Software Maintenance, Sustaining Engineering, and Operational Support

Estimating Software Maintenance Costs for U.S. Army Weapons Systems

Office of the Deputy Assistant Secretary of the Army for Cost and Economics (ODASA-CE)
SCEA-ISPA Conference
28 June 2012

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Software Maintenance, Sustaining Engineering, and Operational Support

Presentation Outline

- **Software maintenance and sustaining engineering - the current DOD environment**

- **Linking software maintenance investment to mission capability**

- **Identifying and addressing the key software maintenance performance factors**

- **U.S. Army weapons system software maintenance cost estimation approach**

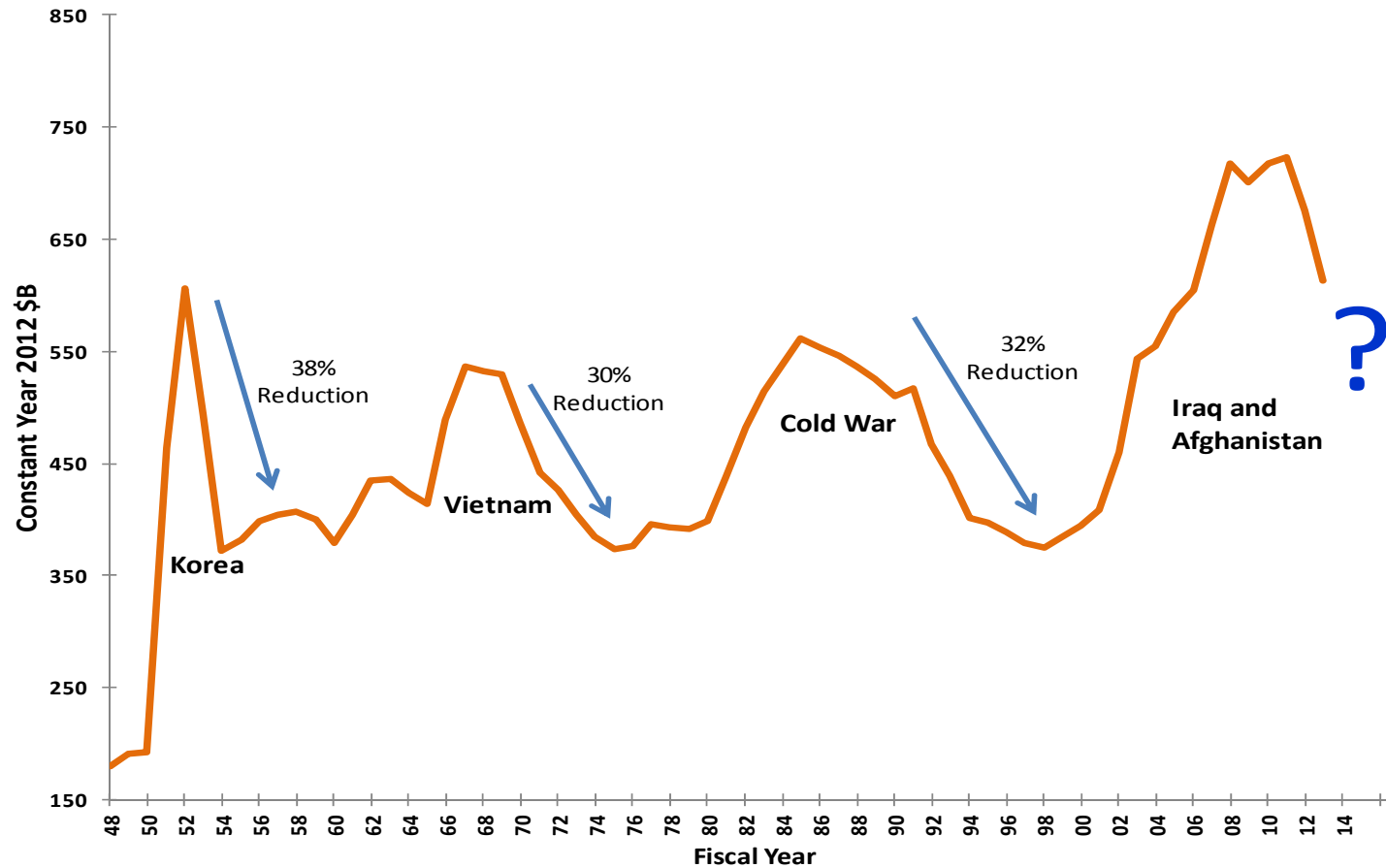## *Software Maintenance, Sustaining Engineering, and Operational Support*

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?

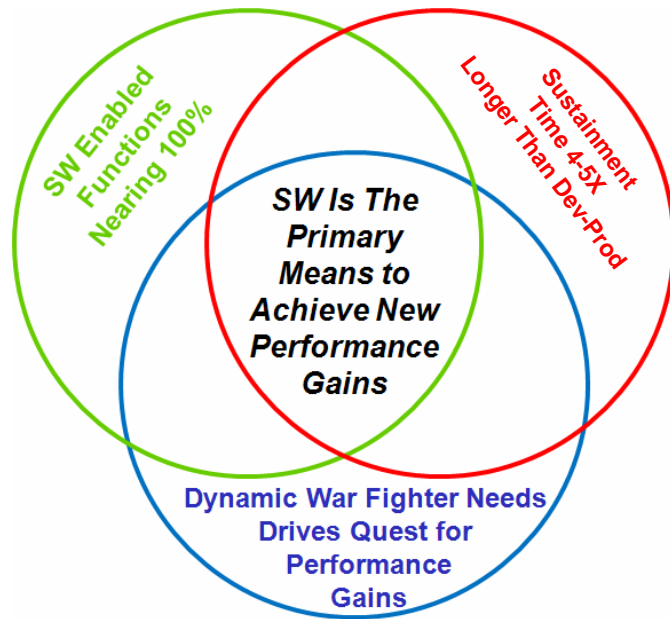Approved for public release - Distribution is unlimited

Software Maintenance, Sustaining Engineering, and Operational Support

DOD Historical Funding

Software Maintenance, Sustaining Engineering, and Operational Support

Significant Growth in DOD Software Maintenance Resource Requirements ($)

SW Enabled Functions Nearing 100%

Sustainment Time 4-5X Longer Than Dev-Prod

SW Is The Primary Means to Achieve New Performance Gains

**Dynamic War Fighter Needs Drives Quest for Performance Gains**

We cannot presently link money invested in software maintenance or sustaining engineering to mission capability

"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

5 - 28 June 2012

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What Does The Software Capability-Cost Curve Look Like?
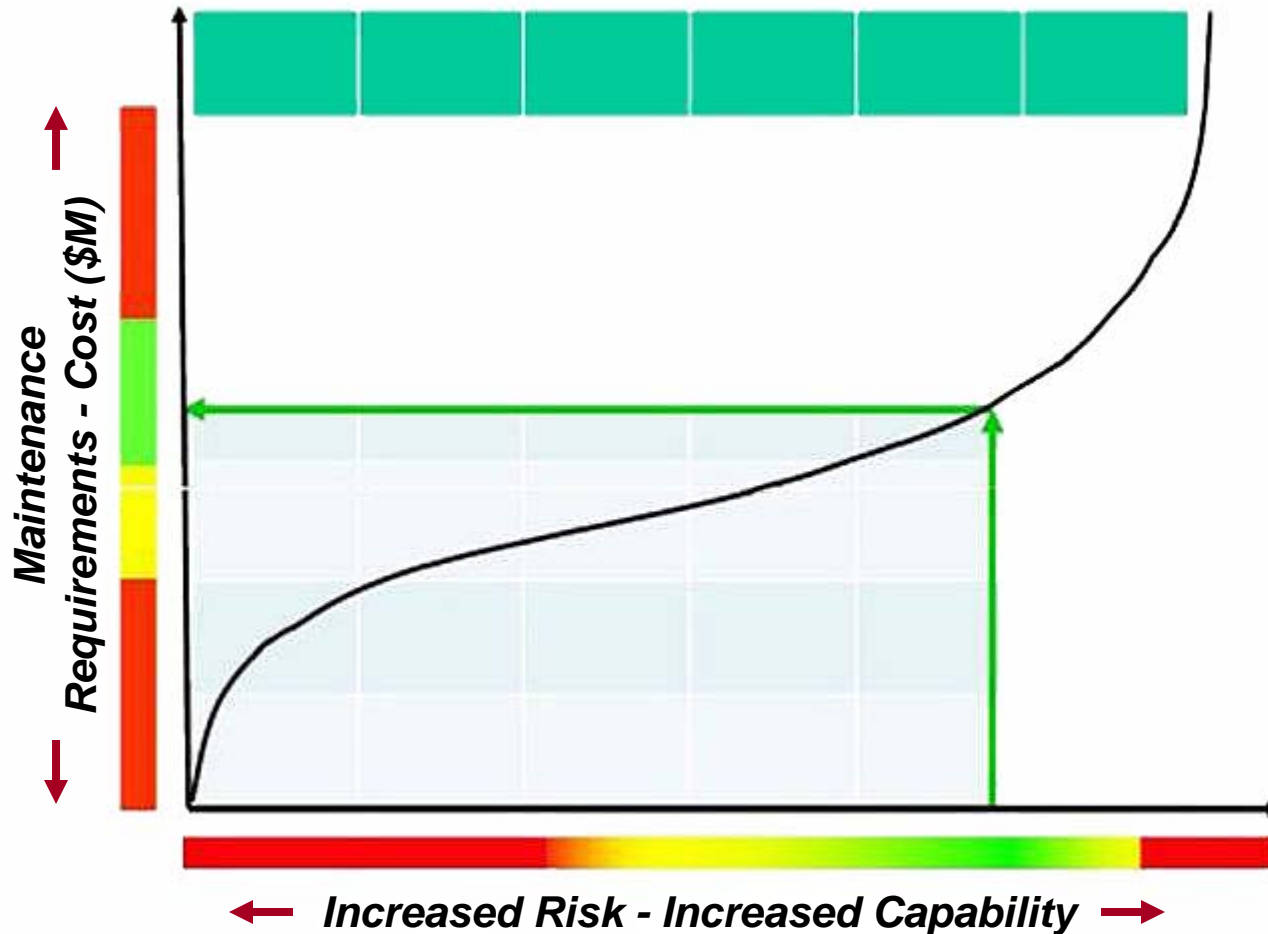
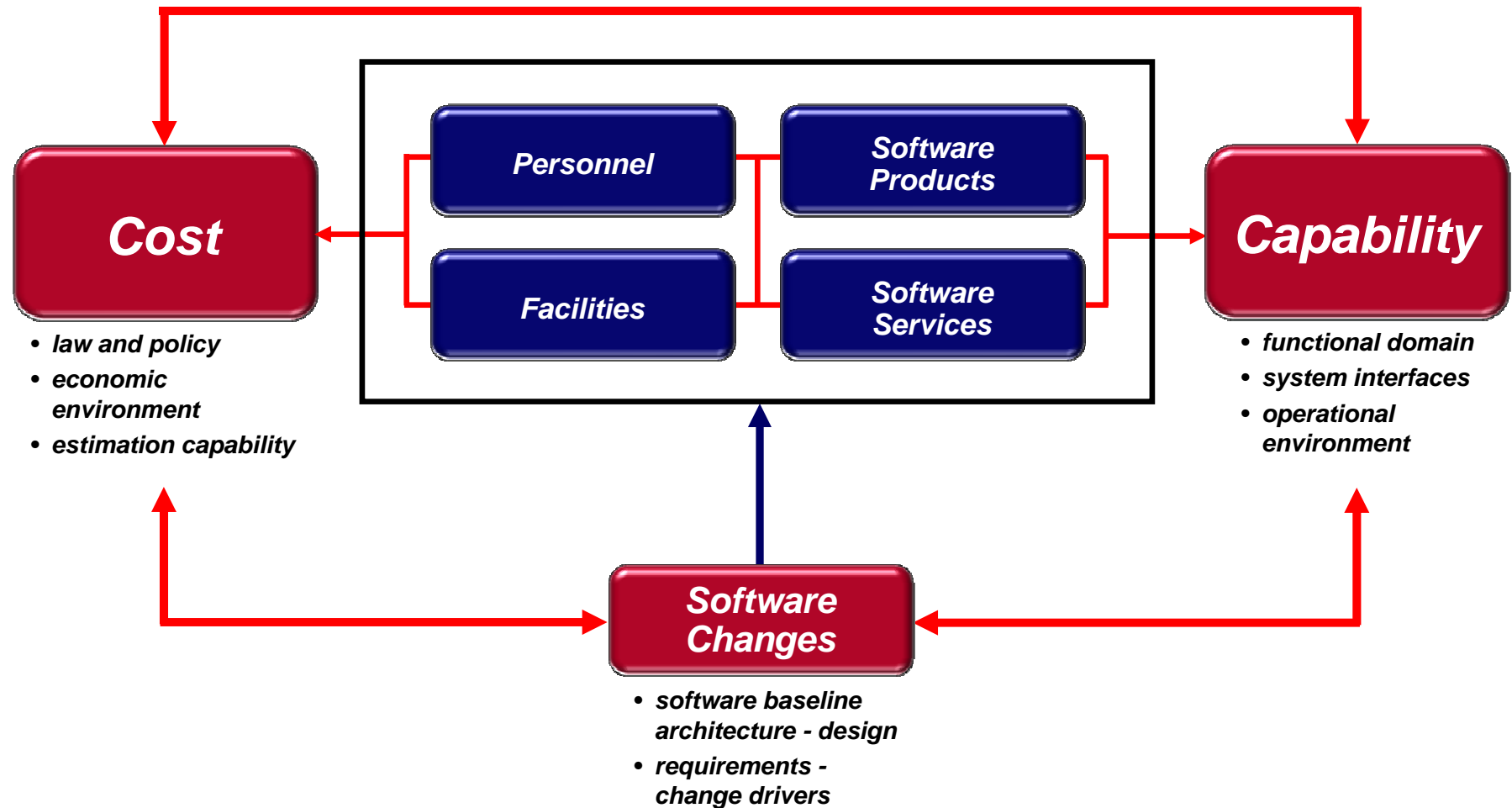*"It's All About the Money", Dr. Chien Huo, CAPE, November 2011*

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DOD 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 support/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*

- *Increasingly complex cost inter-relationships / data sets*

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Software Maintenance Cost-Capability Framework

Cost

- law and policy
- economic environment
- estimation capability

Personnel

Software Products

Facilities

Software Services

Capability

- functional domain
- system interfaces
- operational environment

Software Changes

- software baseline architecture - design
- requirements - change drivers

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Key Questions

- *What are we paying for?*

- *How much does it cost?*

- *How do we accurately estimate these costs?*

- *What is our "return on investment?"*

- *How do we define "output" and "performance"*

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Software Maintenance Top Level Cost Factors

- ## Public Law and DOD Policy
  - Depot maintenance mandates - Title 10
  - Operational funding allocation restrictions
  - Development - PDSS - PPSS program phases
  - Maintenance decision authority

- ## Economic Environment
  - Post conflict downturn
  - Loss of OCO funding
  - System replacement and refurbishment demands
  - Funding consistency

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Software Maintenance Top Level Cost Factors

- ## Cost Estimation Capability
    - identification of maintenance products and activities
    - estimation processes and models
    - maintenance planning vs. execution inconsistencies
    - information infrastructure limitations
    - linking dollars to output
    - data availability and integrity

All of these factors impact the integrity of historical software maintenance cost data and the ability to construct consistent estimating relationships
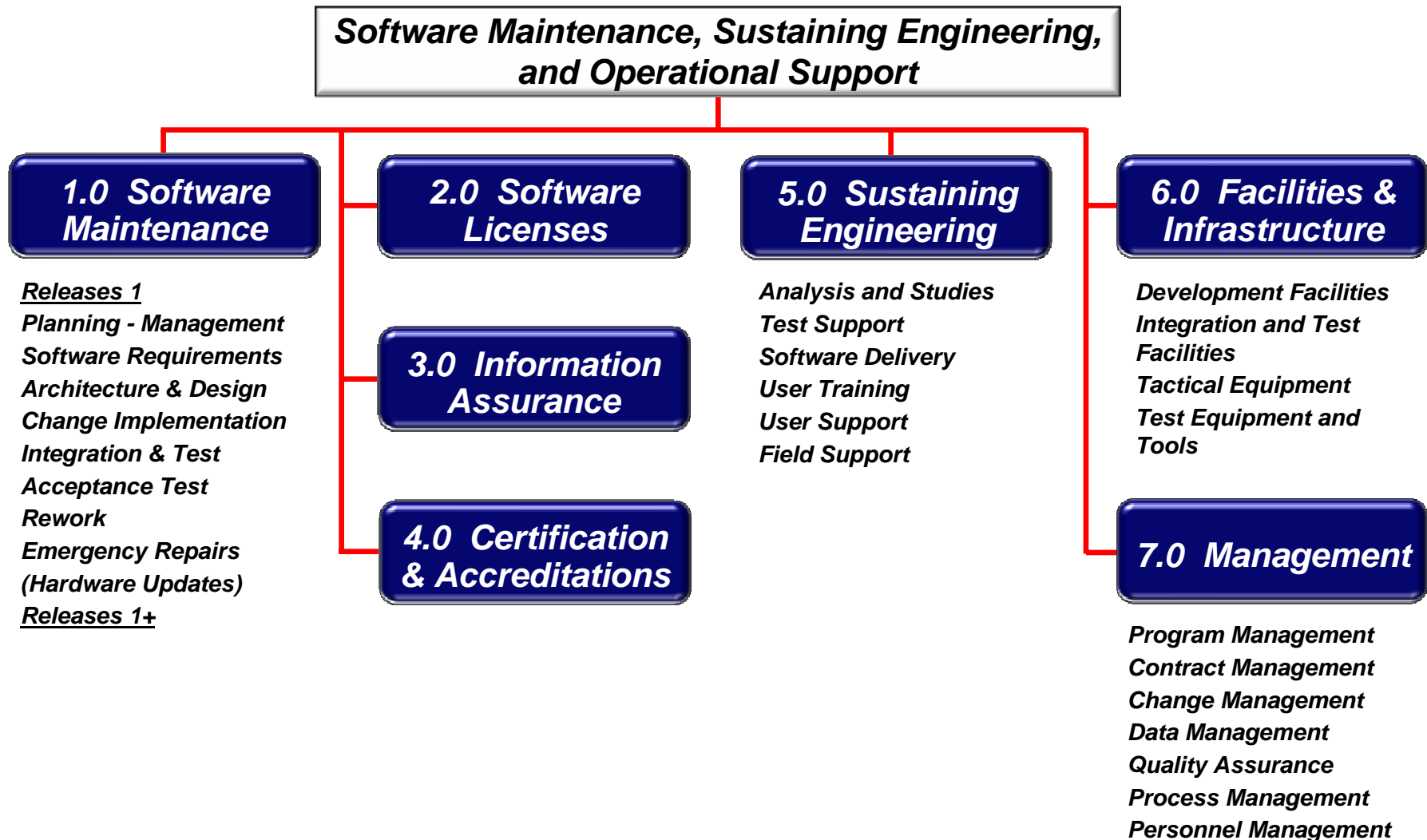
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Software Maintenance Work Breakdown Structure

- **Common structure that includes all potential products and activities "what's in - what's out"**

- **Consistent definitions - terminology**

- **Emphasis on DOD weapons systems**

- **Basis for identifying specific cost elements attributable to a given program or system maintenance/sustaining engineering effort**

- **Applicable to organic and contractor maintenance efforts**

- **Product based - driven by changes to the software baseline(s)**

- **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**

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Summary Work Breakdown Structure

Software Maintenance, Sustaining Engineering, and Operational Support

1.0 Software Maintenance

Releases 1
Planning - Management
Software Requirements
Architecture & Design
Change Implementation
Integration & Test
Acceptance Test
Rework
Emergency Repairs
(Hardware Updates)
Releases 1+

2.0 Software Licenses

3.0 Information Assurance

4.0 Certification & Accreditations

5.0 Sustaining Engineering

Analysis and Studies
Test Support
Software Delivery
User Training
User Support
Field Support

6.0 Facilities & Infrastructure

Development Facilities
Integration and Test Facilities
Tactical Equipment
Test Equipment and Tools

7.0 Management

Program Management
Contract Management
Change Management
Data Management
Quality Assurance
Process Management
Personnel Management

13 - 28 June 2012

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Summary Work Breakdown Structure

1.0 <u>Software Maintenance</u> - products and activities associated with modifying an operational software product or system

2.0 <u>Software Licenses</u> - products and activities associated with the procurement and renewal of software licenses for operational software

3.0 <u>Information Assurance</u> - products and activities associated with ensuring that the software is compliant with externally defined information assurance requirements

4.0 <u>Certifications and Accreditations</u> - products and activities associated with verifying a software system against externally defined domain performance criteria

5.0 <u>Sustaining Engineering</u> - products and activities associated with supporting a deployed software product or system in its operational environment

6.0 <u>Facilities & Infrastructure</u> - 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 <u>Management</u> - products and activities associated with planning, organizing, funding, and controlling the resources required to support operational software products or systems
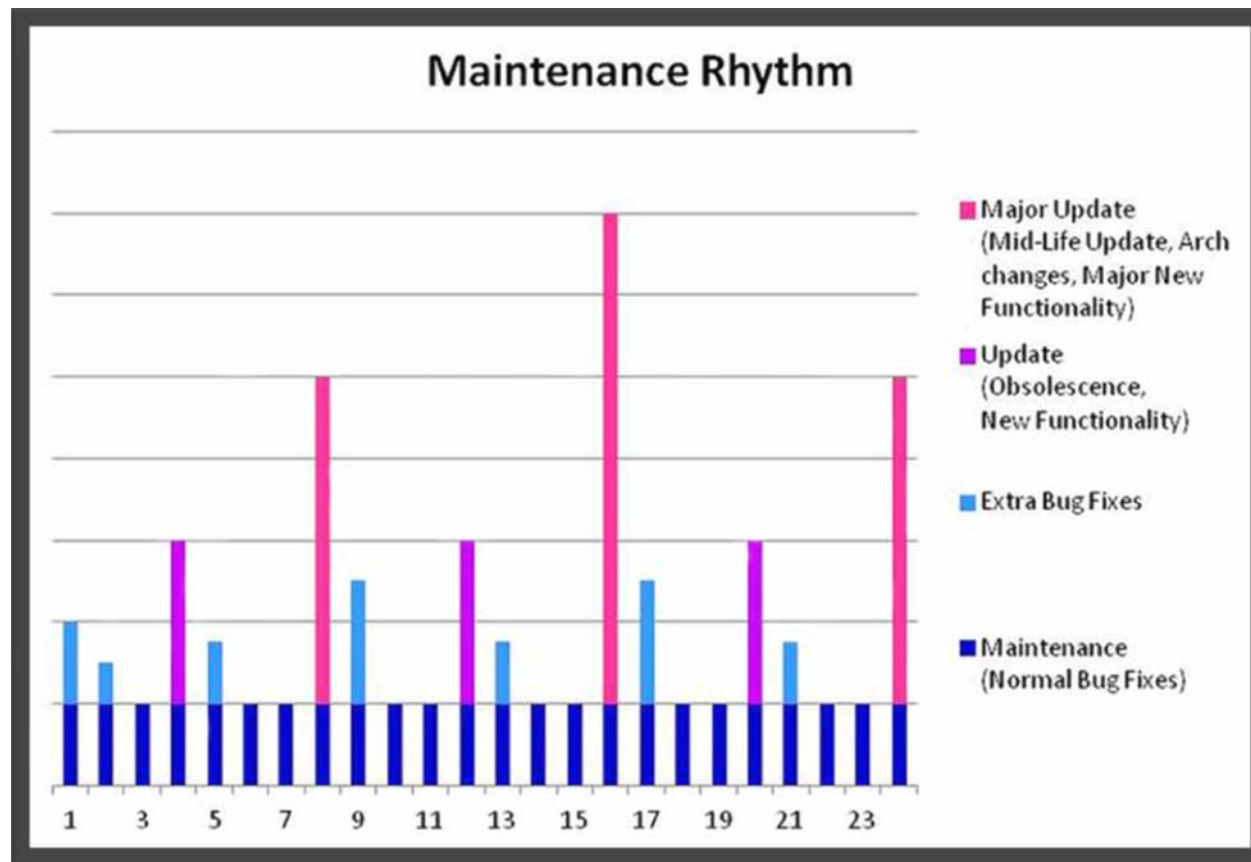
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WBS Application Considerations

- *Two perspectives - program and organization*

- *Includes both products and services*

- *Mandates vs. discretionary products/activities*

- *Diversity of program and organizational perspectives*

- *Sources of funding*

- *Consistency of execution*
  - *PDSS to PPSS*
  - *PPSS year to year*
  - *plan to actual*

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Maintenance - Consistency of Execution

Maintenance Rhythm

- Major Update (Mid-Life Update, Arch changes, Major New Functionality)
- Update (Obsolescence, New Functionality)
- Extra Bug Fixes
- Maintenance (Normal Bug Fixes)

Cycles are different - platform dependent
User needs drive release content

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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*

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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 DOD environment

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Software System Growth

107 - AH-64As

1620 - AH-64Ds

Apache Software Growth
300 KSLOC to Over 1.4 Million SLOC

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Army Software Maintenance Study

Objectives

- *Improve the availability, integrity, and usability of software maintenance and sustaining engineering cost and performance data*

- **Develop methods and models to generate defensible software maintenance and sustaining engineering cost estimates**

- **Provide a basis for objectively relating budgeted software maintenance resources to mission capability**

- **Influence DOD software maintenance and sustaining engineering policy**

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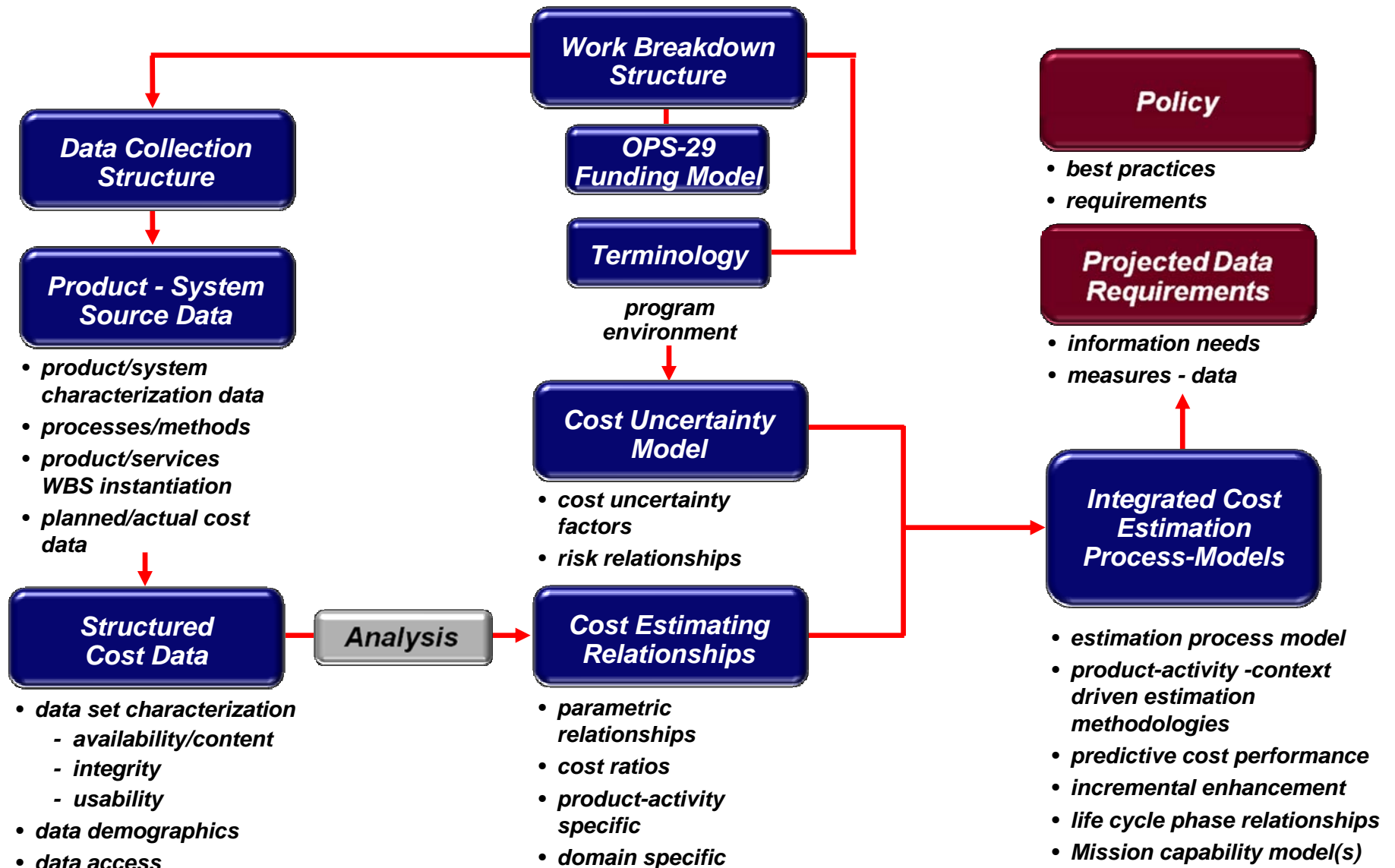# Army Software Maintenance Study

Approach

- **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 weapons system costs**

- **Technical approach based on measurement and estimation best practices**

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Army Software Maintenance Cost Estimation Framework

- *Relates the key products required to develop more viable software maintenance - sustaining engineering cost estimates*
    - *Work Breakdown Structure w/common terminology and OPS-29 alignment*
    - *Information needs - data collection requirements (current and future)*
    - *Collected maintenance data sets - database*
    - *Product - system characterization / context description*
    - *Product and activity specific CERs*
    - *Context driven cost-uncertainty model(s)*
    - *Integrated cost estimation process - model(s)*

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Work Breakdown Structure

Data Collection Structure

OPS-29 Funding Model

Policy

- *best practices*
- *requirements*

Product - System Source Data

Terminology

program environment

Projected Data Requirements

- *information needs*
- *measures - data*

- *product/system characterization data*
- *processes/methods*
- *product/services WBS instantiation*
- *planned/actual cost data*

Cost Uncertainty Model

- *cost uncertainty factors*
- *risk relationships*

Integrated Cost Estimation Process-Models

Structured Cost Data

Analysis

Cost Estimating Relationships

- *data set characterization*
  - *availability/content*
  - *integrity*
  - *usability*
- *data demographics*
- *data access*

- *parametric relationships*
- *cost ratios*
- *product-activity specific*
- *domain specific*

- *estimation process model*
- *product-activity -context driven estimation methodologies*
- *predictive cost performance*
- *incremental enhancement*
- *life cycle phase relationships*
- *Mission capability model(s)*

23 - 28 June 2012

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Software Maintenance Notional Cost Estimation Model

Software Product Release

Software Baseline

SW Change Drivers
- *Mission doctrine*
- *New capability*
- *User identified defects*
- *Information assurance*
- *Obsolescence (HW/SW)*
- *System interfaces*
- *Technical debt*
- *Deferred functionality*
- *Testing - IV&V*

Planning - Management
Software Requirements
Architecture - Design
Change Implementation
Integration & Test
Acceptance Test
Rework
Emergency Repairs
Other

Program Management

Infrastructure

Sustaining Engineering

Cost Estimate

Licenses

Information Assurance

C&As

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Cost Estimation Considerations

- **Aligned estimation methodologies**
- **Work scope - activities performed - products released**
- **Fixed cost elements**
- **Variable cost elements**
- **Cost risk - uncertainty factors**
- **System configuration complexity**
- **Application domain type**
- **Software change drivers**
  - *source*
  - *type/impact*
  - *priority*
  - *relative value*

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WBS - Estimation Framework

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 Planning and Execution	Capability Sets FY(XX/XX) System Mission Capability	Variable	No. of Requirements (Enhancements), No. of Defects, No. of 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	Number of requirements / capabilities / ... / defects / test cases / etc.)
1.1.8	Emergency Repairs	Capability Sets FY(XX/XX) System Mission Capability	Fixed	LOE (number of people) or (average number of repairs x cost of repair)
3.1	IAVA	IAVA	Variable	Parametric model (percentage distribution): Application domain, size, effort staffing, duration, productivity
5.0	Software Sustaining Engineering			Lower level cost roll-up
5.1	Analysis and Studies	Organic Labor	Fixed	LOE
5.6	Field Support	FSEs	Variable	LOE, No. of Field Sites
6.0	Software Facilities & Infrastructure	System infrastructure or System Open Door	Fixed	Facility/Utility Costs, LOE, Licenses
7.0	Management	Organic	Fixed	LOE
7.1	Program Management		Fixed	LOE

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Software Configuration Complexity

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

- **Multiple software releases are being worked on by maintenance staff in parallel during a calendar year**
  - **Development release**
  - **Fielded release**
  - **To be fielded release**
  - **Requirements release**

- **There are many end users with different hardware and/or software configurations**

- **Complex configuration management and change control environment**

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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**

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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**

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Top Level Change Driver Taxonomy

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)**

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Measuring Capability

- *Measures for "capability" exist - predictions are problematic (aircraft availability, ready for tasking, mission capability, etc.)*

- *Difficult to relate the expected "capability contribution" for a system based on software maintenance investment*

- *Multiple and complex factors*

- *Need to relate cost to maintenance outputs - products and services - and be able to accurately predict costs*

- *Need to be able to relate products and services to incremental capability improvements - however capability is measured within the domain*

- *The is an imperfect "workaround" based on "mission weighted software change backlog" (mandatory, mission critical, mission essential, mission enhancing)*

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Summary

- *The performance factors associated with software maintenance and sustaining engineering are more complex and more inter-related than those in software development*

- *These factors all have a bearing on maintenance cost and return on investment in terms of mission capability*

- *The technical and business structures applied to software maintenance are significantly diverse*

- *We need to define and apply consistent processes and mechanisms across the installed operational software base*

- *We need to generate the data required to establish normative cost and output relationships necessary for objective decision making at all levels of the DOD enterprise*

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