	Those products and activities associated with developing unique test tools and software required to drive integration test scenarios	This element focuses on the development of the test tools and drivers required to support the defined integration test scenarios and test cases
1.1.5.4	Test Conduct	Those products and activities associated with implementing the tests, capturing results, verifying that release requirements are satisfied, and generating regression test baselines for use in revalidating the system in the as future changes are implemented	This element focuses on the actual conduct of integration testing
1.1.6	Acceptance Test	Those products and activities associated with functional testing of the revised software baseline to determine if the requirements for the software product-system have been met	Acceptance testing may be conducted by the maintenance organization, the customer-user, or by an independent test organization. Acceptance testing may be conducted in a test facility or in an operational environment. This may serve as qualification testing
1.1.6.1	Test Planning	Those products and activities associated with preparing and reviewing software system acceptance test plans	This element focuses on development of the acceptance test plan(s)
1.1.6.2	Test Scenario and Test Case Development	Those products and activities associated with developing test cases and test scenarios required for acceptance testing	This element focuses on the development of acceptance test scenarios and test cases in accordance with the product-system requirements
1.1.6.3	Test Tool Development	Those products and activities associated with developing unique test tools and software required to drive acceptance test scenarios	This element focuses on the development of the test tools and drivers required to support the defined acceptance test scenarios and test cases
1.1.6.4	Test Conduct	Those products and activities associated with implementing the tests, capturing results, verifying that release requirements are satisfied, and generating regression test baselines for use in revalidating the system in the as future changes are implemented	This element focuses on the actual conduct of acceptance testing.
1.1.7	Rework	Those products and activities associated with rework across any of the software maintenance elements for a defined release	This element captures rework for all software maintenance tasks and products
1.1.8	Emergency Repairs	Those products and activities associated with the development and implementation of critical emergency changes to the operational software baseline	This element includes the products and activities that comprise the delivery of patch released to the end users in the field
1.1.9	Hardware Updates	Those products and activities associated with minor changes to the hardware configuration attributable to software design changes	This element includes those hardware costs driven by required software changes

SMSEOS WBS Ver 2.82 with Definitions

WBS	Title	Description	Notes
1.2	Software Release (N+1)	Instantiation of WBS elements 1.1.1 through 1.1.15 for a separate software release	"Release" may be defined as a software system, product, or component depending on the program planning structure
1.3	Software Release (N+2)		
1.4	Software Release (N+3)		
2.0	Licenses	Those products and activities associated with the procurement and renewal of software licenses for operational software for both deployed and facility based systems	License costs include both the cost of the license as well as the effort required to maintain technical market currency and to execute appropriate procurement actions
2.1	Licenses - Deployed Systems	Those products and activities associated with procuring and maintaining the requisite licenses for integrating and testing an operational software system	This element focuses on the software application licenses required to operate the fielded systems
2.2	Licenses - Facility systems	Those products and activities associated with procuring and maintaining the requisite licenses for integrating and testing an operational software system	This element focuses on the software application licenses required to operate the integration and test facility
3.0	Information Assurance	Those products and activities associated with ensuring that the software is compliant with externally defined information assurance requirements	This element is generally focused on system and computer network protection
3.1	IAVA	The products and activities associated with correcting and verifying application and operating system vulnerabilities as identified by applicable Information Assurance Vulnerability Alerts	This element includes changes to the software system associated with emerging information assurance requirements
4.0	Certifications & Accreditations	Those products and activities associated with verifying a software system against externally defined domain performance criteria inclusive of certifications needed to confirm safety, airworthiness, networkiness, information assurance, and other systems requirements	This element tends to be driven by externally mandated performance and safety requirements and information assurance compliance requirements. Verification methods may vary depending on specific requirements for different functional domains
4.1	Certifications & Accreditations - Non information assurance related	Those products and activities associated with verifying a software system against externally defined domain performance criteria inclusive of certifications needed to confirm safety, airworthiness, networkiness, and other systems requirements	This element tends to be driven by externally mandated performance and safety requirements and information assurance compliance requirements. Verification methods may vary depending on specific requirements for different functional domains
4.2	DIACAP	The products and services associated with the periodic conduct of DIACAP accreditation and certification for those computer networks used to maintain and operate the system.	This element includes all costs associated with certifying the software system for compliance with DOD security requirements and accrediting the system for operational use
5.0	Software Sustaining Engineering	Those products and activities associated with supporting a deployed software product or system in its operational environment	This element focuses on support to the user base for the product-system in question

SMSEOS WBS Ver 2.82 with Definitions

WBS	Title	Description	Notes
5.1	Analysis and Studies	Those products and activities associated with analyses and studies that address product-system operational issues and problems	This element addresses the costs associated with optimizing system employment or correcting operational performance and employment issues. The results may be used to generate both short-term and long-term change requirements
5.2	Test Support	The products and activities associated with supporting system integration testing, acceptance testing, and certification testing of the software release	This element generally includes the costs associated with release team support to various system test events
5.3	Delivery	The products and activities associated with preparing the software delivery package and providing initial user installation support	This element typically includes preparation of the software program package inclusive of required documentation, development of the version description document, and end-user installation support
5.4	User Training	Those products and activities associated with mentoring and training the system user base	This element generally addresses educating the users in new or revised system operational capabilities
5.5	User Support	Those products and activities associated with supporting the software product-system once it becomes operational. Such support includes distribution management, user help desks, technical support, logistics support, etc.	This element focuses on providing assistance to the end users with respect to product implementation, logistics, and identification of potential product changes
5.6	Field Support	Those products and activities associated with providing on-site user implementation technical assistance and support	This element addresses direct, on-site user technical support
6.0	Software Facilities and Infrastructure	Those products and activities associated with establishing and operating the facilities and processes required to modify, integrate, and test operational software products or systems	This element addresses the costs associated with implementing and maintaining a capability to perform software maintenance tasks
6.1	Development Facilities	Those products and activities associated with establishing and maintaining the software development facilities and the systems required to maintain the software for an operational system	This element includes the costs associated with the facility infrastructure, software development hardware and software, applicable networks, required software licenses, and operations, management, and maintenance of the facilities and the installed equipment - Development facilities and assets may be utilized by multiple programs
6.1.1	Equipment	Those products and activities associated with procuring, installing, and maintaining the software development equipment and networks required to maintain the software for an operational system	This element includes all hardware resources required to maintain and sustain the operational software systems
6.1.2	Operations	Those products and activities associated with managing and operating the software development facility	This element includes all costs associated with facility operations, security, and resource management

SMSEOS WBS Ver 2.82 with Definitions

WBS	Title	Description	Notes
6.2	Integration and Test Facilities	Those products and activities associated with establishing and maintaining the software integration and test facilities and systems required to integrate and test the software for a specific program	This element includes the costs associated with the facility infrastructure, integration and test hardware and software, applicable networks, required software licenses, and operations, management, and maintenance of the facilities and the installed equipment - Integration and test facilities and assets may be utilized by multiple programs
6.2.1	Equipment	Those products and activities associated with procuring, installing, and maintaining the software integration and test equipment and applicable networks required to integrate and test the software for an operational system	This element includes all hardware resources required to integrate and test the operational software system
6.2.3	Operations	Those products and activities associated with managing and operating the software integration and test facility	This element includes all costs associated with facility operations, security, and resource management
6.4	Tactical Equipment	Those products and activities associated with establishing and maintaining the suite of tactical hardware required to integrate and test the software for a specific program	This element includes the costs associated with tactical equipment logistics, installation, maintenance, and operation when used to validate and test software products - systems in an operational environment
6.5	Test Equipment and Tools	Those products and activities associated with developing, procuring, installing, and maintaining specialized test equipment and software tools required to test the operational software system	This element includes the costs to establish and maintain the resources necessary to implement a realistic system test environment - These resources may be utilized by multiple programs
7.0	Management	Those products and activities associated with planning, organizing, funding, resourcing, and controlling the resources required to support operational software products or systems to achieve mission and performance objectives	This element addresses the management of all software maintenance and sustaining engineering functions. In general the management products and activities are applied across the entire program product set
7.1	Program Management	Those products and activities associated with planning, organizing, funding, resourcing, and controlling all software maintenance, sustaining engineering, and operational support tasks for a program	This element focuses on the management requirements for a single program, which includes multiple products and releases. Project management for a single product or release is included in WBS element 1.1.1
7.1.1	Project Release Management	Those products and activities associated with planning and managing the portfolio of products and releases for a program	This element focuses on the allocation of requirements across the portfolio of planned releases and the allocation or resources across the entire program product baseline. It also includes distribution management.

SMSEOS WBS Ver 2.82 with Definitions

WBS	Title	Description	Notes
7.1.2	Risk Management	Those products and services associated with identifying, evaluating, treating, and monitoring the risks associated with program software maintenance, sustaining engineering, and operational support efforts	This element focuses on identifying and managing the risks associated with software maintenance, sustaining engineering, and operational support efforts for a program
7.1.3	Measurement/ Analysis	Those products and services associated with planning and implementing a software measurement process that generates objective decision information to evaluate the performance of software maintenance, sustaining engineering, and operational support efforts for a program	This element focuses on measuring and analyzing objective performance related data to support software maintenance, sustaining engineering, and operational support planning and execution decisions for a program
7.2	Contract Management	Those products and activities associated with contracting for software maintenance, sustaining engineering, and operational support services for a program	This element focuses on the management tasks required to define, award, fund, monitor, and evaluate the contracts required to support program software maintenance, sustaining engineering, and operational support tasks. It also includes vendor coordination efforts.
7.3	Change Management	Those products and activities associated with tracking and controlling changes to the program software baselines	This element addresses the entirety of the change management activities and processes for all established and future software baselines for a program - This includes all configuration management activities, including tasks performed by the program change control board, managing user change requests, and other related efforts - Change management costs may be allocated to specific releases or products. Change analysis and investigation is included in this cost element.
7.4	Data Management	Those products and activities associated with establishing, maintaining, securing, and utilizing program data and information resources	This element focuses on the costs related to managing the data resources required to maintain, sustain, and support a software system
7.5	Quality Assurance	Those products and activities associated with ensuring the quality and integrity of the processes implemented and the products generated in software maintenance, sustaining engineering, and operational support for a fielded software system	This element focuses on the quality engineering and system assurance efforts applied to a software release or system product. It may include software IV&V efforts
7.6	Process Management	Those products and activities associated with defining, implementing, and improving the technical and management processes implemented for software maintenance, sustaining engineering, and operational support	This element focuses on the process related activities applied to the software maintenance, sustaining engineering, and operational support tasks
7.7	Personnel Management	Those products and activities associated with establishing and maintaining a qualified workforce with the skills required to maintain, sustain, and support the specific software system	This element focuses on the number of personnel available with the skill sets required to maintain, sustain, and support the operational software system

Software Application Super-Domains

The term "mission critical software" is used as a catchall, sometimes as a synonym for "embedded software" (e.g., hosted in aircraft and tanks) and sometimes defined more broadly. In analyzing the patterns of software maintenance, we found it helpful to be more specific and distinguish among three categories of mission-related software that undergo maintenance: mission critical, embedded; mission critical, nonembedded; and mission support (Table 1-1). Broadly speaking, within a category different organizations may use similar processes; across categories they generally do not.

Table 1-1. Software Maintenance Categories

Type	Cardinal characteristics	Examples	Approximate Cost / LOC / YR
Mission critical, Embedded	<ul style="list-style-type: none"> • Tightly coupled interfaces • Real-time response requirements • Very high reliability requirements (life critical) • Generally severe memory and throughput constraints • Often executed on special-purpose hardware 	<ul style="list-style-type: none"> • B-1 flight software • F-14 flight software • Tanks 	<ul style="list-style-type: none"> • \$110.00
Mission critical, Non-Embedded	<ul style="list-style-type: none"> • Multiple interfaces with other systems • Constrained response time requirement • High reliability but not life critical • Generally executed on commercial off-the- shelf (COTS) 	<ul style="list-style-type: none"> • Command, control, and communications (C3) • Space systems 	<ul style="list-style-type: none"> • \$5.60
Mission Support	<ul style="list-style-type: none"> • Relatively less complex • Self-contained or few interfaces • Less stringent reliability requirement 	<ul style="list-style-type: none"> • Automatic test equipment (ATE) • Test Package Sets (TPSs) • Mission planning • Business systems 	<ul style="list-style-type: none"> • \$0.81A

These categories correspond roughly to those described in Boehm as embedded, semidetached, and organic¹. Because in DoD maintenance the term "organic" is frequently used when referring to the government labor force, we have substituted the term "support" to describe the third class of software. Support software includes Automatic Test Equipment and, more specifically, Test Package Sets as well as software for simulation and training. The distinctions among these three classes of software have several important implications:

- They differ in their complexity and, consequently, in their cost to develop and maintain. [In fact, Boehm's Constructive Cost Model (COCOMO)— the most widely used software cost model—has three different cost and schedule equations to cover these three different

¹Barry W. Boehm, *Software Engineering Economics*, Englewood Cliffs, NJ: Prentice Hall, 1981.
PSM Conf 2012 Workshop #7 SWMX CERs Handout

Software Application Super-Domains

types of software.] Embedded software is much more complex and costly to develop and maintain. It is characterized by tightly coupled interfaces with hardware components and often with other hardware-software systems, real-time response requirements, very high reliability requirements, and often very constrained memory and processing capacity.

- They differ in terms of the nature of the associated maintenance activity, which primarily consists of functional enhancements for the first two and defect corrections for the third.
- They differ in terms of the skill set and amount of tacit knowledge required for maintenance—with implications for who can maintain the software, i.e., organic personnel or original equipment manufacturer (OEM) contractor.

The full report is available from:

<http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA334790>



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1600 – 1645	Working Session #2
1645 -1700	Wrap-up

Attendees

Please sign attendance sheet

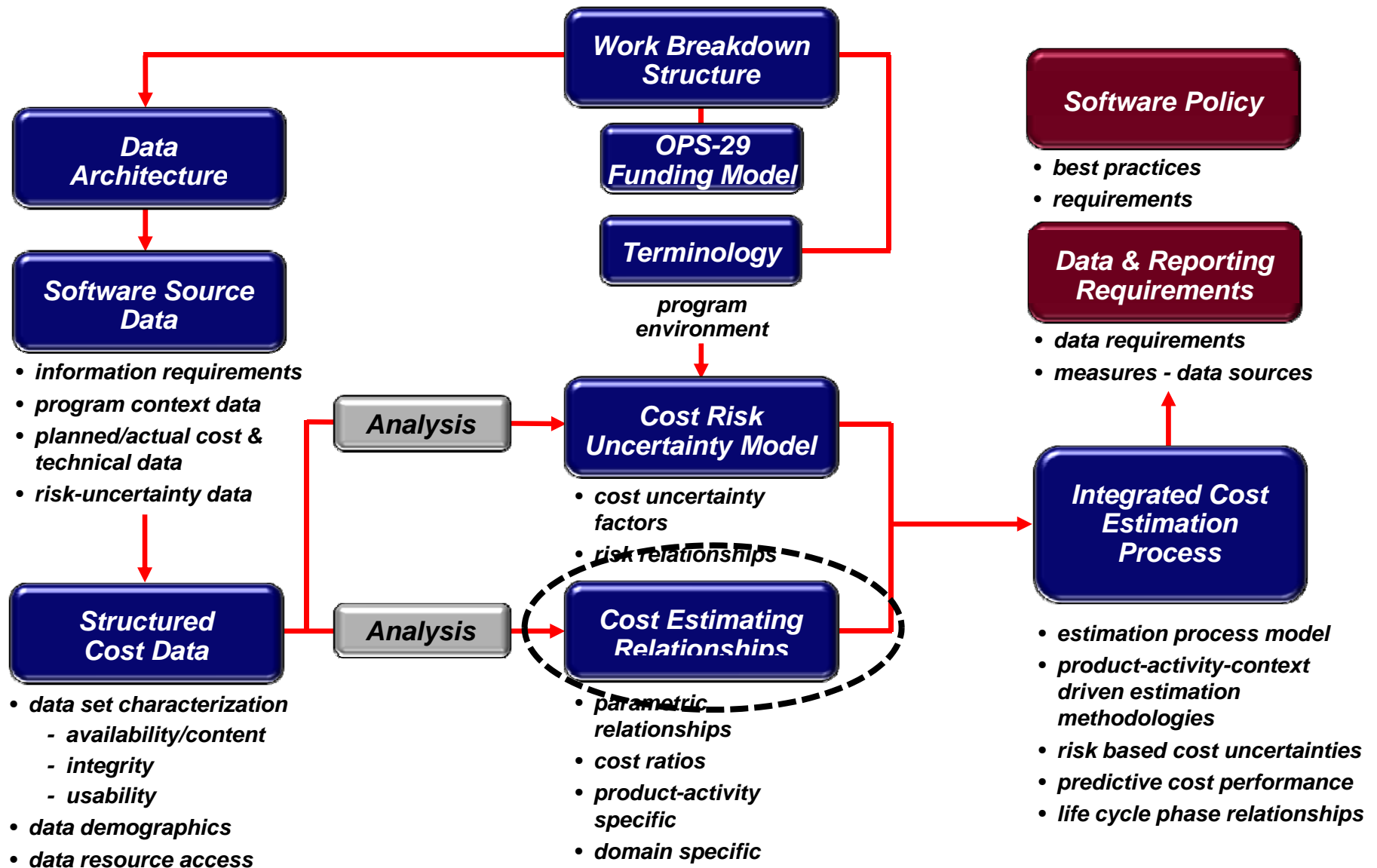
Software Maintenance Study Objective

Provide the Department of the Army with the ability to accurately estimate, budget, allocate, and justify the software maintenance, sustaining engineering, and operational support resources required to meet evolving mission and service affordability requirements across the program life-cycle

Workshop Overview

- **Prerequisites:**
 - ***This workshop will build on the results of the current DoD, Army, Air Force, and Navy initiatives and the 2009 and 2010 PSM Conference Workshops by focusing on software maintenance:***
 - ***Work Breakdown Structure (WBS) as a basis of estimates and***
 - ***Preliminary Cost Estimation Relationships (CER).***
- **Discussion:**
 - ***Participants should come to the workshop prepared discuss their experiences with software maintenance estimation and if possible bring practical applications for estimating software maintenance.***
- **Goals/Products:**
 - ***As stated in the Software Maintenance Study Objective, improve the accuracy of software maintenance cost estimates which should drive budgeting, allocating and justification of maintenance funds.***
 - ***Therefore we are seeking participant input on:***
 - ***Relative costs in different areas of the WBS segmented by Operating Environment and Application Super-Domain***
 - ***How cost in different areas in the WBS might be estimated***
 - ***Our approach to integrating CERs to produce an overall estimate of next year's maintenance cost.***

Software Maintenance, Sustaining Engineering, and Operational Support



Summary Work Breakdown Structure

Software Maintenance, Sustaining Engineering,
and Operational Support



Application Super-Domains

- **Mission Critical, Embedded**
- **Mission Critical, Non-Embedded**
- **Mission Support**
- **Differences:**
 - **They differ in their complexity and, consequently, in their cost to develop and maintain.**
 - **Embedded software is much more complex and costly to develop and maintain.**
 - **It is characterized by tightly coupled interfaces with hardware components and often with other hardware-software systems, real-time response requirements, very high reliability requirements, and often very constrained memory and processing capacity.**
 - **They differ in terms of the nature of the associated maintenance activity, which primarily consists of functional enhancements for the first two and defect corrections for the third.**
 - **They differ in terms of the skill set and amount of tacit knowledge required for maintenance—with implications for who can maintain the software, i.e., organic personnel or original equipment manufacturer (OEM) contractor.**

Relative WBS Costs

Super Domains: Mission Critical-Embedded / Non-Embedded / Mission Support					
WBS Element	Operating Environment				
	Ground	Air	Sea	Missiles	Space
1. Software Maintenance					
2. Software Licenses					
3. Information Assurance					
4. Certifications & Accreditation					
5. Sustaining Engineering					
6. Facilities & Infrastructure					
7. Management					

Rate each element

Scale: 0 means no cost

5 means most of the cost

Break

Summary Work Breakdown Structure

Software Maintenance, Sustaining Engineering,
and Operational Support



Work Breakdown Structure

- 1.0 Software Maintenance - products and activities associated with modifying an operational software product or system**
- 2.0 Software Licenses - products and activities associated with the procurement and renewal of software licenses for operational software**
- 3.0 Information Assurance - products and activities associated with ensuring that the software is compliant with externally defined information assurance requirements**
- 4.0 Certifications and Accreditations - products and activities associated with verifying a software system against externally defined domain performance criteria**
- 5.0 Sustaining Engineering - products and activities associated with supporting a deployed software product or system in its operational environment**
- 6.0 Facilities & Infrastructure - products and activities associated with establishing and operating the facilities and processes required to modify, integrate, and test operational software products or systems**
- 7.0 Management - products and activities associated with planning, organizing, funding, and controlling the resources required to support operational software products or systems**

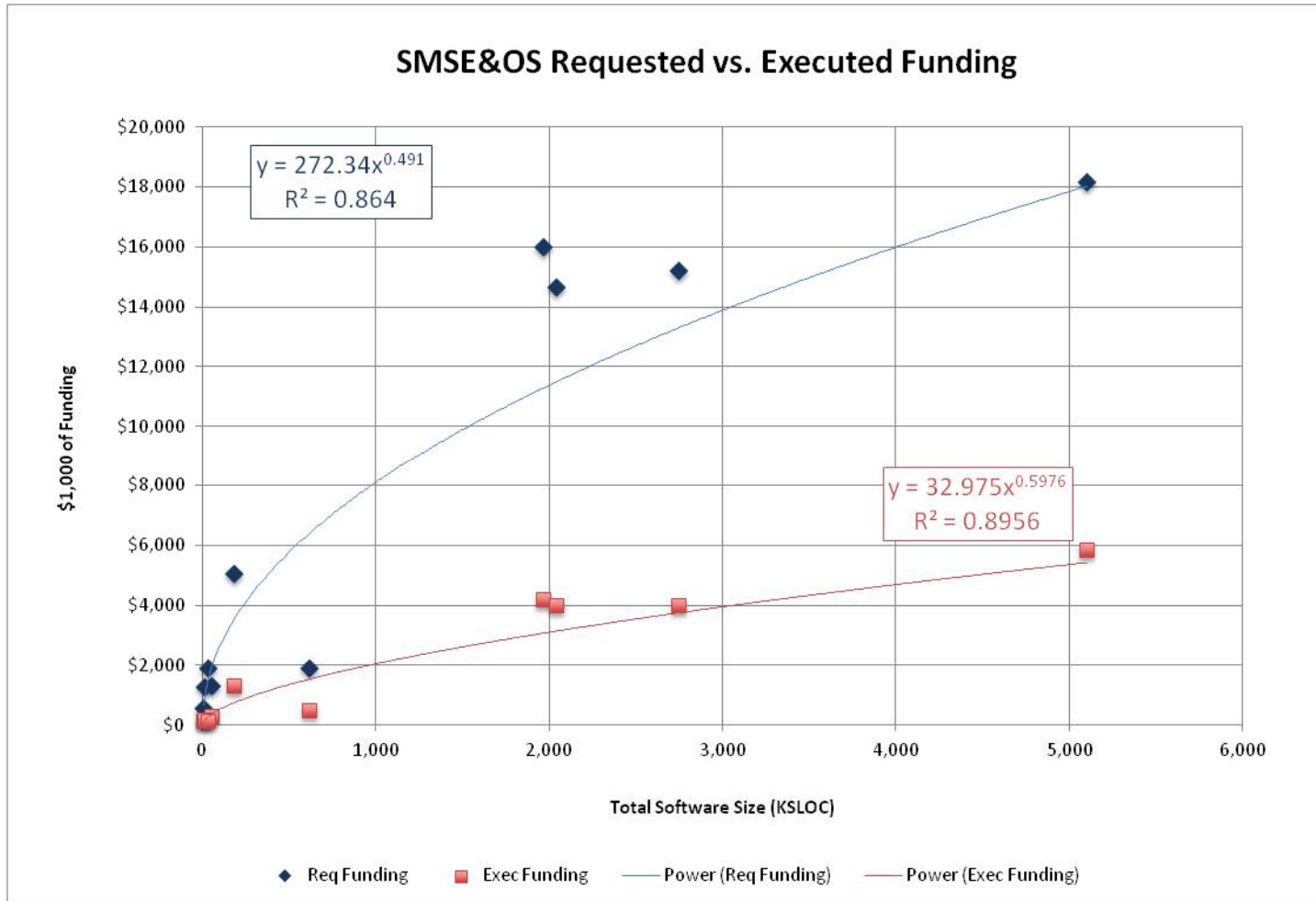
Cost Estimating Relationships

- **Types of cost estimating relationships:**
 - **Systemic ratios**
 - **Parametric models**
 - **Simple relationships**
 - **Historical cost trends**
- **Approach:**
 - **Ratios useful to identify performance relationships**
 - **Product costs structured into software releases - estimated parametrically based on functional change content**
 - **Activity costs estimated using simple CER relationships - unique variables and drivers**
 - **Fixed costs based on historical resource expenditures**
 - **Related factors influence and/or modify the outcomes in all cases**

Correlation Coefficients Matrix

Correlation Coefficients Matrix						
Sample size		8	Critical value (10%)	1.94		
		Interfaces	Age	Est_Total_KSLOC	Req_Fund_FY11	Exec_Fund_FY11
Interfaces	Pearson Correlation Coefficient	1.00				
	<i>R Standard Error</i>					
	<i>t</i>					
	<i>p-value</i>					
	<i>H0 (10%)</i>					
Age	Pearson Correlation Coefficient	0.47	1.00			
	<i>R Standard Error</i>	0.13				
	<i>t</i>	1.31				
	<i>p-value</i>	0.24				
	<i>H0 (10%)</i>	accepted				
Est_Total_KSLOC	Pearson Correlation Coefficient	0.70	0.23	1.00		
	<i>R Standard Error</i>	0.08	0.16			
	<i>t</i>	2.43	0.58			
	<i>p-value</i>	0.05	0.58			
	<i>H0 (10%)</i>	rejected	accepted			
Req_Fund_FY11	Pearson Correlation Coefficient	0.39	0.30	0.87	1.00	
	<i>R Standard Error</i>	0.14	0.15	0.04		
	<i>t</i>	1.04	0.77	4.41		
	<i>p-value</i>	0.34	0.47	0.00		
	<i>H0 (10%)</i>	accepted	accepted	rejected		
Exec_Fund_FY11	Pearson Correlation Coefficient	0.50	0.59	0.81	0.94	1.00
	<i>R Standard Error</i>	0.13	0.11	0.06	0.02	
	<i>t</i>	1.41	1.78	3.40	6.87	
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	<i>H0 (10%)</i>	accepted	accepted	rejected	rejected	

Funding vs. Software Size



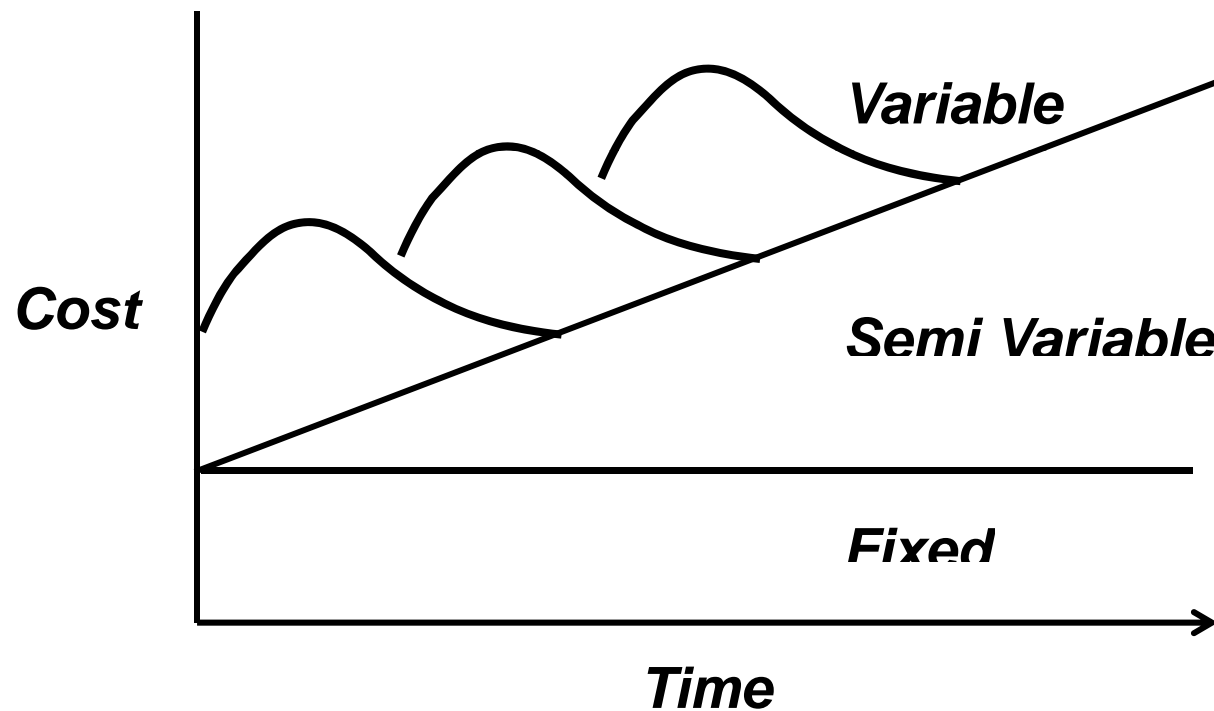
Preliminary Cost Relationships

- **Results**
 - ***Estimated total system KSLOC and number of interfaces had the highest correlation to both funded and executed funding***
 - ***Requested and executed funding varied by a factor of 3***
 - ***There is an implied prioritization of applied funding by subsystem (domain - weapons system vs. training system)***
 - ***System age had no appreciable cost impact***
 - ***There is a non-linear relationship between software system size and cost for software maintenance (resource constraints)***
 - ***Measurable software development characteristics available early in the life cycle may be early predictors of software maintenance life cycle cost***

WBS Based Cost Estimating Relationships

WBS	Title	Army OPS-29 Mapping	Variability	Cost Drivers Examples
1.1	Software Release			Lower level cost roll-up
1.1.1 to 1.1.5	Planning, Req'ts, Design, Implementation, Development, Unit Testing, Integration & Test (typical SW Development)	Capability Sets FY(XX/XX) System Mission Capability	Variable Cost	Parametric modeling - Number of Requirements (Enhancements), Defects, Test Cases - added, reused, modified; App. Domain, Complexity, Reliability, Personnel Factors
1.1.6	Acceptance Test	Capability Sets FY(XX/XX) System Mission Capability	Variable Cost	Number of requirements / capabilities / ... / test cases / etc.)
2.0	Licenses	Licenses	Semi-Var	Type and number of COTS products.
3.1	IAVA	IAVA	Semi-Var Cost	Parametric model (percentage distribution); Application domain, size, effort staffing, duration, productivity
4.0	Certifications & Accreditations	C&A	Fixed	Cost per C&A
5.0	SW Sustaining Engineering		Roll-up	Lower level cost roll-up
5.1 to 5.5	Analysis, Test Support, Delivery, Training	Organic Labor	Semi-Var Cost	LOE
5.6	Field Support	FSEs	Semi-Var	LOE, No. of Field Sites
6.0	Software Facilities & Infrastructure	System Infrastructure or System Open Door	Fixed	# People at facility, Simulation / Test Equip Maintenance
7.0	Management	Organic	Roll-up	Lower level cost roll-up
7.1 to 7.7	Program / Release / Risk / Contract Management		Fixed Cost	LOE

Types of Cost Estimating Relationships



Software Maintenance Cost Estimation Model

- ***Objectives***
 - ***Use available data to construct a multi-CER cost estimate for a sample program - compare to program actuals***
 - ***Identify program cost allocations***
 - ***Validate integrity - usability of provided data***
- ***Scope***
 - ***5 Year PPSS time period - 4 capability sets (2006-2011)***
 - ***All included software maintenance WBS elements***
 - ***Applied CERs - Proof of Concept***
 - ***Parametric model - capability sets / releases (SLIM)***
 - ***Semi-variable - IAVAs, licenses, certification, etc.***
 - ***Fixed costs - infrastructure and management***

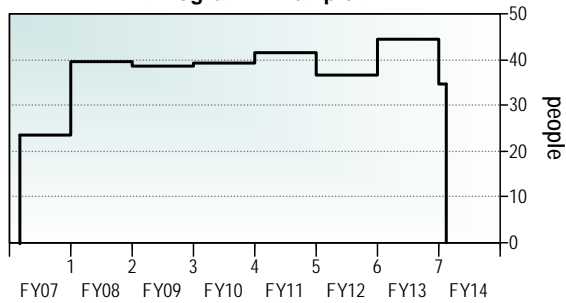
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- ***Results for one sample program***
 - ***Software capability sets are most significant cost item based on program allocations and expenditures (55%)***
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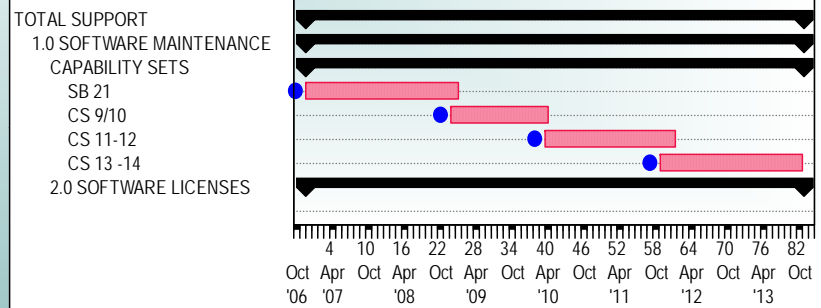
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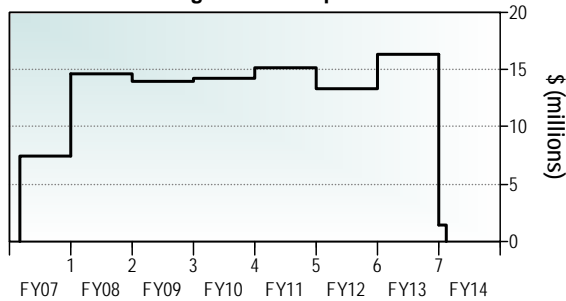
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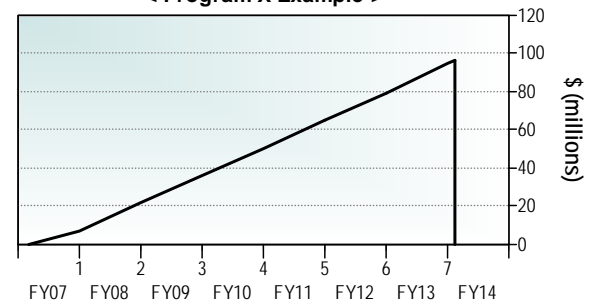
Monthly Gantt Chart (L4)
< Program X Example >



Fiscal Yearly Cost Rate (L2)
< Program X Example >



Fiscal Yearly Cum Cost (L2)
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Software Maintenance, Sustaining Engineering, and Operational Support

Working Session #2: Generate a list of CERs which have been used in practice and discuss practical applications based on attendees experiences

WBS	Title	Variability	CER Examples	Experiences / Practical Applications
1.1	Software Release			
1.1.1 to 1.1.5	Planning, Req'ts, Design, Development, Unit Testing, Integration & Test			
1.1.6	Acceptance Test			
2.0	Licenses			
3.1	IAVA			
4.0	Certifications & Accreditations			
5.0	SW Sustaining Engineering	Roll-up		
5.1 to 5.5	Analysis, Test Support, Delivery, Training			
5.6	Field Support			
6.0	Software Facilities & Infrastructure			
7.0	Management	Roll-up		
7.1 to 7.7	Program / Release / Risk / Contract Management			

22 - 27 June 2012

Workshop Summary

- ***Army***

Back-up

Presentation Outline

- ***Current software maintenance estimation technology does not support objective resource decisions in the emerging Army systems sustainment environment***
- ***Defining a viable software maintenance cost estimation methodology for Army programs - project requirements, approach, and initial results***
- ***Integrated software maintenance life cycle cost estimation model - linking software maintenance resource requirements to program and functional domain sustainment profiles***

***Estimating Software Maintenance Costs
in the Current Army Sustainment
Environment***

Army Software Maintenance Environment

- ***Software is the “default component” for increasing system capability and performance***
- ***Operational requirements are dynamic and complex***
- ***Maintenance budgets are becoming more constrained and vulnerable***
- ***Difficult to defend program software life cycle cost estimates and annual maintenance budget requests***
- ***Limited understanding of the relationships between software investments, applied resources, product outputs, and mission capability***
- ***Multiple perspectives: enterprise - program - maintenance organization - user base***
- ***Existing software maintenance estimation methodologies are inadequate***

Software System Growth



107 - AH-64As



1620 - AH-64Ds

***Apache Software Growth
300 KSLOC to Over 1.4 Million SLOC***

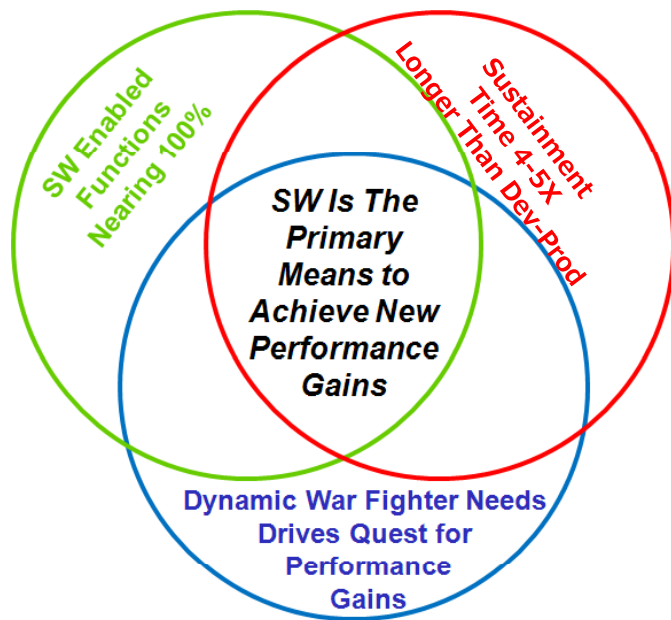
Software Configuration Complexity



4,300 - M1A1 & variants
580 - M1A2 & variants
580 - M1A2 SEP & variants

- **Multiple system variants drive multiple parallel software release baselines**
- **Different “types” of concurrent software releases**
 - **Correct defects**
 - **Fault prevention - mandates**
 - **Enhance functionality**
 - **Adapt to new environments**
- **Multiple change drivers**
 - **End user requirements**
 - **Mission evolution**
 - **System interoperability**
 - **Change mandates**
 - **Technology**
 - **Technical debt**

Significant Growth in Army Software Maintenance Resource Requirements (\$)



- **Reliance on software changes to meet evolving mission requirements**
- **Proliferation of system software variants**
- **Increasingly complex system to system functional interfaces**
- **Proliferation of change drivers**
- **Functional change backlogs**
- **Budget realignments**

“We’ve lived in a rich man’s world where there has been less emphasis on cost over the past 10 years.”

Dr. Jacques Gansler

Current Software Maintenance Estimation Methods

- **Parametric models**
 - **Only include corrective, perfective, adaptive changes & enhancements**
 - **Invalid assumptions about sustaining engineering tasks**
 - **Historical data not visible in all models**
 - **Not calibrated - validated**
- **Past software maintenance funding - effort**
 - **Limited access to historical FTE - Budget data**
 - **Represent “rolled-up” costs**
 - **Requirements or LOE funding?**
 - **Availability of correlated program development - sustainment cost data**

Current Estimation Methods (continued)

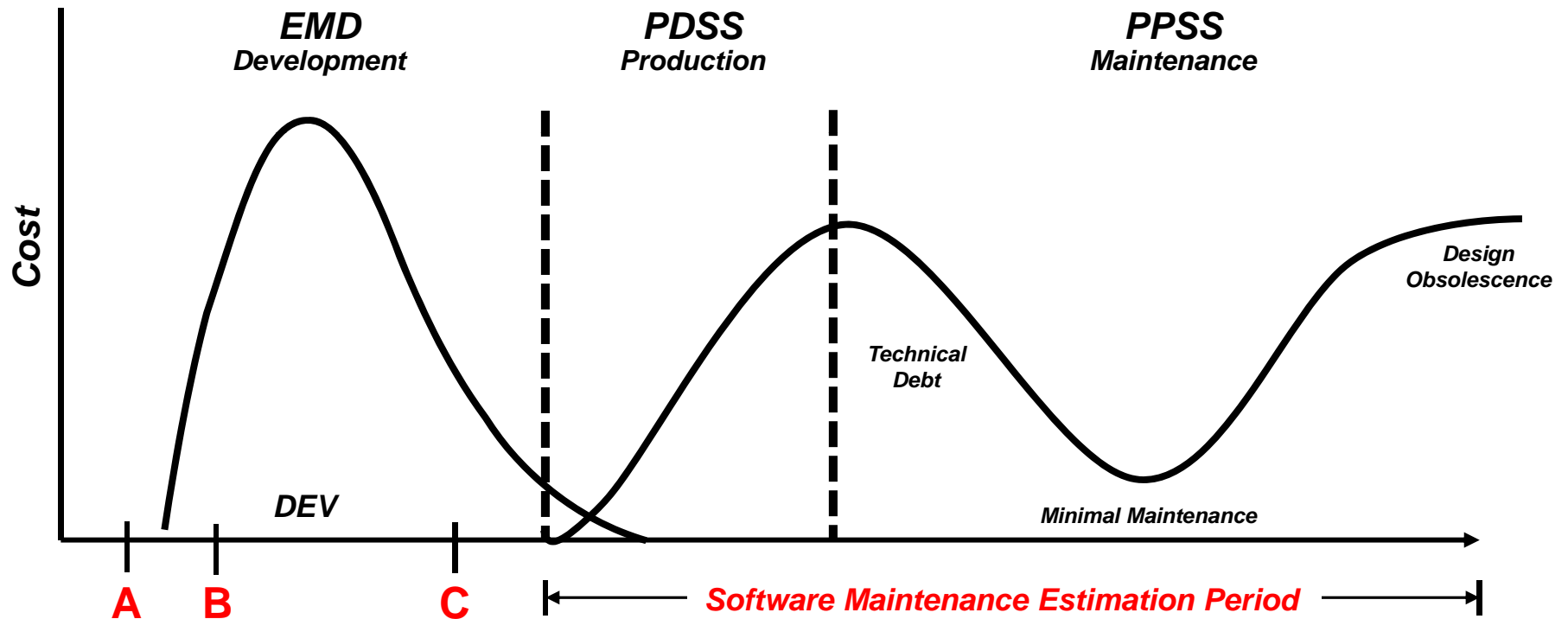
- ***Number of lines of code per software engineer***
 - *Each engineer can maintain 20K-25K LOC/ESLOC*
 - *Does not reflect the impact of software reuse or COTS*
- ***Software maintenance estimated as a percentage of development costs***
 - ***Rule(s) of thumb - development based:***
 - *S/W maintenance costs - 2/3 of total S/W life cycle costs*
 - *S/W maintenance costs - 60% to 75% of total S/W life cycle costs*
 - *Annual S/W maintenance costs - 5% to 10% of total S/W life cycle costs*
 - *Ignores total system life cycle software growth and maintenance requirements/strategy/tasks*

***All of these methods have significant limitations
in the current and future Army environment***

Key Estimation Issues

- ***Current software maintenance estimation methods:***
 - ***Do not align with an individual program's unique life cycle sustainment profile***
 - ***Assume software maintenance resource requirements are consistent after system deployment***
 - ***Do not take into account specific software maintenance products and related activities for a given program (what's in and what's out)***
 - ***Do not encompass multiple types of cost relationships***
 - ***Do not address the differences across functional software domains***
 - ***Are high level constructs based on significant assumptions of commonality***

Notional Software Maintenance Life-Cycle Cost Model



Summary

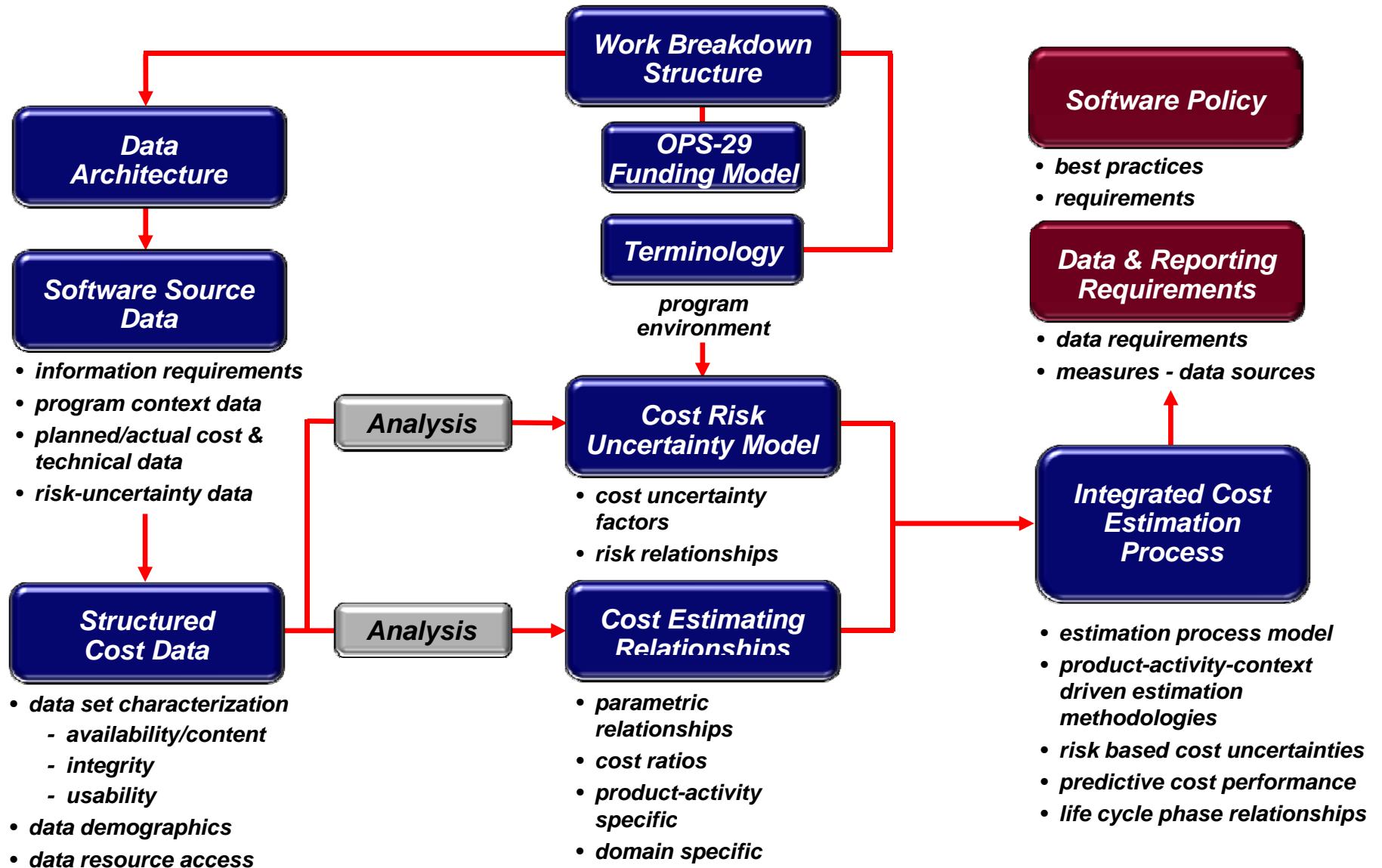
- ***Army system mission capability is dependent upon the adequate resourcing of program software maintenance requirements***
- ***To ensure this the Army needs a software maintenance estimation methodology that better reflects the software change profile and related employment characteristics of the system***

***Software Maintenance Estimation Project
Requirements, Approach, and
Initial Results***

Estimation Methodology Requirements

- ***Define a software maintenance cost estimation methodology that integrates the product release and software support costs over the life-cycle of a program***
 - ***Configurable to the specific program software maintenance improvement and release strategy***
 - ***Encompasses PDSS and PPSS efforts***
 - ***Applicable at Milestones A, B, and C***
 - ***Integrates component cost estimates from multiple CER based product and activity estimates (WBS defined)***
 - ***Directly related to development parameters and performance***
 - ***Can incorporate cost risk uncertainty at component and higher levels***
 - ***Practical - defensible - data derived - adaptable***

Software Maintenance, Sustaining Engineering, and Operational Support



Project Approach

- **Establish software maintenance technical standards and baselines**
 - **Software maintenance products and activities**
 - **Configurable and adaptable WBS**
 - **Army software maintenance and sustaining engineering process model**
 - **Common terminology**

- **Collect, evaluate, and structure relevant Army software maintenance data**
 - **Data collection**
 - **Army program cost data - all relevant parameters**
 - **Army program, organizational, and enterprise context data**
 - **Navy, Air Force, and contractor data**
 - **Data evaluation - availability, integrity, usability**
 - **Data schema and accessible data store**
 - **Historical cost data**
 - **Derived CERs**
 - **Estimation data requirements**

Project Approach (continued)

- **Independent analysis and model development**
 - *Data and information model*
 - *Product sizing models*
 - *Cost estimation relationships*
 - *Cost risk - uncertainty model*
 - *Life cycle integrated cost estimation model*

- **Define Army software maintenance data collection and policy change requirements**
 - *Information driven program and organization data requirements*
 - *Post development policy requirements*
 - *Required information infrastructure changes*

- **Implement and improve**
 - *Data stores - estimation assets*
 - *Estimation and risk-uncertainty model*
 - *Estimation processes*
 - *Emerging stakeholder information requirements*

Work Breakdown Structure

- ***Common structure that includes all potential products and activities - “what’s in - what’s out”***
- ***Common definitions - terminology***
- ***Emphasis on DOD weapons systems***
- ***Basis for identifying specific cost elements attributable to a given program or system maintenance/sustaining engineering effort***
- ***Product based - driven by changes to the software baseline(s)***
- ***Release focused - primary software maintenance product***
- ***Intended to be tailored and adapted for each program or organization:***
 - ***Addition/deletion of lower level cost elements***
 - ***Re-binning of lower level cost elements***
- ***Foundation for cost estimation process/models***
- ***Basis for defining cost estimating relationships***

Work Breakdown Structure

Software Maintenance, Sustaining Engineering,
and Operational Support



Version 2.81

Work Breakdown Structure

- 1.0 Software Maintenance - products and activities associated with modifying an operational software product or system**
- 2.0 Software Licenses - products and activities associated with the procurement and renewal of software licenses for operational software**
- 3.0 Information Assurance - products and activities associated with ensuring that the software is compliant with externally defined information assurance requirements**
- 4.0 Certifications and Accreditations - products and activities associated with verifying a software system against externally defined domain performance criteria**
- 5.0 Sustaining Engineering - products and activities associated with supporting a deployed software product or system in its operational environment**
- 6.0 Facilities & Infrastructure - products and activities associated with establishing and operating the facilities and processes required to modify, integrate, and test operational software products or systems**
- 7.0 Management - products and activities associated with planning, organizing, funding, and controlling the resources required to support operational software products or systems**

Program WBS Element Coverage

WBS	Title	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.0	Software Maintenance	17																														
1.1	Software Release (N)	7																														
1.1.1	Planning and Management	19																														
1.1.2	Software Requirements	24																														
1.1.3	Architecture and Design	24																														
1.1.4	Change Implementation	23																														
1.1.4.1	Change Development	7																														
1.1.4.2	Unit Testing	7																														
1.1.5	Integration and Test	24																														
1.1.5.1	Test Planning	8																														
1.1.5.2	Test Scenario and Test Case Development	8																														
1.1.5.3	Test Tool Development	8																														
1.1.5.4	Test Conduct	8																														
1.1.6	Acceptance Testing	29																														
1.1.6.1	Test Planning	7																														
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1.1.6.3	Test Tool Development	7																														
1.1.6.4	Test Conduct	7																														
1.1.7	Rework	7																														
1.1.8	Emergency Repairs	25																														
1.1.9	Hardware Updates	15																														
1.2	Software Release (N+1)	0																														
1.3	Software Release (N+2)	0																														
1.4	Software Release (N+3)	0																														
2.0	Licenses	11																														
3.0	Information Assurance	27																														
3.1	IAVA	12																														
3.2	DIACAP	11																														
4.0	Certifications & Accreditations	12																														

Army Software Maintenance Data

		Number of Releases	WBS Task Performed	Interfaces	Effort	Cost (\$)	Schedule	Software Change Requests (SCRs)	Requirements	Defects	Backlog	Source Lines of Code	OPS-29 Data
Org 1	Program 1	3											
	Program 2	1											
	Program 3	1											
	Program 4	4											
	Program 5	1											
	Program 6	3											
	Program 7	1											
	Program 8	1											
	Program 9	1											
	Program 10	4											
	Program 11	4											
	Program 12	1											
	Program 13	1											
Org 2	Program 1	2											
	Program 2	2											
	Program 3	5											
	Program 4	3											
	Program 5	1											
	Program 6	4											
	Program 7	2											
	Program 8	2											
	Program 9	1											
Org 3	Program 1	1											
Org 4	Program 1	6											
	Program 2	2											
	Program 3	3											
	Program 4	7											
Org 5	Program 1	Multiple											
	Program 2	Multiple											
	Program 3	Multiple											
Org 6	Program 1	3											
	Program 2	6											
	Program 3	3											
	Program 4	8											
	Program 5	1											
		88											

Data Analysis Summary

- **Availability of data varied significantly by organization and program**
- **Execution data (actuals) was very limited - most data was planning data aligned with the OPS-29 funding model**
- **Multiple funding streams exist for similar work**
- **Data was cost based - not product/activity based**
- **Software engineering data derived from different source artifacts for a given release were sometimes inconsistent**
- **The aggregation levels of provided data were inconsistent (details vs. summary)**
- **The data that was available provided significant insight into potential cost estimating relationships and maintenance products and activity allocations**

Operating Environments - Domains

Count of Operating Environment					
	Helicopter	UAV	Ground	Missile	Grand Total
Mission Processing			5		5
Real Time Embedded - Other	3		5		8
System			4		4
Training			6		6
Vehicle Control		2		2	4
Vehicle Payload			2		2
Grand Total	3	2	22	2	29

Count of Super-Domain					
	Helicopter	UAV	Ground	Missile	Grand Total
Mission Critical - Embedded	3	2	7	2	14
Mission Critical - Non-Embedded			9		9
Mission Support			6		6
Grand Total	3	2	22	2	29

Application Domain Types

Embedded

- ***Sensor Control and Signal Processing***
- ***Vehicle Control***
- ***Vehicle Payload***
- ***Real Time Embedded***
- ***Mission Processing***

Non Embedded

- ***Systems Software***
- ***Automation and Process Control***
- ***Simulation & Modeling***

Mission Support

- ***Training***
- ***Test***
- ***Data Processing***

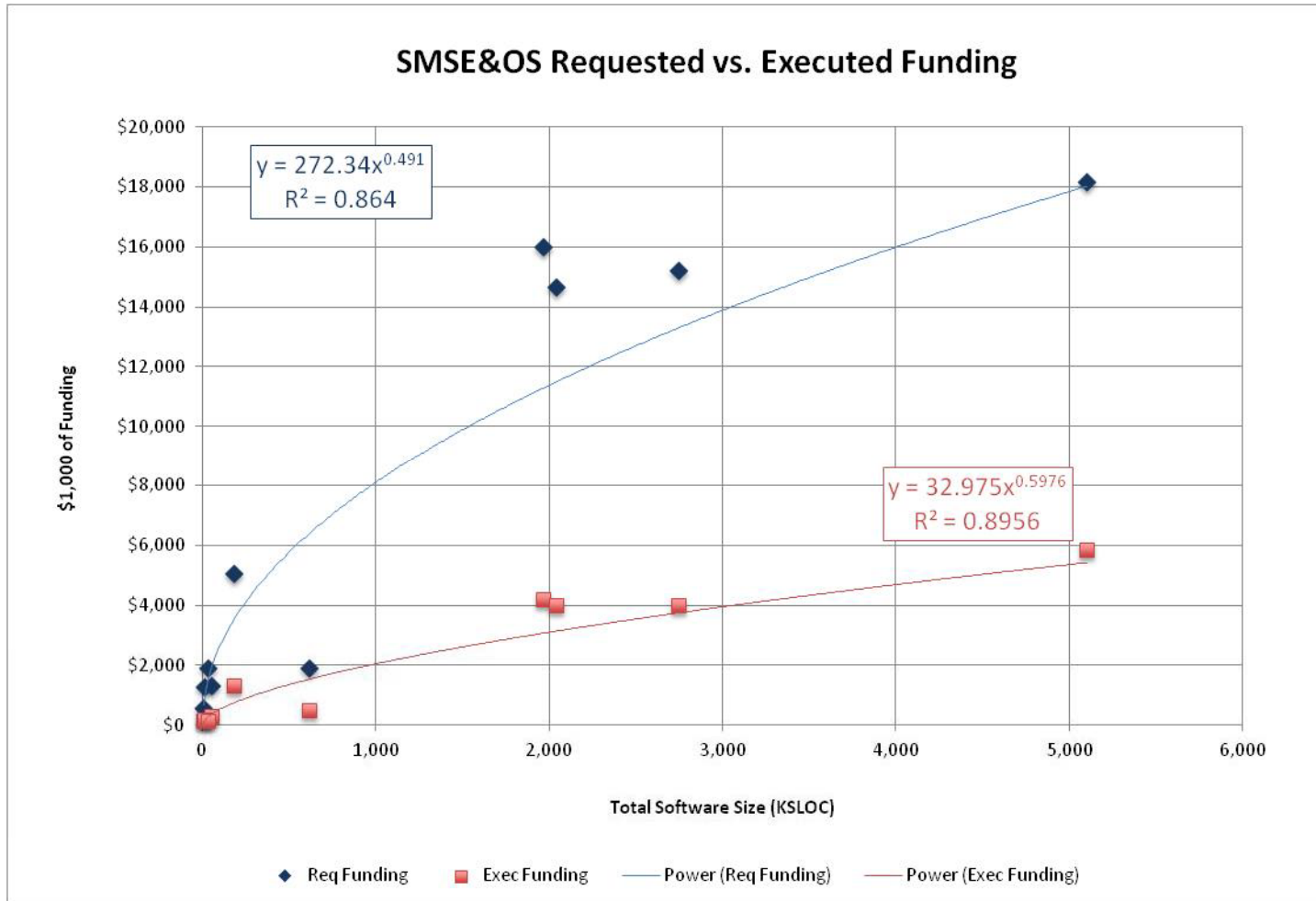
Cost Estimating Relationships

- **Types of cost estimating relationships:**
 - **Systemic ratios**
 - **Parametric models**
 - **Simple relationships**
 - **Historical cost trends**
- **Approach:**
 - **Ratios useful to identify performance relationships**
 - **Product costs structured into software releases - estimated parametrically based on functional change content**
 - **Activity costs estimated using simple CER relationships - unique variables and drivers**
 - **Fixed costs based on historical resource expenditures**
 - **Related factors influence and/or modify the outcomes in all cases**

Correlation Coefficients Matrix

Correlation Coefficients Matrix						
Sample size		8	Critical value (10%)	1.94		
		Interfaces	Age	Est_Total_KSLOC	Req_Fund_FY11	Exec_Fund_FY11
Interfaces	Pearson Correlation Coefficient	1.00				
	<i>R Standard Error</i>					
	<i>t</i>					
	<i>p-value</i>					
	<i>H0 (10%)</i>					
Age	Pearson Correlation Coefficient	0.47	1.00			
	<i>R Standard Error</i>	0.13				
	<i>t</i>	1.31				
	<i>p-value</i>	0.24				
	<i>H0 (10%)</i>	accepted				
Est_Total_KSLOC	Pearson Correlation Coefficient	0.70	0.23	1.00		
	<i>R Standard Error</i>	0.08	0.16			
	<i>t</i>	2.43	0.58			
	<i>p-value</i>	0.05	0.58			
	<i>H0 (10%)</i>	rejected	accepted			
Req_Fund_FY11	Pearson Correlation Coefficient	0.39	0.30	0.87	1.00	
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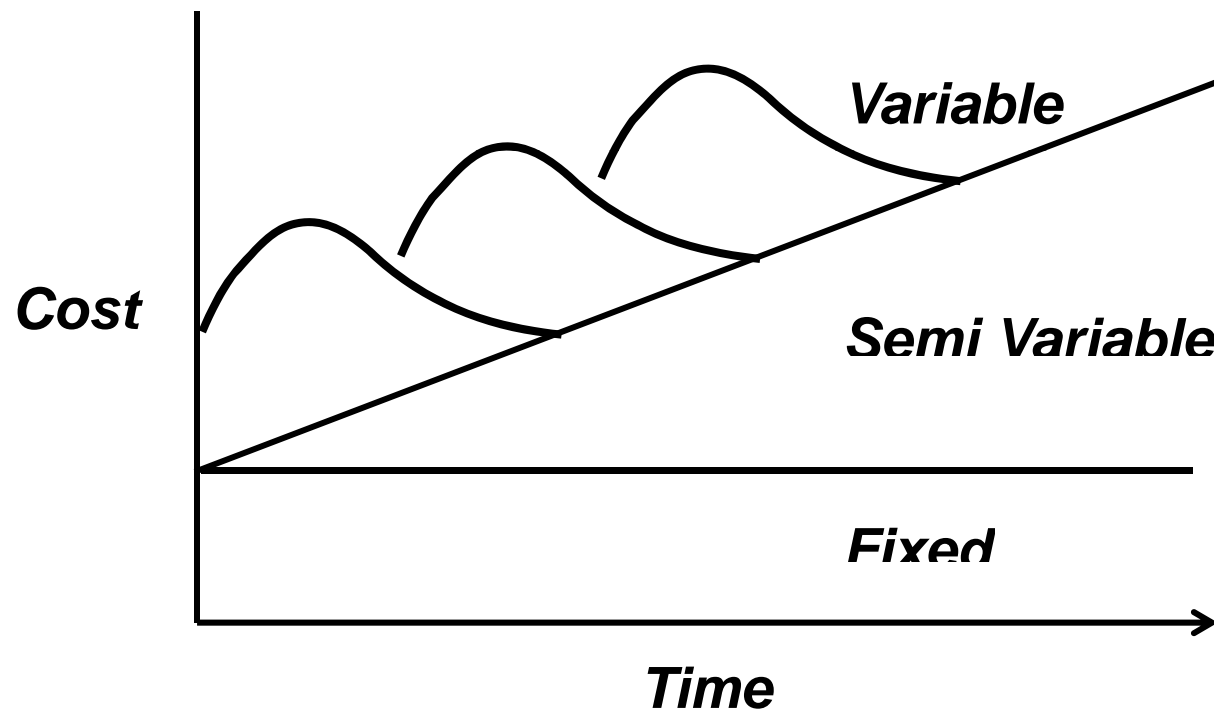
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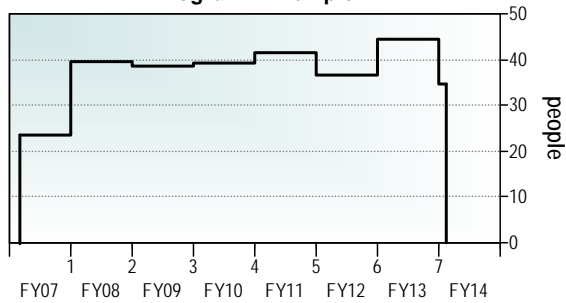
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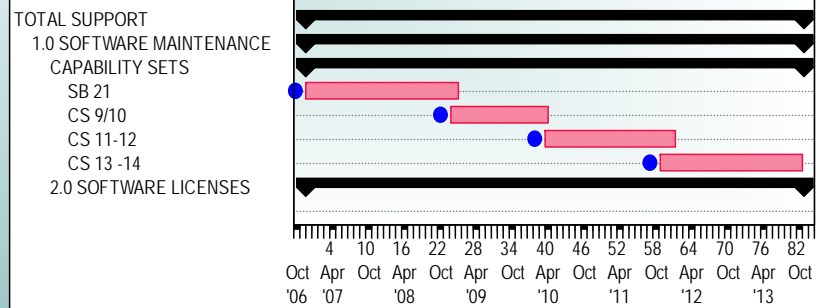
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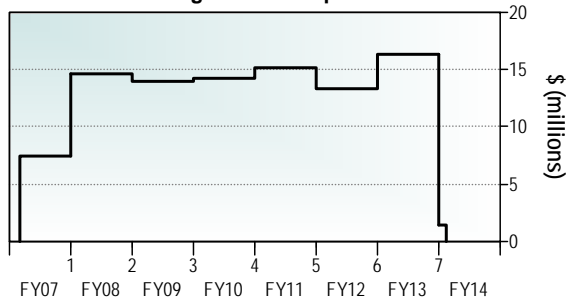
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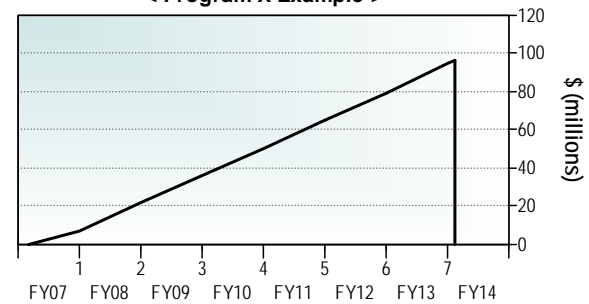
Monthly Gantt Chart (L4)
< Program X Example >



Fiscal Yearly Cost Rate (L2)
< Program X Example >



Fiscal Yearly Cum Cost (L2)
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***Integrated Software Maintenance Life Cycle
Cost Estimation Model***

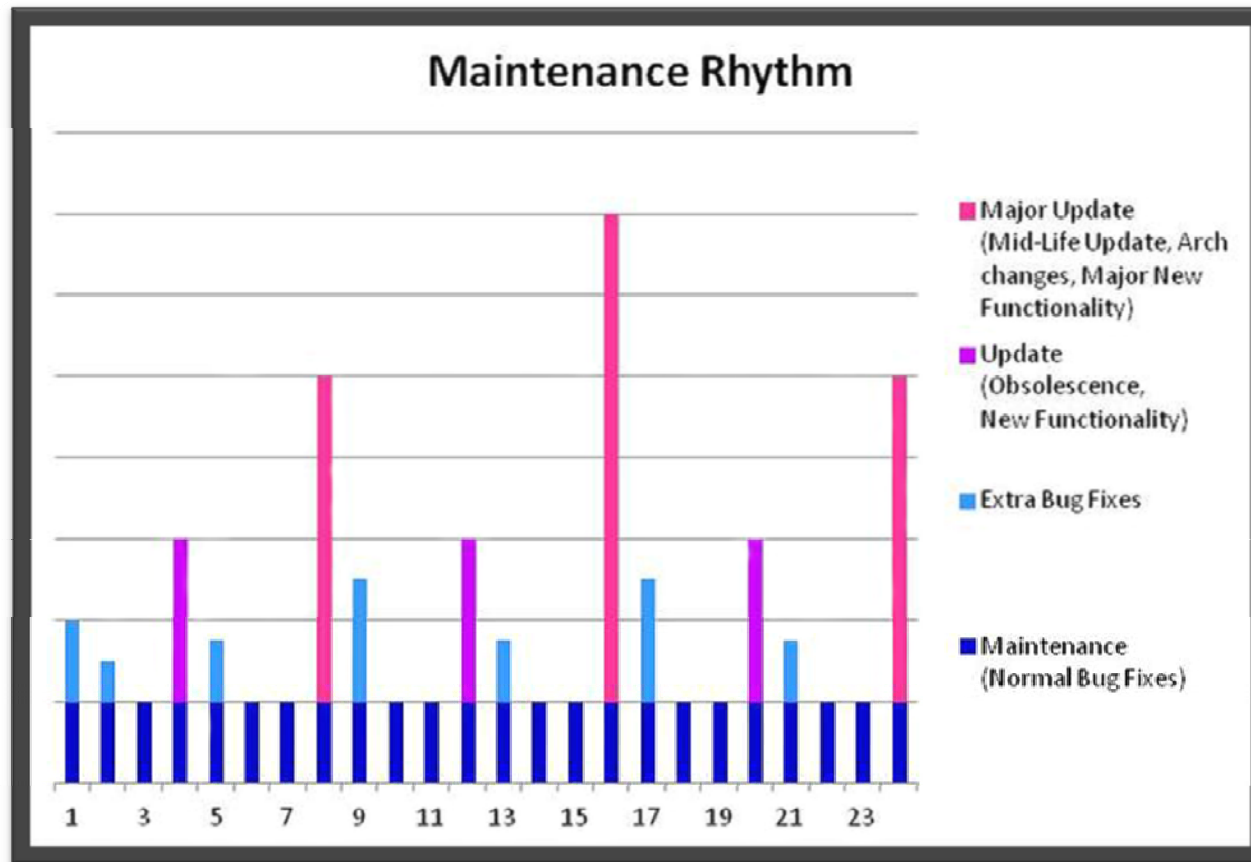
Integrated Cost Estimation Life Cycle Model

- ***Two key components***
- ***Software maintenance cost risk-uncertainty model***
 - ***Risk information model***
 - ***Risk interdependency analysis model***
 - ***Cost estimation application process model***
- ***Integrated life cycle cost allocation model***
 - ***Program software life cycle product-activity profile***
 - ***Post-development software releases***
 - ***Fielded software sustaining engineering support***
 - ***Software maintenance site infrastructure***
 - ***Maintenance resource-funding allocation model(s)***
 - ***Integrated cost estimation results***

Cost Risk-Uncertainty Model

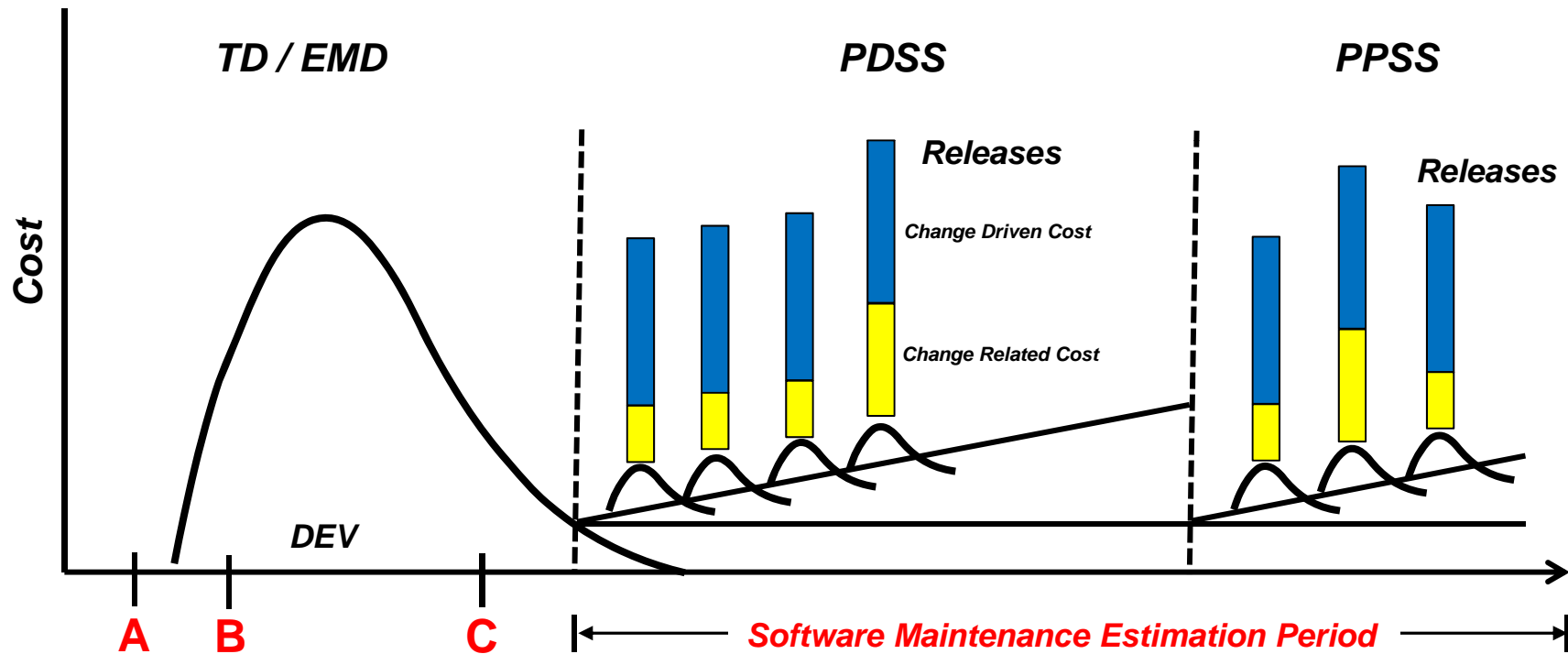
- ***Create a mechanism for identifying and evaluating software maintenance program risks at all pertinent decision levels***
- ***Identify those risks that directly impact program software maintenance cost uncertainty***
- ***Develop a methodology for integrating risk-uncertainty information into program software maintenance life cycle cost estimates***

Program Software Maintenance Release Profile



Cycles are different - platform dependent
User needs drive release content

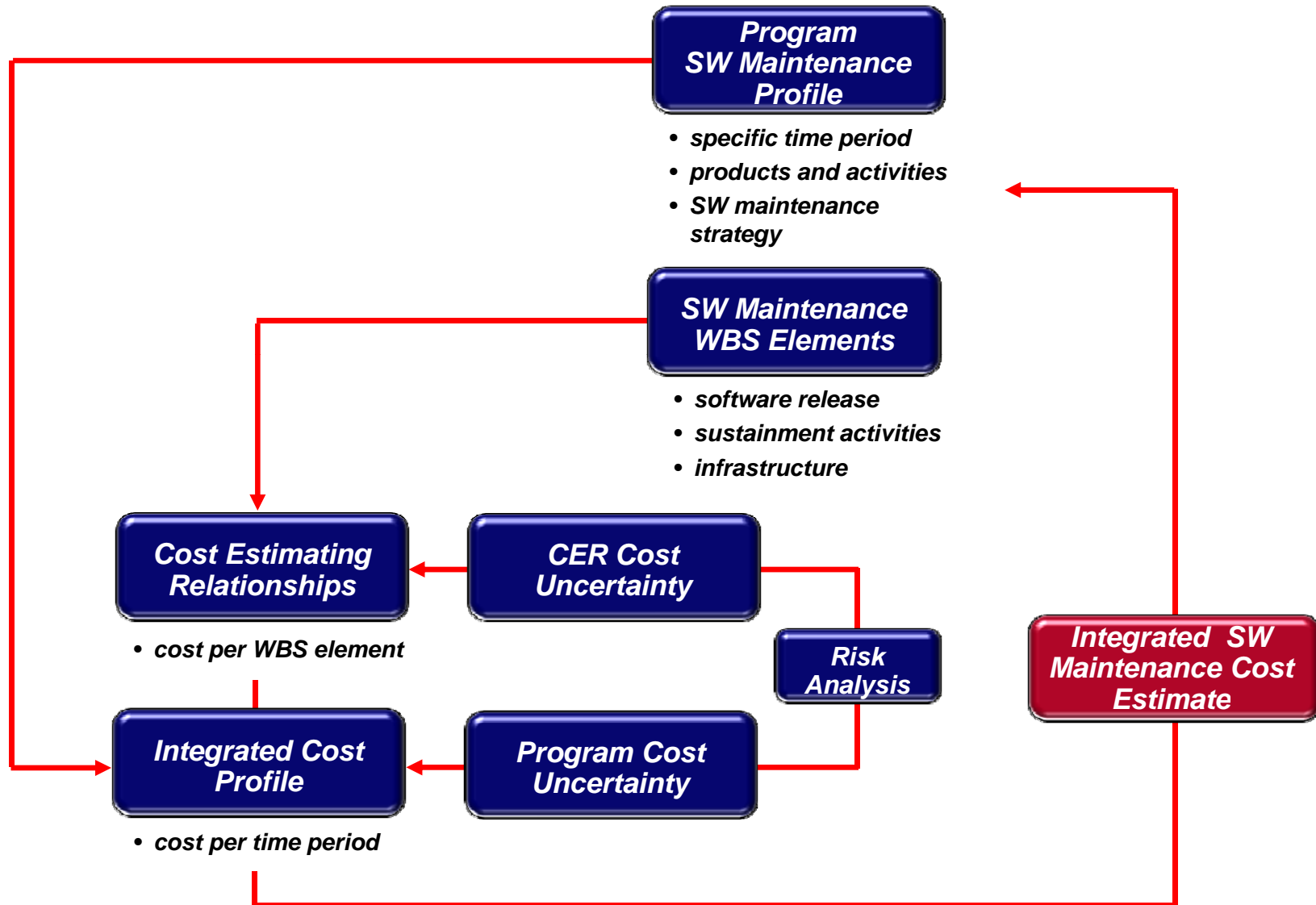
Notional Software Maintenance Life-Cycle Cost Allocation Model



Program Information Requirements

- ***System and software maintenance strategy***
- ***Included products and activities***
- ***Software release profile - PDSS/PPSS***
 - ***Release type and schedule (high level)***
 - ***Release profile stability***
 - ***User base - deployment strategy***
 - ***Configuration information***
 - ***Performing organizations***
 - ***Projected operational environment***
 - ***Program and software risk analysis***
 - ***Historical profile information (later)***

Software Maintenance, Sustaining Engineering, and Operational Support



Long Term Objective

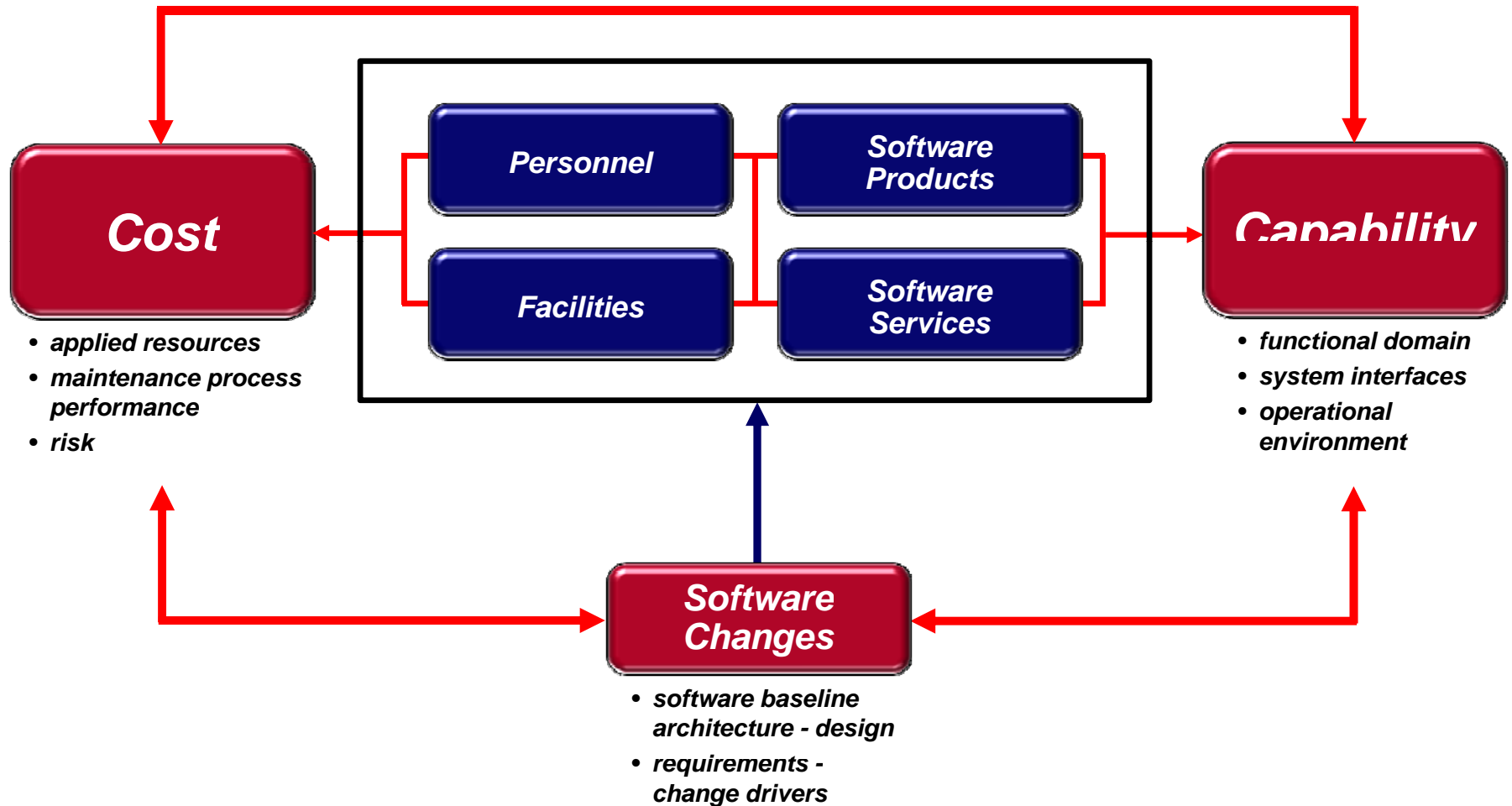


**AH-64D Longbow “Night Fury”
10,000 Flying Hours Reached on 28 June 2011**

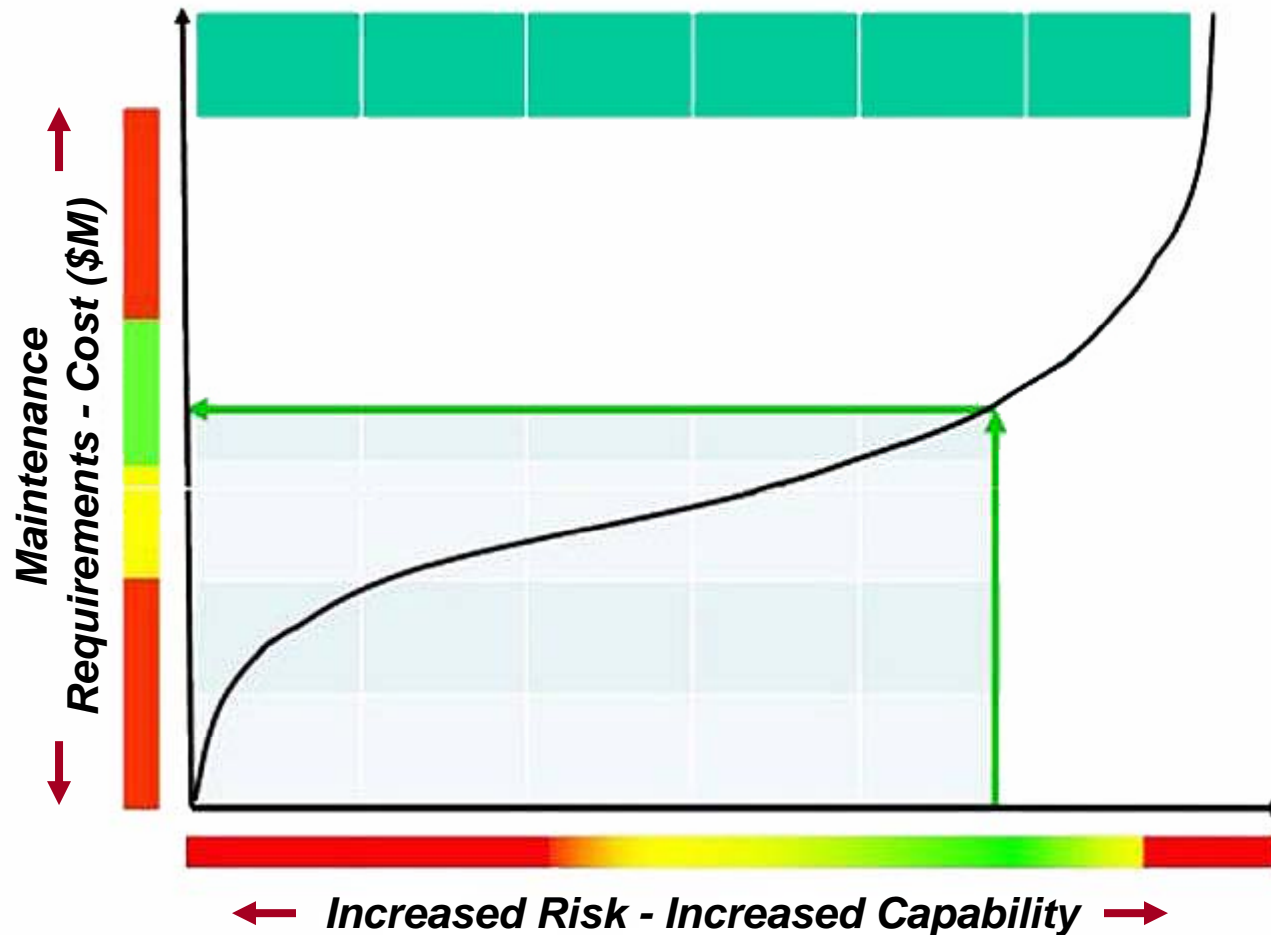
340,000 hours of maintenance by hundreds of weapons technicians in conjunction with countless hours of repairs and inspections performed by avionics, electrical and environmental, engine, fuels and structural personnel

***If there was a 20% cut on avionics software maintenance,
what would be the mission impact?***

Software Maintenance Cost-Capability Framework



How much should software maintenance cost?



"It's All About the Money", Dr. Chien Huo, CAPE, November 2011

Summary

- ***The projected Army operational and economic environment places an increasing emphasis on the performance of software maintenance and sustaining engineering efforts***
- ***Accurate software maintenance life cycle cost estimates are critical to ensuring that objective resource information is available to program decision makers***
- ***The estimation methodology must be configured to address the unique characteristics and projected sustainment profile of each program***

Contact Information

Jim Judy

**U.S. Army Office of the Deputy Assistant
Secretary of the Army for Cost &
Economics (ODASA-CE)
5701 21st Street
Building 216
Fort Belvoir, VA 22060-5546
(703) 697-1612
james.m.judy.civ@mail.mil**

Jeramia Poland

**U.S. Army ODASA-CE
5701 21st Street
Building 216
Fort Belvoir, VA 22060-5546
(703) 697-1640
Jeramia.poland.civ@mail.mil**

Cheryl Jones

**U.S. Army RDECOM - ARDEC
Quality Engineering & System
Assurance
RDAR-QES-A
Building 62
Picatinny Arsenal, NJ 07806-5000
(973) 724-2644
cheryl.jones5@us.army.mil**

Dr. Brad Clark

**Software Metrics, Inc.
4345 High Ridge Road
Haymarket, Va. 20169
(703) 754-0115
brad@software-metrics.com**

Additional Information

Army Software Maintenance Study

- ***Sponsored by U.S. Army Office of the Deputy Assistant Secretary of the Army for Cost & Economics (ODASA-CE)***
- ***Collaborative environment - diverse perspectives***
- ***Army, Air Force, Navy, OSD, Industry participation***
- ***Initial focus on ACAT-1 weapons system software maintenance costs***
- ***Technical approach based on measurement and estimation best practices***

Software Maintenance Product Sizing

- ***Overall concept of “E size” for maintenance products***
- ***E Size for types of changes (different drivers)***
- ***Composite E Size for different types of releases***
- ***Concept - profile the program maintenance strategy based on numbers and types of releases (variable costs) - add semi-fixed costs related to supporting the fielded software (costs not based on amount of work to construct a release)***
- ***Variable costs driven by type and number of product changes***
- ***Semi-fixed costs driven by number of deployed platforms, domain, operating tempo, etc.***
- ***Similar to software development sizing “E Sloc” but focused on change drivers/release content and support scope***

Software Maintenance Change Drivers

- ***The factors that cause the changes that are made to an operational software baseline***
- ***Software changes characterized by:***
 - ***source of change***
 - ***type of change***
 - ***impact of change (scope, complexity, etc.)***
 - ***priority of implementation***
- ***Change drivers can impact the operational software configuration, associated sustaining engineering activities, and the implemented maintenance infrastructure***
- ***Most change requirements are allocated to planned releases per time period***
- ***Deferred change requirements are defined as “backlog”***
- ***Drivers with different characteristics are costed differently***

Software Change Drivers

External Drivers

- **Operational User**
 - **Functional modifications**
 - **Functional additions**
 - **Functional deletions**
- **Stakeholder**
 - **Threat**
 - **Mission doctrine**
 - **System interoperability**
 - **External testing/IV&V**
 - **External audits**
- **Mandate**
 - **Legal/Regulatory/Policy**
- **Technology**
 - **Technology obsolescence**
 - **Infrastructure changes**

Internal Drivers

- **Legacy**
 - **Technical debt**
 - **Deferred functionality**
- **Maintenance Operations**
 - **Maintainer skill set**

Types of Changes

- **Corrective (identified defects)**
- **Preventive (latent faults)**
- **Perfective (functional enhancements)**
- **Adaptive (new HW/SW environments)**

Summary Work Breakdown Structure

**Software Maintenance, Sustaining Engineering,
and Operational Support**



WBS - Estimation Framework

WBS	Title	Army OPS-29 Mapping	Variability	Cost Drivers Examples
1.0	Software Maintenance: Planning, Req'ts, Design, Implementation, Development, Unit Testing, Integration, Test Planning and Execution, Emergency Release	Capability Sets FY(XX/XX) System Mission Capability Organic Labor	Variable	Parametric No. of SCRs, LOC, requirements, defects - added, reused, modified App. Domain, Complexity, Reliability, Personnel Factors
2.0	Software Licenses	Licenses	Fixed	Based on # and cost of each license needed
3.0	Info Assurance – IAVA	IAVA	Fixed	Fairly stable over the year
4.0	Certifications & Accreditations	C&As	Variable	Based on # and type of each C&A needed
5.0	Software Sustaining Engineering	Organic Labor Contractor Labor	Variable	Based on the types of services required and # of people providing services
5.6	Field Support	FSEs	Variable	LOE, No. and location of Field Sites
6.0	Software Facilities & Infrastructure	System infrastructure or System Open Door	Fixed	Facility/Utility Costs, LOE
7.0	Management	Organic Labor Contract Labor	Fixed	LOE

1.0 Maintenance (up to M/S C)

- ***Maintenance strategy***
 - ***How many years to be supported?***
 - ***Block release strategy***
 - ***Profile (# of platforms/users/sites)***
- ***Application domain***
- ***Volume of capabilities anticipated / possible (SLOC, requirements, SCRs, defects (priority 1,2), interfaces)***
- ***Effort/cost of development program (software development thru testing labor - time)***
- ***List of analogous programs (and their software maintenance historical data)***

1.0 Maintenance (after M/S C)

- **Maintenance strategy**
 - **How many years to be supported?**
 - **Block release strategy**
 - **Profile (# of platforms/users/sites)**
 - **Organic or contractor?; SIL location; contracting strategy**
- **Application domain**
- **History (IOC date, years in service, planned retirement date)**
- **Actual volume of changes made during maintenance to date (technical debt, SLOC, requirements, SCRs, defects, interfaces)**
- **Sked/effort/cost of previous maintenance releases**

- **Complications in data**
 - **Funding by year, releases over multiple years**
 - **Funding is reported by program, multiple releases in parallel**

2.0 Software Licenses

- ***# of products that have to be purchased***
- ***# of platforms (units)***
- ***Cost of license***
- ***Frequency and type of license (annual, one-time, every 3 years, when new update is available)***
 - ***Decisions on when to upgrade to newer COTS package has implications***
- ***License maintenance approach (included in purchase price, separate contract for COTS maintenance/support)***
- ***Analogous systems (with similar timeframes)***

- ***Complications in data***
 - ***For early milestone A, may not know all COTS products***
 - ***Army-wide or DOD-wide licenses and mandates affect COTS costs***

5.0 Software Sustaining Engineering

- ***Variable based on the types of services and studies required and number of people providing service***
- ***Variable based on PM requests***

5.6 Field Support

- ***# and location of field support sites***
- ***# of people providing service***
- ***Application domain, complexity of systems***
- ***Analogy to similar systems***
- ***Includes labor and travel***

6.0 Software Facilities & Infrastructure

- ***Facility strategy, approach, and location***
- ***LOE , Actual costs***
- ***Analogy to similar programs***

7.0 Management

- ***Management structure (hierarchy)***
- ***LOE , Actual costs***
- ***Analogy to similar programs***

WBS	Title	Variability	CER Examples	Experiences / Practical Applications	Notes	
1.1	Software Release (N)		<i>Roll-Up</i>			
1.1.1	Planning and Management	Variable	Defects by priority; SLOC; Requirements, Use Cases, Enhancements, HW/SW obsel., External interfaces, Language type, Release frequency	Parametric models as in SW Development; Ratio: LOC/FTE LOC/Time; LOE from last year		
1.1.2	Software Requirements					
1.1.3	Architecture and Design					
1.1.4	Change Implementation					
1.1.5	Integration and Test					
1.1.6	Acceptance Test					
1.1.7	Rework				Historical quality from previous releases; Defects	
1.1.8	Emergency Repairs				Semi-Variable	Drive by new capability; operational usage
1.1.9	Hardware Updates					?
2	Licenses		<i>Roll-up</i>	Vendor Catalogue		
2.1	Licenses - Deployed Systems	Semi-Variable	Cost of license x Number of licenses	Vendor Catalogue; consider discounts		
2.2	Licenses - Facility systems	Fixed	Cost of license x Number of licenses	Vendor Catalogue		
3	Information Assurance		<i>Roll-up</i>			
3.1	IAVA	Semi-Variable	Average cost/yr; number of IAVAs/yr; cost/IAVA	Number of vendor alerts		
4	Certifications & Accreditations		<i>Roll-up</i>			
4.1	Certifications & Accreditations - Non information assurance related	Fixed	Average cost for a specific C&A	External organization		

4.2	DIACAP	Fixed	Average cost for a specific C&A	Set schedule	
5	SW Sustaining Engineering		<i>Roll-up</i>		
5.1	Analysis and Studies	Variable	Number of Analysis Studies	Captured under SE/PM or just PM	
5.2	Test Support	Semi-Variable	Depends on # of test events		
5.3	Delivery	Semi-Variable	Number of Docs		Consider adding Delivery to release. Consult thought leaders on this subject.
5.4	User Training	Variable	Number of locations, users, user experience level	Painful	
5.5	User Support	Variable	Number of locations, users, user experience level		
5.6	Field Support	Variable	Number of system configurations, locations, Op-Tempo	Perform training, installation, trouble shooting	System available requirement drives cost
6	Software Facilities & Infrastructure				
6.0	Software Facilities and Infrastructure	Fixed	# of components & # of people to support them	Security, SCIF	
6.1	Development Facilities				
6.2	Integration and Test Facilities				
6.4	Tactical Equipment				
6.5	Test Equipment and Tools				
7	Management				
7.1	Program Management	Variable	Based on "Size" of software system; system criticality; system location		
7.2	Contract Management				
7.3	Change Management				
7.4	Data Management				
7.5	Quality Assurance				
7.6	Process Management				
7.7	Personnel Management				

#	WBS Element	Sensor Processing	Ground Sys Space	C4 Sys	AC Avionics	Spacecraft
1	Software Maintenance	H	H	H	H	M-H
2	Software Licenses		M	M-H	M-H	0
3	Information Assurance		L	M	L	M
4	Certifications & Accreditation		L	L	L	M
5	Sustaining Engineering	H	H	L-M	L	M
6	Facilities & Infrastructure		M-H	0	H	H
7	Management	H	M	L-M	M-H	H