Tutorial: Integrating Systems Engineering with Earned Value Management

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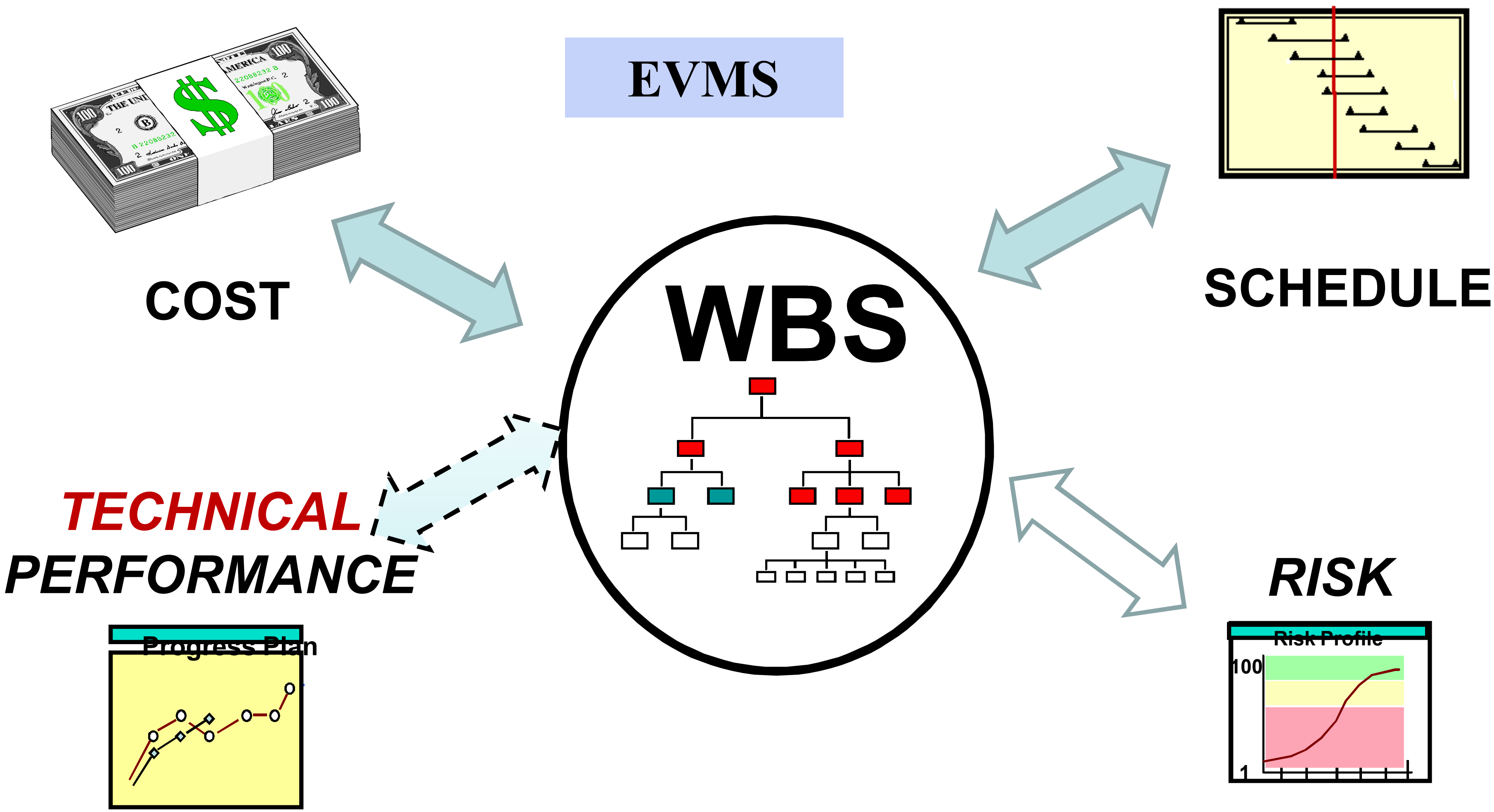
Agenda

- Link EV to Technical Performance/Quality
- Government Needs and Acquisition Reform
- Guidance in Standards, Models and DoD Guides
- Practical Application: 4 Opportunities
  - Base EV on Technical Performance
  - Account for Deferred Functionality
  - Track Systems Engineering Tasks Discretely
  - Plan Rework and Track it Discretely
- Acquisition Management and Reform
- Framework for Process Improvement

Does EVMS Really Integrate?



Value of Earned Value

"EVM data will be reliable and accurate only if:

- **The right base measures of technical performance are selected**

  and

- **Progress is objectively assessed" (a)**

(a) "Integrating Systems Engineering With Earned Value Management"
in *Defense AT&L Magazine*, May 2004

Government Needs and Acquisition Reform

Office of Management and Budget (OMB)

- **OMB Circular No. A-11, Section 300**

  Planning, Budgeting, Acquisition and Management of Capital Assets

  - **Section 300-5**
    - ***Performance-based*** **acquisition management**
    - **Based on EVMS standard**
    - **Measure progress towards milestones**
      - **Cost**
      - ***Capability to meet specified requirements***
      - **Timeliness**
      - ***Quality***

Federal Acquisition Regulation (FAR) 2.101.b; EVMS

EVMS Definition:

- **Program management tool that effectively integrates project scope of work with:**
  - **Cost**
  - **Schedule**
  - ***Performance* elements**
- **Qualities and operating characteristics of an EVMS are described in ANSI-748 (EVMS)**

But ANSI-748 has

Performance/Quality gap

DoD EVM Report to Congress

2009 Report: ***DoD Earned Value Management: Performance, Oversight, and Governance*** **(1)**

"Utility of EVM has declined to a level where it does not serve its intended purpose."

Findings and Recommendations:

- ***Inaccurate*** **EVM status data provided by vendors**
- **Use** ***Technical Performance Measures*** **(TPM)**
- **Integrate** ***Systems Engineering*** **(SE) with EVM**

(1) Required by Section 887 of the of the FY 2009 NDAA, "Weapon Systems Acquisition Reform Act of 2009" (WSARA), Sept. 2009

EVM Challenges in Report to Congress

Challenge: Technical Performance
• EVM can be an effective program management tool only if it is integrated with technical performance • The engineering community should establish technical performance measures (TPM) that enable objective confirmation that tasks are complete;

EVM Challenges in Report to Congress

Challenge: Technical Performance
• If good TPMs are not used, programs could report 100 percent of earned value (or credit for work performed), even though they are behind schedule in terms of: • validating requirements • completing the preliminary design • meeting weight targets • or delivering software releases that meet the requirements.

EVM Challenges in Report to Congress

Challenge: Technical Performance
• The earned value completion criteria • must be based on technical performance • the quality of work must be verified, and • criteria must be defined clearly and unambiguously. • The PM should ensure that the EVM process measures the quality and technical maturity of technical work products instead of just the quantity of work performed.

EVM Challenges in Report to Congress

Challenge: SE/Technical Baseline
EVM can be an effective program management tool only if • the EVM processes are augmented with a rigorous SE process • the SE products are costed and included in EVM tracking. If the SE life-cycle management method is integrated with the planning of the Performance Measurement Baseline (PMB), then EVM will accurately measure technical performance and progress.

DoD Need:
Integrated Testable Requirements

Memo: Test & Evaluation of DoD Programs (1)

1. **Improve relationship among testing, require-ments, and program management communities**
2. **Well defined, testable requirements**

- Requirements development must be informed by technical feasibility and ***rigorous trade-off analysis***.
- Define requirements in ways that are clear and ***testable***…should be achieved as early as possible.
- Define requirements in ways that provide *meaningful* ***increments of operational capability.***
- Define requirements in ways that enable efficient program execution.

(1) 6/3/2011, signed by USD for AT&L, Ashton Carter and Director OT&E, J. Michael Gilmore.

Deferred Functionality

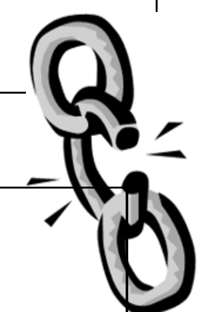
GAO Report	Title	Findings and Recommendations
08-448	Defense Acquisitions: Progress Made in Fielding Missile Defense, but Program Short of Meeting Goals (Missile Defense Agency (MDA)	<u>Deferred Functionality</u> MDA *did not track* the cost of work *deferred* from one block to another. • Cost of first block understated . • Cost of second block overstated.

EVMS Quality Gap

Quality Gap

EVMS Standard shortfall (3.8):

- **"EV is..measurement of *quantity* of work"**
- ***"Quality* and *technical* content of work performed are *controlled by other means" !?***



EVMS Standard shortfall (Guideline 2.2b):

Identify physical products, milestones,

- **technical performance goals**

"or" **other indicators that will be used to measure progress.**

Quality Gap

"or"* not *"and;" technical performance is optional

EVMS Quality Gap

EVMS Standard, **Federal Acquisition Regulation (FAR) and Defense FAR Supplement (DFARS) are deficient:**

No **guidance or requirement to link**

- **Reported EV**

  with

- **Progress toward meeting *Quality/technical performance requirements***

Management Reserve (MR)
Quality Gap

EVMS loopholes enable misuse of MR:

3.5.4 "MR is held for *unexpected growth* within the currently authorized *work scope*"

How is MR misused?

1. **Frequent causes of additional testing and rework:**
   - **Unrealistic baseline assumptions**
     - **Low estimates of rework %, software defects etc.**
   - **Failure of design to meet technical requirements**
2. **MR used to *budget additional tests and rework, masked as "scope growth"***
3. ***Results: Accurate progress and true cost overrun are not reported***

Standards, Models, Guides: Guidance on Quality

Standards, Models, and Guides

- Processes for Engineering a System (ANSI/EIA-632)
- Standard for Application and Management of the SE Process (ISO/IEC 26702:2007/IEEE 1220) (a)
- Capability Maturity Model Integration (CMMI®)
- Guide to the Project Management Institute Body of Knowledge (PMBOK Guide®), 4th Edition
- SE Leading Indicators Guide, Version 2.0
- Space and Missile Systems Center (SMC) Standard SMC-S-001 Systems Engineering Requirements and Products
- USAF Weapon Systems Software Management Guidebook
- NAVAIR Using Software Metrics and Measurements for Earned Value Toolkit

(a) Cited in DAG 4.2.1

Technical Baselines, Success Criteria, and Requirements Traceability

Requirements and Product Metrics

ISO/IEC 26702	EIA-632
6.8.1.5 Performance-based progress measurement	4.2.1 Req. 10: Progress against requirements
6.8.1.5 d) Assess • *Development maturity* • Product's ability to *satisfy requirements* 6.8.6 *Product metrics at pre-established control points:* • Evaluate system *quality* • *Compare to planned goals and targets*	Assess *progress …* • Compare system definition *against requirements* a) Identify *product metrics* and *expected values* ▪ *Quality* of product ▪ Progress towards *satisfying requirements* d) *Compare* results against *requirements*

Requirements-based Success Criteria

ISO/IEC 26702, (6.6): Success Criteria (CDR)

- **Design solution meets:**
  - ***Allocated performance requirements***
  - ***Functional performance requirements***
  - **Interface requirements**
  - **Workload limitations**
  - **Constraints**
  - **Use models and/or prototypes to determine success**

SE Leading Indicators Guide: Requirements Trends

Leading Indicator	Insight Provided	Base Measures
Requirements Validation Trends	Progress against plan in assuring that the customer requirements are valid and properly understood.	1. Requirements 2. Requirements Validated
Requirements Verification Trends	Progress against plan in verifying that the design meets the specified requirements.	1. Requirements 2. Requirements Verified

PMBOK® Guide

5 Project Scope Management

In the project context, the term scope can refer to

- ***Product scope.*** **The *features* and *functions* that characterize a product, service, or result**
- **Project scope. The *work* that needs to be accomplished to deliver a product, service, or result with the specified features and functions.**

Manage the Technical Baseline

DAG 4.5.1. Systems Engineering Plan

- **Include the system's technical baseline approach**
  - **How the *technical baseline* will be developed, managed, and used to control**
    - ***System requirements***
    - **Design integration**
    - **Verification**
    - **Validation**
  - **Discuss *TPMs and how they will be used to measure progress***

Functional Baseline (DAG)

What

- **Definition of the required system functionality**
  - Functional and interface characteristics of overall system
  - Verification required to demonstrate their achievement
- **Derived from the Capabilities Development Document (CDD)**
- **Includes**
  - Detailed functional performance specification for the overall system
  - Tests necessary to verify and validate system performance.

When:

- Established at System Functional Review (SFR)
- Verified at System Verification Review (SVR)

Allocated Baseline (DAG)

<u>What</u>

- **Definition of the configuration items (CI) making up a system**
- **All functional and interface characteristics allocated from the top level system or higher-level CIs**
- **Derived requirements**
- ***Performance* of each CI in the allocated baseline**
- **Tests necessary to verify and validate CI performance**

<u>When:</u> At each CI's Preliminary Design Review (PDR)

Product Baseline (DAG)

What

Necessary functional and physical characteristics of a CI

- **Selected functional and physical characteristics designated for production acceptance testing**
- **Tests necessary for deployment/installation, operation, support, training, and disposal of the CI**
- **Initial product baseline includes "build-to" specifications for hardware (product, process, material specifications, engineering drawings and software (software module design— "code-to" specifications)**

When:

- **At each CI's Critical Design Review (CDR)**
- **System product baseline established at system-level CDR**

USAF on Requirements Baseline

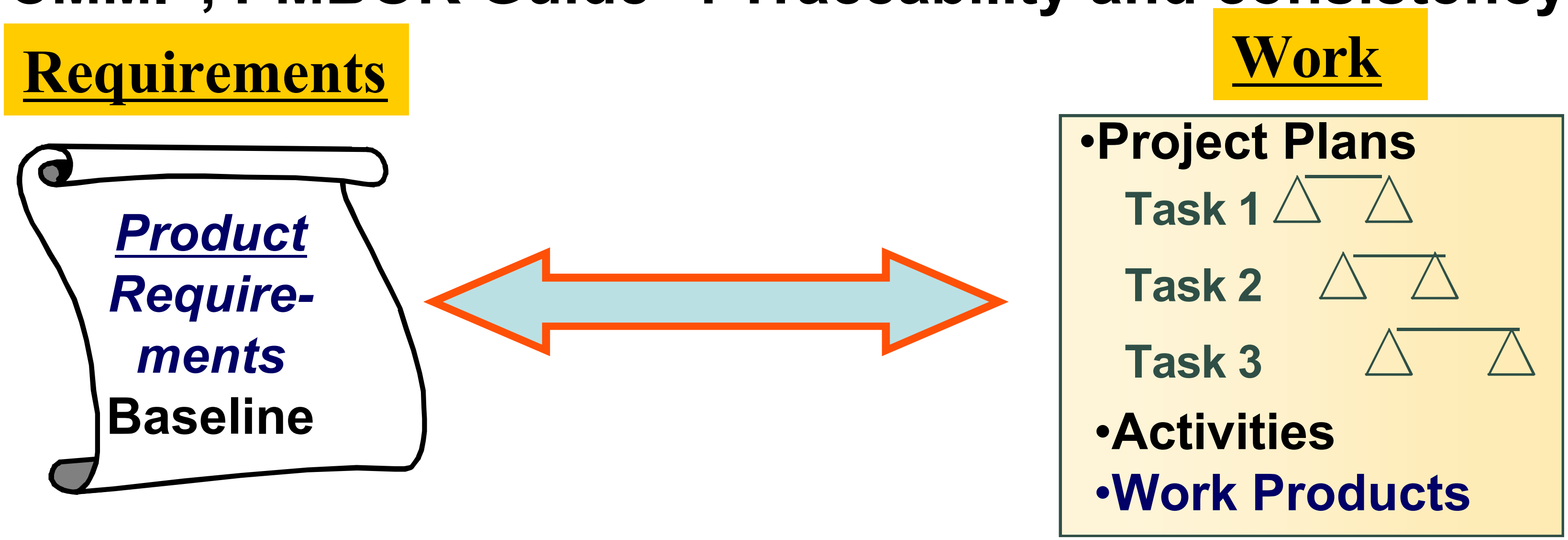
3.6.2 Requirements and Incremental Software Development

b. Map/allocate the requirements into all planned builds.

- **Failure to do so will increase likelihood that**
  - **Functionality will migrate to later builds**
  - **Initial delivery will not meet user expectations**
  - **Unplanned builds will become necessary**
  - **Delivery of full functionality will be delayed.**

Trace Product Requirements Baseline to Plans

- CMMI®, PMBOK Guide® : Traceability and consistency



Source: CMMI Requirements Management Process Area (PA), Specific Practice (SP) 1.5

DoD Guides: Integrated Planning

DoDI 5000.02, Operation of the Defense Acquisition System (POL) 12/08
Defense Acquisition Guidebook (DAG)
Systems Engineering Plan (SEP) Preparation Guide 4/08
WBS Handbook, Mil-HDBK-881A (WBS) 7/30/05
Integrated Master Plan (IMP) & Integrated Master Schedule (IMS) Preparation & Use Guide 10/21/05
Guide for Integrating SE into DOD Acquisition Contracts (Integ SE) 12/06
Defense Acquisition Program Support Methodology (DAPS) V2.0 3/20/09

DoD: Technical Baselines And Reviews

DoD Policy or Guide	POL	DAG	SEP	WBS	IMP/ IMS	Integ SE	DAPS
Technical Baselines **in IMP/IMS (Milestones):** • Functional (SFR) • Allocated (PDR) • Product (CDR)		X				X	X
Technical Reviews:							
• Event-driven timing of technical reviews	X	X	X	X	X	X	X
• Success criteria of technical reviews	X	X	X	X	X	X	X
• Include entry and exit criteria for technical reviews in IMP and IMS		X	X			X	X
• Assess technical maturity in technical reviews		X	X	X		X	

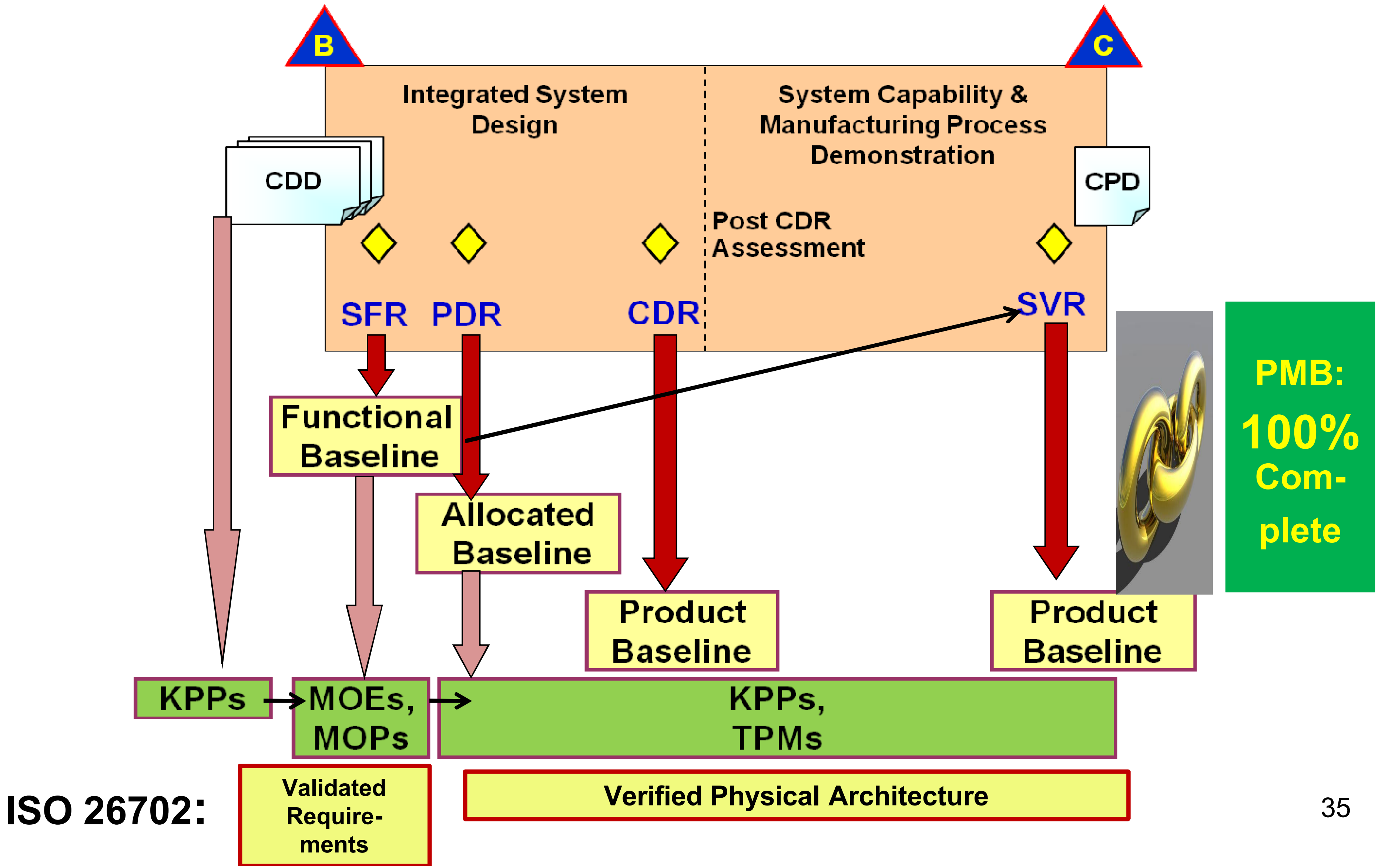
DoD: Integrated Plans

DoD Policy or Guide	POL	DAG	SEP	WBS	IMP/ IMS	Integ SE	DAPS
Integrate SEP with: • IMP/IMS • *TPMs* • EVM		X	X		X	X	X
Integrate WBS with • *Requirements specification* • Statement of work • IMP/IMS/EVMS		X		X	X	X	X
Link risk management (including risk mitigation plans), technical reviews, *TPMs*, EVM, WBS, IMS		X				X	X

DoD: Integrated Plans

DoD Policy or Guide	POL	DAG	SEP	WBS	IMP/ IMS	Integ SE	DAPS
Integrate SEP with: • IMP/IMS • *TPMs* • EVM		X	X		X	X	X
Integrate WBS with • *Requirements specification* • Statement of work • IMP/IMS/EVMS		X		X	X	X	X
Link risk management (including risk mitigation plans), technical reviews, *TPMs*, EVM, WBS, IMS		X				X	X

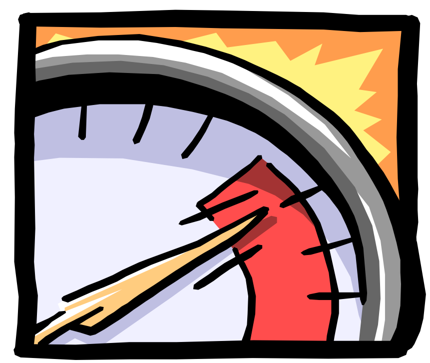
Link PMB to Technical Baselines, Reviews, and Measures



Technical Performance Measures

TPM

- How well a system is achieving performance requirements
- Use actual or predicted values from:
  - Engineering measurements
  - Tests
  - Experiments
  - Prototypes
- Examples:
  - Payload
  - Response time
  - Range
  - Power
  - Weight



Technical Performance Measures (TPM)

ISO/IEC 26702: 6.8.1.5, Performance-based progress measurement	EIA-632: Glossary	CMMI for Development Requirements Development
TPMs are key to progressively assess technical progress	*Predict* future value of *key technical parameters* of the end system based on current assessments	Specific Practice (SP) 3.3, Analyze Requirements Typical work product: *TPMs*
Establish *dates* for – Checking progress – Meeting full conformance to requirements	*Planned value* profile is time-phased achievement projected • *Achievement to date* • *Technical milestone where TPM evaluation is reported*	Subpractice: Identify TPMs that will be tracked during development

TPMs in INCOSE SE Handbook

4.3.1.4: The architectural design baseline ...includes:

- **TPM Needs – TPMs are measures tracked to influence the system design**
- **TPM Data – Data provided to measure TPMs**

5.1.2.2 Systems Engineering Plan (SEP)

- **TPMs are a tool used for project control**
- **The extent to which TPMs will be employed should be defined in the SEP.**

5.7.2.4 TPMs

- **Without TPMs, a project manager could fall into the trap of relying on cost and schedule status alone**
- **This can lead to a product developed on schedule and with cost that does *not meet* all *key requirements*.**
- **Values are established to provide limits that give early indications if a TPM is out of tolerance.**

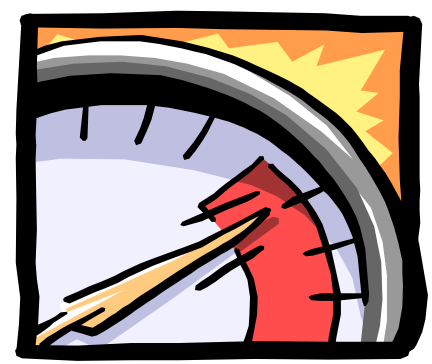
SE Leading Indicators Guide: Technical Measurement Trends

Leading Indicator	Insight Provided	Base Measures
Technical Measure-ment Trends	Progress towards meeting Measures of Effectiveness (MOE) / Measures of Performance (MOP)/ Key Performance Parameters (KPP)s and TPM	Values of Technical Measure

TPMs in DAG

DAG:

- **Performance measurement of WBS elements, using objective measures:**
  - ***Essential for EVM*** **and Technical Assessment activities**
- ***Use TPMs*** **and Critical Technical Parameters (*CTP*)** ***to report progress in achieving milestones***
- **Plan is defined in terms of:**
  - **Expected performance at specific points**
    - **Defined in the WBS and IMS**
  - **Methods of measurement at those points**
  - **Variation limits for corrective action.**



TPMs in DAG

- **TPM parameters to be tracked**
  - ***Cost drivers*** **on the program,**
  - **On the** ***critical path***
  - **Represent** ***high technical risk*** **items.**
- **Contract Deliverable**
  - ***Report of TPMs*** **that are traceable to:**
    - **Needs of the operational user**
    - **Key Performance Parameters (KPP), Critical Technical Parameters**
    - **Key system attributes**
- **Contractor's internal TPMs**
  - ***TPMs at a more detailed level***

PMBOK TPM Guidance

11.6.2.4 Technical Performance Measurement

- **TPM compares technical accomplishments during project execution to the … schedule of technical achievement.**
- **It requires definition of objective, quantifiable TPMs which can be used to compare actual results against targets (11.6.2.4).**

SE Tasks, Work Products, and Completion Criteria

Validated Requirements (Functional) Baseline

<u>ISO/IEC 26702, (6.1, 6.2): Work Products</u>
• Customer expectations • Project, enterprise and external constraints • *Operational scenarios* • *MOEs* • Interfaces • *Functional requirements* • *MOPs* • Modes of operation • Design characteristics • Documented trade-offs

SFR Success Criteria (CMMI/DAG)

Requirements Development	SG 3: Analyze and Validate Requirements	DAG
SP 3.2 Establish a Definition of Required Functionality	Example work products: • Functional architecture • Activity diagrams and use cases Subpractices 1. Analyze and quantify functionality required by end users 2. Allocate functional and performance requirements to functions and subfunctions	4.2.3.1.6.2 Establish Configura-tion Baselines - SFR success criteria

PDR Success Criteria

DAG 4.3.2.4.2.3 (partial)

• Preliminary design satisfies the CDD
• System allocated baseline established and documented to enable detailed design to proceed with proper configuration management
• Program schedule executable (technical/cost risks)
• Producibility assessments of key technologies completed
• Program executable with
    • Existing budget
    • Approved system allocated baseline
• Risks known and manageable for testing

Note: Software success criteria discussed in later section

PDR,CDR Success Criteria (CMMI/DAG)

CMMI Requirements Development	SG 2: Develop Product Requirements	DAG
SP 2.2 Allocate product component requirements	Example work products: • Requirement allocation sheets • Design constraints • Derived requirements Subpractices 1. Allocate requirements to functions 2. Allocate requirements to product components	4.2.3.1.6.2 Establish Configuration Baselines – PDR, CDR Success Criteria

CDR Success Criteria

<u>ISO/IEC 26702</u>, (6.6): Success Criteria (CDR)
• Design solution meets: – *Allocated performance requirements* – *Functional performance requirements* – Interface requirements – Workload limitations – Constraints – Use models and/or prototypes to determine success

CMMI Example
SE Work Products

Requirements Development PA

- **Prioritized customer requirements**
- **Customer constraints on the conduct of verification**
- **Customer constraints on the conduct of validation**
- ***Activity diagrams and use cases***
- **Derived requirements**
- **Relationships among derived requirements**
- ***Product requirements***
- **Definition of *required functionality* and *quality attributes***
- ***TPMs***

CMMI Example
SE Work Products

Requirements Management PA:

- ***Requirements traceability matrix (RTM)***

Verification PA:

- ***Verification methods*** **for each selected work product**
- ***Verification criteria***
- ***Exit and entry criteria for work products***
- **Verification results**

Measurement and Analysis PA:

- ***Measurement objectives***
- ***Specifications of base and derived measures***

CMMI Example
SE Work Products

Technical Solution PA:

- **Documented relationships between *requirements* and product components**
- **Product component design**
- **Interface specification criteria**
- **Implemented design**

Practical Application

Four Opportunities

Specific Opportunities Underlying the Challenges

1. Base EV on Technical Performance	2. Account for Deferred Functionality	3.Track SE tasks discretely	4. Plan rework and track it discretely

2 steps

- Top Down Planning
- Measure Interim Progress

Proposed Solution for Basing EV on Technical Performance

Top Down Planning

1 0f 3

- **Make the IMP a contractual requirement with correct, requirements-based accomplishment criteria**
  - **Examples:**
    - **MOPs defined at SFR**
    - **TPMs defined at PDR**
    - **At CDR, subsystem design is finalized and meets all allocated design, interface and all derived requirements**
- **Use the IBR to reach agreement on the accomplishment criteria for IMP events**

Proposed Solution for Basing EV on Technical Performance

Top Down Planning

2 0f 3

- **Require that requirements-based accomplishment criteria for major technical reviews are traceable from:**

  IMP → IMS → Work Package

Proposed Solution for Basing EV on Technical Performance

Top Down Planning

3 0f 3

- **When planning incremental functionality**
  - **Document the functional requirements baseline of each block, version, or build (all called "builds")**
  - **Establish interim and completion build milestones based on functional requirements**
  - **Establish work packages for builds that support the IMS milestones**

Note: Contractual requirement communicated via IMP.

Example 1: Work Package Completion Tied to CDR Success Criteria (1 of 4)

- 90% of engineering design drawings are complete and releasable to manufacturing.
- All stakeholders agree that the design is producible.
- Completion of component design reviews:
  - Enclosure
  - Radio transmitter
  - Battery
  - Control
  - Software

Ex 1: Work Package Completion Tied to CDR Success Criteria (2 of 4)

- **Prototype of enclosure demonstrated that the design meets the following requirements (RQMT) in the Requirements Data Base (RDB) :**
  - **RQMT 001: Weight: no greater than 40 lb**
    - **PROD 1: The overall weight of the Mobile C2 Center shall not exceed 40 lbs**
  - **RQMT 2: Waterproof in continuous rain**
    - **PROD 2: The Mobile C2 Center shall be waterproof in continuous (up to 2 hours) driving rain with a wind speed of up to 65 miles per hour and rainfall of up to 4 inches per hour.**
      - **ENCL 2: The Mobile C2 Center shall be waterproof in continuous (up to 2 hours) driving rain with a wind speed of up to 65 miles per hour and rainfall of up to 4 inches per hour.**

Ex 1: Work Package Completion Tied to CDR Success Criteria (3 of 4)

- RQMT 3: Impact resistant
  - PROD 3: The Mobile C2 Center shall show no damage after at least 3 successive impacts with a hard abrasive surface of up to 15 lbs./sq. in.
    - ENCL 3: Same as above.

Ex 1: Work Package Completion Tied to CDR Success Criteria (4 of 4)

- RQMT 4: Software (SW) Functionality: Terrain)
  - SW integration testing results demonstrated that the SW meets the following functional (FUNC) requirements:
    - Func 7: The Mobile C2 center shall allow the user to select a visible image of the terrain being surveilled.
    - FUNC 8 The Mobile C2 center shall allow the user to select an infrared image of the terrain being surveilled.
    - FUNC 9 The Mobile C2 center shall allow the user to select either a high-pass or a low-pass filter to enhance the visible image of the terrain being surveilled.
  - All stakeholders agree that there are no critical, Priority 1 SW defects

Opportunity 1:
Base EV on Technical Performance

Measure Interim Progress

EVMS Issue:

2. Interim EV progress may not be based on actual progress towards achieving 100% of baselined technical performance or functionality.

Basing interim EV on technical performance or quality is optional; rarely used in practice. Typical % complete may fail to provide early warning.

Solution for Basing EV on Technical Performance

Measure Interim Progress

1 of 2

- **Establish objective linkage between technical performance planned values and EVM:**
  - For physical objectives, use TPMs
  - For planned functionality, base on functional requirements
- **Compare reported EV with technical performance**
- **If EV exceeds technical performance:**
  - Do root cause analysis to determine reasons for disconnect
  - Refine base measures of EV to reflect technical performance

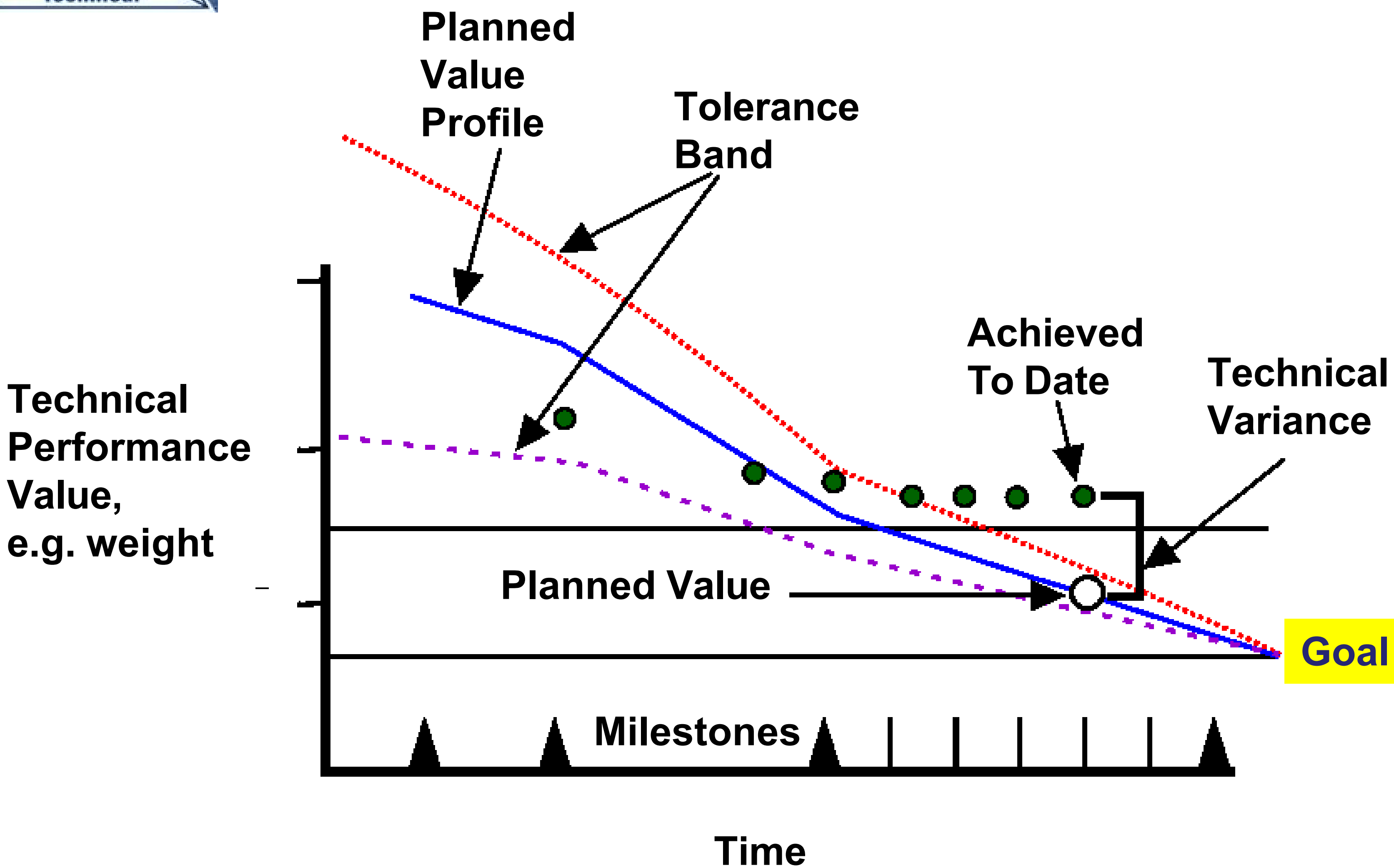
Solution for Basing EV on Technical Performance

Measure Interim Progress

2 of 2

- **If behind schedule on technical performance, perform variance analysis and develop corrective actions**
  - **Revise ETC *forward* → for work packages with corrective actions**
  - **Correct EV to reflect technical performance status**
    - **Backwards ← adjustment to EV is appropriate for work packages with corrective actions**
    - **Enables use of EV to track corrective actions to resolution and closure**

TPM Performance vs. Baseline



Ex 2: EV Based on Drawings and TPMs (1 of 8)

- SOW: Design a component, Enclosure, with 2 TPMs:
  - Maximum (Max) weight
    - Planned Value (PV): 6 lb. (May)
  - Max dimensions (length + width + height)
    - PV: 32 inches (when 80% drawings complete, April)
- Enabling work products: 50 drawings
- BAC: 2000 hours
  - Drawings: 40 hours/drawing @ 50 = 2000
  - If TPM PVs *not* met on schedule:
    - Develop recovery plan (RP)
    - Negative adjustment to EV based on RP

Ex 2: EV Based on Drawings and TPMs (2 of 8)

Recovery Plan Adjustment to EV:

1. **Develop RP to reduce weight from 7 to 6 lb.**
2. **Determine duration and completion date of RP**
3. **Move ETC *forward* to completion date of RP**
4. **Make negative adjustment to cum. BCWP = (duration of RP) x BCWS/period = (*backwards* adjustment)**

Example:

- **If RP = 1.5 months and**
- **BCWS = 400 / month**
- **Then RP *backwards* EV adjustment = - 600**

Benefits:

1. **Cum. EV reflects realistic schedule variance**
2. **Track RP with EV**

Ex 2: EV Based on Drawings and TPMs (3 of 8)

Schedule	Total	Jan	Feb	Mar	Apr	May	Total
	<u>Draw-ings</u>						
Drawings/ period	**50**	**8**	**10**	**12**	**10**	**10**	**50**
Meet requirements:							
Weight	**6 lb.**					▲	
Dimensions	**32 in.**				▲		

Ex 2: EV Based on Drawings and TPMs (4 of 8)

Date	April 30	May 31
Drawings completed	41	49
Weight met	No	No
Dimensions met	Yes	Yes

Ex 2: EV Based on Drawings and TPMs (5 of 8)

Design (drawings)	Jan.	Feb.	Mar.	Apr.	May	Total
Planned drawings cur	8	10	12	10	10	50
Planned drawings cum	8	18	30	40	50	
BCWS cur	320	400	480	400	400	2000
BCWS cum	320	720	1200	1600	2000	2000
Actual drawings completed cur	9	10	10	12	8	
Actual drawings completed cum	9	19	29	41	49	
EV (drawings) cum	360	760	1160	1640	1960	
RP EV adjustment				0		
Net EV cum	360	760	1160	1640	*1360*	*1360*

SV = - 640

Ex 2: EV Based on Drawings and TPMs (6 of 8)

May schedule variance (drawings and requirements):

- **1 drawing behind schedule** **- 40**
- **Dimensions requirement met** **- 0**
- **Weight requirement *not* met and recovery plan will extend ETC**
  - **RP EV adjustment = 1.5 x (- 400/month) =** **- 600**

Schedule variance (SV)

Ex 2: EV Based on Drawings and TPMs (7 of 8)

May comprehensive schedule variance analysis

- **Primary driver of SV is weight reduction (- 600)**
- **Recovery plan**
  - **Use magnesium alloy instead of aluminum; 1 lb. reduction**
  - **15 drawings to be reworked; dimensions and interfaces**
- **Recovery plan will take 6 weeks**
  - **Reflected in negative EV adjustment and IMS status**
- **Typical EAC and schedule impacts:**
  - **ETC extended 6 weeks until July 15**
  - **Non-recurring EAC: + $50K**
  - **Recurring material and fabrication costs: $800/unit**
  - **Schedule impact on CDR; slip 4 weeks**

Ex 2: EV Based on Drawings and TPMs (8 of 8)

Schedule	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	
Plan: Drawings/ period	50	8	10	12	10	10			
Weight	6 lb.								
Original EV cum		360	760	1160	1640	1960			
Rework Drawings							10	5	
Negative EV						-600			
Adjusted EV						1360			
IMS	Before After								

EVMS Guideline Inhibits Accurate Reporting

- **Most practitioners, and DCMA, believe that it is wrong (non-compliant) to make negative adjustments to EV**
- **Some contractors and DCMA require Program Office and DCMA prior approval**
- **They misinterpret EVMS Guideline 30 by focusing on the first statement below and ignoring the second statement:**
  - **Control retroactive changes to …work performed.**
  - **…Adjustments should only be made..to *improve the accuracy* of performance measurement data.**
- **This misinterpretation inhibits accurate reporting and condones overstatement of true progress when previously reported technical performance is no longer true**

TPMs Work for Software Too

Same technique wor□s for hardware□

- **Substitute computer software units for drawings**
- **Use SW TPMs such as:**
  - **Defect density**
  - **Throughput**

Ex 3: TPM at Higher WBS Level (1 of 3)

- Design of a component at the work package level
- Completion of the component design depends on
  - Achieving allocated TPMs values at
    - Component level (work package) and
    - Configuration Item (CI) level (summary level)
- EV depends on planned TPM values achieved at both levels

Ex 3: TPM at Higher WBS Level (2 of 3)

- **Assumptions:**
  - **Component 1 in Example 1 is one of 5 components (work packages) that form a CI**
  - **CI's TPM objective is 40 lb.**
  - **Systems Engineering Plan states:**
  - **Some components may be overweight at completion if there are offsets in other components (Comp) as long as the total CI weight does not exceed 40 lb.**

Ex 3: TPM at Higher WBS Level (3 of 3)

Work Pkg/ Comp	TPM PV (lb)	Comp Mile-stone	CI Mile-stone	RP Nega -tive EV
1 Enclosure	6	April	May	(a)
2 Transmitter	10	April	May	(a)
3 Battery	4	May	May	(a)
4 Controller	20	May	May	(a)
Total	40			

(a) If component will be redesigned in Recovery Plan, make backwards adjustment to EV based on forward ETC revision

Opportunity 2: Deferred Functionality

EVMS Issue:

EV may not account for deferred functionality from one build, release, or block to another.

Solution for Account for Deferred Functionality

- **Account for deferred functionality (in a block or release)**
  - **If build is behind schedule and is released short of planned functionality:**
    - **(Preferred) Take partial EV and close work package**
      - **Transfer deferred scope and Budgeted Cost of Work Remaining to first month of work package of next increment**
        - » **EV mirrors technical performance**
        - » **Schedule variance is retained**
      - **Disclose shortfall and slips on higher schedules**

    or
    - **Take partial EV and leave work package open**

Solution for Account for Deferred Functionality

Account for deferred functionality (in a block or release)

- **If build is behind schedule and is released short of planned functionality:**
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      - **EV mirrors technical performance**
      - **Schedule variance is retained**
    - **Disclose shortfall and slips on higher schedules**

    or
  - **Take partial EV and leave work package open**

NAVAIR on Deferred Functionality

NAVAIR 3.1.4 Deferred Functionality or Requirements
Deferring functional requirements has the following impacts:

1. **If all the requirements planned for a phase are not completed, then the earned value for these deferred requirements cannot be earned as part of the build.**
5. **Although requirements may be deferred to a subsequent build, the earned value must continue to show a behind schedule condition. The deferred effort should not be replanned beyond the current month.[4]**

"No matter what software measures are used to drive EV, requirements must also be used if actual program status is to be determined."

Ex 4: Deferred Functionality (1 of 5)

SOW: Software Requirements in 2 Builds:

Build	Allocated Req.	Budget/Req.	BAC
A	100	5	500
B	60	5	300

Ex 4: Deferred Functionality (2 of 5)

Plan and Performance	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Budget/Req: 5							
Build A							
Planned Reqs met	25	25	25	25	0	0	100
BCWS - cur	125	125	125	125			500
BCWS - cum	125	250	375	500			
Build B							
Planned Reqs met				20	20	20	60
BCWS - cur				100	100	100	300
BCWS - cum				100	200	300	

Ex 4: Deferred Functionality (3 of 5)

Plan and Performance	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Build A							
Planned Reqs met	25	25	25	25	0	0	100
Actual Reqs. Met - cur	20	20	25	25	0	0	90
BCWS - cur	125	125	125	125	0	0	500
BCWS - cum	125	250	375	500			500
EV-cur	100	100	125	125			
EV - cum	100	200	325	450			450
Schedule Variance (SV)							
Reqs met - cur	-5	-5	0	0	0	0	-10
SV - cur	-25	-25	0	0			
SV - cum	-25	-50	-50	-50			-50

Corrective Action:

1. Release Build A.

2. Move 10 reqs to Build B.

Ex 4: Deferred Functionality (4 of 5)
Deferred Functionality Replan

Plan and Performance	Period 3	Period 4	Period 5	Period 6	Total
Close Build A work package:					
Schedule variance:					
Reqs met - cum	-10				
SV - cum	-50				
Build B before replan					
Planned Reqs met		20	20	20	60
BCWS - cur		100	100	100	300
Plus transfer from Build A					
Deferred Reqs		+ 10			+ 10
PV remaining		+ 50			+ 50
Build B after replan:					
Planned Reqs met		30	20	20	70
BCWS- cur		150	100	100	350

Transfer BCWS to 1st month of receiving work package to retain negative schedule variance (behind schedule)

Ex 4: Deferred Functionality (5 of 5)
Deferred Functionality Replan

Plan and Performance	Period 3	Period 4	Period 5	Period 6	Total
Build B after replan:					
Planned Reqs met		30	20	20	70
BCWS - cur		150	100	100	350
Period 4 performance:					
Reqs. Met - cur		20			
EV – cur		100			
SV		-50			

The work package will still be behind schedule at the end of Period 4 if only the original 20 requirements are met

3 Track SE tasks discretely

Solution to Track SE Tasks Discretely (1 of 3)

- **Include significant accomplishments and accomplishment criteria for SE tasks and work products in IMP**
- **Include progress towards completing SE work products in IMS and work packages**
  - **Typical SE work products include:**
    - **System architecture (functional and physical)**
    - **Interface controls**
    - **Specifications**
    - **Trade studies**
    - **Test procedures**

Solution to Track SE Tasks Discretely (2 of 3)

- For SE work products with IMP accomplishment that include product requirements, derived requirements and allocated requirements:
  – Develop requirements-based, time-phased BCWS for interim performance measurement
  – Base EV on requirements status in requirements data base:
    - Typical examples
      – Defined
      – Early Validated
      – Determined verification method
      – Approved
      – Allocated
      – Traced to test procedure

Solution to Track SE Tasks Discretely (3 of 3)

- For work packages that result in SE work products that are technical measures, base EV on progress towards meeting the IMP criteria for their completion.

  Examples:

  - MOEs
  - MOPs
  - TPMs

Correlate with SE Tasks

- Base EV on progress of
  - Enabling work products (drawings, code) and
  - RM/SE tasks and work products
- Use Requirements Traceability Matrix
  - Set milestones for RM/SE work products
  - Measure progress vs. plan
- Compare SE EV with EV at pertinent WBS levels
  - SE progress is like a tracking stock for the whole program
  - Red Flag: if WBS level progress > RM/SE progress

Ex 5: Requirements Management (RM) 1 of 3

- Discretely measure SE RM tasks
- Use RTM to control plan

% of Budget	RM Task
15	Define
15	Validate
15	Determine verification (ver) method
0	Approve
20	Allocate
15	Trace to test procedure (ver document)
0	Test
20	Verify

- Key indicator of project performance

Ex 5: Time-Phased Budget 2 of 3

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Total
Enclosure									
Schedule									
Defined		3							
Validated			2	1					
Verif. Method				1	2				
Allocated						3			
Traced to Verif.							3		
Verified								3	
BCWS current	Budget/Activity								
Defined	12	36							36
Validated	12		24	12					36
Verif. Method	12			12	24				36
Allocated	16					48			48
Traced to Verif.	12						36		36
Verified	16							48	48
Total		36	24	24	24	48	36	48	240
BCWS cumulative		36	60	84	108	156	192	240	

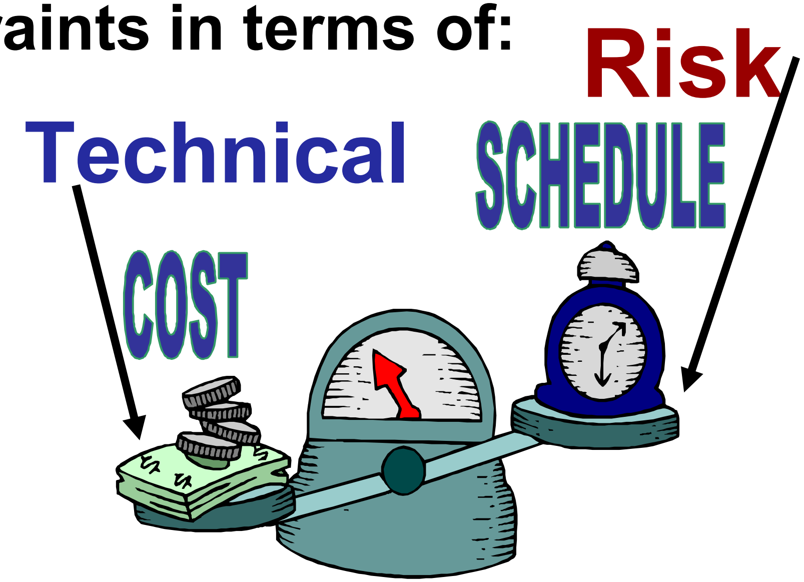
Ex 5: Earned Value 3 of 3

		Jan.	Feb.	Mar.	Apr.	May
Enclosure						
Completed	Budget/Activity					
Defined	12		3			
Validated	12				1	1
Verif. Method	12				1	
BCWP cumulative		0	36	36	60	72
BCWS cumulative		36	60	84	108	156
Schedule Variance		-36	-24	-48	-48	-84

Trade Studies

Trade Studies

- Performed during all phases of the engineering life cycle
- Provide objective foundation to select an approach to the solution of an engineering problem.
- Systems definition: Identify the recommended set of requirements and constraints in terms of:
  - Risk
  - Cost
  - Schedule
  - Performance impacts
- Design solution



Trade Studies and Requirements

- Typical trade results:
  - Select user/operational concept
  - Select system architectures
  - Derive requirements
    - Alternative functional approaches to meet requirements
    - Requirements allocations
  - Cost analysis results
  - Risk analysis results

Trade Study is a Work Product

- Outcome is usually a recommendation that is needed to make a decision.
- Decision constrains and guides further progress.
- Work product: documented trade study results.
- Engineering processes should include a process and structured approach for performing trade studies.
  - Process should include both interim and final work products that can be:
    - Planned, scheduled
    - Measured discretely.

Ex 6: Trade Study – Determine Design Solution 1 of 4

Total Budget (BAC): 1000

- Test and evaluate candidates (cand): 600
  - Original estimate: 4 candidates
  - 150 per candidate
    - Milestone (MS) 1, test setup: 25
    - MS 2, Tests completed: 75
    - MS 3, Test results analyzed 50
  - Take 100% EV even if candidate is discarded before test complete
- Down select to 2 candidates, 150
- Document final recommendation: 250

Ex 6: Trade Study Original PMB 2 of 4

Task	Jan	Feb	Mar	Apr	May	June	BAC
	BCWS	BCWS	BCWS	BCWS	BCWS	BCWS	
Cand 1	25	75	50				150
Cand 2	25	75	50				150
Cand 3		25	75	50			150
Cand 4		25	75	50			150
Subtotal	50	200	250	100			600
Select 2 cands					150		150
Recom- mend						250	250
Total Current BCWS	50	200	250	100	150	250	1000
Cumu- lative BCWS	50	250	500	600	750	1000	1000

Ex 6: Trade – Determine Design Solution 3 of 4

- **Project on schedule but candidate (cand) 2 failed in Feb, after completing 50% of test**
- **A new candidate, # 5, was discovered and added in March.**
  - ***Not additional scope or budgetable from MR.***
  - ***Cannot establish "EAC" work package because of need to track progress with EV***
  - ***Allocate budget for cand 5 from Budgeted Cost of Work Remaining (BCWR) of open work packages.***
  - ***Must baseline in original period of performance even if ETC extends further.***
- ***As often happens, there is a need to develop an internal replan because of changing conditions.***

Ex 6: Trade Study Internal Replan

4 of 4

Task	Jan	Feb	Cum BCWP	BCWR (a)	Transfer 20% to New Cand (b)	New BCWR	Mar	Apr	May	June	Orig-inal BAC	Re-plan BAC
BCWP							Replanned BCWS					
Cand 1	25	75	100	50	-10	40	40				150	140
Cand 2 (e)	25	125	150	0		0					150	150
Cand 3		25	25	125	-25	100	50	50			150	125
Cand 4		25	25	125	-25	100	50	50			150	125
New Cand 5 (c) (d)	0	0	0		60	60		60				60
Down-select 2 candidates				150		150			150		150	150
Make recom-mendation				250		250				250	250	250
Current BCWP	50	250	300	700		Current BCWS	140	160	150	250	1000	1000
Cumulative BCWP	50	250	250	-250								

(a) BCWR = Budgeted Cost of Work Remaining

(b) Transfer 20% of BCWR from open work packages to new work package for replanned PMB

(c) Period of Performance for new work package cannot exceed Cand 4, even if ETC extends further.

(d) Cand. 5 is not additional scope. SOW is to select best candidate. No use of MR.

(e) Cand. 2 is 100% complete even though the test was aborted. Objective was achieved.

Rework

Why Plan Rework Separately?

- **Better knowledge of schedule progress towards *initial* development of requirements, design, code**
  - **Earlier warning of slip to completion of initial development**
  - **Better cost variance analysis**
- **Better cost and schedule variance analysis**

NAVAIR on Rework

- **Plan rework in separate work packages from the initial development of**
  - **Requirements**
  - **Design**
  - **Code**
- **All incremental builds must include budget and schedule for rework to correct defects that were found in the current and previous builds**

Solution to Plan and Track Rework Discretely (1 of 3)

- Verify realistic rework assumptions and estimates are included in suppliers' proposals and negotiated values
  - Including productivity/quality measures such as rework % and defect density
- Review adequacy of budget and schedule for rework that is included in PMB vs. MR
  - Verify during IBRs and technical reviews

Solution to Track Rework Discretely (2 of 3)

- Option 1: (Preferred) Rework is in a separate work package
  - Discrete EV based on technical maturity targets
  - Establish interim milestones with associated TPM planned values or quantified functionality based on meeting requirements
  - Take interim EV based on net achieved technical performance
    - Make negative adjustment to earned value when necessary for accurate status reporting

Solution to Track Rework Discretely (3 of 3)

- **Option 2: If rework is not in a separate work package and if EV was taken for achieving a technical milestone, make negative adjustment to EV when work product is returned**
- **Cumulative EV must reflect net technical progress**

Ex 7: Negative EV for Rework in Same Work Package

- **SOW: 50 drawings to design a product**
- **PMB: 2000 hours over 5 months**
- **Rework was not planned in a separate work package**

- **Status at end of 4th month:**
  - **Behind schedule to complete initial drawings**
  - **5 drawings returned for rework**

Lesson: Drawings Returned for Rework Cause Negative EV

Ex 7: Negative EV for Rework in Same Work Package

Design (drawings)	Jan.	Feb.	Mar.	Apr.	May	Total
Planned drawings –cur.	8	10	12	10	10	50
Planned drawings –cum.	8	18	30	40	50	50
BCWS – cum.	320	720	1200	1600	2000	2000
Drawings completed	9	10	10	4		
Drawings returned				- 5		
Net drawings – cur.	9	10	10	-1		
Net drawings – cum.	9	19	29	28		
Net EV – cur.	360	400	400	-40		
EV – cum.	360	760	1160	1120		
SV – cum.	0	40	-40	-480		

Acquisition Management

Acquisition Management

Ensure Contractors Integrate Technical Performance/Quality with EVM

Guidance from:

- **CMMI for Acquisition (ACQ)**
- **Space and Missile Systems Center (SMC) Standard SMC-S-001 Systems Engineering Requirements and Products**

CMMI-ACQ

Acquisition Technical Management

SP 1.1 Subpractices

3. Identify the quality and functional attribute requirements to be satisfied by each selected technical solution
   – Use a traceability matrix to identifying the requirements for each selected technical solution and relates requirements to work products
4. Identify analysis methods to be used for each selected technical solution
   – Simulations, prototyping, architectural evaluation, demonstrations

Space and Missile Systems Center (SMC)

<u>Systems Engineering Requirements and Products</u>

4.1.2 System-Level Constraints, Concepts, and Architectures

- Required SE products with the product attributes specified in this document.

SMC SE Products: Design Solution

4.2.3.1 Required SE Products:

- **Validated, approved, and maintained (design-to) baseline**
  - **In specifications and interface documents**
  - **Grouped by each system element such as**
    - **Segment**
    - **Subsystem**
    - **Component (hardware and software)**

SMC Shall: Plan the SE Effort

5.2.1.1 Planning

5.2.1.1.1 Required SE Products

- **In IMP: SE accomplishments, accomplishment criteria, narrative**
- **IMS: tasks**
- **EVMS: work packages**

SMC Shall: Monitor Progress Against the Plan

5.2.1.2 Monitoring

Contractor *SHALL* monitor progress against plan to validate, approve, and maintain each baseline and functional architecture

5.2.1.1.1 Required SE Products

- **Documented SE assessments linked in database to initial plans**
- **Results of each iteration to include tradeoffs**

5.2.1.1.2 Required Product Attributes

a. Each documented assessment includes:

- ***TPMs*, metrics**
- **Metrics and technical parameters for tracking that are critical indicators of technical progress and achievement and include system parameters, configuration item (CI) parameters, or both**

Proposed EVM Acquisition Reform

Revise Acquisition Policy and Regulations

- Federal
  - OMB policy and FAR
- DoD
  - DFARS
  - DoDI 5000.02
  - DoD acquisition and SE guides

Interim Solution: New Contract Requirements (1 of 2)

- New contract requirements in SOW
- Objectives:
  - Refocus management attention from work scope to the product scope
  - Focus on technical performance
- Means:
  - All requirements via SOW
  - Or combination of SOW and tailored EVMS Guidelines

Interim Solution: New Contract Requirements (2 of 2)

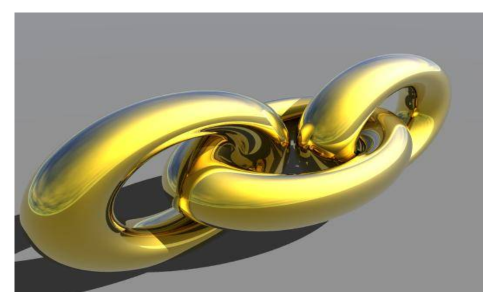
- For top down planning, make the IMP a contractual requirement and use a tailored CWBS DID.
- Specify EVM techniques in the SOW and/or use tailored EVMS guidelines or to:
  - Incorporate the product scope or technical baseline in the PMB.
  - Tie EV to technical performance.
  - Account for deferred functionality.
  - Track specified SE tasks discretely.
  - Plan rework and track it discretely.

Note: Detailed contractual guidance is proposed in *CrossTalk* article, "Basing Earned Value on Technical Performance," Jan. 2013

URL http://www.pb-ev.com/Pages/AdvancedEV.aspx

Program Management Tips

- Make IMP a contractual requirement
- Require SE best practices and tailored EVMS clause in RFP and SOW
- Verify compliance in Integrated Baseline Review (IBR)
- Confirm achievement of success criteria in technical reviews
- Monitor consistency and validity of status reports, variance analyses, EAC
- Close the Quality Gap



IBR: SE Implementation Review

- **Requirements management and traceability**
- **Milestones for SE requirements work products by WBS**
  - Derived requirements
  - Definition of required functionality and quality attributes
  - Verification methods and criteria
- **Milestones for establishing product metrics**
  - SFR: MOEs, MOPs defined
  - PDR: TPMs defined

IBR: SE Implementation Review

- **Milestones with technical maturity success criteria**
  - **TPM planned values**
  - **Meeting requirements**
  - **Percent of designs complete**
- **Define entry and success criteria for event-driven technical reviews/IMP events**
  - **Revise/clarify criteria for CDR and subsequent events based on**
    - **Knowledge of revised and derived requirements to be met**
    - **TPM planned values**
- **Flow down of SE milestones to work packages**
- **Define correct base measures of EV**

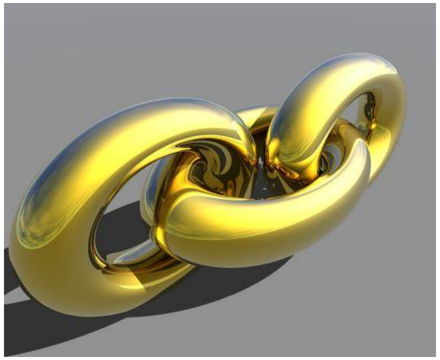
Framework for Process Improvement

Process Improvement Goal

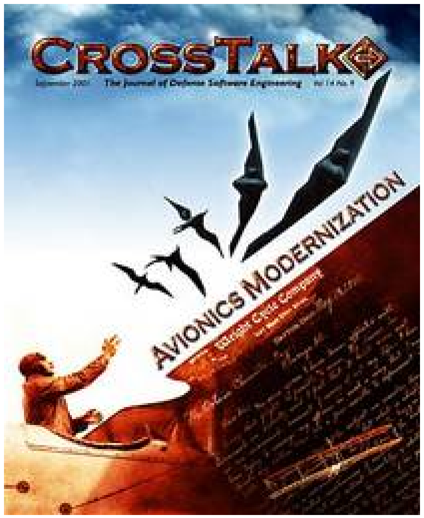
EVMS **SE** **Integrated Planning**

Close the EVMS Quality Gap

- PMB includes technical/quality parameters
- Insightful IBRs and technical reviews
- *Valid* contract performance reports
  - Objective technical/schedule status
  - Credible EAC
- Early detection of problems
  - Program performance
  - EV measurement and compliance
- Consider revisions to
  - DFARS
  - DoDI 5000.02



Resources Online



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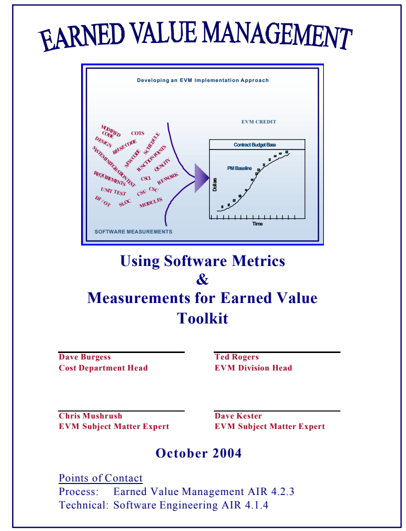


NAVAIR

DOD DAU

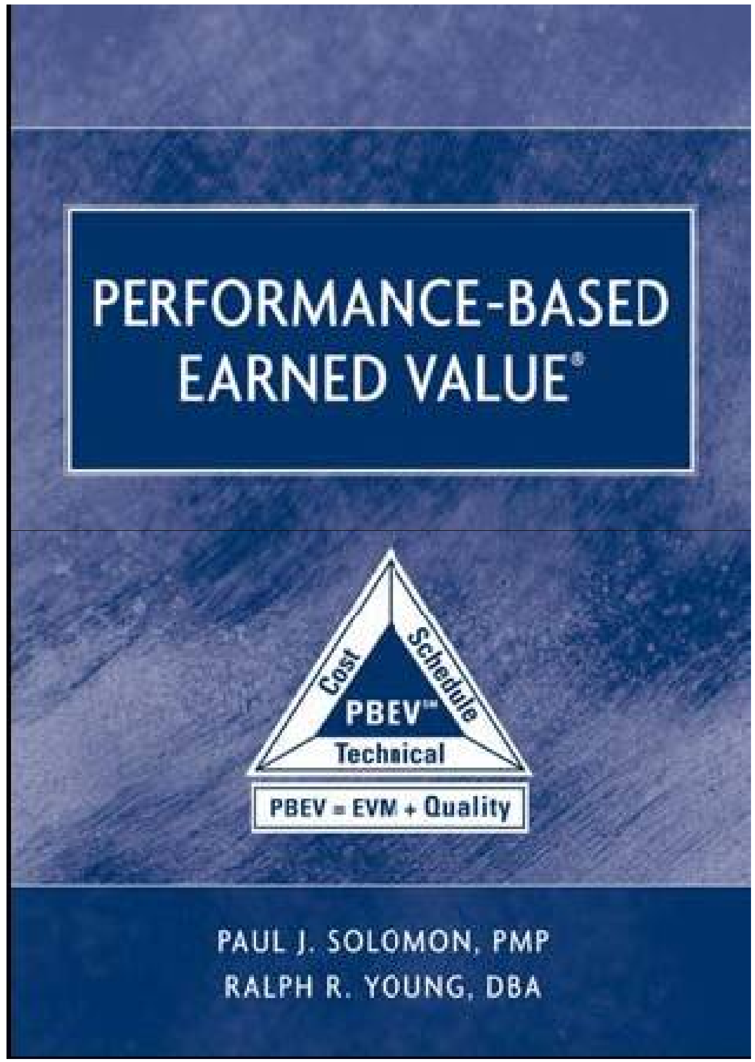
ICFAI U. Press, India

College of Performance Management "Measurable News"

www.PB-EV.com

Process Improvement Resources

Book includes
- Examples
- Templates
- Tips
- Standards
- Acquisition guidance



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Acronyms/Contact

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CDR: Critical Design Review
EAC: Estimate at Completion
EVM: Earned Value Management
IBR: Integrated Baseline Review
IMP: Integrated Master Plan
IMS: Integrated Master Schedule
KPP: Key Performance Parameter
MOE: Measure of Effectiveness
MOP: Measure of Performance
OMB: Office of Management and Budget
PDR: Preliminary Design Review
PMB: Performance Measurement Baseline
SE: Systems Engineering
SFR: System Functional Review
TPM: Technical Performance Measure

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Just in Case

TPM (CMMI/DAG)

Requirements Development	SG 3: Analyze and Validate Requirements	DAG
SP 3.3 Analyze Requirements	Example work products: • Requirements defects reports • Key requirements • TPMs Subpractices 4. Identify key requirements that have as strong influence on cost, schedule, functionality, risk, or performance 5. Identify TPMs that will be tracked during the development effort	2.1.1.4, 4.5.6.1 TPMs

TPM (CMMI/DAG)

Measurement and Analysis	SG 1: Align Measurement and Analysis Activities	DAG
SP 1.2 Specify Measures	Example work products: Specifications of base and derived measures Subpractices 3. Specify operational definitions for the measures..in precise and unambiguous terms	4.5.4.2, WBS: Objective measures.. essential for EVM… integrated with TPMs and CTPs

TPM (CMMI/DAG)

Project Monitoring & Control	SG 1: Monitor Project Against the Plan	DAG
SP 1.1 Monitor Project Planning Parameters	Monitor actual values of planning parameters against plan Subpractices: Monitor: 1. Progress against schedule 2. Cost 3. Attributes of work products and tasks	4.5.6.1 TPMs and CTPs