Tutorial: Integrate Systems Engineering with Earned Value Management

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Abstract 12982
Agenda

• Link EV to Technical Performance/Quality
• Government Needs and Acquisition Reform
• Guidance in Standards, Models and DoD Guides
• Practical Application
  – Technical Performance Measures
  – Rework
  – Trade studies
  – Requirements Management and Traceability
  – IT/Software Development Measures and Issues
  – Agile methods
• Acquisition Management
• Framework for Process Improvement
Does EVMS Really Integrate?

WBS

EVMS

COST

SCHEDULE

TECHNICAL PERFORMANCE

RISK

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“EVM data will be reliable and accurate only if:

- The right base measures of technical performance are selected
- 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

- Circular No. A-11, Section 300
  Planning, Budgeting, Acquisition and Management of Capital Assets
- Section 300-5
  - Performance-based acquisition management
  - Based on EVMS standard
  - Measure progress towards milestones
    - Cost
    - Capability to meet specified requirements
    - Timeliness
- Quality
Federal Acquisition Regulation (FAR) 2.101.b; EVMS

EVMS Definition:

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

But ANSI-748 has *Performance/Quality gap*
Weapons System Acquisition Reform Act of 2009 (WSARA)

Directs DOD to provide recommendations to improve EVM and its implementation:
- *Discuss merits of possible alternatives*
- *Submit plan for possible improvements*

Sen. Collins, conference report:
- GAO observed that contractor EVM reporting
  - Lacks consistency
  - Leads to inaccurate data and faulty application of the EVM metric.
- “In other words, garbage in, garbage out.”
- “With improved EVM data quality,
  - Both the government and the contractor will be able to improve program oversight,
    leading to better acquisition outcomes.”
Report: *DoD Earned Value Management: Performance, Oversight, and Governance, 2010*

“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
- Change in...**culture** is necessary
- Use **Technical Performance Measures** (TPM)
- Integrate **Systems Engineering** with EVM
Accuracy of EVM status data provided by vendors

- **Schedules** often cannot show downstream impacts of problems or cannot determine the critical path driving contract completion
- When assessing cost and schedule *variances*, contractors cannot effectively identify the *root cause, impact, and appropriate corrective actions*
- Contractors do not have a process for developing reliable **EAC**
- Contractor change control processes do not maintain the **integrity of the PMB**
DoD Report: Accuracy (2 of 2)

• Many instances of inappropriate changes
  – Arbitrarily changing past variances
  – Moving budgets to mask overruns
  – Making changes that were not properly authorized

• End result
  – Many Defense contractors cannot accurately predict outcomes that affect program costs or deliveries
  – Data quality problems hinder the government's ability to meet program objectives by delaying or masking insight into developing problems
DoD Report: Culture

Change in...culture is necessary

- Program Managers should identify and quantify the impacts of schedule slips and cost overruns
- Contractors may circumvent proper EVM practices to keep EVM metrics favorable and problems hidden
- Engineering community should establish TPMs that enable objective confirmation that tasks are complete
DoD Report : SE

Integrate SE with EVM

- EV process is reliable and accurate only if
  - Augmented with a rigorous SE process
  - SE products are costed and included in EVM tracking
Use TPMs

- EV process is reliable and accurate only if
  - **TPMs** are identified and **associated with completion of appropriate work packages**
  - **Quality of work** must be verified
  - **Criteria** must be defined clearly and unambiguously
Use TPMs

- If good TPMs are not used:
  - Programs could report 100 percent of earned value, even though behind schedule
    - Validating requirements
    - Completing the preliminary design
    - Meeting weight targets
    - Delivering software releases that meet the requirements

- PM ensure that the EVM process measures the quality and technical maturity of technical work products instead of just the quantity of work performed

Sec. Def. to review defense acquisition guidance, including DoDI 5000.02

- Consider “whether measures of Quality and technical performance should be included in any EVMS.”

- Submit report to the Congress by Sept. 27
  - Changes in acquisition guidance, if needed
  - Actions to implement changes

Pertinent articles:

- Defense AT&L Magazine, May/June 2011: ”Path to EVM Acquisition Reform"

- DoD Journal of Software Technology, August 2011: ”Improving the Quality of EVM Information“
DoD Need: Integrated Testable Requirements

Memo: Test & Evaluation of DoD Programs (1)

1. Improve relationship among testing, requirements and program management communities

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

## Deficiencies in Use of EVM

<table>
<thead>
<tr>
<th>GAO Report</th>
<th>Title</th>
<th>Findings and Recommendations</th>
</tr>
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</table>
| 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. |
Deficiencies and Loopholes in ANSI-748
EVMS Quality Gap

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

*No* guidance or requirement to link

- Reported EV
- with
- Progress toward meeting *Quality/technical performance requirements*
EVMS 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 (ID)
• physical products
• milestones
• technical performance goals

“or” "and"
• other indicators that will be used to measure progress.

“or” not “and”
Management Reserve (MR) Quality Gap

EVMS loopholes facilitate use of MR for cost overruns:

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. Initial design work packages reported as “95% complete” based on quantity of work completed, *not technical performance* (3.8)

3. MR used to budget additional testing and rework

4. **Results:** Accurate progress and cost overrun are not reported
Standards, Models, Guides: Guidance on Quality
Guidance in Standards, Models, and DoD Guides

• 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 1.3
  • CMMI for Acquisition, Version 1.3
  • *Using CMMI to Improve Earned Value Management*, 2002
Keystones of Integrated Planning

- *Technical baselines*
- *Technical performance*
- *Success criteria*
- *SE/quality work products*
# DOD Guides: Integrated Planning

<table>
<thead>
<tr>
<th>Title</th>
<th>Publication Date</th>
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<tbody>
<tr>
<td>DoDI 5000.02, Operation of the Defense Acquisition System (POL)</td>
<td>12/08</td>
</tr>
<tr>
<td>Interim Defense Acquisition Guidebook (DAG)</td>
<td>6/15/09</td>
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<tr>
<td>Systems Engineering Plan (SEP) Preparation Guide</td>
<td>4/08</td>
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<tr>
<td>WBS Handbook, Mil-HDBK-881A (WBS)</td>
<td>7/30/05</td>
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<tr>
<td>Integrated Master Plan (IMP) &amp; Integrated Master Schedule Preparation &amp; Use Guide (IMS)</td>
<td>10/21/05</td>
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<tr>
<td>Guide for Integrating SE into DOD Acquisition Contracts (Integ SE)</td>
<td>12/06</td>
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<tr>
<td>Defense Acquisition Program Support Methodology (DAPS) V2.0</td>
<td>3/20/09</td>
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</tbody>
</table>
# DoD: Technical Baselines and Reviews

## Technical Baselines in IMP/IMS (Milestones):
- Functional (SFR)
- Allocated (PDR)
- Product (CDR)

## Technical Reviews:
- Event-driven timing of technical reviews
- Success criteria of technical reviews
- Include entry and exit criteria for technical reviews in IMP and IMS
- Assess technical maturity in technical reviews

<table>
<thead>
<tr>
<th>DoD Policy or Guide</th>
<th>POL</th>
<th>DAG</th>
<th>SEP</th>
<th>WBS</th>
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<td><strong>Technical Baselines in IMP/IMS (Milestones):</strong></td>
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## DoD: Integrated Plans

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<td>Integrate SEP with:</td>
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<td>• <em>Requirements specification</em></td>
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<tr>
<td>Link risk management (including risk mitigation plans), technical reviews, <strong>TPMs</strong>, EVM, WBS, IMS</td>
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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 *TPMs and how they will be used to measure progress*
Functional Baseline (DAG)

What

• Definition of the required system functionality
  – Functional and interface characteristics of overall system
  – Verification required to demonstrate their achievement

• Derived from the Capabilities Development Document (CDD)

• Includes
  – Detailed functional performance specification for the overall system
  – Tests necessary to verify and validate system performance.

When:

• Established at System Functional Review (SFR)
• Verified at System Verification Review (SVR)
Allocated Baseline (DAG)

**What**

- 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

**When:** At each CI’s Preliminary Design Review (PDR)
Product Baseline (DAG)

What

Necessary functional and physical characteristics of a CI

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

When:

- At each CI’s Critical Design Review (CDR)
- System product baseline established at system-level CDR
## Baseline (CMMI/DAG)

<table>
<thead>
<tr>
<th>Requirements Development</th>
<th>SG 2: Develop Product Requirements</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP 2.1</td>
<td>Example work products:</td>
<td>4.2.3.1.6.2</td>
</tr>
<tr>
<td>Establish and maintain product and product component requirements, based on customer requirements</td>
<td>• Derived requirements</td>
<td>Establish Configuration Baselines</td>
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<tr>
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<td>• Product requirements</td>
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<td></td>
<td>• Product component requirements</td>
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<tr>
<td>Subpractices</td>
<td>1. Develop requirements in technical terms necessary for product and product component design</td>
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<td>2. Derive requirements that result from design decisions</td>
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</tbody>
</table>

**SG:** Specific Goal  
**SP:** Specific Practice
SE Life Cycle Baselines, IEEE 1220

- Requirements Analysis
  - Requirements Baseline *
  - Requirements Validation
    - Validated Requirements Baseline *
    - Functional Analysis
      - Functional Architecture *
      - Functional Verification
        - Verified Functional Architecture *
    - Synthesis
      - Physical Architecture *
      - Design Verification
        - Verified Physical Architecture *
  - Functional trade studies and assessments
  - Design trade studies and assessments

* Work Products
Technical Baselines

System Integration

System Demonstration

Design Readiness

Review

SFR

PDR

CDR

PRR

DAG:

System Functional Baseline

Allocated Baseline

Product Baseline

Product Baseline

IEEE 1220: Validated Requirements

Verified Physical Architecture

PMBOK Guide: Performance Measurement Baseline (PMB) including technical and quality parameters
## Baselines (CMMI/DAG)

<table>
<thead>
<tr>
<th>Requirements Management</th>
<th>SG 1: Manage Requirements</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SP 1.4</strong> Maintain bidirectional traceability among the requirements and work products</td>
<td>Example work products: Requirements traceability matrix (RTM) <strong>Subpractices</strong> 1. Maintain requirements traceability from a requirement to its derived requirements and allocation to functions, interfaces, objects, people, processes, and work products. 2. Generate the RTM</td>
<td>4.2.3.1.6.2 Establish Configuration Baselines: Product baseline; necessary functional and physical characteristics of a configuration item</td>
</tr>
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</table>


SP 1.2 Obtain commitment to requirements

Example Work Products:
- Documented comments to requirements and requirements changes.

SP 1.4 Maintain bi-directional traceability:
- Requirements
- Plans
- Work products

Example Work Products:
- Requirements traceability matrix

SP 1.5 Ensure that project plans and work products remain aligned with requirements

Subpractices:
Identify changes that need to be made to the plans and work products resulting from changes to the requirements baseline

CMMI: Requirements Management
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.
Product Requirements Baseline

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

Requirements

Product Requirements Baseline

Work

- Project Plans
  - Task 1
  - Task 2
  - Task 3
- Activities
- Work Products

Source: CMMI Requirements Management Process Area (PA), Specific Practice (SP) 1.5
Technical Performance
TPMs in DAG

DAG:

• Performance measurement of WBS elements, using objective measures:
  – *Essential for EVM* and Technical Assessment activities

• *Use TPMs* and Critical Technical Parameters (CTP) to report progress in achieving milestones

• Plan is defined in terms of:
  – Expected performance at specific points
    • Defined in the WBS and IMS
  – Methods of measurement at those points
  – Variation limits for corrective action.
TPMs in DAG

- TPM parameters to be tracked
  - Cost drivers on the program,
  - On the critical path
  - Represent high technical risk items.
- Contract Deliverable
  - Report of TPMs that are traceable to:
    - Needs of the operational user
    - Key Performance Parameters (KPP), Critical Technical Parameters
    - Key system attributes
- Contractor’s internal TPMs
  - TPMs at a more detailed level
<table>
<thead>
<tr>
<th>Requirements Development</th>
<th>SG 3: Analyze and Validate Requirements</th>
<th>DAG</th>
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<tbody>
<tr>
<td>SP 3.3 Analyze Requirements</td>
<td>Example work products:</td>
<td>2.1.1.4, 4.5.6.1</td>
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<tr>
<td></td>
<td>• Requirements defects reports</td>
<td>TPMs</td>
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<td>• Key requirements</td>
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<td>• TPMs</td>
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<td><strong>Subpractices</strong></td>
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<td>4. Identify key requirements that have as strong influence on cost, schedule, functionality, risk, or performance</td>
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<td>5. Identify <strong>TPMs</strong> that will be tracked during the development effort</td>
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</table>
# TPM (CMMI/DAG)

<table>
<thead>
<tr>
<th>Measurement and Analysis</th>
<th>SG 1: Align Measurement and Analysis Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SP 1.2</strong> Specify Measures</td>
<td><strong>Example work products:</strong></td>
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<tr>
<td></td>
<td>Specifications of base and derived measures</td>
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<td><strong>Subpractices</strong></td>
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<td>3. Specify operational definitions for the measures..in precise and unambiguous terms</td>
</tr>
</tbody>
</table>
## TPM (CMMI/DAG)

<table>
<thead>
<tr>
<th>Project Monitoring &amp; Control</th>
<th>SG 1: Monitor Project Against the Plan</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP 1.1 Monitor Project Planning Parameters</td>
<td>Monitor <strong>actual values of planning parameters against plan</strong> Subpractices: Monitor: 1. <strong>Progress</strong> against schedule 2. Cost 3. <strong>Attributes of work products and tasks</strong></td>
<td>4.5.6.1 TPMs and CTPs</td>
</tr>
</tbody>
</table>
## Requirements and Product Metrics

<table>
<thead>
<tr>
<th>IEEE 1220</th>
<th>EIA-632</th>
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<tbody>
<tr>
<td><strong>6.8.1.5 Performance-based progress measurement</strong></td>
<td>4.2.1 Req. 10: Progress against requirements</td>
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<tr>
<td><strong>6.8.1.5 d) Assess</strong></td>
<td>Assess progress …</td>
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<tr>
<td>• Development maturity</td>
<td>• Compare system definition against requirements</td>
</tr>
<tr>
<td>• Product’s ability to satisfy requirements</td>
<td>a) Identify product metrics and expected values</td>
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<tr>
<td><strong>6.8.6 Product metrics at pre-established control points:</strong></td>
<td>• Quality of product</td>
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<tr>
<td>• Evaluate system quality</td>
<td>• Progress towards satisfying requirements</td>
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<tr>
<td>• Compare to planned goals and targets</td>
<td>d) Compare results against requirements</td>
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- **IEEE 1220**
  - 6.8.1.5 Performance-based progress measurement
  - 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
## Technical Performance Measures (TPM)

<table>
<thead>
<tr>
<th>IEEE 1220: 6.8.1.5, Performance-based progress measurement</th>
<th>EIA-632: Glossary</th>
<th>CMMI for Development Requirements Development</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TPMs</strong> are key to progressively assess technical progress</td>
<td><strong>Predict</strong> future value of key technical parameters of the end system based on current assessments</td>
<td>Specific Practice (SP) 3.3, Analyze Requirements Typical work product: <strong>TPMs</strong></td>
</tr>
</tbody>
</table>

| Establish dates for | Planned value profile is time-phased achievement projected | Subpractice: Identify TPMs that will be tracked during development |
| — Checking progress | • Achievement to date • Technical milestone where TPM evaluation is reported | |
| — Meeting full conformance to requirements | | |

49
Technical performance measurement compares technical accomplishments during project execution to the ... schedule of technical achievement.

It requires definition of objective, quantifiable TPMs which can be used to compare actual results against targets (11.6.2.4).
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 Profile
- Tolerance Band
- Achieved To Date
- Technical Variance
- Technical Performance Value, e.g. weight
- Planned Value
- Milestones
- Time
- Goal
## Derivation and Flowdown of TPMs

<table>
<thead>
<tr>
<th>Document, Baseline, IMS, EVM</th>
<th>Parameter</th>
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<tbody>
<tr>
<td>CDD</td>
<td>Key Performance Parameter (KPP)</td>
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<tr>
<td>Functional Baseline</td>
<td>Measures of Effectiveness (MOE)</td>
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<tr>
<td>Functional Baseline</td>
<td>Measures of Performance (MOP)</td>
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<tr>
<td>Allocated Baseline</td>
<td>TPM</td>
</tr>
<tr>
<td>IMS</td>
<td>TPM Milestones and Planned Values</td>
</tr>
<tr>
<td>Work packages</td>
<td>TPM-based % complete criteria</td>
</tr>
</tbody>
</table>
Technical Reviews, Baselines, Measures
Success Criteria
### Success Criteria (CMMI/DAG)

<table>
<thead>
<tr>
<th>Requirements Development</th>
<th>SG 3: Analyze and Validate Requirements</th>
<th>DAG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SP 3.2</strong></td>
<td>Example work products:</td>
<td>4.2.3.1.6.2</td>
</tr>
<tr>
<td>Establish a Definition of Required Functionality</td>
<td>- Functional architecture</td>
<td>Establish Configuration Baselines - SFR success criteria</td>
</tr>
<tr>
<td></td>
<td>- Activity diagrams and use cases Subpractices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Analyze and quantify functionality required by end users</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Allocate functional and performance requirements to functions and subfunctions</td>
<td></td>
</tr>
</tbody>
</table>
## PDR Success Criteria

<table>
<thead>
<tr>
<th>DAG 4.3.2.4.2.3 (partial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preliminary design satisfies the CDD</td>
</tr>
<tr>
<td>• System <strong>allocated baseline</strong> established and documented to enable detailed design to proceed with proper configuration management</td>
</tr>
<tr>
<td>• Program schedule executable (technical/cost risks)</td>
</tr>
<tr>
<td>• Producibility assessments of key technologies completed</td>
</tr>
<tr>
<td>• Program executable with</td>
</tr>
<tr>
<td>• Existing budget</td>
</tr>
<tr>
<td>• Approved system allocated baseline</td>
</tr>
<tr>
<td>• Risks known and manageable for testing</td>
</tr>
</tbody>
</table>

Note: Software success criteria discussed in later section
CDR Success Criteria

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
<table>
<thead>
<tr>
<th>Requirements Development</th>
<th>SG 2: Develop Product Requirements</th>
<th>DAG</th>
</tr>
</thead>
</table>
| **SP 2.2** Allocate product component requirements | Example work products:  
• Requirement allocation sheets  
• Design constraints  
• Derived requirements | 4.2.3.1.6.2 Establish Configuration Baselines – PDR, CDR Success Criteria |
|                          | Subpractices  
1. Allocate requirements to functions  
2. Allocate requirements to product components |   |
SE/Quality
Work Products

- Establish milestones on IMS
- Discrete EV measurement, not LOE
Validated Requirements (Functional) Baseline

<table>
<thead>
<tr>
<th>Work Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Customer expectations</td>
</tr>
<tr>
<td>• Project, enterprise and external constraints</td>
</tr>
<tr>
<td>• <em>Operational scenarios</em></td>
</tr>
<tr>
<td>• <em>MOEs</em></td>
</tr>
<tr>
<td>• Interfaces</td>
</tr>
<tr>
<td>• <em>Functional requirements</em></td>
</tr>
<tr>
<td>• <em>MOPs</em></td>
</tr>
<tr>
<td>• Modes of operation</td>
</tr>
<tr>
<td>• Design characteristics</td>
</tr>
<tr>
<td>• Documented trade-offs</td>
</tr>
</tbody>
</table>

IEEE 1220, (6.1, 6.2): 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
Guidelines for Performance-Based EVM (PBEV)

16 guidelines distilled from standards and models
Why Use More EV Guidelines?

• Link EV to technical performance, design maturity and *quality*
  • “Quantify *quality*” measures
    – Functionality: Percent of product requirements met (weighted)
    – Technical performance achieved
    – Plan and track rework
  • *Measure quality* of work products
  • *Status quality* in requirements traceability matrix
  • Address quality in variance analyses

*EV without Quality has less management value*
PBEV Guidelines

Augment EVMS

Guideline 1.1

Guidelines 1.2, 2.2, 2.5, 2.6

(P) Establish product requirements and components (technical baseline)

(P) Integrate product requirements and quality with plan

(P) Measure progress towards meeting product requirements and quality

(P) = Supplemental Integration Process

(P) = Supplemental Integration Process

Guideline 2.7

Incorporate internal/external changes

Execute the plan

Execute the plan

Measure the work

Analyze variances

Implement corrective action

EVMS

Define the work (WBS)

Plan the work (Schedule & Budget)
PBEV 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.

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*
PBEV 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*
LEAN Benefits

• Minimize costs; measurement costs money
• Fewer work packages with right base measures
  – Requirements-driven plan
  – TPMs
  – SE and technical work products
Practical Application
Technical Performance Measures
Example (Ex) 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
  – If TPM PVs \textit{not} met on schedule:
    • \textbf{Negative} adjustment to EV
      – Weight: \textbf{-100}
      – Diameter \textbf{-200}
### Ex 1: EV Based on Drawings and TPMs

**Schedule**

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Total</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawings/ period</td>
<td>50</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td><strong>Meet requirements:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Ex 1: Status

<table>
<thead>
<tr>
<th>Date</th>
<th>April 30</th>
<th>May 31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawings completed</td>
<td>41</td>
<td>49</td>
</tr>
<tr>
<td>Weight met</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Diameter met</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Ex 1: EV Based on Drawings and TPMs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned drawings cur</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Planned drawings cum</td>
<td>8</td>
<td>18</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>BCWS cur</td>
<td>320</td>
<td>400</td>
<td>480</td>
<td>400</td>
<td>400</td>
<td>2000</td>
</tr>
<tr>
<td>BCWS cum</td>
<td>320</td>
<td>720</td>
<td>1200</td>
<td>1600</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Actual drawings completed cur</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Actual drawings completed cum</td>
<td>9</td>
<td>19</td>
<td>29</td>
<td>41</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>EV (drawings) cum</td>
<td>360</td>
<td>760</td>
<td>1160</td>
<td>1640</td>
<td>1960</td>
<td></td>
</tr>
<tr>
<td>Negative EV Reqs cum</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>-100</td>
<td></td>
</tr>
<tr>
<td>Net EV cum</td>
<td>360</td>
<td>760</td>
<td>1160</td>
<td>1640</td>
<td>1860</td>
<td>1860</td>
</tr>
</tbody>
</table>

SV = -140
Ex 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
Same technique works for hardware:

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

<table>
<thead>
<tr>
<th>Comp/Work Pkg</th>
<th>TPM PV (lb)</th>
<th>Comp Milestone</th>
<th>Comp EV Penalty</th>
<th>Sub Milestone</th>
<th>Sub EV Penalty</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>April</td>
<td>-100</td>
<td>May</td>
<td>-50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>April</td>
<td>-500</td>
<td>May</td>
<td>-250</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2000</td>
<td>May</td>
<td>-1000</td>
<td>May</td>
<td>-500</td>
<td>2000</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>May</td>
<td>-400</td>
<td>May</td>
<td>-200</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4000</td>
<td></td>
<td>-2000</td>
<td></td>
<td>-1000</td>
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</tr>
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</table>
# Ex 2: Component 3

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned drawings cur</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Planned drawings cum</td>
<td>8</td>
<td>18</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>BCWS cur</td>
<td>320</td>
<td>400</td>
<td>480</td>
<td>400</td>
<td>400</td>
<td>2000</td>
</tr>
<tr>
<td>BCWS cum</td>
<td>320</td>
<td>720</td>
<td>1200</td>
<td>1600</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Actual drawings completed cur</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Actual drawings completed cum</td>
<td>9</td>
<td>19</td>
<td>29</td>
<td>41</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>EV (drawings) cum</td>
<td>360</td>
<td>760</td>
<td>1160</td>
<td>1640</td>
<td>1960</td>
<td></td>
</tr>
<tr>
<td>Negative EV Reqs cum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-1500</td>
<td></td>
</tr>
<tr>
<td>Net EV cum</td>
<td>360</td>
<td>760</td>
<td>1160</td>
<td>1640</td>
<td>460</td>
<td></td>
</tr>
</tbody>
</table>
Rework
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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned drawings –cur.</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Planned drawings –cum.</td>
<td>8</td>
<td>18</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>BCWS – cum.</td>
<td>320</td>
<td>720</td>
<td>1200</td>
<td>1600</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Drawings completed</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>4</td>
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<tr>
<td>Drawings returned</td>
<td></td>
<td></td>
<td></td>
<td>-5</td>
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</tr>
<tr>
<td>Net drawings – cur.</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>-1</td>
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</tr>
<tr>
<td>Net drawings – cum.</td>
<td>9</td>
<td>19</td>
<td>29</td>
<td>28</td>
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<td></td>
</tr>
<tr>
<td>Net EV – cur.</td>
<td>360</td>
<td>400</td>
<td>400</td>
<td>-40</td>
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</tr>
<tr>
<td>EV – cum.</td>
<td>360</td>
<td>760</td>
<td>1160</td>
<td>1120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SV – cum.</td>
<td>0</td>
<td>40</td>
<td>-40</td>
<td>-480</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Negative Adjustments to EV

• Why make negative adjustments to EV?
  – More accurate status
  – Earlier warning of real deviations
  – More effective variance analysis
Negative Adjustments to EV

• If change in milestones, # of units etc:
  – Previous progress, as % complete, is no longer accurate
  – CPI, base on old EV, is not current or accurate
  – EAC, based on old CPI, is not current or accurate
  – Estimated completion date may need change
• **Technique 1: Interim milestones**
  – Discrete based on success targets
  – Example: Interim Milestones
    • Final month: 100% of requirements met
    • Final month – 1: 90% of requirements met
    • Final month - 2: 85% of requirements met

• **Technique 2: Negative EV when “completed” work product is returned for rework**
  – Update cumulative EV based on current technical progress
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.
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
• During IBR, can determine if sufficient budget and time for rework is included in PMB
  • Preclude use of MR for rework
• Better cost and schedule variance analysis
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 4 : 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 4 : Trade – Determine Design Solution**

**PMB:**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candidate 1</td>
<td>25</td>
<td>75</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Candidate 2</td>
<td>25</td>
<td>75</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
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<tr>
<td>Candidate 3</td>
<td>25</td>
<td>75</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
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<td>Candidate 4</td>
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<td></td>
<td></td>
<td></td>
<td>150</td>
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<tr>
<td>Select 2 candidates</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Make recommendation</td>
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<td></td>
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<td>250</td>
</tr>
<tr>
<td>Current BCWS</td>
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<td>200</td>
<td>250</td>
<td>100</td>
<td>150</td>
<td>250</td>
<td>1000</td>
</tr>
<tr>
<td>Cumulative BCWS</td>
<td>50</td>
<td>250</td>
<td>500</td>
<td>600</td>
<td>750</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>
Ex 4 : 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 4a: Prepare Feb cumulative performance report (Ignore actuals)**
• **Problem 4b: Develop internal replan for March forward, with revised base measures of EV**
### Ex 4a, Trade Study
#### Feb Worksheet

<table>
<thead>
<tr>
<th>Activity</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candidate 1 BCWS</td>
<td>25</td>
<td>75</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Candidate 2 BCWS</td>
<td>25</td>
<td>75</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
</tr>
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Ex 4b, Trade Study
March Replan

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Hint: Must allocate budgeted cost of work remaining to 5th candidate.
Discrete Earned Value for SE Requirements Management Activities
Requirements Management – Not Level of Effort (LOE)

- LOE: Unmeasured effort of general nature without a deliverable end product
  - Supervision, administration

- Requirements Management (RM) outputs are Measurable work products
  - Validated requirements
  - Allocated requirements
  - Verification document (test procedure)
  - Verified requirements (Verification Cross Reference Index)
Method

• Base EV on progress of
  – Enabling work products (drawings, code)
  – RM tasks and work products
• Use Requirements Traceability Matrix
  – Set milestones for RM work products
  – Measure progress vs. plan
• Compare RM EV with total project EV
  – SE progress is like a tracking stock for the whole program
  – Red Flag: if WBS product progress > SE progress
Ex 5: Requirements Management (RM)

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

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- Key indicator of project performance
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| BCWS cumulative    |                | 36   | 60   | 84   | 108  | 156 | 192  | 240  |       |
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IT/Software Progress Measurement Issues

- DoD Guidance
- Base measures of EV
- Rework
- Deferred functionality
- Trade studies
DoD Software Guidance
Guidance in Models and DOD Publications

- Capability Maturity Model Integration (CMMI®)
  - Using CMMI to Improve Earned Value Management, 2002

- Practical Software and Systems Measurement: A Foundation for Objective Project Management, v. 4.0 (PSM); sponsored by U.S. Army

- Naval Air Systems Command (NAVAIR)
  - Using Software Metrics & Measurements for Earned Value Toolkit, 2004

- USAF Weapon Systems Software Management Guidebook
# Success Criteria for Requirements Status

## Category: Work Unit Progress

## Measure: Requirements Status

Collect for Each: Requirements Specification

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<th>Data Item</th>
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<td>Successful Completion of all Tests, in Appropriate Test Sequence</td>
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<td>Test Specifications</td>
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# Success Criteria for Incremental Capability

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*Image: PSM*
3.6.2 Requirements and Incremental Software Development

b. Map/alocate 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.
Rework

To ensure adequate budget and period of performance:

• Planning assumptions for rework should include:
  • Planned rate or number of defects expected
  • Budgeted resources to fix the defects, including retest
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
SW Base Measures of EV
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
Integration and test planning
- # requirements traced to test specifications
- # test cases
- # use cases
SW Rework
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

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Deferred Functionality
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 6: Deferred Functionality

SOW: Software Requirements in 2 Builds:

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© Copyright 2009, Paul Solomon
### Ex 6: SW Build Plan

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<td>25</td>
<td>0</td>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>PV - cur</td>
<td>125</td>
<td>125</td>
<td>125</td>
<td>125</td>
<td>0</td>
<td>0</td>
<td>500</td>
</tr>
<tr>
<td>PV - cum</td>
<td>125</td>
<td>250</td>
<td>375</td>
<td>500</td>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>EV-cur</td>
<td>100</td>
<td>100</td>
<td>125</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EV - cum</td>
<td>100</td>
<td>200</td>
<td>325</td>
<td>450</td>
<td></td>
<td></td>
<td>450</td>
</tr>
</tbody>
</table>

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.

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Ex 6: Deferred Functionality Replan

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

Transfer PV to 1st month of receiving work package to retain negative schedule variance (behind schedule)
Ex 6: Deferred Functionality Replan

<table>
<thead>
<tr>
<th>Plan and Performance</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Period 5</th>
<th>Period 6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build B after replan:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned Req met</td>
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<td>30</td>
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<td>20</td>
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</tr>
<tr>
<td>PV - cur</td>
<td></td>
<td>150</td>
<td>100</td>
<td>100</td>
<td>350</td>
</tr>
<tr>
<td>Period 4 performance:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reqs. Met - cur</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EV – cur</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>-50</td>
</tr>
<tr>
<td>SV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The work package will **still** be behind schedule at the end of Period 4 if only the original 20 requirements are met.
Agile Methods and EV
Agile Methods
Characteristics

• Next iteration of work is detail planned in work package (WP)
• Product burndown is a planning package for remaining product burndown items or features
• Features often deferred from the current iteration to the product burndown
• Features and priorities frequently revised
Agile Method

Product Backlog

Product Backlog Item (PBI) 1, 2 (TR 1, 2)

PBI 3 - n
PBI 3 - ?
PBI ? - ?
PBI ? - n

Sprint 1
Task 1
Task n
Task 2
Task n
Task 4
Task 3
Task 4
Task 3

Sprint 2
Task 1
Task n
Task 2
Task n
Task 4
Task 3
Task 4
Task 3

Sprint 3
Task 1
Task n
Task 2
Task n
Task 4
Task 3
Task 4
Task 3

Sprint 4
Task 1
Task n
Task 2
Task n
Task 4
Task 3
Task 4
Task 3

Sprint 5
Task 1
Task n
Task 2
Task n
Task 4
Task 3
Task 4
Task 3

WP/$ Budget 1
Release 1
Jan 31

Planning Package/$ Budget 2
Release 2
Mar 31

Release 3
May 31

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Agile Focus on Near Term May Break Link with PMB

Giving full credit to meeting monthly goals
• May break link with the PMB
• Lose track of progress of plan to satisfy requirements
Baseline maintenance considerations

• Most features/PBIs are derived requirements
  • Derived from higher level functionality
  • Features changes usually do not change contract scope or total budget
• Maintain PMB and technical baseline
• Account for deferred features
  • Transfer budget with SOW
  • Maintain schedule variance (SV)
Agile EV Replan Guidance

Internal replanning guidance (a):

- 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
- Reallocation remaining EV to remaining PBI tasks (including delta PBIs) after each iteration
- Revise EAC, compare to funding, reprioritize

(a) Additional information in “Agile Earned Value and the Technical Baseline” in *Software Tech News*, Sept. 2009 (now called Journal of Software Technology)
Acquisition Management
Acquisition Management

Ensure Contractors Integrate Technical Performance/Quality with EVM

Guidance from:

• CMMI for Acquisition (ACQ)
• AF Space Command-Space and Missile Systems Center/Aerospace Corp. Report
Acquisition Technical Management

SP 1.1 Subpractices

3. Identify the quality and functional attribute requirements to be satisfied by each selected technical solution
   - Use a traceability matrix to identifying the requirements for each selected technical solution and relates requirements to work products

4. Identify analysis methods to be used for each selected technical solution
   - Simulations, prototyping, architectural evaluation, demonstrations
Space and Missile Systems Center (SMC)

**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
SMC SE Products: Design Solution

4.2.3.1 Required SE Products:
- Validated, approved, and maintained (design-to) baseline
  - In specifications and interface documents
  - Grouped by each system element such as
    - Segment
    - Subsystem
    - Component (hardware and software)
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
SMC 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
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
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, variance analyses, EAC
IBR: SE Implementation Review

• Requirements management and traceability

• Milestones for SE requirements work products by WBS
  – Derived requirements
  – Definition of required functionality and quality attributes
  – Verification methods and criteria

• Milestones for establishing product metrics
  – SFR: MOEs, MOPs defined
  – PDR: TPMs defined
IBR: SE Implementation Review

- Milestones with technical maturity success criteria
  - TPM planned values
  - Meeting requirements
  - Percent of designs complete

- Define entry and success criteria for event-driven technical reviews/IMP events
  - Revise/clarify criteria for CDR and subsequent events based on
    - Knowledge of revised and derived requirements to be met
    - TPM planned values

- Flow down of SE milestones to work packages

- Define base measures of EV
Framework for Process Improvement
Process Improvement Goal

EVMS

SE

Integrated Planning

Cost

Schedule

Risk

“Performance?”

Requirements/
Quality/
Technical
Performance

+
Close the EVMS Quality Gap

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

PMI Community of Practice
“Measurable News”
Process Improvement Resources

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

Published by:
Questions?

Comments?
References

® Performance-Based Earned Value is registered by Paul Solomon in the U.S. Patent and Trademark Office.
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- CMMI, Using CMMI to Improve Earned Value Management, 2002
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