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Estimating Software Maintenance Costs for U.S. Army Systems

COCOMO Forum 2013
Broadening the Use of cost Models to Understanding -ilities, Tradeoffs, and Business and Engineering Decisions

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Executive Summary

- Army software maintenance requirements are growing significantly across all mission domains - there is an increasing demand for fewer dollars
- Army executives do not have the objective information they need to make critical software maintenance budget determination, funding allocation, and program trade decisions
- Two primary issues:
  - current estimation methods are inadequate - we cannot generate defensible cost numbers
  - lack of execution data - expended software maintenance dollars cannot be traced to the delivered products or capabilities
- Other factors:
  - diverse program PDSS and PPSS management and funding strategies - multiple funding streams and management constructs
  - level of effort vs. requirements driven resource strategies
  - planned and funded requirements are not always what is executed
  - “locally managed” SWM activities and programs
  - Limited Army enterprise level SWM policy, information structure, and governance

Software System Size Growth

107 - AH-64As

1620 - AH-64Ds

Apache Software Growth
300 KSLOC to Over 1.4 Million SLOC

Software System Complexity Growth

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

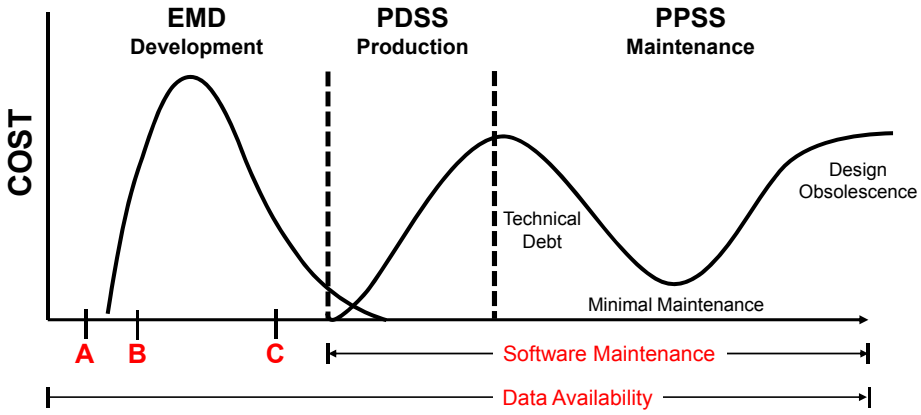
- Multiple system variants
- Complex system interfaces
- Multiple operational software releases
- Multiple software change drivers
  - end user requirements
  - mission evolution
  - system interoperability
  - change mandates
  - security requirements
  - technology updates
  - technical debt

Army Software Maintenance Cost Estimation Project Objective

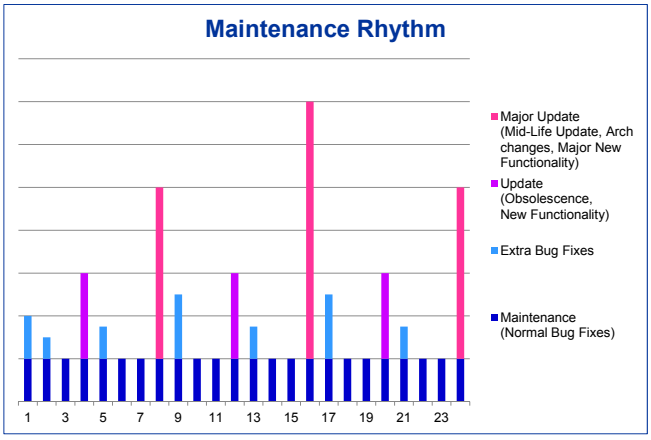
Provide the Department of the Army with the ability to accurately estimate, budget, allocate, and justify the software maintenance resources required to meet evolving mission and service affordability requirements across the system life-cycle

U.S. Army Software Maintenance Integrated Cost Estimation Methodology (SWM-ICEM)

Notional Software Maintenance Life-Cycle Cost Model



Software Maintenance Release Profile

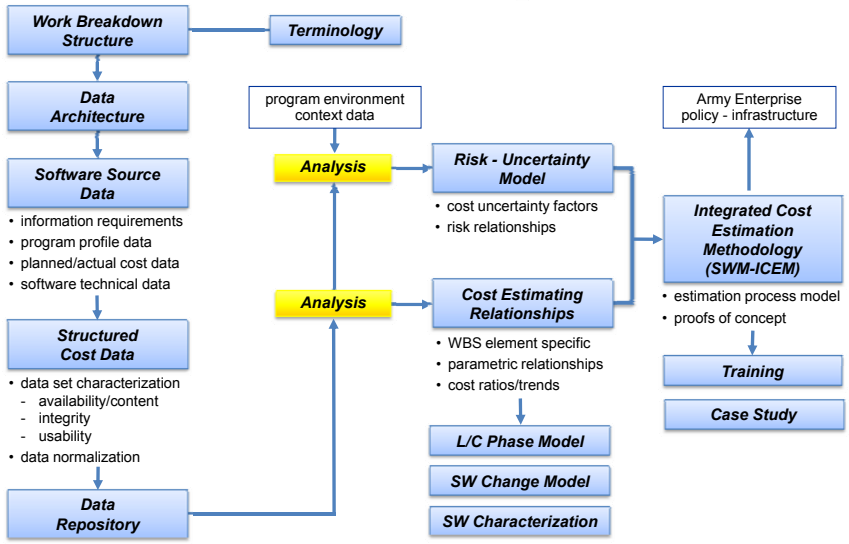


Cycles are different for different programs
User needs drive release content

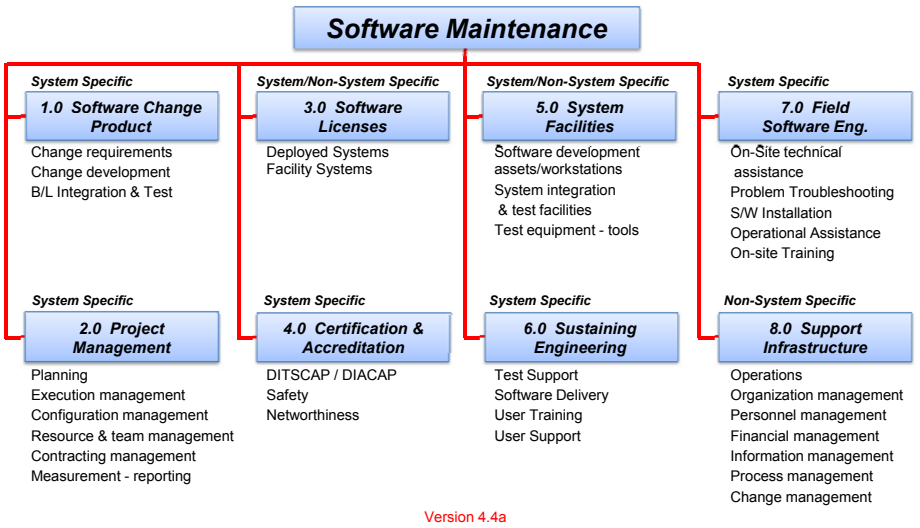
SWM-IECM Requirements

- Generate defensible software maintenance cost estimates across the program life cycle
- Develop a revised cost estimation methodology that more accurately maps to the actual software maintenance activities and output products for each program within the defined estimation period
- Develop, validate, and improve applicable SWM cost estimating relationships
- Apply risk and uncertainty to refine SWM cost estimates
- Account for differences in program maintenance strategies, mission domains, types of software changes, and applied maintenance processes
- Identify program software maintenance cost estimation data and information infrastructure requirements
- Establish a viable software maintenance historical data resource
- Develop a practical estimation process that can be effectively implemented by Army cost estimation professionals
- Create a collaborative project environment with DOD, the services, industry, and the technical community

SWM-ICEM Components



Software Maintenance WBS



Version 4.4a

Software Maintenance WBS

- Common structure that includes all potential software maintenance products and activities - “what’s in” - “what’s out”
- Defines the superset of program software maintenance cost elements
- Foundation for common software maintenance definitions and terminology
- Basis for defining cost estimating relationships
- Product based - system and organizational cost elements identified as those required to make changes to an operational software baseline(s)
- Cost elements represent both system allocated and non-system specific products and activities
- The SWM-WBS is equally applicable to:
  - software maintenance estimation and planning
  - tracking software maintenance execution

Army Software Maintenance Data

Data Evaluation

- System processes and data aligned closely with the SWM-WBS
- Data sets were evaluated for quality (Data Confidence) and availability (Data Completeness)
- Large variance in data evaluation results across programs - multiple factors
- Inconsistent business, technical, project management processes across systems
- Most data focused on the budgeting process - funding requests - dollars - OPS-29
- Minimal execution data available
- Correlation of cost and technical data in general was problematic
- Cost data not generally mapped to activity and product outputs
- Army enterprise level impacts on quality and availability of SWM data

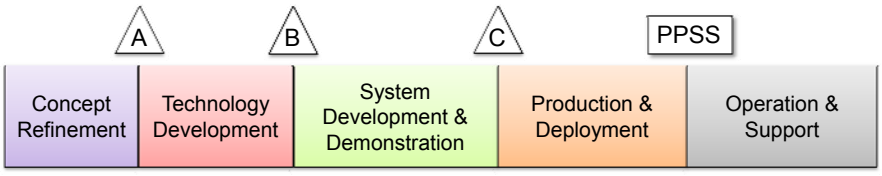
SWM Data Evaluation

		Data Completeness					Data Confidence				
Organization	Program	Profile Data	Size	Effort/Cost	Schedule	Overall	Size	Licenses	C&A	FSE	Overall
Org 1	Pgm 1	0.41				0.10		0.80	0.15		0.24
Org 1	Pgm 4	0.34				0.09					
Org 1	Pgm 5	0.98		0.98	0.90	0.72		0.20	0.15	0.15	0.13
Org 1	Pgm 6	0.34				0.09			0.33		0.08
Org 1	Pgm 7	0.27				0.07			0.33		0.08
Org 1	Pgm 8	0.41	0.80	0.61	0.90	0.68	1.00	0.85	0.75	0.15	0.69
Org 1	Pgm 29	0.20	0.20		0.65	0.26	0.85	0.20	0.15		0.30
Org 1	Pgm 30					0.00					
Org 1	Pgm 31	0.98	0.60	0.79		0.59	1.00	0.20	0.15		0.34
Org 1	Pgm 32	0.27				0.07					
Org 1	Pgm 35	0.20				0.05					
Org 1	Pgm 38	0.20	0.20	0.20		0.15	0.85				0.21
Org 1	Pgm 40	0.27	0.20			0.12	0.50				0.13
Org 1	Pgm 41	0.20	0.20			0.10	0.50				0.13
Org 1	Pgm 43	0.34	0.30	0.32	0.90	0.47	1.00	0.20			0.30
Org 2	Pgm 33	0.27	0.65	0.46	0.70	0.52	0.93				0.23
Org 2	Pgm 34	0.20	0.20	0.20	0.90	0.38	0.10				0.03
Org 2	Pgm 37	0.20	0.45	0.33	0.70	0.42	0.65				0.16
Org 2	Pgm 42	0.20	0.75	0.48	0.80	0.56	0.95				0.24
Org 3	Pgm 11	0.41				0.10		0.65	0.33	0.40	0.35
Org 3	Pgm 12	0.20				0.05		0.65	0.33	0.40	0.35
Org 3	Pgm 13	0.34				0.09		0.65	0.33	0.33	0.33
Org 3	Pgm 14	0.27				0.07		0.65	0.33	0.33	0.33
Org 3	Pgm 15	0.41				0.10		0.65	0.33	0.40	0.35
Org 4	Pgm 2	0.13				0.03					
Org 4	Pgm 3	0.49		0.49	0.40	0.35		0.60	0.33	0.40	0.33
Org 4	Pgm 9	0.13	0.85	0.49		0.37	0.65	0.20			0.21
Org 4	Pgm 10	0.49	0.20	0.35	0.30	0.33	0.50	0.60	0.33		0.36
Org 4	Pgm 16	0.13	0.95	0.54		0.41	0.73	0.20			0.23
Org 4	Pgm 17	0.49	0.20	0.35	0.30	0.33	0.50	0.65	0.33	0.40	0.47
Org 4	Pgm 18	0.13			0.10	0.06					
Org 4	Pgm 19	0.49				0.12			0.33		0.08
Org 4	Pgm 20	0.13	0.90	0.52		0.39	0.73	0.20			0.23
Org 4	Pgm 21	0.49	0.20	0.35	0.30	0.33	0.10	0.65	0.33	0.40	0.37
Org 4	Pgm 22	0.49		0.49	0.30	0.32			0.33		0.08
Org 4	Pgm 23	0.13	0.75	0.44		0.33	0.63	0.20			0.21
Org 4	Pgm 24	0.49	0.20			0.17	0.50	0.70	0.33		0.38
Org 4	Pgm 25					0.00		0.20	0.33		0.13
Org 4	Pgm 26	0.49	0.20	0.35	0.30	0.33	0.50	0.60	0.33	0.40	0.46
Org 4	Pgm 27	0.13	0.85	0.49		0.37	0.65	0.20			0.21
Org 4	Pgm 28	0.49		0.49	0.40	0.35			0.33		0.08
Org 4	Pgm 36	0.49		0.49	0.40	0.35					
Org 4	Pgm 39	0.49		0.49	0.40	0.35			0.33		0.08
Org 5	Pgm 44	0.27				0.07					

SWM Cost Estimating Relationships

- Software maintenance CERs - quantitative relationships mapped to SWM-WBS
- Multiple CER types:
  - parametric
  - ratios
  - trends
- SWM CER constructs - modifiers:
  - phase based data defined CERs
  - software system characterization model
  - software change classification model
- System specific and organizational (multi-system) costs

DOD Acquisition Lifecycle Model



- Programs may be in any lifecycle phase
- Estimates are required at the major milestones and periodically after milestone C
- Estimation considerations:
  - Availability and quality of program data
  - Different CERs at different estimation points
  - Accuracy of the estimate
  - Estimation consistency across the life cycle
  - Information related risk/uncertainty

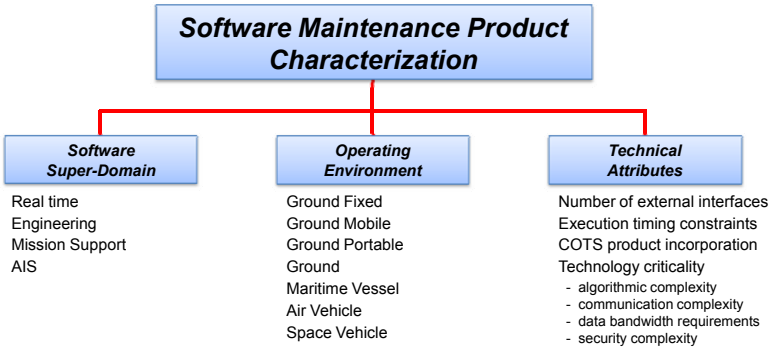
SWM Phase Driven CERs

WBS Element	MS A	MS B	MS C	Post MS C
1 & 2 - Software Change Produce & Project Management	Analogy for cost	Analogy for size Proxy tables for sizes	Development (baseline) size and build info Formulas for schedule, effort, and cost	MS C information plus actual maintenance data from completed releases
3 - Software Licenses (Cost of)	Analogy based on type of system and anticipated maintenance depot	Information by system type – used in analogy	List of actual products with costs – license quoted costs	List of actual products with costs – license quoted costs (changes for obsolescence)
4 - Certifications & Accreditations	Analogy for cost by system domain	Analogy for cost by system domain	List of actual C&As with costs (by release or annual)	List of actual C&As with costs (by release or annual)
5 - Software Maintenance Facilities	Analogy for cost by maintenance depot	Analogy for cost by depot	Budget cost (percentage) by depot plus extras	Actual cost (percentage) by depot plus extras
6 - Sustaining Engineering	Analogy for cost by system domain	Analogy for cost by system domain	Analogy for cost by system domain	Actual cost (percentage) by actual maintenance data from completed releases
7 - Field Software Engineering	Analogy for cost by system domain	Analogy for cost by system domain	Analogy for cost by system domain	Actual cost (percentage) based on sites/users/platforms
8 – Support Infrastructure	Analogy for cost by maintenance depot	Analogy for cost by maintenance depot	Budget cost (percentage) by maintenance depot plus extras	Actual cost (percentage) by maintenance depot plus extras

Software System Characterization Model

- Software maintenance cost relationships vary based on the technical characteristics of the software system
- Premise - software maintenance productivity is different between groups of software with different characteristics and similar within a group
- If we can characterize the software product in question, we can apply CERs calibrated to the characteristics of that particular group
- Simple taxonomic models are limited
- SWM Characterization Model:
  - typology integrating multiple cost-related factors
  - minimal number of software attributes
  - captures primary impacts to SWM productivity/cost
  - based on available system data
- Software product characterization is part of the estimation process

Software System Characterization Model



Software Change Classification Model

- Individual software changes can be classified using four key characteristics:
  - the source of the change
  - the type and technical characteristics of the change
  - the functional impact of the change
  - the relative priority of the change
- Each software change has a different relative cost impact based on a combination of these characteristics
- By extension, the cost of a composite change product (release, capability set) is based on the characteristics of the included changes
- Classifying each change, and the makeup of composite change products, allows for better predictive costing for software maintenance products
- The ability to allocate planned and actual costs at the individual change level will allow for more accurate SWM estimates

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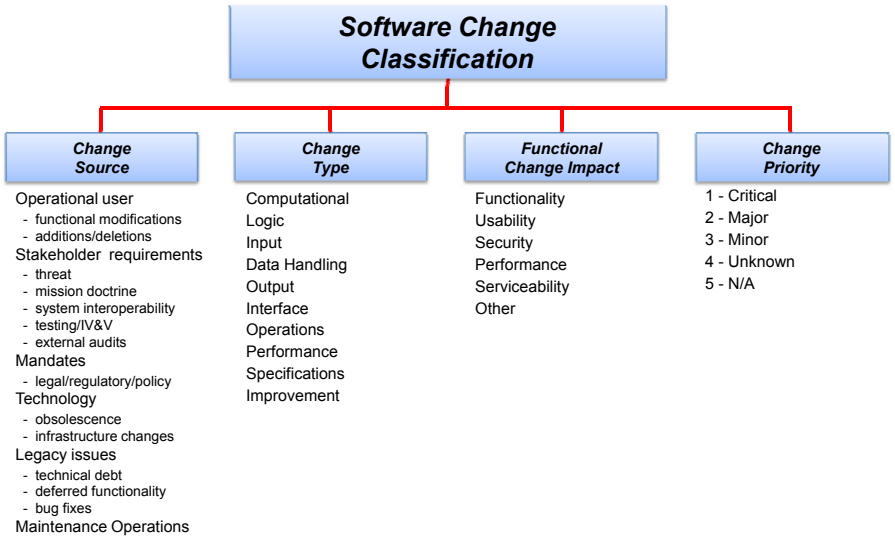
Software Change Classification Model



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Cost Risk - Uncertainty Determination (CRED) Model

Objective is to improve the credibility of the cost estimate by:

(1) Identifying, characterizing and accounting for different cost performance factors (e.g., software product attributes, management factors, external program activities) and human estimation biases (e.g., anchoring, optimism bias, etc.) that may be sources of risk/uncertainty that can result in creating material impacts on a software sustainment and maintenance cost estimate.

(2) Making visible the "knowledge gap" (if any) between what should be known and what is known about the system being is used to calculate a range of uncertainty associated the estimate.

(3) Fully documenting the key program issues and related performance factors that may influence the cost estimate and why.

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CRED Model Example

10 = "Full" Understanding

Internal Software Product Attributes				
Operation & Support Phase	Number Of External Interfaces	Execution Timing Constraints	COTS Product Incorporation	Critical Technology
What do we know?	10	10	3	6
What should we know?	10	10	10	10
Individual Exposure	0	0	-7	-4
Exposure			-11	

Program/Project Management Attributes					
Operation & Support Phase	Management Personal Capability	Technical Personal Capability	Technical Process Capability	Facilities & Infrastructure Support	Local Maintenance /Funding Rhythm
What do we know?			5	5	5
What should we know?			10	10	10
Individual Exposure			-5	-5	-5
Exposure			-15		

External Driver Attributes				
Operation & Support Phase	Project & Program Management	External Stakeholders	Mandates	Policy-driven Maintenance /Funding Rhythm
What do we know?	10	8	10	5
What should we know?	10	10	10	10
Individual Exposure	0	-2	0	-5
Exposure		-7		

Assessment of Risks - Uncertainty

Determine Risk-Uncertainty Impact on Working Estimate

Operation & Support	Risk/ Uncertainty Level	Estimation Range Multiplier: Best Case	Most Likely Case	Worst Case
Total exposure equal to zero	Low	0.95	1.05	1.10
Total exposure less than zero but greater than -20	Medium	1.00	1.10	1.15
Total exposure less than -20	High	1.10	1.15	1.25

Final Estimate = Multiplier x Working Estimate

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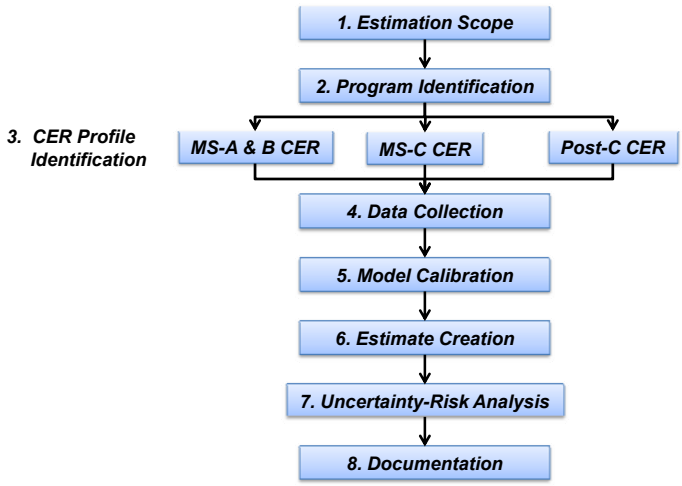
SWM-IECM Process Model



Summary

- Accurate cost estimates are necessary for objective software maintenance resource related decision-making across the system life cycle
- Current software maintenance cost estimation methods are inadequate and not defensible - they do not reflect actual program SWM activities and products
- The ODASA-CE Software Maintenance Integrated Cost Estimation Methodology addresses the key estimation issues - it provides a transparent estimation approach that maps to Army system SWM cost requirements across the system life cycle
- The SWM-ICEM and its component CERs are adaptable to available program data and to end user information requirements
- The availability of systemic Army SWM planning and actual cost and technical data across the program base is critical
- This data largely exists - Army policy and infrastructure must be adapted to collect it and use it
- The project has established a firm basis for addressing a primary Army issue - effectively estimating and allocating required SWM resources

Next Steps

- Systemic Army SWM data collection - focus on execution cost data - expanded data store
- WBS cost element CER refinement - quantitative relationships - phase dependent models
- CER calibration based on system software domains and technical characteristics
- Enhance the risk-uncertainty model - refine quantitative uncertainty ranges - incorporate technical and programmatic risk
- Develop historical release profiles based on system domain and technical characteristics
- Develop CERs based on individual software change classifications
- Support ODASA-CE SWM-IECM implementation - training and direct program application support
- Army enterprise support - technical collaborations

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