Tutorial: Integrate Systems Engineering with Earned Value Management and Program Management, Contractually and Practically

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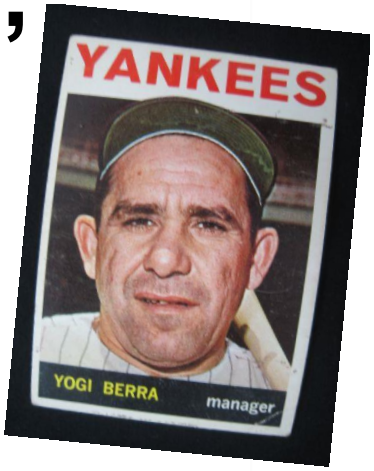
Agenda

- **“Déjà vu all over again”**
- **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 including Agile Methods**
  - **Track Systems Engineering Tasks Discretely**
  - **Plan Rework and Track it Discretely**
- **Integrated Plans and Performance**
- **Acquisition Management and Reform**
- **Framework for Process Improvement**

“It’s déjà vu all over again,”
Yogi Berra



Integrating Systems Engineering, Risk and Earned Value Management

CPM Spring Conference 2001

San Diego, CA

24 May 2001

Presented by:
Paul Solomon
Northrop Grumman Corp.

Threats to Program Success

- Inadequate Early Warning
- Schedules, Metrics Overstate True Progress
- Remaining Work Underestimated
- Product Will Not Meet User Needs

CAN BE PREVENTED BY INTEGRATING:
- SYSTEMS ENGINEERING (SE)
- RISK MANAGEMENT (RM)
- EARNED VALUE MANAGEMENT (EVM)

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Requirements Management Products

- Concept of Operations
- System Integration Requirements Document (SIRD)
- Design Constraints / Key Drivers
- System Description Document (SDD)
- System Requirements Review (SRR) Documentation
- Functional Description Document (FDD)
- Specification / Document Tree
- Technical Performance Metrics (TPM) and Plan
- Trade Study Documentation
- Requirements Traceability Database (RTD)
- Configuration Baseline

Best Practices to Monitor Program Technical Progress with SE Tasks

- SE products, milestones on IMS
- Discrete SE work packages and EV measures
  - Track progress of key SE products
  - Track progress of completing RTD
- Monitor SE schedule variances
  - ~~Mirrors~~ program's overall technical progress
  - Small absolute value; high impact

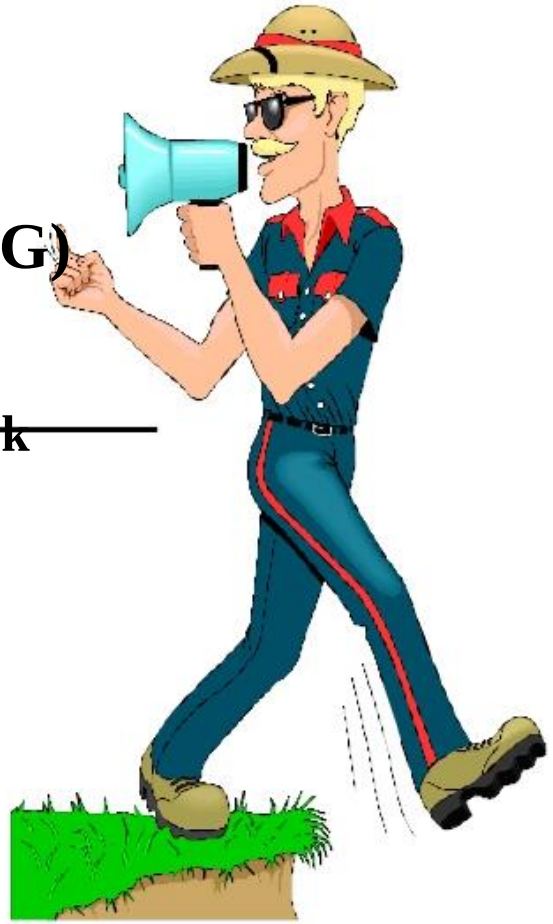
- Use TPMs as a basis of Performance-based EV (PBEV) for technical tasks
- Compare SE schedule variances with technical PBEV

What Is Risk Management?

- **Risk: Uncertain event or condition that, if it occurs, has a negative (or positive) effect on a project objective**
- **Systematic process of identifying, analyzing and responding to project risk**
- **Part of the SE Process**
- **Proactively Working to Prevent an Unfavorable Event from Occurring which Threatens Objectives**
  - **Cost, Schedule, Technical**

~~EVM GUIDES SILENT ON RISK~~

- **Industry Standard**
- **EVM Implementation Guide (EVMIG)**
- **Company EVMS**
  - **Most EVM System D~~escriptions silent on risk~~**
  - **Risk mitigation plans not ~~always budgeted or scheduled~~**
  - **Program projections inc~~onsistent with~~ risk assessments and risk mitigation plans**



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Best Practices to Integrate RM with EV

- Include RM Activities on the Baseline Schedule
  - Define Exit Criteria for RM Decision Points
  - Establish Dependencies
- Budget the RM Effort, Track with EV
- Address RM in Performance Analysis
- Incorporate RM in EAC Development
  - If probability and impact are high (Most Likely)

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ACS EVM System Description (1)
Linked to SE and Risk Procedures

- **CAM Responsibilities**
  - **Integrate budget and schedule with technical SOW**
  - **Identify technical metrics**
  - **Use *TPMs* as a basis for *EV***
  - **Incorporate *risk* assessment and corrective actions into EVMS**
- **Program Manager Responsibilities**
  - **Assess *EAC* based on pressures, *risks*, opportunities**

1) Air Combat Systems Procedure DTM F208

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ACS SE Procedure Links TPMs to EV

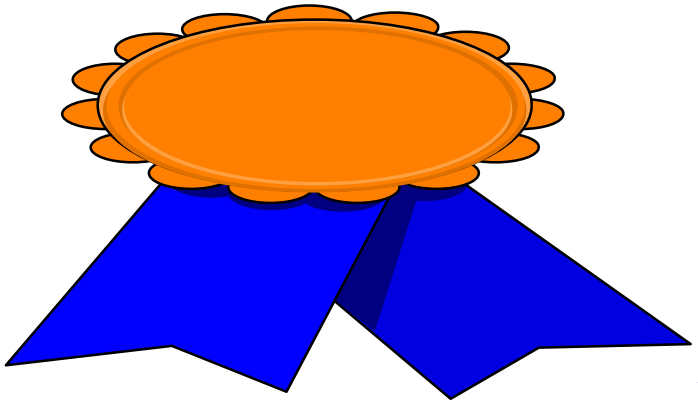
- **SE Tracking and Oversight (E1-0401.9)**
  - **–*TPMs* track key technical parameters**
  - **–*EV* should be based on *TPMs* which best indicate progress towards meeting technical requirements**

~~ACS Risk Procedure – Links to EVMS and SE~~

- **Risk Management (D1-5002)**
  - **Sources of risk identification:**
    - **Projected or actual adverse performance**
      - **Technical performance based on *TPMs***
      - **Cost or schedule performance per *EVMS***
  - **Significant *risk* management activities are *planned, budgeted and tracked in the EVM and scheduling* systems**
  - **If the *risk* cannot be fully mitigated, immediately:**
    - **Revise the *EAC***
    - **Report *schedule* impacts on affected schedules**

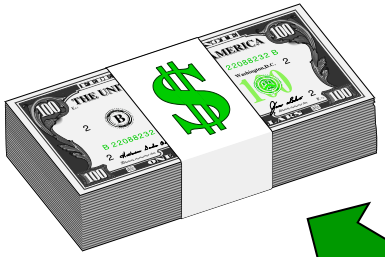
SUMMARY FOR SUCCESS

- **Operational Needs: Define, Decompose, Validate, Verify**
- **Requirements Management Traceability**
- **Plan SE Tasks in PMB**
- **Use TPMs and Performance-Based Earned Value**
- **Correlate Progress of SE Tasks with Technical Progress**
- **Include Risk Management Activities in PMB**
- **Integrated, Documented Processes**

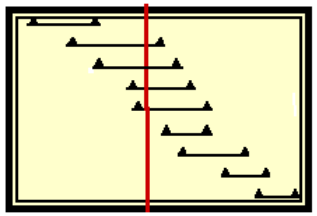


TODAY

Does EVMS Really Integrate?



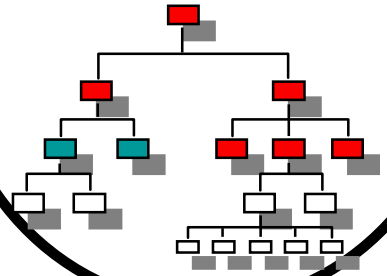
EVMS



COST

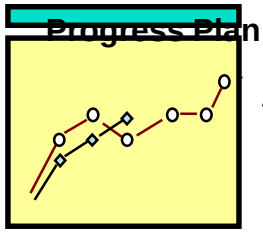
WBS

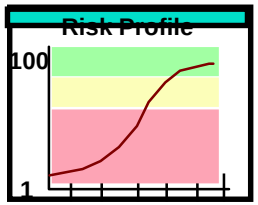
SCHEDULE



TECHNICAL PERFORMANCE

RISK





Product

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

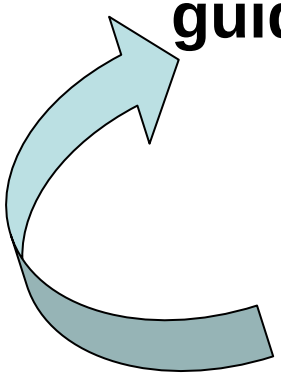
Government Needs and Acquisition Reform

Office of Management and Budget (OMB)

- **Capital Programming Guide V. 3.0, Supplement to OMB Circular No. A-11: Planning, Budgeting, Acquisition and Management of Capital Assets**
- **Appendix 3**
  - **Earned value is a management technique that relates resource planning to schedules and to technical, cost, and schedule requirements.**

Defense Federal Acquisition Regulation Supplement (DFARS) 252.234-7002; EVMS

“Earned value management system” means an earned value management system that complies with the earned value management system guidelines in EIA-748.”



EIA-748 Deficiencies:

Product/Quality Gap and Silence on Risk

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

DoD EVM Report to Congress

Integrate EVM with other tools:

- **To maximize its effectiveness, EVM must be integrated with other management tools**
- **Examples of tools under the umbrella of acquisition management:**
  - **Program management**
  - **Procurement or contract management**
  - **Risk management**
  - **Cost management**
  - **Change control management**
  - **Configuration management**
  - **Engineering management**
  - **Quality management**
  - **Logistics management.**

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.**

Program Management Improvement and Accountability Act of 2016 (PMIAA)

OMB:

- **Adopt and oversee implementation of government-wide standards, policies, and guidelines for program and project management (P/PM) for executive agencies;**
- **Establish standards and policies…*consistent with widely accepted standards for P/PM* planning and delivery;**
- ***not applicable to DoD* "to the extent that the *provisions*…are *substantially similar* to or *duplicative* of…policy, guidance, or instruction of the Department related to PM."**

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, and Defense FAR Supplement (DFARS) are deficient:

No **requirement to link**

- **Reported EV with**
- **Progress toward meeting *Quality/technical performance requirements***

Quality Gap Persists

Jan, 2018: DoD Section 809 *Report of the Advisory Panel on Streamlining and Codifying Acquisition Regulations*, Vol.1:

"substantial shortcoming of *EVM* is that it *does not measure product quality*. A program could perform ahead of schedule and under cost according to EVM metrics but deliver a capability that is unusable by the customer."

April, 2016, DCMA report to NDIA:

Common, EVM finding: lack of objective measures to assess performance, including "Measurement does not indicate technical accomplishment."

Management Reserve (MR) Loophole

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***

Fallacy of % Complete EV Technique

1. **Ignores technical performance**
   - **% of drawings, lines of code, test points is "objective" but, as practiced, may indicate original plan, not current estimate**
2. **Misleading if denominator increases**
   - ***"Hold"* % at 95% until done; Common practice (trick?)**
   - **Numerator may include rework**
   - **DAG 4.3.3.4.2 (Critical Design Review) propagates the fallacy**
     - **Rule of thumb: 75%-90% of…product drawings, software design specifications and associated instructions…complete**
3. **EV and the cost performance may be overstated when…based on % of drawings or code completed without regard to the technical maturity of the evolving design. As a result, the EAC may be understated."**

Source: Basing Earned Value on Technical Performance, CrossTalk—January/February 2013

Misleading Information

Examples of "compliant" practice that lead to *misleading management* information:

· EV based on % of drawings or software (SW) modules complete even though the hardware design did not meet requirements or the SW < planned functionality (a).

· Budget and schedule for tests and rework in MR instead of in the initial PMB.

· Taking EV for rework and engineering changes based on the actual vs. estimated percent of units, iterations, or problem reports instead of on the % of requirements met.

(a) Source: "*Basing Earned Value on Technical Performance*," CrossTalk, January/February 2013

Misleading Information

More examples:

· Taking EV for software releases based on turning over the release, even though some of its baselined functionality was deferred to the next release.

· Not taking negative EV to show the true, net percent complete when the number of drawings or other units increased from the baselined number, with no change in the technical requirements.

· Not taking negative EV for drawings or other units returned for rework, when rework is planned in the same work package as the initial work.

Source; "EVM Acquisition Reform," Nov. 2010

Guidance in Standards, Models, and DoD Guides

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®)
- Systems Engineering Plan Outline Vs. 2 (SEP)
- Guide to the Project Management Institute Body of Knowledge (PMBOK Guide®), 7th 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

What Should be Integrated?”

Technical Baselines (Product Scope)
Requirements
Success Criteria
SE Tasks and Work Products
TPMs
Risk Mitigation Plans
EVM

Manage the Technical Baseline

DAG 4.5.1. SEP

- **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***

Technical Scope in EVM

DAG 4.5.4.1. EVM

SE is responsible for characterizing the entire technical scope of effort in the Work Breakdown Structure (WBS) and the corresponding event driven program implementation in the Integrated Master Schedule (IMS).

The WBS and IMS form the basis of the PMB and the foundation of EVM.

Functional Baseline (DAG)

DAG 4.2.3.1.6.2

<u>What</u>

- **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.**

<u>When</u>:

- **Established at System Functional Review (SFR)**

Allocated Baseline (DAG)

DAG 4.2.3.1.6.2

<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)

DAG 4.2.3.1.6.2

<u>What</u>

Necessary functional and physical characteristics of a CI

- **Selected functional and physical characteristics designated for production acceptance testing**
- **Initial product baseline includes "build-to" specifications for hardware (product, process, material specifications, engineering drawings and software (software module design— "code-to" specifications)**

<u>When</u>:

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

PMBOK on Product Scope

Standard or Principle	Description
Scope	Scope can refer to: **Product scope** - the **features and functions** that characterize a product **Project** scope - the *work performed* to deliver a product...with the specified features and functions
Product scope description	Documents the characteristics of the product that the project will be undertaken to create. Progressively elaborates the characteristics of the product.

PMBOK on Product Scope

Standard or Principle	Description
Scope Baseline	**Includes product scope description, project deliverables, and defines product user acceptance criteria.**
Control Scope	**The process of monitoring the status of the project and product scope and managing changes to the scope baseline. Completion of the product scope is measured against the product 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**

Requirements Traceability (DAG)

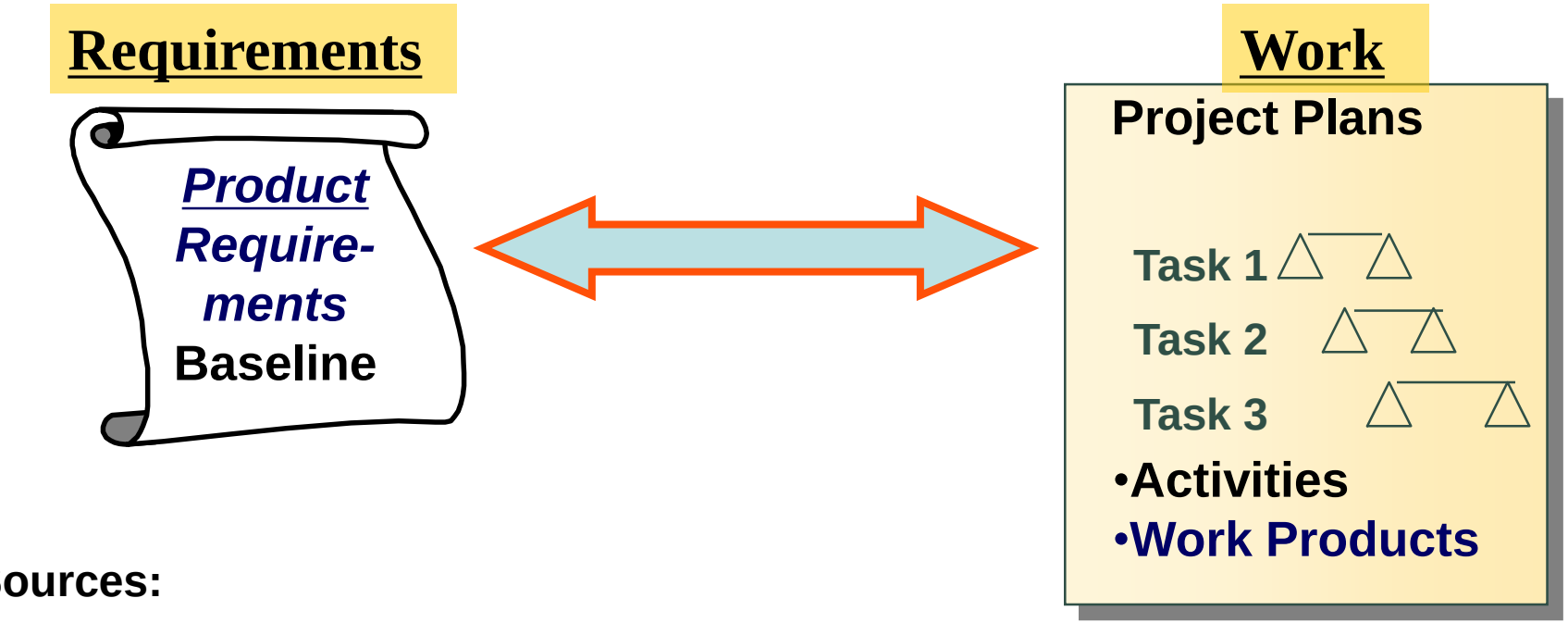
DAG 4.2.3.1.4

- **Requirements traceability is conducted throughout the system life cycle and confirmed at each technical review.**
- **The program manager should institute requirements management**

to maintain the traceability of all requirements from capabilities needs through design and test

Trace Product Requirements Baseline to Plans

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



Sources:

CMMI Requirements Management Process Area (PA), SP 1.5

PMBOK 5.2.3.2 Requirements traceability matrix (RTM) links product requirements from their origin to the deliverables that satisfy them.

Tracing requirements includes project scope (product and work) and WBS deliverables

PMBOK on Requirements/WBS

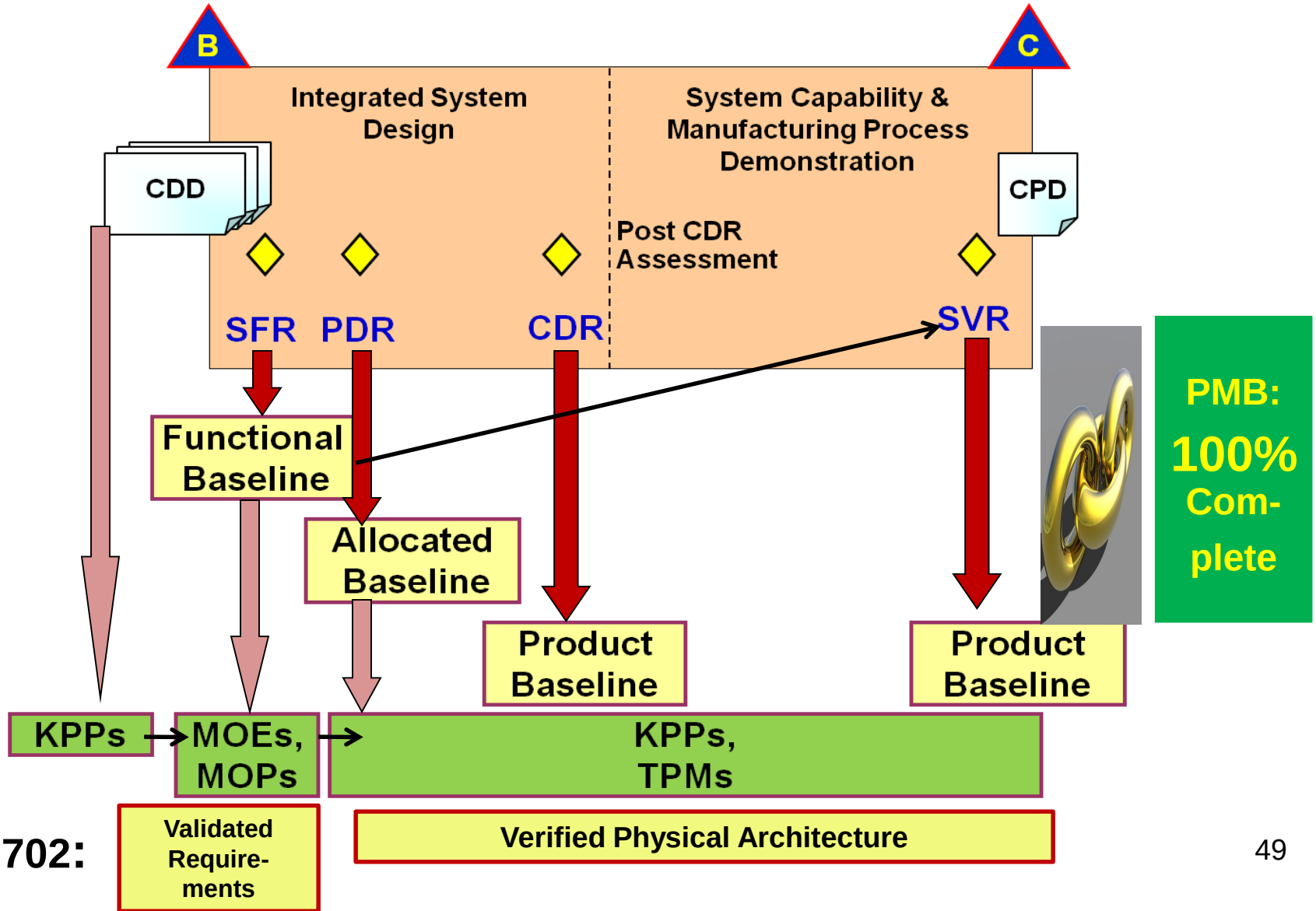
Standard or Principle	Description
Requirements	**Requirements become the foundation of the WBS. Cost, schedule, quality planning, and procurement…based on these requirements.**
WBS Dictionary	**Includes quality requirements, acceptance criteria**
Requirements Documentation	**Requirements baseline; unambiguous (measurable and testable), traceable, complete, consistent, and acceptable to key stakeholders. Components include, functional requirements, non-functional requirements, quality requirements, and acceptance criteria.**

PMBOK on Requirements/WBS

Standard or Principle	Description

Requirements Traceability Matrix	• **Includes requirements to project (including product) scope/WBS objectives, product design, test strategy and test scenarios.**
	• **Typical attributes…may include:**
	  • **Current status (such as active, cancelled, deferred, added, approved, assigned, completed)**
	  • **Status date**
	  • **Acceptance criteria**

Link PMB to Technical Baselines, Reviews, and Measures



USAF on Requirements Baseline

3.6.2 Requirements and Incremental Software Development

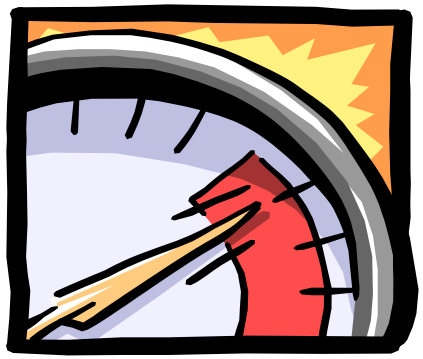
b. Map/allocate the requirements into all planned builds.

- **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.**

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



TPMs in DAG

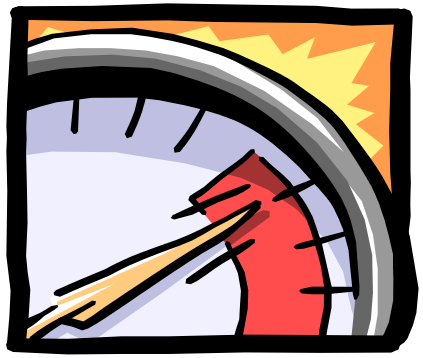
4.5.4.2
Performance measurement of WBS elements, using objective measures:

- **Essential for EVM and Technical Assessment activities to determine program progress.**
- **These objective measures are used to report progress in achieving milestones and should be integrated with TPMs and Critical Technical Parameters (CTP)**

TPMs in DAG

4.5.6.1:

- **Performance measurement of WBS elements, using objective measures:**
  - ***Essential for EVM*** **and Technical Assessment activities**
- ***Use TPMs*** **and** ***CTPs 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

4.5.6.1

- **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), CTPs**
    - **Key system attributes**
- **Contractor's internal TPMs**
  - ***TPMs at a more detailed level***

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*

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

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

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.**

PMBOK on TPMs

Standard or Principle	Description
Requirements Management Plan	Include…**product metrics** that will be used.
Project Procurement Management	• Work Performance Data contains seller data on project status such as technical performance activities that have started, are in progress, or have completed; and costs that have been incurred or committed. • Work Performance Information includes information on how a seller is performing by comparing the deliverables received, the technical performance achieved, and the costs incurred and accepted against the SOW budget for the work performed.

SE Tasks, Work Products, and Completion Criteria

Validated Requirements (Functional) Baseline

ISO/IEC 26702, (6.1, 6.2): Work Products

- **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	**4.3.2.4.22** **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	4.3.2.4.2.3, 4.3.3.4.2 PDR, CDR Success Criteria

CDR 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**

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**

Risk Mitigation Plans

SEP
3.2 Engineering Resources and Cost/Schedule Reporting **Include cross-linkage to the IMP in the offeror's IMS, WBS, BOE, and risk mitigation steps(a)**

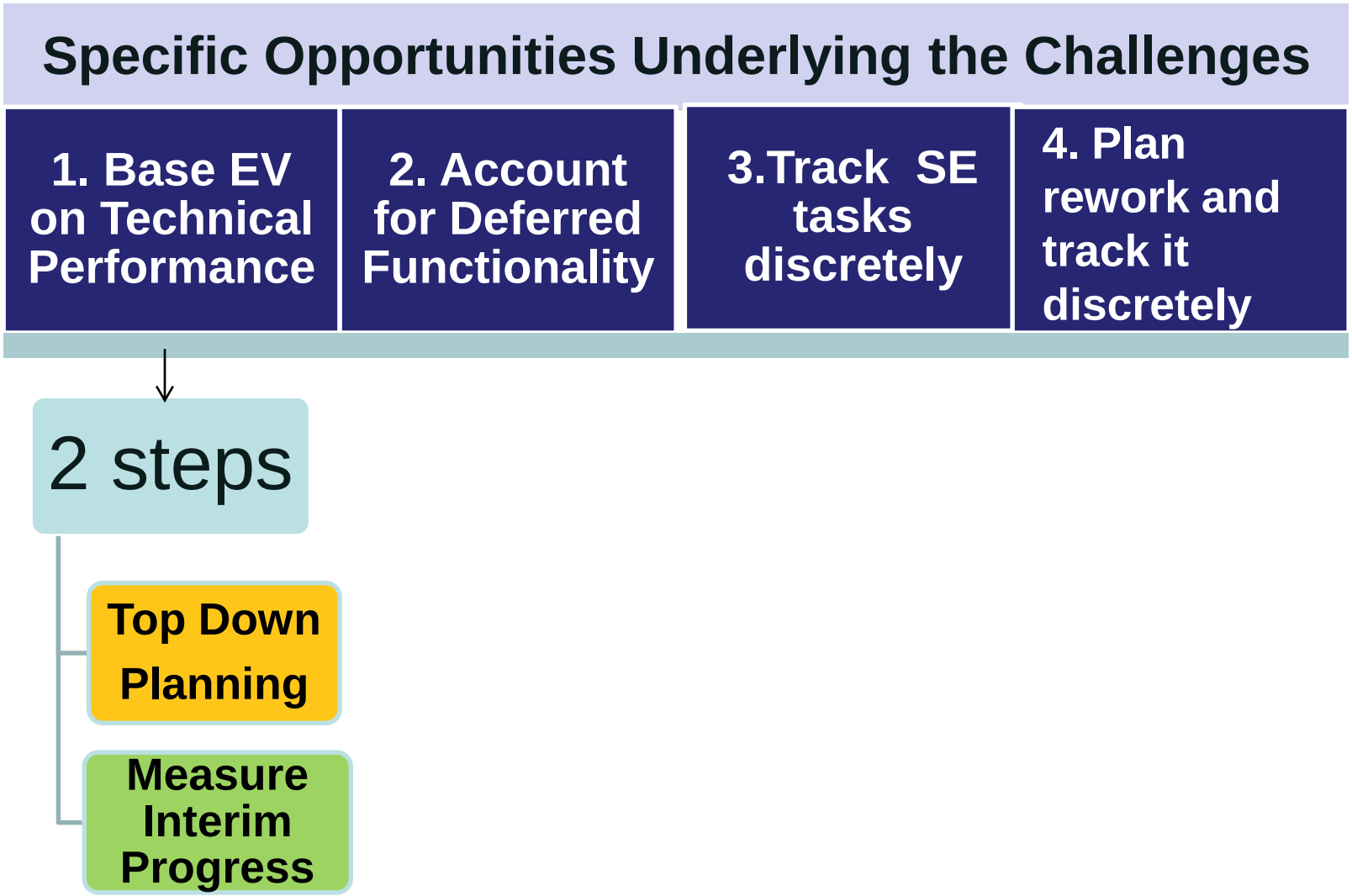
(a) See article, "Integrating Risk Management with Earned Value Management (Risk Management Comes Out of the Closet)", *Measurable News*, June1998 and *Carnegie Mellon U./Software Engineering Institute Technical Note* CMU/SEI-2002-TN-016, Oct. 2002, "Using CMMI® to Improve Earned Value Management"

PMBOK on Risk Mitigation

Standard or Principle	Description
Conduct Risk Management	Including planning, identification, risk analysis, response planning, and monitoring risk.
Risk Responses (Mitigation Plans) in Baselines	Schedule baseline. Changes in the schedule baseline are incorporated in response to approved changes in schedule estimates that may arise from agreed-upon risk responses. Cost baseline. Changes in the cost baseline are incorporated in response to approved changes in cost estimates that may arise from agreed-upon risk responses.

Practical Application

Four Opportunities



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**

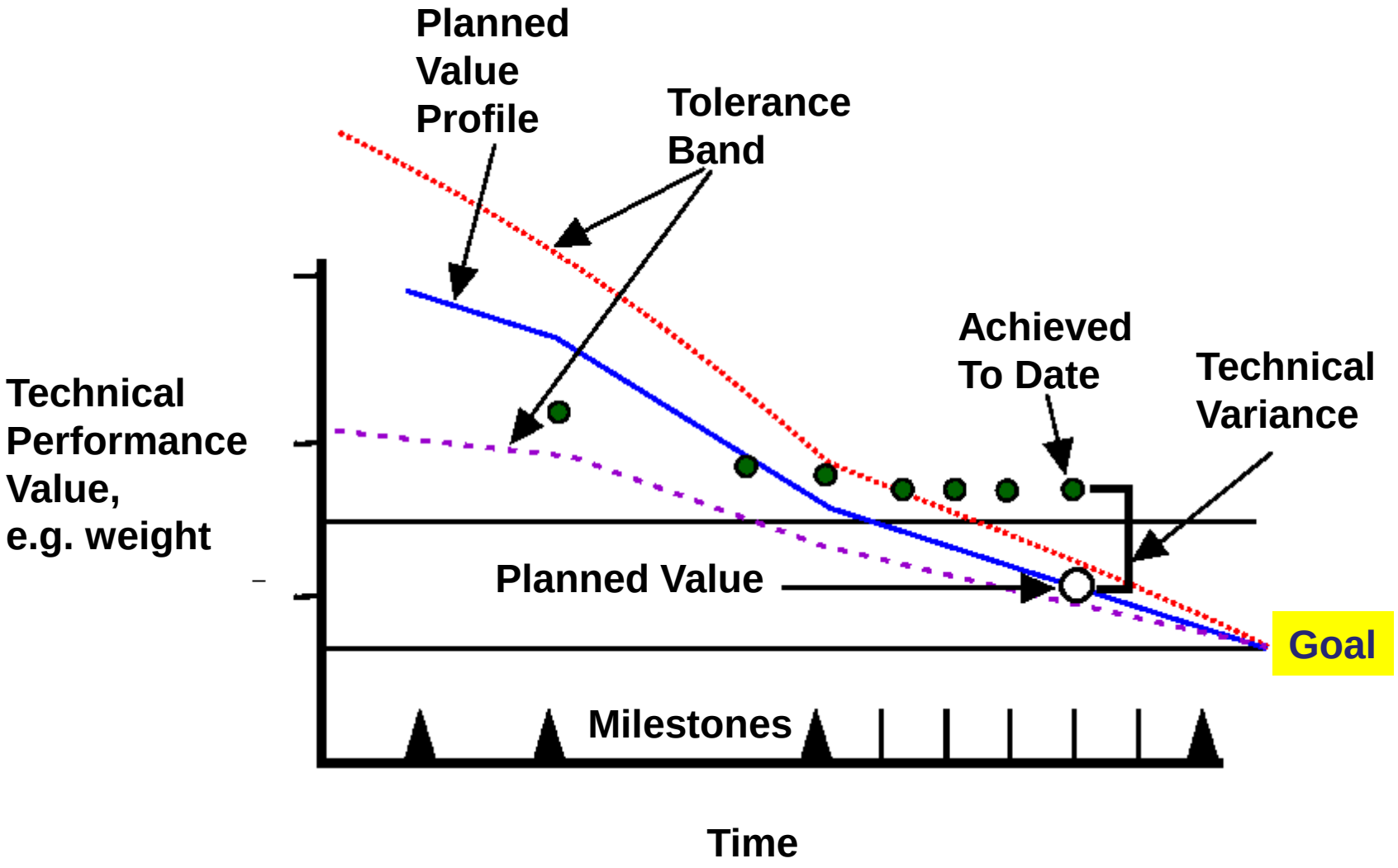
Solution for Basing EV on Technical Performance

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)

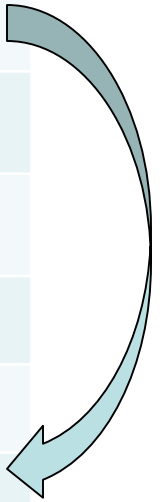
Schedule	Total	Jan	Feb	Mar	Apr	May	Total
	Draw-ings						
Drawings/ period	50	8	10	12	10	10	50
Meet requirements:							
Weight	6 lb.						
Dimensions	32 in.						

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)

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	-600	
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) - 640

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 works for software:

- **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.

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)	**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.

Incremental Software Capability

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

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 based on functionality achieved and close work package**

    - **Transfer deferred functionality 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**

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."

Agile Methods and EV

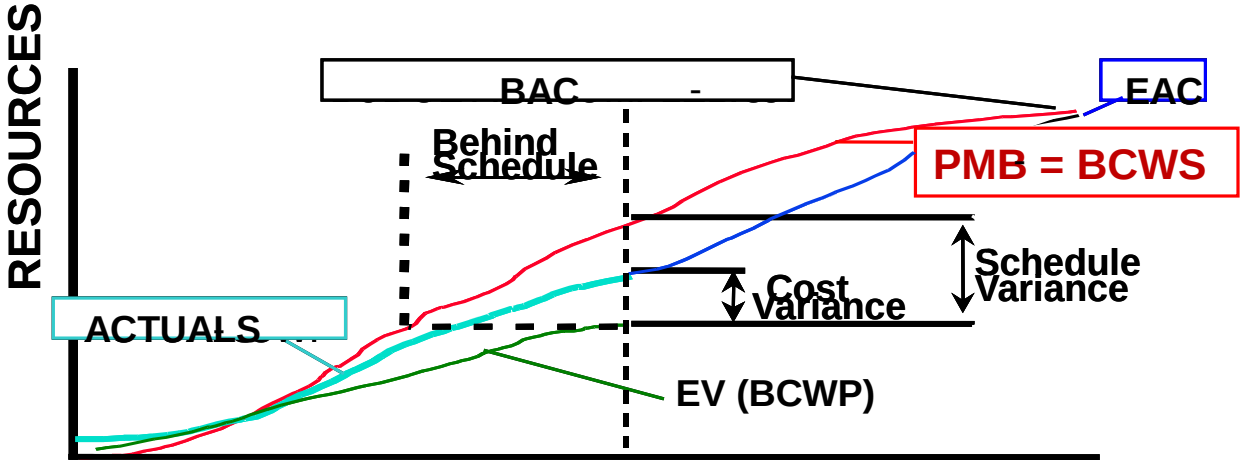
Agile Methods Characteristics

- **Next iteration of work is detail planned in work package**
- **Product burndown is a planning package for remaining features**
- **Features often deferred from the current iteration to the product burndown**
- **Features and priorities frequently revised**

Agile and EVMS Constraints

But EVMS Guideline requires *maintaining* the Performance Measurement Baseline (PMB)

- **Time-phased, resourced plan against which the accomplishment of authorized work is measured. (a)**



(a) DoD EVMS Intent Guide (EVMSIG), Guideline 8

Agile Focus on Near Term May Break Link with PMB

Giving full credit to meeting near term goals may: (a)

- **Break link with the PMB**
- **Lose track of progress of plan to satisfy requirements**
- **Mask need for corrective actions**
  - **DoD EVMSIG, Guideline 8: The accurate reporting of progress against a mutually recognized plan facilitates the implementation of actions by management to maintain or bring the program back on plan.**

(a) Journal of Software Management,
"Agile Earned Value and the Technical Baseline," Sept. 2009, page 9

Risks/Shortcomings of Agile Methods

Agile's focus on meeting near-term customer priorities may lead to a loss of focus on progress towards the next major technical review or software build. (a)

- **During development of the functional, allocated and product baselines, the team may fail to track progress towards meeting the success criteria for the SFR, PDR, and CDR.**
- **During Demonstration, the continual reprioritization and revision of the backlog may blur vision of progress towards meeting all the requirements in the baselined blocks and builds.**
- **By placing the remaining Product Backlog Items (PBI) in a planning package, the team may fail to establish sufficient, interim milestones and fail to perform variance analysis of the impact of schedule and cost variances on downstream tasks and block releases.**

(a) Journal of Software Management,
"Agile Earned Value and the Technical Baseline," Sept. 2009, page 9

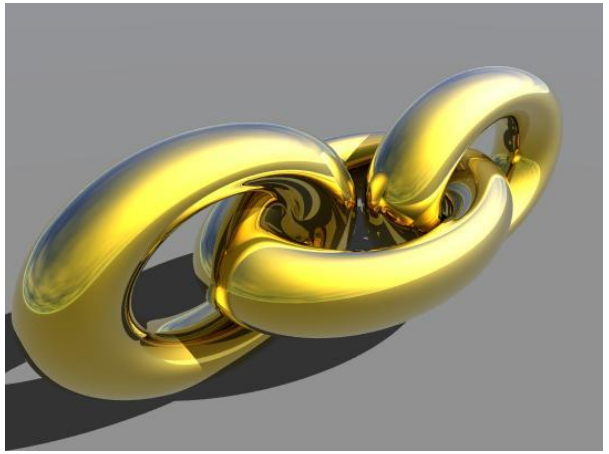
Agile EV Guidelines

Internal replanning guidance:

- **Maintain PMB when PBI burndown changes**
  - **Baseline finish dates of major releases**
  - **Technical baseline**
  - **Cumulative BCWS**
- **Transfer budget for deferred features to first period of next iteration/sprint**
- **Reallocate budget for descoped features to PBI unless a function was also descoped**
- **Maintain reported schedule variances**
- **Reallocate remaining EV (BAC – Cum. EV) to revised product backlog after each iteration**
- **Revise EAC, compare to funding, reprioritize**

Agile EV Guidelines

- **Maintain link with PMB**
- **Measure delivered features vs. plan**
- **Flexible planning for new priorities**
  - **But measure progress towards meeting all requirements in the technical baseline**



Agile Progress may be Misleading

More examples:

· Taking EV for software releases based on turning over the release, even though some of its baselined functionality was deferred to the next release.

· Not taking negative EV for drawings or other units returned for rework, when rework is planned in the same work package as the initial work.

Source; "EVM Acquisition Reform," Nov. 2010

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.

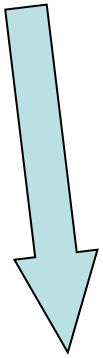
Ex 4: Deferred Functionality (4 of 5)
Deferred Functionality Replan

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

Scrum Application

See tutorial, “Agile Methods with Performance-Based Earned Value,” Systems & Software Technology Conference. April 20, 2009

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**

Requirements Traceability Matrix (PMBOK)

5.2.3.2

Typical attributes used in the requirements traceability matrix may include:

- **Current status (such as active, cancelled, deferred, added, approved, assigned, completed)**
- **Status date**
- **Acceptance criteria**

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	

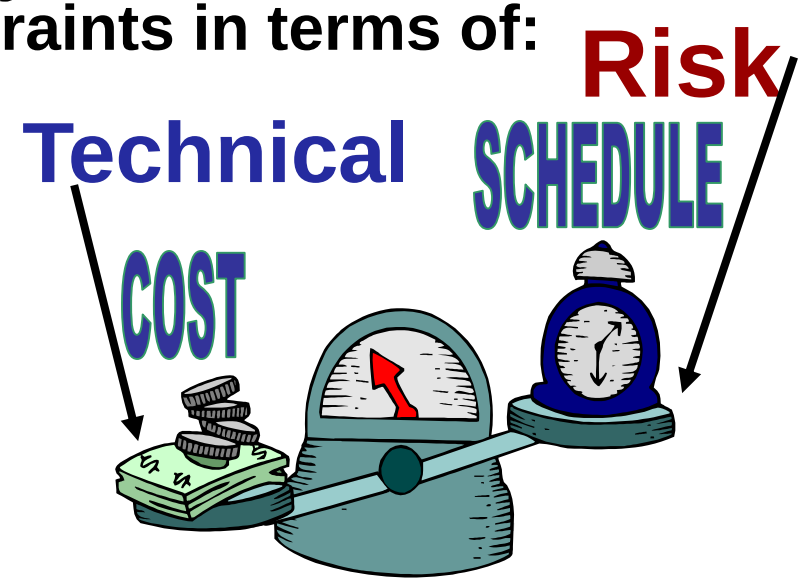
Ex 5: Earned Value 3 of 3

		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		

Integrated
Plans and Performance

DoD Guides:
Integrated Plans and Performance

DAG
SEP Preparation Guide 4/08 **WBS Standard Practice for Defense Materiel Items, MIL-STD-881C, 3 Oct. 2011**
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

Technical Baselines and Reviews

DoD						EIA-748	PMBOK
Guide or Standard	**DAG**	**SEP**	**WBS**	**IMP/ IMS**	**Integ SE**		
Technical Baselines **in IMP/IMS (Milestones):** • **Functional (SFR)** • **Allocated (PDR)** • **Product (CDR)**	X				X		X (Product Baseline)
Technical Reviews:							
• **Event-driven timing of technical reviews**	X	X	X	X	X		
• **Success criteria of technical reviews**	X	X	X	X	X		X (acceptance criteria)
• **Include entry and exit criteria for technical reviews in IMP and IMS**	X	X		X	X		X

Integrated Plans

DoD						EIA-748	PMBOK
Guide or Standard	DAG	SEP	WBS	IMP/ IMS	Integ SE		
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
Requirements Traceability Matrix to PMB							X
Link risk management (including risk mitigation plans), technical reviews, *TPMs*, EVM, WBS, IMS					X		X
Procurement Management			X	X			X

Acquisition Management and Contract Requirements

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**

SMC SE Products: Design Solution

3.2.3.1.a 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)**
    - **Computer software unit, and part**

SMC Shall:
Plan the SE Effort

4.2.1.1 Planning

4.2.1.1.1 Required SE Products

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

SMC Shall:
Monitor Progress Against the Plan

4.2.1.2 Monitoring

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

4.2.1.1.2 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**

PMBOK on Procurement

Standard or Principle	Description
Project Procure-ment Manage-Ment Inputs	Documents…inputs to this process include: • Requirements documentation may include …**technical requirements** the seller is required to satisfy • **Requirements traceability matrix**…links product requirements from their origin to the deliverables that satisfy them. • Work Performance Data contains seller data on project status such as **technical performance activities that have started, are in progress, or have completed**

Contract Requirements in DAG

3–2.7 Systems Engineering Role in Contracting

- PM should ensure that the EVMS, tied to any incentive, measures the **quality and technical maturity of technical work products instead of just the quantity of work.**
- If contracts include EV incentives, the criteria should be stated clearly and should be **based on technical performance.**
- **EV incentives should be linked quantitatively with:**
  - **Technical performance measurement**
  - **Progress against requirements**
  - **Development maturity**
  - **Exit criteria of life-cycle phases**

Incentives to Integrate SE

Article in Defense AT&L Magazine 1 of 2 (a)

- **SE standards and EVM provide a framework for linking award fees to desired program outcomes.**
- **Provides practical advice for defining the technical performance requirements and desired program outcomes in SE terms.**

(a) "**SE and EVM Support for Performance-Based Awards," Jan. 2007**

Requirements to Integrate SE

Article in Defense AT&L Magazine 2 of 2

- **Link discrete work packages to defining milestones for key technical and management deliverables.**
- **Define TPM planned values and measurement milestones**
- **IMS that identifies all SE products**
  - **Technical baselines**
  - **Requirements traceability matrices**
  - **Success criteria for major technical reviews**
- **Product metrics reports.**

Tailored EVMS Guidelines

Tailor 3 EVMS Guidelines to incorporate technical baseline, TPM, and rework (1 of 2) (a)		
Guide-line #	**Guideline Topic**	**Tailored Guideline**
2.1a	**Define the authorized work.**	**Add, "Include the work necessary to produce the product scope of the program, including rework (when applicable). The product scope is the technical baseline. It includes the features and functions that characterize a product or result."**
2.2b	**Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure progress.**	**Add, "All technical performance measures that have been identified at major technical reviews shall be used to measure progress in appropriate work packages."**

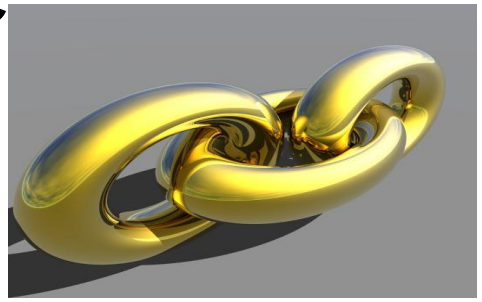
Tailored EVMS Guidelines

Tailor 3 EVMS Guidelines to incorporate technical baseline, TPM, and rework (2 of 2) (a)		
Guide-line #	**Guide-line Topic**	**Tailored Guideline**
2.5c	Revisions and Data Mainten-ance, control retro-active changes.	Add, "Retroactive changes to earned value, including negative adjustments to correct cumulative earned value so that it is consistent with ***achieved vs. planned technical performance***, must be made to improve the accuracy of performance measurement data."

(a) From white paper, "DoD Acquisition Reform: EVMS-lite to Program/Project Management," 7/27/18 (www.pb-ev.com, PMIAA Project Management tab)

Program Management Tips

- **Make IMP a contractual requirement**
- **Require SE best practices and tailored EVMS guidelines 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

Verify inclusion of:

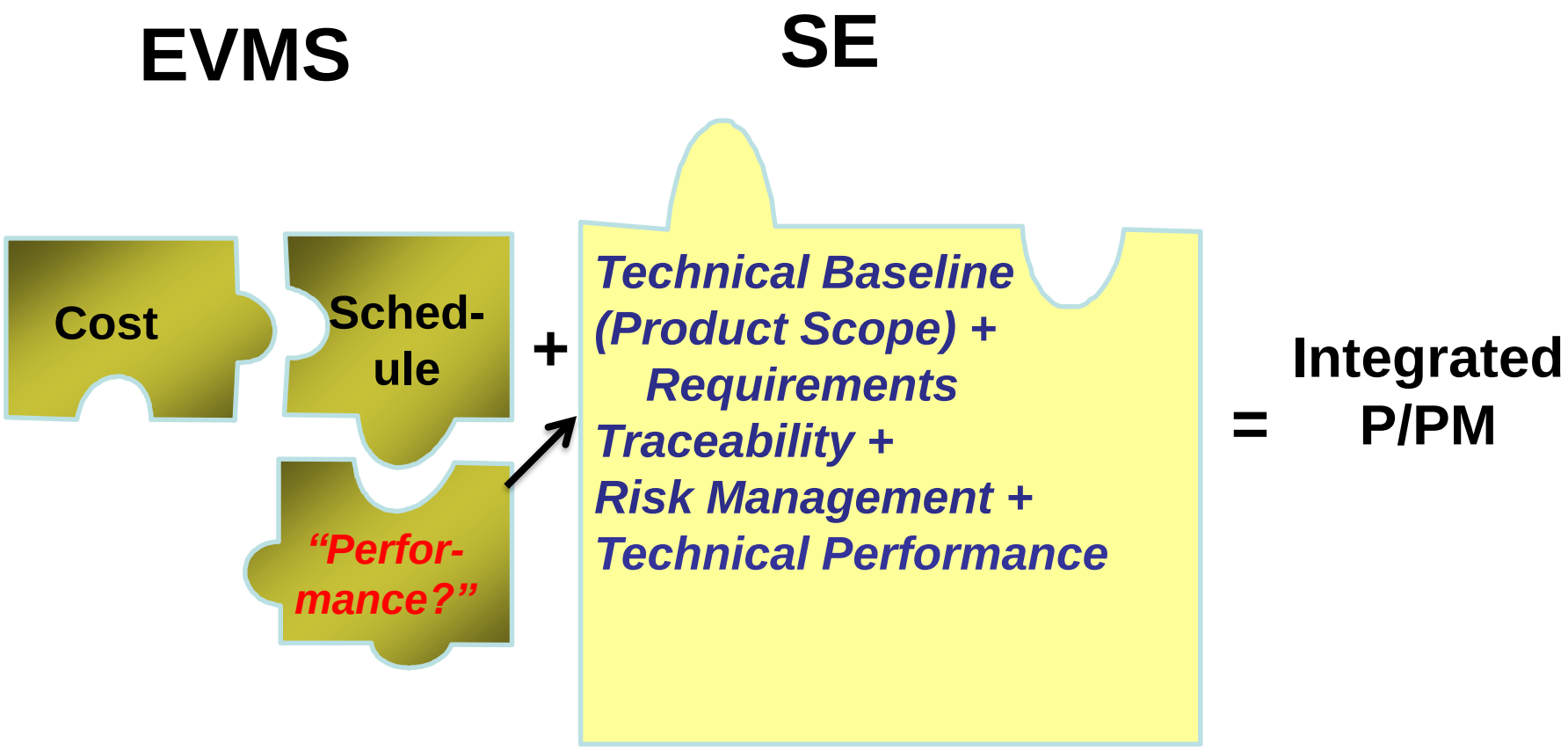
- **Requirements traceability to IMS and work packages**
- **Milestones for SE requirements work products by WBS**
  - **Derived requirements**
  - **Definition of required functionality and quality attributes**
  - **Verification methods and criteria**
- **Milestones for establishing product metrics**
  - **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**

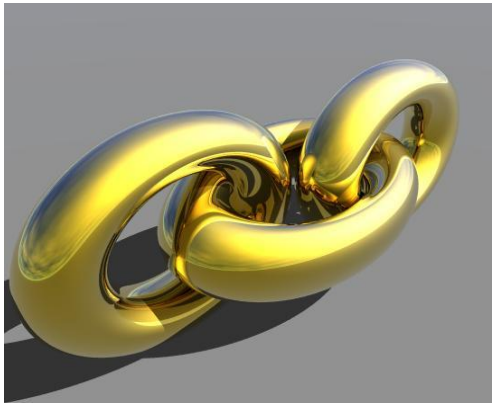
Framework for Process Improvement

Process Improvement Goal



Close the EVMS Quality Gap

- **PMB includes technical baselines**
- **Insightful IBRs and technical reviews**
- ***Valid* contract performance reports**
  - **Objective technical/schedule status**
  - **Credible EAC**
- **Enable early detection of problems**
  - **Real program performance**
  - **EV measurement and compliance**
- **Contractually-required**



PMIAA Provisions similar to or Duplicative of DoD Guidance

PMBOK Standard or Principle substantially similar to or duplicative of…policy, guidance, or instruction of the Department related to PM	DoD Source
Product Scope (Technical Baseline) vs. Work Scope	DAG
Product scope description	DAG
Scope Baseline includes product scope description, project deliverables, and defines product user acceptance criteria.	DAG
Control Product Scope	DAG
Requirements Documentation	DAG
Requirements Management Plan include product metrics	DAG, SEP

Close Gap with PMIAA

PMBOK provisions ***NOT*** substantially similar to or duplicative of…policy, guidance, or instruction of the Department related to PM (1 of 2)
Requirements: Foundation for cost, schedule, quality planning, and procurement
Requirements: basis of WBS
Requirements traceability matrix: includes requirements to project (including product) scope/WBS objectives
WBS Dictionary includes quality requirements, acceptance criteria
Risk Mitigation Plans in IMS and PBS

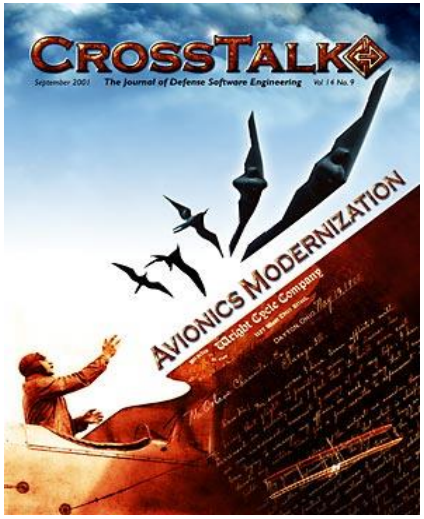
Close Gap with PMIAA

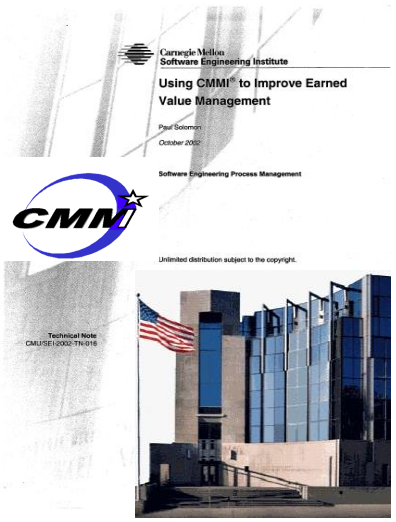
PMBOK provisions NOT substantially similar to or duplicative of…policy, guidance, or instruction… (2 of 2)

Project Procurement Management inputs:

- **Requirements documentation may include…*technical requirements* the seller is required to satisfy**
- ***Requirements traceability matrix*…links product requirements from their origin to the deliverables that satisfy them.**
- **Work Performance Data contains seller data on project status such as *technical performance* activities that have started, are in progress, or have completed; and costs that have been incurred or committed.**
- **Work Performance Information includes information on how a seller is performing by comparing the deliverables received, the *technical performance* achieved, and the costs incurred and accepted against the SOW budget for the work performed.**

Resources Online





DOD **SEI** **DOD DAU**

College of Performance Management

"Measurable News"

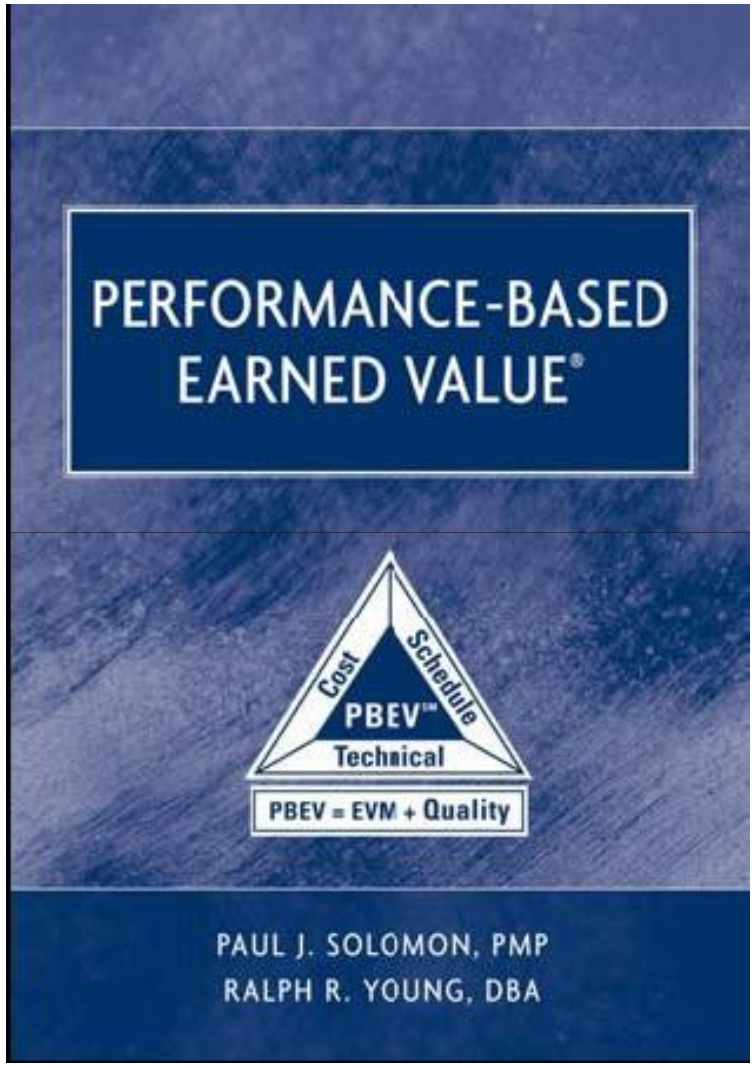
White Paper:
"EVMS-Lite"

www.PB-EV.com

Process Improvement Resources

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

Published by:



Questions?

Comments?

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References

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Acronyms

PMBOK Guide ® is registered by the Project Management Institute in the U.S. Patent and Trademark Office
CDR: Critical Design Review
EAC: Estimate at Completion
EVM: Earned Value Management
IBR: Integrated Baseline Review
IMP: Integrated Master Plan
IMS: Integrated Master Schedule
IP/PM: Integrated Program/Project Management
KPP: Key Performance Parameter
MOE: Measure of Effectiveness
MOP: Measure of Performance
OMB: Office of Management and Budget
PBI: Product Backlog Item
PDR: Preliminary Design Review
PMB: Performance Measurement Baseline
SE: Systems Engineering
SFR: System Functional Review
TPM: Technical Performance Measure