Integrating Systems Engineering with Earned Value Management
Tutorial

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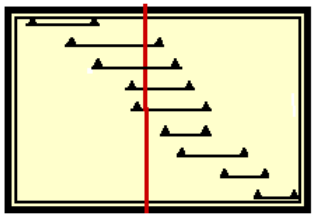
Systems & Software Technology Conference
Salt Lake City **April 20, 2009**

Agenda

- **Measuring Technical Performance/Quality**
- **Customer Needs (Government)**
- **Standards and Models for Quality**
- **Integrating SE with EVM**
- **Practical Application**
- **Acquisition Management**
- **Process Improvement**

Does EVMS Really Integrate?

EVMS

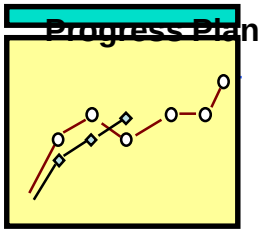


COST

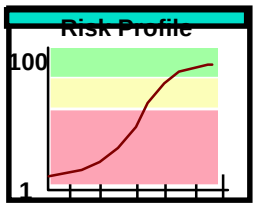
WBS

SCHEDULE

TECHNICAL PERFORMANCE



RISK



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**

Government Needs

Need: Accurate Performance Measurement

GAO Rpt. 06-250 (a)	Findings and Recommendations
Information Technology: Improve the Accuracy and Reliability of Investment Information	2. If EVM is ***not implemented effectively***, decisions based on inaccurate and potentially misleading information 3. Agencies ***not measuring*** actual vs. expected ***performance*** in meeting IT performance goals.

(a) Government Accountability Office

GAO Best Practices

GAO Report	Title	Findings and Recommendations
04-722 06-215	Information Technology: DOD's Acquisition Policies and Guidance DOD Systems Modernization	Best Practices and Controls: • Ensure that ***requirements*** are ○ ***Traceable*** ○ Verifiable ○ Controlled • Continually measure an acquisition's ○ ***Performance*** ○ ***Cost*** ○ ***Schedule*** against ***approved baselines***.

Deficiencies in Use of EVM

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)	**Deferred Functionality** MDA *did not track* the cost of work *deferred* from one block to another. • Cost of first block understated. • Cost of second block overstated. **Level of Effort (LOE)** • Discrete work incorrectly planned as LOE. • Program *lost ability to gauge performance*

DoD Discontent

USD AT&L Memo, *Use of EVM in the DoD, 7/3/07*

- **Use of EVM in program management, department-wide, is *insufficient***
- **Unfavorable audit findings indicate *EVM is not serving* its intended function in the internal control process**

Navy Discontent

Dept. of the Navy Memo, *EVM Reviews for ACAT I Programs, 2/20/08*

- **Broad deficiencies in EVM compliance**
  - **Failure to manage and document *changes to the baseline***
  - ***Lack of integration* across the cost, schedule, and work authorization systems**
  - ***Intentional masking* of cost and schedule variances**
  - ***Inadequate reporting* of Estimates at Complete**

Office of Management and Budget

- **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***

DOD Guides: Technical Performance

DoDI 5000.02, Operation of the Defense Acquisition System (POL), 12/2008

Defense Acquisition Guidebook (DAG) 10/8/04

Systems Engineering Plan (SEP) Preparation Guide 4/08

WBS Handbook, Mil-HDBK-881A (WBS) 7/30/05

Integrated Master Plan (IMP) & Integrated Master Schedule Preparation & Use Guide (IMS) 10/21/05

Guide for Integrating SE into DOD Acquisition Contracts (Integ SE) 12/06

DOD Need: Integrated Plans

DoD Guide	DAG	SEP	WBS	IMP IMS	Integ SE
Integrated Plans (1 of 2)					
Integrate SEP with: • IMP/IMS • TPMs • EVM	X	X		X	X
Integrate WBS with • Requirements specification • Statement of work • IMP/IMS/EVMS			X	X	X
Link risk management (including risk mitigation plans), technical reviews, TPMs, EVM, WBS, IMS					X

DOD Need: Integrated Plans

DoD Guide	Integ SE
Integrated Plans (2 of 2)	

• **Flow *integrated program plans* to teammates, subs, suppliers**
• **Integrate across:**
  • **SOW, SEP**
  • **IMP/IMS**
  • **Other plans and processes to support**
  • **Critical path analysis**
  • **EVM**
  • **Risk management**
	X

Proposal matrix correlates Government SEP with integrated SEP, SOW, IMP/IMS, WBS	**X**

Technical Baselines & IBR

DoD Guide	Integ SE
Technical Baselines:	
Include technical baselines in IMP/IMS: • **Functional baseline** • **Allocated baseline** • **Product baseline**	**X**
Integrated Baseline Review (IBR):	

During IBR, review:
• **Plans for event-based technical reviews including**
  ○ **Entry and exit criteria**
  ○ **Independent subject matter expert participation**
• **Technical tasks and products resulting from the IMS tasks**
• **Correlation of the technical metrics and measures, IMP/IMS, EVMS**
	X

Technical Reviews

DoD Policy or Guide	POL	DAG	SEP	WBS	IMP/ IMS	Integ SE
Technical Reviews:						
Event-driven timing	X	X	X	X	X	X
Success criteria	X	X	X	X	X	X
Include entry and exit criteria in IMP and IMS			X			X
Assess technical maturity		X	X	X		X

EVMS Standard Quality Gap

***But* EVMS Standard and Defense Federal Acquisition Regulation (DFAR):**

***Lack* guidance or requirement to link**

- **Reported EV**

  with

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

EVMS Quality Gap

Quality Gap

EVMS Standard Shortcoming (3.8):

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

Standards and Models: Guidance on Quality

Guidance in Standards and Models

- Processes for Engineering a System (ANSI/EIA-632)
- Standard for Application and Management of the SE Process (IEEE 1220)
- Capability Maturity Model Integration (CMMI®)
  - CMMI for Development, Version 1.2
  - CMMI for Acquisition, Version 1.2
  - *Using CMMI to Improve Earned Value Management*
- Guide to the Project Management Institute Body of Knowledge (PMBOK Guide®), 4th Edition
- International Council on Systems Engineering (INCOSE) Handbook, Version 3

Keystones of Integrated Planning

- ***Technical baselines***
- ***Requirements*** **and** ***Quality***
- ***Success criteria***
- ***Quality work products***

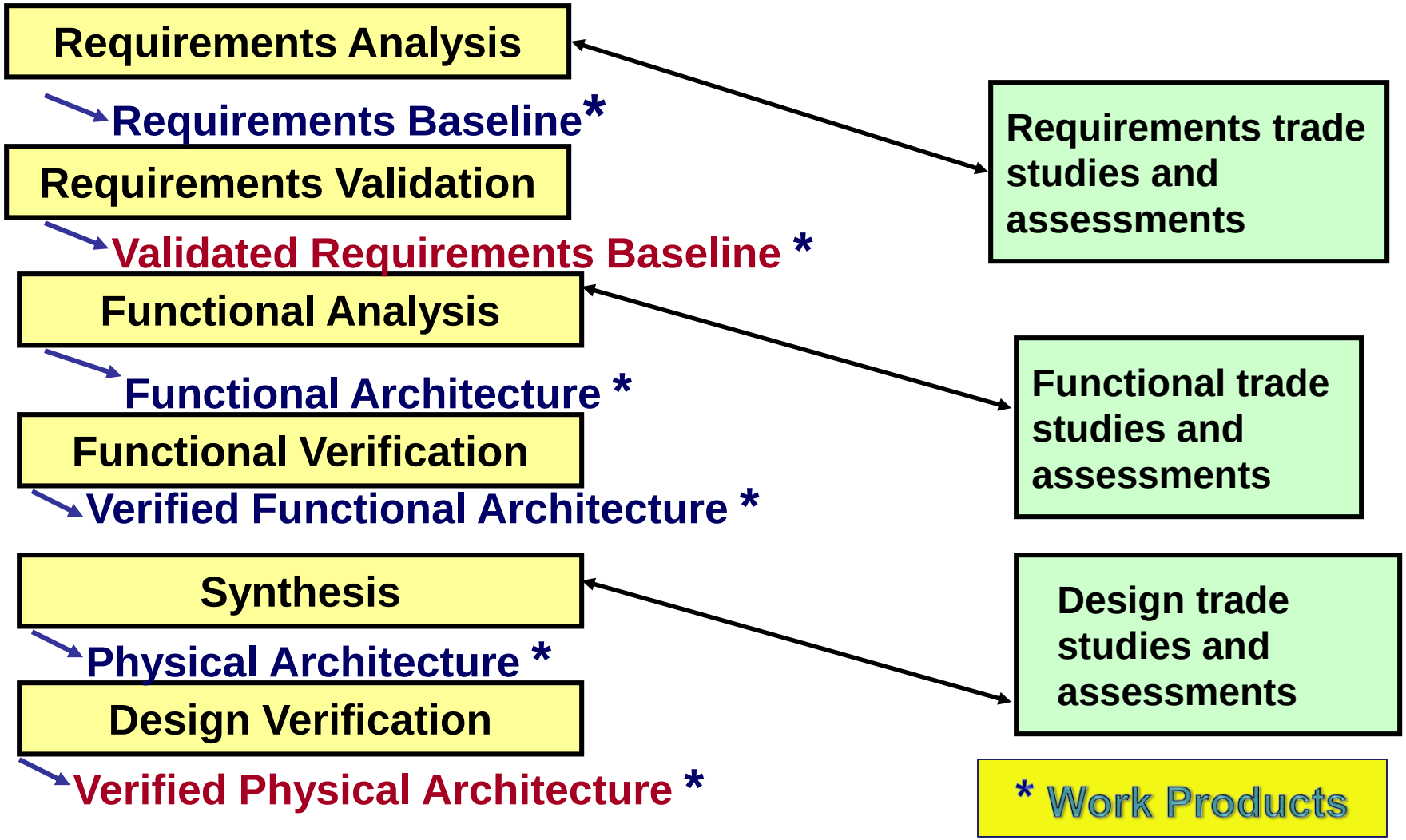
Technical Baselines

Manage the Technical Baseline

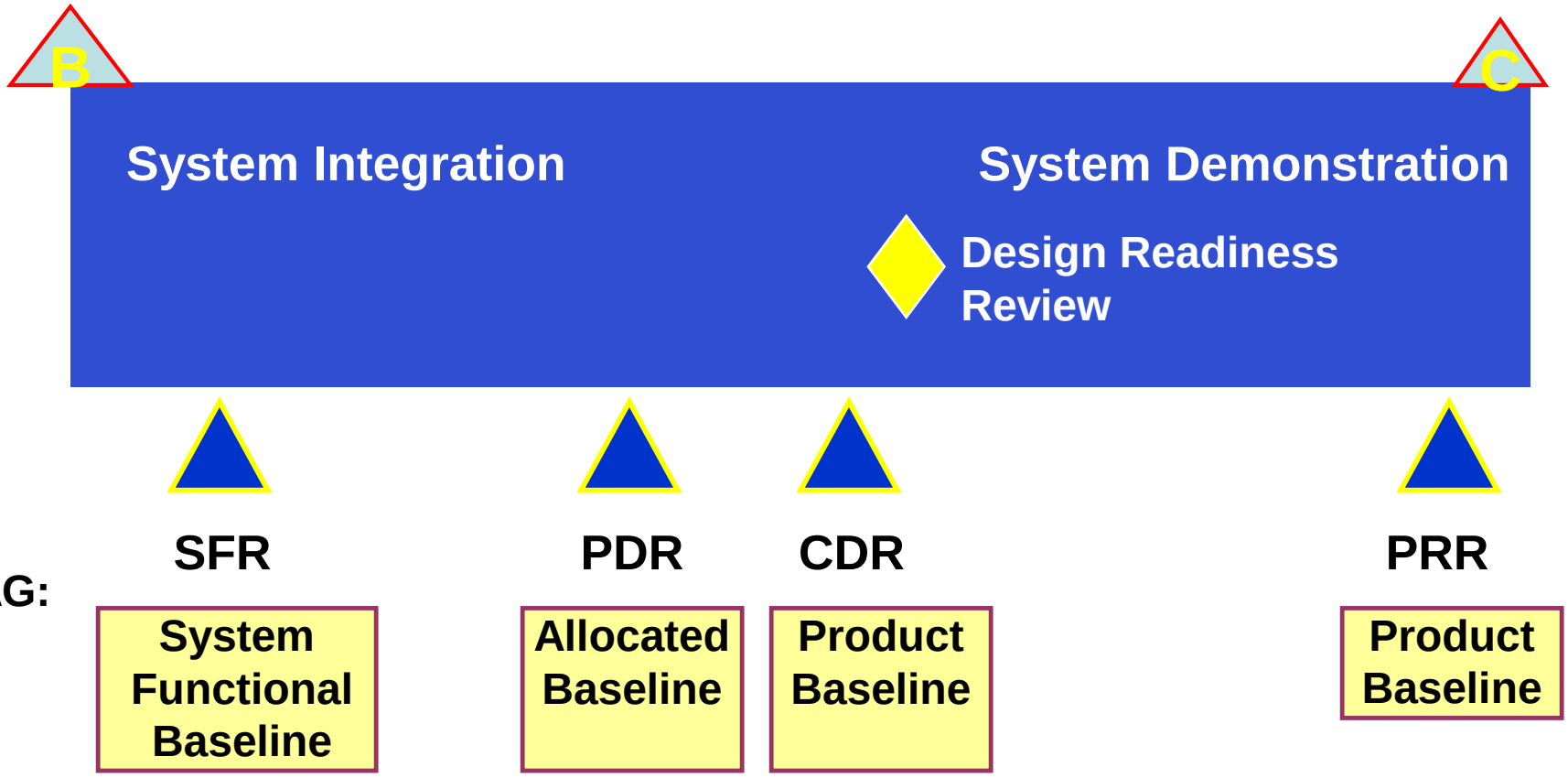
DAG 4.5.1. Systems Engineering Plan

- **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 *technical performance measures (TPM)***

SE Life Cycle Baselines, IEEE 1220

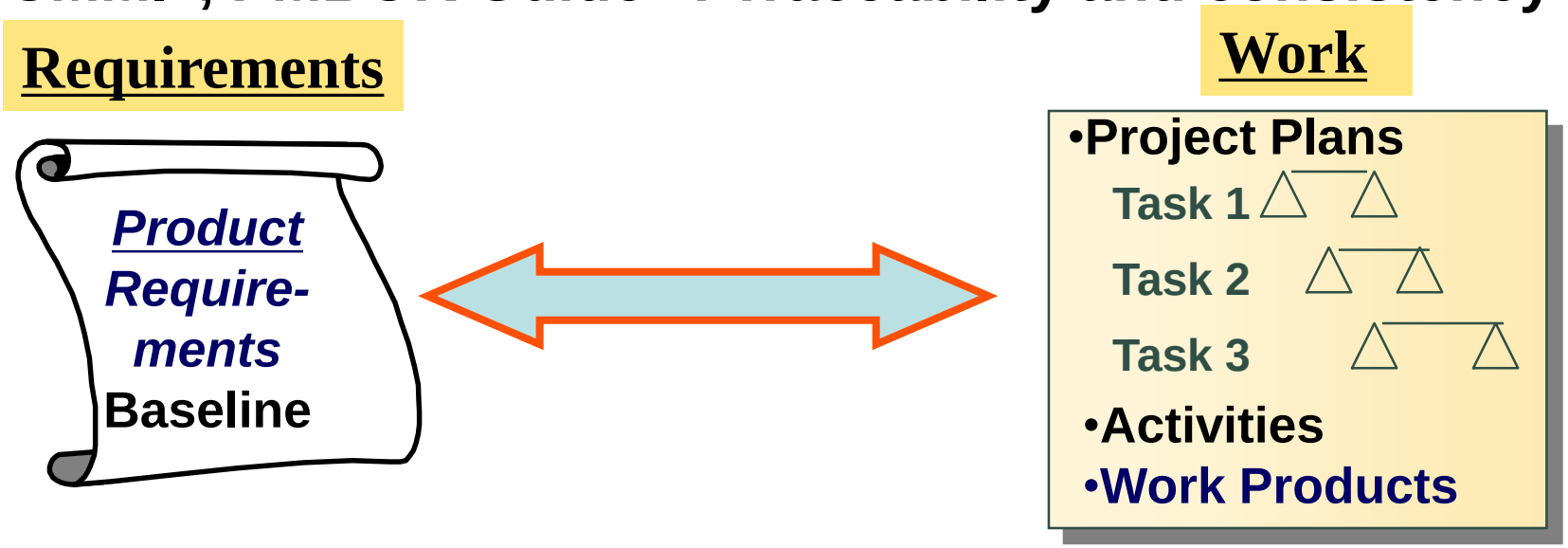


Technical Baselines



Product Requirements

- **CMMI®, PMBOK Guide® : Traceability and consistency**



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

Requirements and Quality

CMMI on Quality

- **CMMI Process and Product *Quality* Assurance PA, SP 1.2**
  - ***Objectively* evaluate work products against *clearly stated criteria***
  - ***Evaluate at selected milestones in their development***

Requirements and Product Metrics

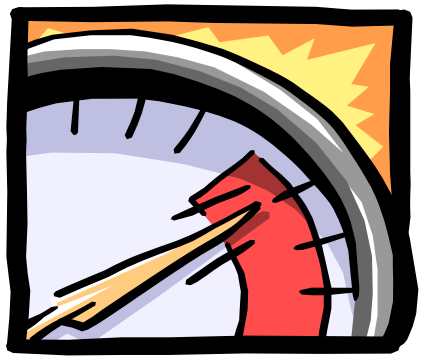
IEEE 1220	EIA-632
6.8.1.5 Performance-based progress measurement	4.2.1 Req. 10: Progress against requirements
6.8.1.5 d) Assess • *Development maturity* • Product's ability to *satisfy requirements* 6.8.6 *Product metrics at pre-established control points:* • Evaluate system *quality* • *Compare* to *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*

Technical Performance Measures (TPM)

IEEE 1220: 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

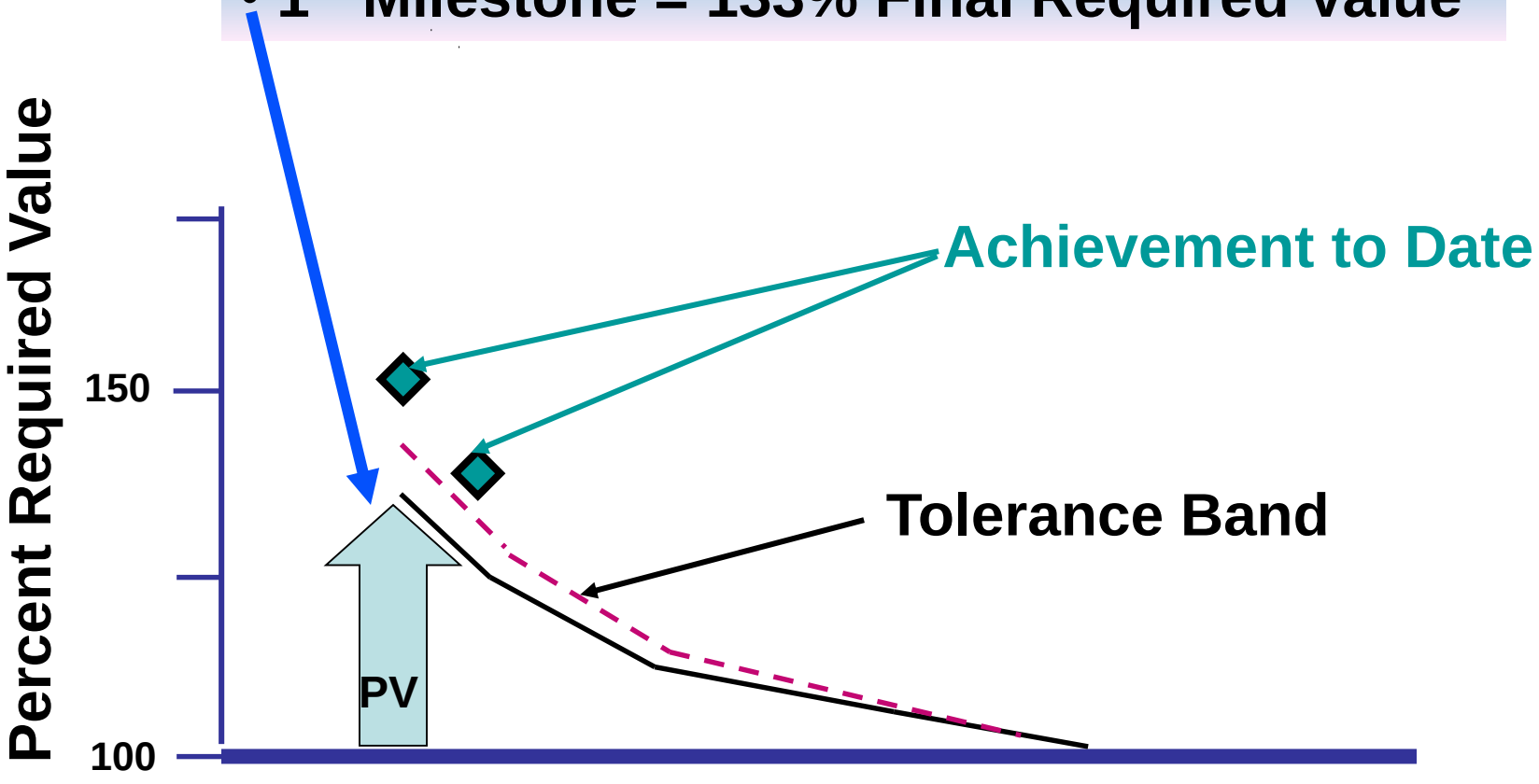
TPM

- 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



TPM Performance vs. Baseline

Planned Value (PV) Profile
- 1st Milestone = 133% Final Required Value



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.**

PMBOK® Guide

10.5.1.1 Project Management Plan

- **PMB:**
  - **Typically integrates scope, schedule, and cost parameters of a project**
  - **May also include *technical and quality parameters***

PMBOK® Guide

8.3.5.4 Work Performance Measurements

Used to produce project activity metrics

- **Evaluate actual progress as compared to planned progress**
- **Include, but are not limited to:**
  - **Planned vs. actual *technical performance***
  - **Planned vs. actual schedule performance, and**
  - **Planned vs. actual cost performance.**

PMBOK® Guide

11.6.2.4 Technical Performance Measurement

- **Compares technical accomplishments…to.. project management plan's schedule of *technical* achievement**
- **Requires definition of *objective quantifia*ble measures of *technical performance* which can be used to compare actual results against targets.**
- **Might include weight, transaction times, number of delivered defects, storage capacity etc.**
- **Deviation, such as demonstrating more or less functionality than planned at a milestone…forecast degree of success in achieving the project's scope.**

EV and Quality

- **Link EV to design maturity or *quality***
- ***"Quantify quality"* measures**
  - **Percent of product requirements met (weighted)**
  - **Technical performance achieved**
  - **Account for rework**
- ***Measure quality* of work products**
- ***Status quality* in requirements traceability matrix**
- **Address quality in variance analyses**

EV without Quality has less management value

Success Criteria

Verified Functional Architecture

IEEE 1220, (6.4): Success Criteria

- **Meets requirements of *validated requirements baseline***
- **System functions decomposed to *lower-level functions* that shall be satisfied by elements of the system design**
  - **Subsystems**
  - **Components**
  - **Parts**
- **Requirements upwardly traceable to the validated requirements baseline**

Success Criteria for Design

IEEE 1220, (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**

Success Criteria for Requirements Status

Category: Work Unit Progress Measure: Requirements Status Collect for Each: Requirements Specification	
Data Item	**Completion Criteria**
• *Total # of Requirements* • # of Requirements Traced to: • Detailed Specifications • Software Components • Test Specifications • *Tested Successfully*	• Completion of Specification Review • Baselining of Specifications • *Baselining of Requirements Traceability Matrix* • Successful Completion of all Tests, in Appropriate Test Sequence

Success Criteria for Incremental Capability

Category: Incremental Capability Measure: Increment Content – Functions Collect for Each: Function	
Data Item	**Completion Criteria**
• *# of Functional Requirements* • # of Functional Requirements *Successfully Implemented*	• Successful testing • Successful integration

SE Work Products

Validated Requirements Baseline

IEEE 1220, (6.1, 6.2): Work Products

- **Customer expectations**
- **Project, enterprise and external constraints**
- ***Operational scenarios***
- ***Measures of effectiveness (MOE)***
- **Interfaces**
- ***Functional requirements***
- ***Measures of performance (MOP)***
- **Modes of operation**
- **Design characteristics**
- **Documented trade-offs**

Design Solution
Enabling Work Products

IEEE 1220, (6.5, 6.6): Work Products

- **Integrated data package to document the selected design elements:**
  - **Drawings**
  - **Schematics**
  - **Software documentation**
  - **Manuals**
  - **Procedures**

Design Solution
Enabling Work Products

IEEE 1220, (6.5, 6.6): Work Products
• Physical interfaces • Models and prototypes • Failure modes and effects analyses (FMEA) • *Requirements traceability and allocation matrices* • *Trade off analysis results* • Finalized design and description of interfaces

CMMI Typical Work Products

Requirements Development PA

- **Functional architecture**
- ***Product requirements***
- ***Activity diagrams and use cases***
- **Key requirements**
- ***TPMs***

Requirements Management PA:

- **Requirements traceability matrix (RTM)**

Verification PA:

- ***Exit and entry criteria for work products***
- **Verification results**

Measurement and Analysis PA:

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

CMMI Typical Work Products

Technical Solution PA:

- **Product architecture description**
- ***Allocated requirements***
- **Product component descriptions**
- **Key product characteristics**
- ***Required physical characteristics and constraints***
- **Interface requirements**

CMMI Typical Work Products

Technical Solution PA:

- **Materials requirements**
- **Fabrication and manufacturing requirements**
- ***Verification criteria used to ensure that requirements have been achieved***
- **Conditions of use (environments)**
- **Operating/usage scenarios**
- **Modes and states**

For operations, support, training, manufacturing, disposal, and verifications

SE Integration Guidelines

SE Integration Guidelines

- **16 Guidelines augment EVMS (1)**
- **Quality and LEAN characteristics**

(1) www.PB-EV.com link to 16 guidelines, *CrossTalk*, "Performance-Based EV," Aug. 2005

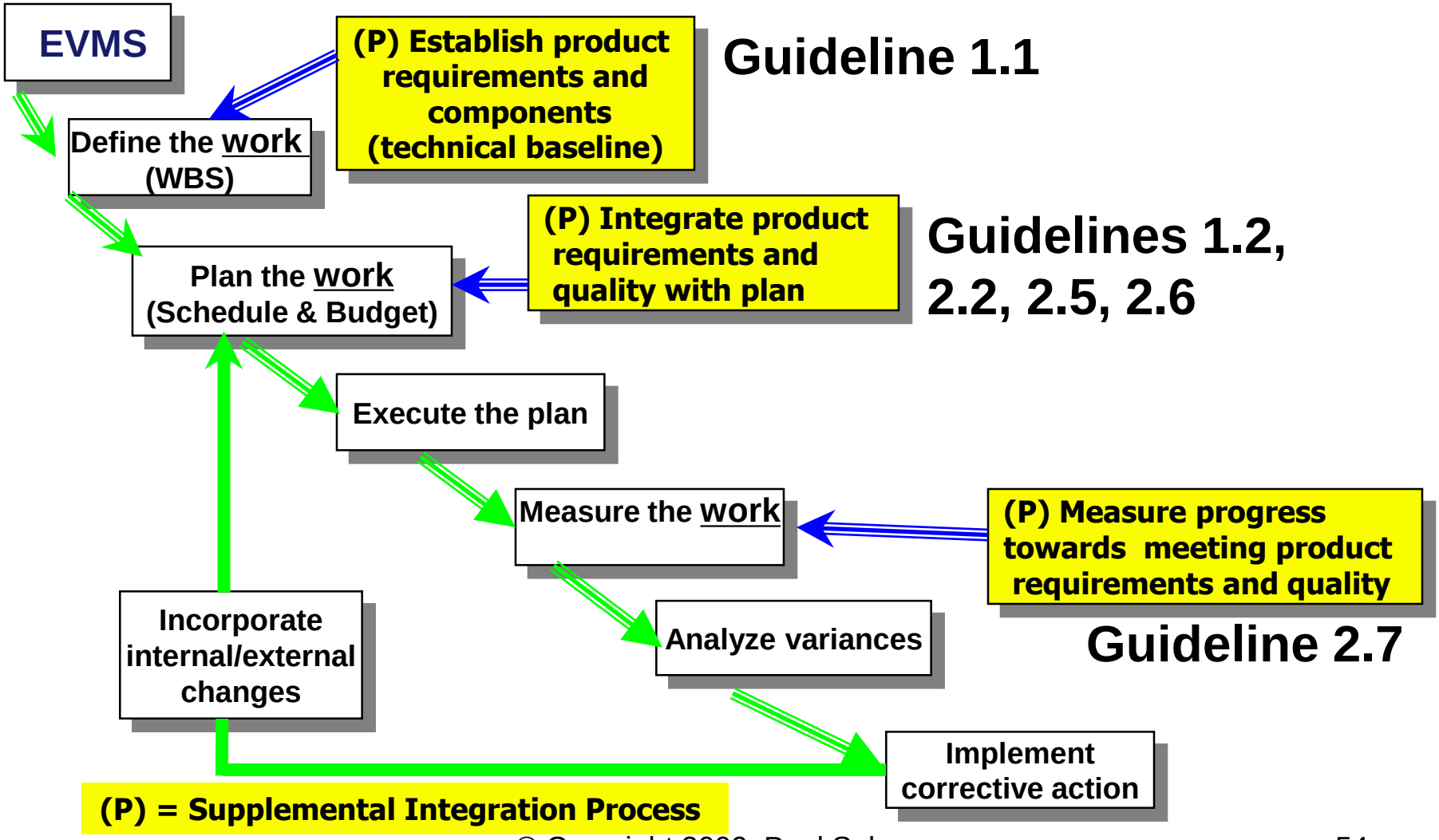
Variance Analysis

- **Consistent analyses and impacts of deviations from plan:**
  - ***Technical maturity/quality***
  - **Schedule**
  - **Cost**

LEAN Benefits

- **Minimizes costs; measurement costs money**
- **Fewer work packages with right base measures**
  - **Requirements-driven plan**
  - **Quality measures**
  - **Work products**

SE Integration Guidelines Augment EVMS



SE Integration Guidelines

1.1 Establish *product requirements* and allocate these to product components.

1.2 Maintain *bidirectional traceability* of *product* and product component *requirements among:*

- **Project plans**
- **Work packages and planning packages**
- **Work products.**

SE Integration Guidelines

2.2 Specify *work products* and performance-based *measures* of progress for meeting *product requirements* as *base measures of earned value*.

2.5 Establish:

- **Time-phased, *planned values* for measures of *progress towards meeting product requirements***
- **Dates or frequency for checking progress**
- **Dates when *full conformance will be met***

SE Integration Guidelines

2.6 Allocate budget in discrete work packages to measures of progress towards meeting *product requirements*.

2.7 Compare

- **Amount of planned budget and**
- **Amount of budget earned**

for achieving progress towards meeting *product requirements*

Practical Application

Example 1: EV Based on Drawings and TPMs

- **SOW: Design a subsystem with 2 TPMs:**
  - **Maximum (Max.) weight**
    - **Planned Value (PV): 200 lb. (May)**
  - **Max. diameter**
    - **PV: 1 inch (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:**
    - **Negative adjustment to EV**
      - **Weight: -100**
      - **Diameter -200**

Example 1: EV Based on Drawings and TPMs

Plan:

Schedule Plan	Jan.	Feb.	Mar.	Apr.	May	Total
Drawings	8	10	12	10	10	50
Requirements met:						
Weight						
Diameter						

Example 1: EV Based on Drawings and TPMs

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

Example 1: EV Based on Drawings and TPMs

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	
Negative EV Reqs cum				0	-100	
Net EV cum	360	760	1160	1640	*1860*	

SV = - 140

Example 1: Variance Analysis

May variance analysis (drawings and requirements):

- **1 drawing behind schedule** **- 40**
- **Diameter requirement met** **- 0**
- **Weight requirement *not* met:** **- 100**

Schedule variance **- 140**

EVMS Allows Retroactive Changes

EVMS Guideline 30:

Control retroactive changes to …work performed …Adjustments should only be made..to *improve the accuracy* of performance measurement data.

TPM at Higher WBS Level

- For a weight TPM, all components play a part
- For other TPMs, such as response time
  - *Subsets* of the components *combine* to meet subsystem performance objectives
    - Hardware components
    - Software components

TPM at Higher WBS Level

- **Design of a component at the work package level**
- **Completion of the component design depends on**
  - **Achieving allocated TPMs values at**
    1. **Component level *and***
    2. **Subsystem level**
- **EV depends on planned TPM values achieved at *both* levels**

EX 2: TPM at Higher WBS Level

Assumptions:

- **Component in Example 1 is one of four components that form a subsystem**
- **Subsystem's TPM objective is 4000 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 subsystem (Sub) weight does not exceed 4000 lb.

EX 2: TPM at Higher WBS Level

Comp/ Work Pkg	TPM PV (lb)	Comp Mile-stone	Comp EV Penalty	Sub Mile-stone	Sub EV Penalty	Bud-get
1	200	April	-100	May	-50	
2	1000	April	-500	May	-250	
3	2000	May	-1000	May	-500	2000
4	800	May	-400	May	-200	
Total	4000		-2000		-1000	

EX 2: Component 3

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	
Negative EV Reqs cum					- 1500	
Net EV cum	360	760	1160	1640	*460*	

Component: 1000
Subsystem: 500

Ex. 3: 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**
  - **Drawings returned for rework**

Lesson: Drawings Returned for Rework Cause Negative EV

Ex. 3: 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		

IT/Software Progress Measurement Issues

Initial Development Measures

Design:

- $ – **Base EV on**
  - **# Enabling work products and**
  - **# Requirements met**
- $ – **Example:**
  - **# Components designs completed and**
  - **# Requirements met traced to components**

$ **- Recommended Measure**

Initial Development Measures

Implementation: Code and test

- **Source Lines of Code (SLOC) coded**
- **# components implemented, component tested, configuration item tested**
- **# of tasks completed and functionality achieved**

Initial Development Measures

- **Integration and test planning**
  - **# requirements traced to test specifications**
  - **# test cases**
  - **# use cases**

Incremental Software Capability

- **Document baseline content of each build**
  - **# functional requirements**
- **Establish build milestones and completion criteria (# functional requirements)**
- **Establish work packages and EV metrics for builds**
- **Take EV based on enabling work products and functionality *achieved***
- **Account for deferred functionality**

Internal Replanning of Deferred Functionality

- If build is released short of planned functionality:
  - Take partial EV and leave work package open
    or
  - Take partial EV and close work package
    - Transfer deferred scope and budget to first month of work package for next incremental build
      - EV mirrors technical performance
      - Schedule variance retained
    - Disclose shortfall and slips on higher schedules

EX 4: Deferred Functionality

SOW: Software Requirements in 2 Builds:

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

EX 4: SW Build Plan

	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
Build A								
Planned Reqs. met	**25**	**25**	**25**	**25**				**100**
Budget/Req.: 5 hours								
BCWS current (cur)	**125**	**125**	**125**	**125**				**500**
BCWS cumulative (cum)	**125**	**250**	**375**	**500**				**500**
Build B								
Planned Reqs. Met					**20**	**20**	**20**	**60**
BCWS cur					**100**	**100**	**100**	**300**

EX 4: Deferred Functionality Status

	Jan	Feb	Mar	Apr	Total
Build A					
Planned Reqs. Met cur	25	25	25	25	100
Actual Reqs. Met cur	20	20	25	25	90
BCWS cur	125	125	125	125	500
EV cur	100	100	125	125	450
BCWS cum	125	250	375	500	
EV cum	100	200	325	450	
Schedule variance (SV):					
Reqs. Met	-5	-10	-10	-10	
SV	-25	-50	-50	-50	

Release Build A.

Move 10 reqs to Build B.

EX 4: Deferred Functionality Replan

	Apr	May	Jun	Jul	Total
Close Build A work package					
Schedule variance (cum.):					
Req Not Met	**- 10**				-10
BCWP remaining	**- 50**				-50
Build B					
Before Replan					
Planned Req Met		**20**	20	20	**60**
BCWS cur		**100**	100	100	**300**
Plus transfer budget from Build A:					
Req Not Met		**+10**			
BCWP remaining		**+50**			
After replan:					
Planned Req Met		**30**	20	20	**70**
BCWS cur		**150**	100	100	**350**

Transfer to 1st month of receiving work package to retain schedule variance

EX 4: Deferred Functionality Status

	May	Jun	Jul	Total
Build B After Replan:				
Planned Reqs. Met	30	20	20	70
BCWS cur	150	100	100	350
Actual Reqs. Met cur	20			20
EV cur	100			100
Schedule variance cum:				
Reqs. Met	-10			
SV	-50			

May status: 20 reqs met, still behind schedule

Rework of Requirements and Software

- **S/W quality: problems, defects**
  - **# problem reports reported**
  - **# problem reports resolved**
  - **May indicate EAC problems, but not progress**

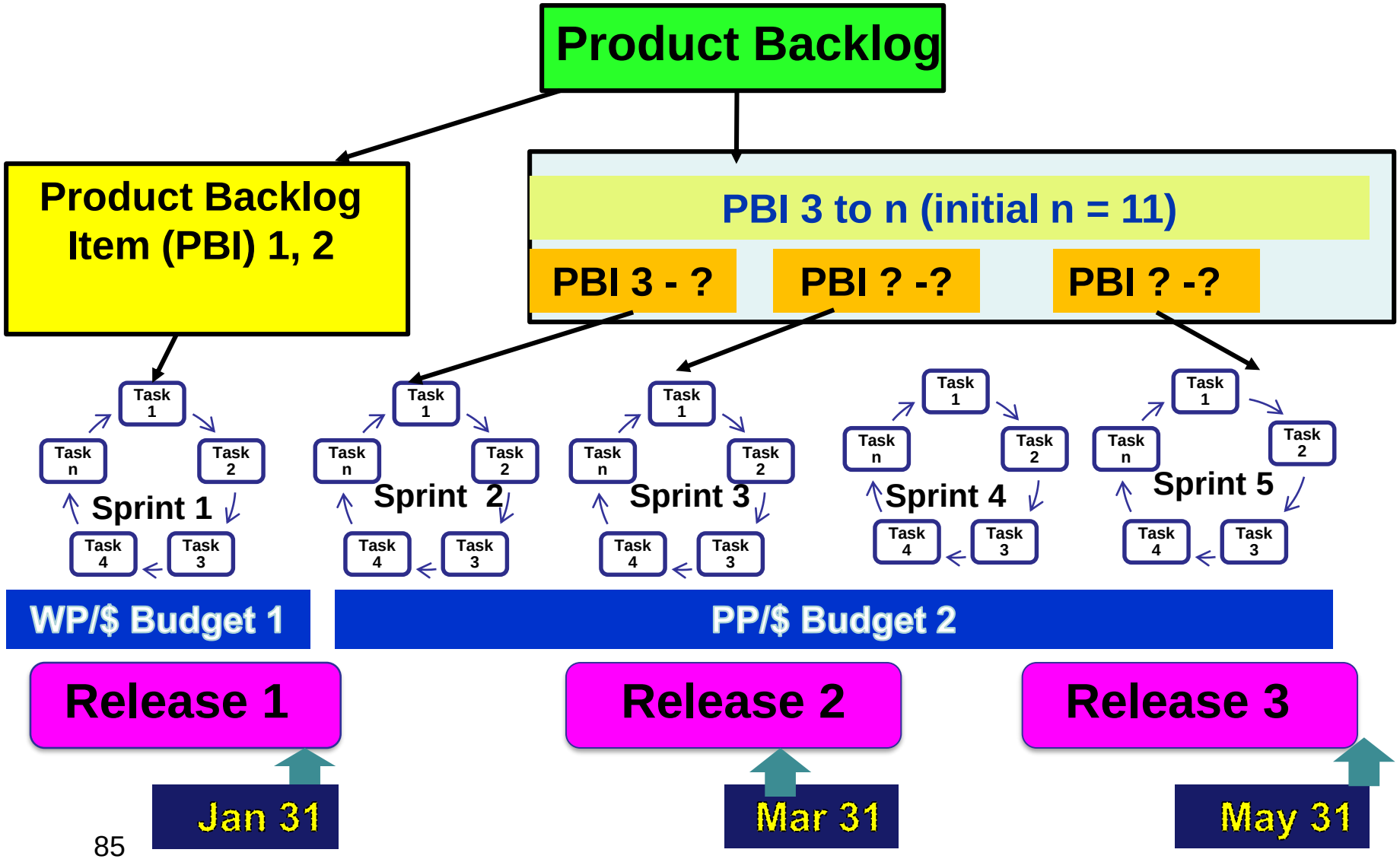
- ***OVERALL TEST SUCCESS*:**
  - **# test cases attempted**
  - **# test cases passed**

  - ***# requirements tested successfully or verified by inspection***

Software Quality Measures

- **Software quality measures are TPMs**
  - **Defect density**
  - **Number of problem reports**
- **Failure to achieve planned quality indicates**
  - **More rework during development**
  - **More problems after product delivery**

EX 5: Agile Method



Agile EV Constraints

Internal replanning guidance:

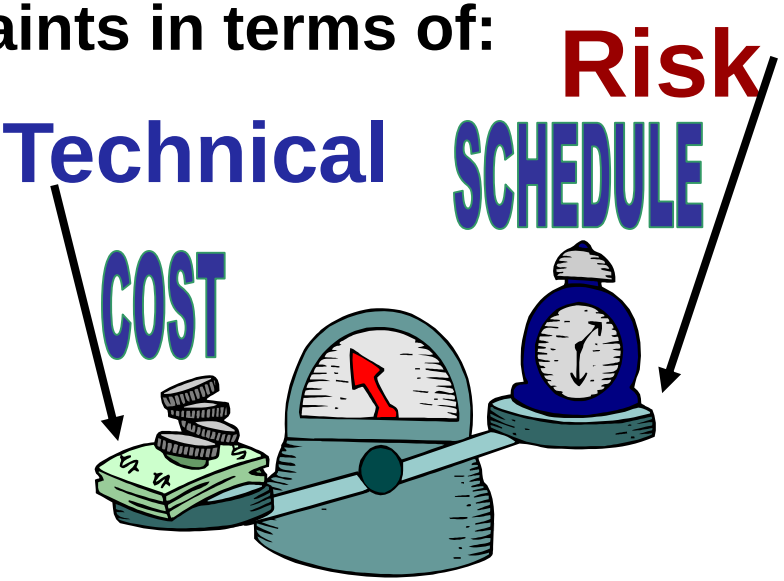
- **Hold PMB despite changes to PBI burndown**
  - **Hold baseline finish dates of major releases**
  - **Hold cumulative BCWS at major milestones**
- **Transfer budget for deferred PBIs to first period of next iteration/sprint**
- **Maintain reported schedule variances**
- **Reallocate remaining EV to remaining PBI tasks (including delta PBIs) after each iteration**
- **Revise EAC, compare to funding, reprioritize**

But wait. There's more! Monday, 3:35: *Agile Methods with Performance-Based Earned Value®*

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, and measured.**

EX 6 : Trade – Determine Design Solution

- **Total Budget: 1000**
  - **Test and evaluate 4 candidates: 600**
    - **150 per candidate**
      - **Milestone (MS) 1, test setup: 25**
      - **MS 2, Tests completed: 75**
      - **MS 3, Test results analyzed 50**
    - **Take EV even if candidate discarded before test complete**
  - **Down select to 2 candidates, 5th month: 150**
  - **Document final recommendation: 250**
- **Period of Performance: 6 months**

EX 6 : Trade – Determine Design Solution

PMB:

Activity	Jan	Feb	Mar	Apr	May	June	Total
Candidate 1	25	75	50				150
Candidate 2	25	75	50				150
Candidate 3		25	75	50			150
Candidate 4		25	75	50			150
Select 2 candidates					150		150
Make recommendation						250	250
Current BCWS	50	200	250	100	150	250	1000
Cumulative BCWS	50	250	500	600	750	1000	1000

EX 6 : Trade – Determine Design Solution

- **Project on schedule until candidate 2 failed in Feb, after completing 50% of test**
- **CPI = 1**
- **A new candidate, # 5, was added on March 1**
- **Down-select to 2 candidates and final document slip 2 months on March 1**
- ***Problem 6a: Prepare Feb cumulative performance report (Ignore actuals)***
- ***Problem 6b: Develop internal replan for March forward, with revised base measures of EV***

EX 6a, Trade Study
Feb Worksheet

Activity	Jan	Feb	Mar	Apr	May	June	Total
Candidate 1 BCWS	25	75	50				150
Candidate 2 BCWS	25	75	50				150
Candidate 3 BCWS		25	75	50			150
Candidate 4 BCWS		25	75	50			150
Subtotal	50	200	250	100			600
Select 2 candidates					150		150
Make recommendation						250	250
Current BCWS	50	200	250	100	150	250	1000
Cumulative BCWS	50	250	500	600	750	1000	1000
Cum. BCWP	50						

Ex 6b, Trade Study
March Replan

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Total
Candidate 1 BCWS	25	75							
Candidate 2 BCWS	25	75							
Candidate 3 BCWS		25							
Candidate 4 BCWS		25							
Candidate 5 BCWS									
Subtotal	50	200							600
Select 2 candidates					150				150
Make recommendation						250			250
Current BCWS	50	200	250	100	150	250			1000
Cumulative BCWS	50	250	500	600	750	1000			1000
Cum. BCWP	50	300							
Actuals ETC	50	263							

Hint: Must provide budget to 5th candidate.

Acquisition Management

Acquisition Management

Ensure Contractors Integrate Technical Performance/Quality with EVM

Guidance from:

- **CMMI for Acquisition**
- **AF Space Command-Space and Missile Systems Center/Aerospace Corp. Report**
- **EVM Implementation on NASA Contracts (NPG 9501.3)**
- **USAF Weapon Systems Software Management Guidebook**

Acquisition Management

Ensure Contractors Integrate SE with EVM

- **Requirements, incentives, insight:**
  - **Establish contractual requirements**
  - **Analyze proposed technical solutions**
  - **Confirm integrated planning during IBR**
  - **Monitor consistency and validity of reports**
  - **Verify EV = performance in technical reviews**
  - **Independent EAC and risk assessments**
  - **Incentive and Award fee criteria**

CMMI-ACQ

Product Acquisition Requirements Development

<u>SP 2.1 Establish contractual requirements</u>

Establish and maintain contractual requirements based on customer requirements

- **Contract requirements: expression of customer requirements in technical terms that can be used for design solutions**
  - **Interface requirements**
  - **Functional requirements**
  - **TPMs**
  - **Verification requirements**

CMMI-ACQ

Acquisition Technical Management

<u>SP 1.1 Subpractices</u>

3. Identify 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**

CMMI-ACQ

Acquisition Technical Management

SP 1.3 Conduct Technical Reviews

Conduct technical reviews with supplier as defined in supplier agreement or SEMP

- **Confirm that products and services being developed or produced meet user needs and requirements**
- **Characteristics**
  - **Conduct when technical solution satisfies review entry criteria (event-driven, not schedule driven)**
  - **Address processes and requirements required by supplier agreement**

CMMI-ACQ

Acquisition Technical Management

SP 1.3 Conduct Technical Reviews

Technical review activities

- **Examples of technical reviews**
  - **Integrated Baseline Review (IBR)**
  - **System Requirements Review (SRR)**
  - **PDR**
  - **CDR**
  - **Test Readiness Review**
  - **System Verification Review**
  - **Production Readiness Review**
  - **Operational Test Readiness Review**
  - **Physical Configuration Audit**

CMMI-ACQ

Acquisition Technical Management

SP 1.3 Conduct Technical Reviews

Typical supplier deliverables

- **Progress reports and process, product, and service level measurements**
- **TPMs**
- **Documentation of product and document deliveries**

NASA EVM Guide: Technical Performance

- **NASA EVM Guide NPG 9501.3**
  4.5 Technical Performance Requirements (TPR):
  When TPRs are used,
  appropriate and relevant metrics…
  must be defined in the solicitation
  Appendix A.7, 14.1 TPR
  - **Compares:**
    - **Expected performance and**
    - **Physical characteristics**
    - **With contractually specified values.**
  - **Basis for reporting established milestones**
  - **Progress toward meeting technical requirements**

Space and Missile Systems Command Center (SMS)

Systems Engineering Requirements and Products

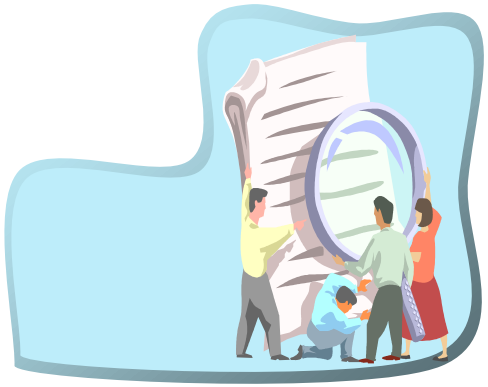
The Aerospace Corporation Report, TOR-2005(8583)-3, Rev A

- Contractually binding requirements defined in terms of required SE products and required attributes of those products

THE AEROSPACE CORPORATION

SMS SHALL:
Requirements Analysis & Validation

4.2.1 Requirements Analysis and Validation
The contractor *SHALL*
• Iteratively perform requirements analysis and validation
• Develop the associated required SE products with the product attributes specified in this document.



SMS SE Products: Requirements Analysis & Validation

4.2.1.1 Required SE Products

a. Validated requirements baseline

Define all system-level requirements and constraints and their allocations to the next lower level

b. System architecture and requirements traceability matrices

c. Source and engineering basis including each trade-off or analysis for

- **Each system-level system performance and functional requirement**
- **Its allocation to the next lower level**

SMS Product Attributes: Requirements Analysis & Validation

4.2.1.2 Product attributes

a. Requirements baseline

(1) Includes and *traces* to the operator/user capabilities

- **For which the system is being designed**
- **To the missions for which it is intended.**

(2) Includes analyses of each lower-level requirement to ensure that it is

- **Valid**
- **Necessary**
- **Sufficient to satisfy higher level**
  - **Capabilities**
  - **Requirements**
  - **Constraints**

SMS Product Attributes: Requirements Analysis & Validation

4.2.1.2 Product attributes

a. Requirements baseline

(3) Consists of verifiable requirements with the method of verification documented.

(5) Includes all *functional and performance requirements* and constraints and those imposed by each specialty function

(8) Is validated through customer review/approval to ensure:

- **Compliance with the above attributes**
- **Two way traceability between the requirements baseline and the requirements source is documented in a system specification**

SMS Shall:
Design Solution

4.2.3 System Element Design Solution and Validation

– The contractor *SHALL*

- **– Determine the design solution**
- **– Support a validation of the design solution**
- **– Develop associated *SE products with product attributes specified***

SMS 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)**

SMS Product Attributes: Design Solution

4.2.3.2 Required Product Attributes

a. The allocated baseline:

(3) Includes the design-to technical *functional* and *performance requirements* and design constraints for each product.

(4) Includes all derived design-to requirements and design constraints for each product.

(5) Includes all interfaces and addresses how the interface will be implemented, as well as the logical issues such as data formats, data semantics, etc.

(6) Includes the verification method(s) selected for each requirement.

SMS Shall:
Design for Implementation

4.2.4 Design for Implementation, Deployment, Operations, and Support

Contractor *SHALL*

- **Design the products that constitute the system to include implementation (fabrication and code) and sustainment assets**
- **Develop the associated required systems engineering documentation with the attributes specified in this document.**

SMS SE Products:
Design for Implementation

4.2.4.1 Required System Engineering Products

a. The validated, approved, and maintained design release baseline.

SMS Product Attributes: Design for Implementation

4.2.4.2 Required Product Attributes

a. The design release baseline:

(1) Fully *satisfies the allocated baseline* over the system life cycle.

(5) Corroborates the functional and physical interface designs and associated functions and requirements across systems.

SMS Shall:
Plan the SE Effort

4.2.12.1 Planning

4.2.12.1.1 Required SE Products

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

SMS Shall:
Plan the SE Effort

4.2.12.1 Planning

4.2.12.1.2 Required Product Attributes

- **IMP, IMS, EVMS:**
  - **Reflect all technical execution and management efforts**
  - **Establish schedules in approved baselines consistent with all other program plans for:**
    - **Completion of To Be Determined (TBD) by Developer**
    - **Formalization of To Be Supplied (TBS) by Customer to Developer**
    - **Resolution of To Be Resolved (TBR)**

SMS Shall:
Monitor Progress Against the Plan

4.2.12.2 Monitoring

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

4.2.12.2.1 Required SE Products

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

4.2.12.2.2 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**

USAF Weapon Systems Software Management Guidebook

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.**

USAF Weapon Systems Software Management Guidebook

Appendix B SOW
K. Contractor shall ensure that the IMP and IMS include

- **Events and criteria to manage**
  - **Technical performance characteristics**
  - **Associated margins and tolerances of the hardware and software**

Acquisition Tips

Acquisition Tips

- **Require SE best practices in Request for Proposal (RFP)**
- **Confirm contractor's proposal includes integration of SE with EVM**
- **Verify Integration in IBR**
- **Confirm achievement of success criteria in technical reviews**
- **Monitor consistency and validity of status reports and variance analyses**

RFP

- **RFP includes SE Best Practices**
  - **Event-driven entry and exit criteria for IMP events**
  - **Contractor's proposal describes technical approach including**
    - **Approach for requirements traceability and requirements verification**
    - **Tools and methods for tracing TPMs to the key product performance parameters**

Contractor Proposal

- **Confirm that contractor's proposal describes**
  - **Processes for integrating the technical approach with overall program management planning and control:**
    - **Technical baseline in requirements traceability matrix (RTM)**
    - **WBS**
    - **IMP/IMS**
    - **EVM**
    - **Risk management**

IBR

- **Review implementation of SE:**
  - **Entry and success criteria for event-driven technical reviews/IMP events**
  - **Requirements management and traceability**
  - **Control points for product metrics and TPMs**
  - **Milestones with technical maturity success criteria**
    - **TPM planned values**
    - **Meeting requirements**
    - **Percent of designs complete**
  - **SE life cycle work products in IMS**

IBR

- **Confirm integration of**
  - **Technical baseline in RTM**
  - **WBS**
  - **IMP/IMS**
  - **TPMs**
  - **EVM**
  - **Risk management**

Success Criteria for Technical Reviews

- All success criteria for event-driven technical reviews met on schedule
  - Development maturity is on schedule
  - Issues resolved
    - All subsystems
    - Products
    - Life cycle processes
- Unacceptable risks are mitigated

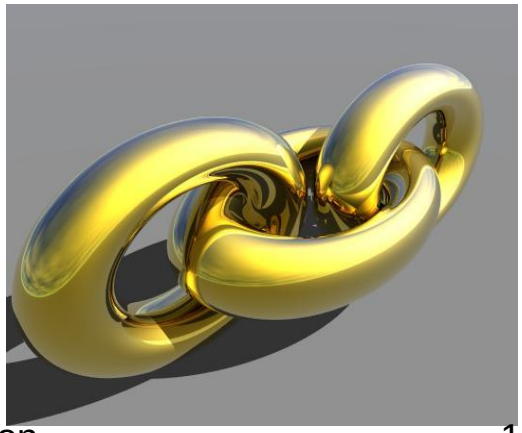
Monitor Consistency and Validity of Reports

- **Compare performance reports for consistency:**
  - **Program status**
    - **Technical**
    - **Schedule**
    - **EV**
  - **Variance analyses**
    - **Root causes**
    - **Corrective action plans**
    - **Impacts on cost and schedule**

Framework for Process Improvement

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**



Process Improvement Goal

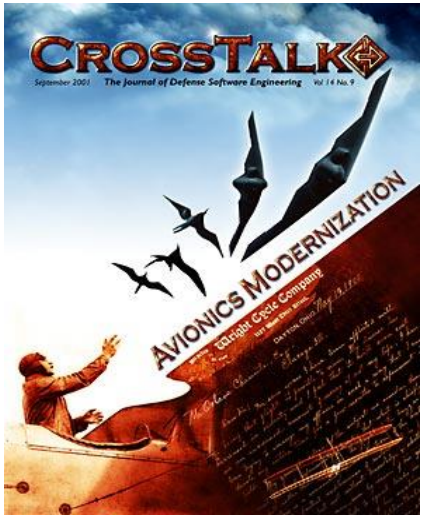
EVMS + **SE** = **Integrated Planning**

EVM Foundation for Software-Intensive Programs

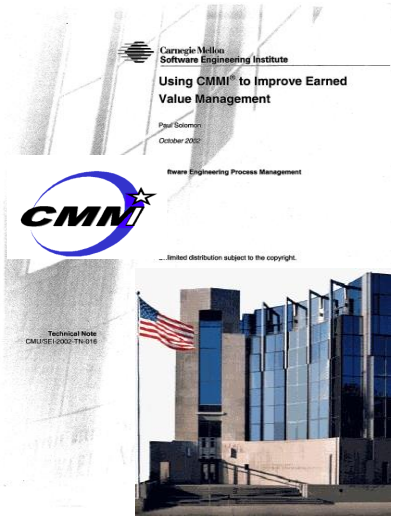
- Using EVM to plan and manage software intensive programs can prevent expensive failures.
- EV should be based on foundation of: (1)
  - Establishing the requirements
  - Developing a reliable baseline estimate for cost and schedule
  - Selecting effective software metrics
  - Applying Performance-Based Earned Value
  - Using analytic processes to project cost and schedule based on actual performance

(1) Galorath, Hunt, Solomon.
DoD Software Tech News, April 2009,
"Applying EVM to Software Intensive Programs"

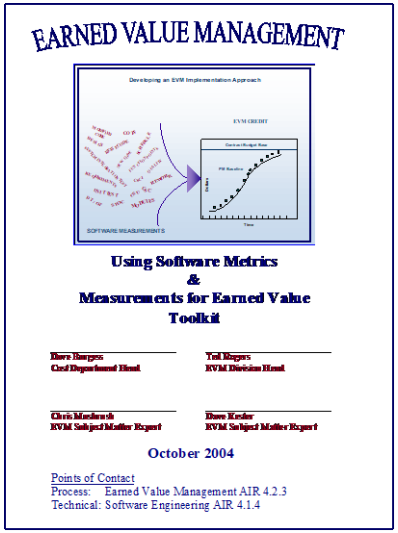
PBEV Resources in Online Media



DOD



SEI



NAVAIR

DOD

ICFAI U. Press, India

PMI College of Performance Mgt., "Measurable News"

DoD Data & Analysis Center for Software

www.PB-EV.com

Process Improvement Resources

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

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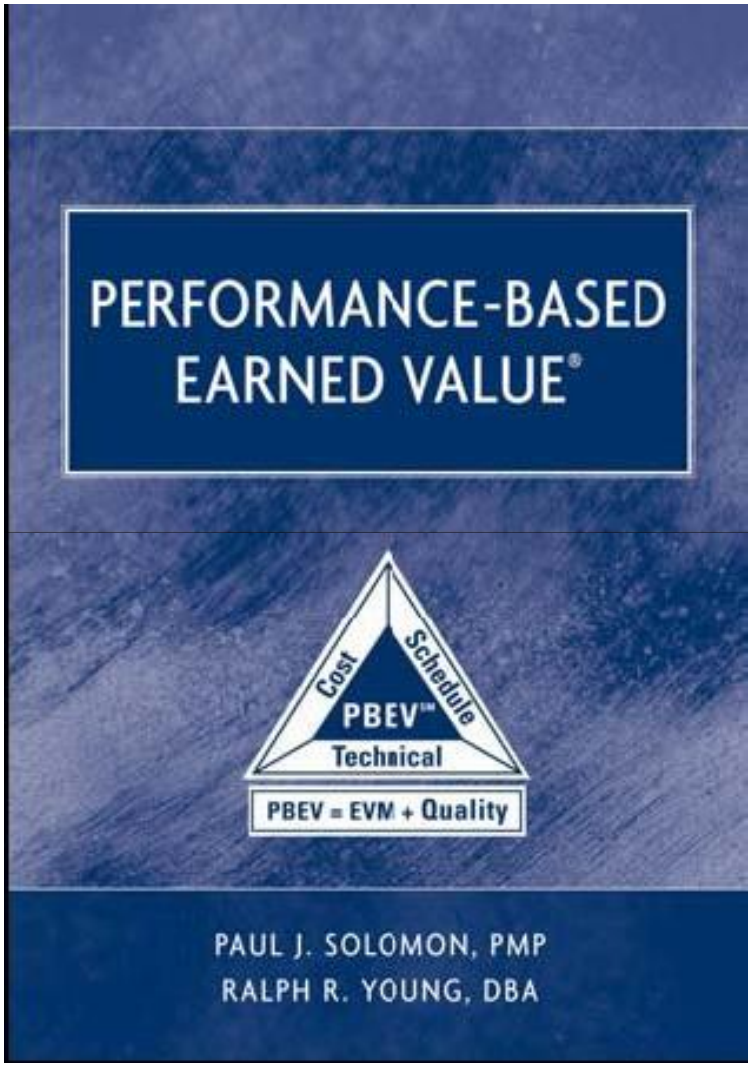

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- **Process improvement**
- **EV training**
- **EV compliance**
- **Acquisition guidance**
- **IBR leadership**
- **Assess EAC and risk**

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Questions?

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- **Solomon, Paul: Many publications at www.pb-ev.com**

Acronyms

EVM: Earned Value Management
CPI: Cost Performance Index
PBI: Product Backlog Item
PMB: Performance Measurement Baseline
PV: Planned Value (for a TPM)
RTM: Requirements Traceability Matrix
SE: Systems Engineering
SEP: Systems Engineering Plan
TPM: Technical Performance Measure or Measurement